

**STUDIES ON THE INFLUENCE OF BIOTIC AND ABIOTIC FACTORS ON
SEED YIELD, QUALITY AND STORABILITY OF RICE
(Oryza sativa L.)**

**Thesis submitted in part fulfilment of the requirements for
the degree of DOCTOR OF PHILOSOPHY (AGRICULTURE) IN SEED
TECHNOLOGY to the TAMIL NADU AGRICULTURAL UNIVERSITY,
COIMBATORE.**

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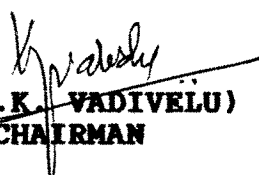
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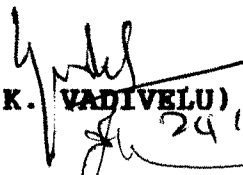
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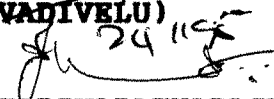

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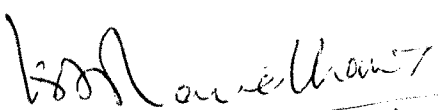
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***DEDICATED TO...,
THE ALMIGHTY AND
MY BELOVED FAMILY***

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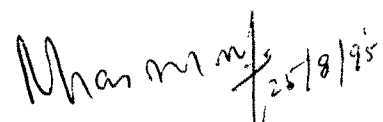
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(M. BHASKARAN)

ABSTRACT

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STUDIES ON THE INFLUENCE OF BIOTIC AND ABIOTIC FACTORS ON SEED YIELD, QUALITY AND STORABILITY OF RICE

(Oryza sativa L.)

by

M. BHASKARAN

**DEGREE : DOCTOR OF PHILOSOPHY
(AGRICULTURE - SEED TECHNOLOGY)**

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1995.

Investigations were taken up to elicit information on the influence of season and population density, age of seedling, nitrogen levels, seed hardening on direct seeding and gypsum application in sodic soil on growth, seed yield and quality and storability of resultant seeds of the rice (*Oryza sativa* L.) cultivars IR 50 and ADT 38. The effect of gypsum + green manure on seed yield and quality and storability of resultant seeds of Co 43, the influence of stages of harvest and foliar sprays on seed shattering and seed quality of ADT 38 and bioassay of seed vigour in IR 50 and ADT 38 was also studied.

The rice cultivars IR 50 and ADT 38 raised in Kharif 1992 with population densities of 100 and 80 hills per m² attained early flowering as compared to the crops raised in other seasons and population densities, while the lower population densities recorded higher seed yield and better quality. The resultant seeds of the crop raised in Kharif season with the population densities of 50 and 44 hills per m² maintained higher germination potential over a period of 15 months. The varieties differed in their degree of deterioration as measured by natural and accelerated ageing.

Planting of aged seedlings drastically affected the yield and quality of the seed. However, the combination of aged seedlings with higher dose of nitrogen application can probitably be adopted for getting reasonably good seed yield.

Among the seed hardening treatments in direct seeded rice, the maximum augmentation of seed yield and quality attributes were obtained with the seeds hardened with potassium dihydrogen phosphate 0.5 per cent and potassium chloride 1.0 per cent irrespective of varieties. However, the varieties differed in their response to hardening treatments. The variety ADT 38 responded well as compared to IR 50. The resultant seeds of the crop raised with hardened seeds maintained higher viability and vigour over a period of 15 months under storage than control.

Application of gypsum at 3600 kg ha⁻¹ in sodic soil maintained higher population per m² and recorded higher seed yield and seed recovery. The resultant seeds from this treatment maintained better viability and vigour over a period of 15 months of storage under ambient conditions. Between the varieties (IR 50 and ADT 38) ADT 38 responded well for gypsum treatment.

The conjoint application of green manure (*Sesbania aculeata*) at 10 t ha⁻¹ + gypsum 3.4 t ha⁻¹ nullified the effect of sodicity and induced higher seed yield in rice variety Co 43 under sodic soil. The resultant seeds from the above treatment maintained higher germination and vigour over a period of 15 months than the other treatments and control.

Spraying of 0.5 per cent and 1 per cent DAP reduced the seed shattering loss besides improving the seed quality in the rice variety ADT 38.

The bioassay clearly proved the existence of differences among the seed lots with high, medium and low vigour irrespective of method of ageing.

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Abbreviation used

Variety

V₁	-	IR 50
V₂	-	ADT 38

Period of storage

P₀	-	Initial evaluation
P₁	-	3 months after storage
P₂	-	6 months after storage
P₃	-	9 months after storage
P₄	-	12 months after storage
P₅	-	15 months after storage

INTRODUCTION

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L) is the most important tropical cereal. It is the primary staple food of two thirds of World's population that live in Asian countries and supplies half of the daily caloric intake of the human race. Though significant improvement in production and productivity is made, it is eclipsed under the burgeoning population growth, shrinking land and water. Although the population of rice growing countries increased by 70 per cent over the last 25 years, the higher yields were made possible through the adoption of new technologies.

In India rice occupies an area of 42 million hectares with an annual production of 112.50 million tonnes (Rengasamy, 1995). Tamil Nadu produces 62.23 tonnes of rice annually from an area of 20.1 ha with an average productivity of 3092 kg ha⁻¹ (Rengasamy, 1995). However the potential yield remains to be realised and the national average is not even half of this and is very low compared to other countries.

Further improvement in plant type and modification in cropping technology is needed to increase the production. This technology should rely less on off-the

farm-inputs and more on knowledge based management and should maintain the natural resource base, while raising yields. New technologies are needed across rice ecosystems, in the risky environments as well as in the favourable environments with advanced crop management techniques.

One of the most essential inputs in planning for high yields in crops is the availability of quality seeds. Quality seed supply is the main goal of seed production. Seed production has the twin objectives of high yield and reasonable quality standards, which cannot be sacrificed one for the other. Quality seed not only provides the bridge between the seed technologists and the farmers, but also acts as a catalyst in the adoption of better management practices and scientific production technologies. A suitable agro-ecological condition (Malabuyoc et al., 1993), good land, presowing seed treatments (Balakrishnan et al., 1994), mother crop management and nutrition (Agrawal, 1965), field sanitation and optimum plant density (Austin and Longman, 1980) and proper harvest and post harvest techniques are the essential features for increasing the yield of good quality seeds.

A mature seed during its development, harvest, processing, in transit and storage or in the soil is subjected to damage and deterioration by manifold factors such as mechanical damage, infection by micro-organisms,

insect infestation, supra and sub-optimal temperatures, drought, flooding, salinity, toxic gases and chemicals or polluted environments. These factors often cause changes in physical, physiological and bio-chemical nature of seed which have been related to poor viability, field emergence and establishment. Hence, it is not easy to produce seed against all these hazards. Therefore it has become increasingly important to bestow attention on seed production and to evolve management techniques that begins with a good start of seed in the soil.

Ecological implications namely, presowing treatments, method of sowing, density of mother plant and planting ratio play a vital role and have drawn attention of the Physiologists with regard to Agricultural and Horticultural crops. These assume paramount importance, since they affect the initial vigour and growth of the plant and ultimately the yield and quality of seed (Siddique, 1993).

Considerable variation in harvesting and conversion of solar energy into biological production in crop species has been reported (Eagles, 1984). However, cereals like rice belonging to C-3 group of plants are considered to be less efficient in the utilisation of solar radiation for both biological and economical yield.

Direct seeding is becoming an increasingly popular alternative to transplanting in Asian rice culture. Modern tropical rice cultivars, when direct seeded, because of vegetative overgrowth and foliar N dilution during reproductive growth, often fall short of their biological yield potential (Dingkuhn et al., 1992). However, direct seeding in rice is gaining momentum among the farmers of India in the last few years because of the high cost involved in transplanting, scarcity of labour and irrigation water. Because of the early harvest of direct seeded rice, it is possible to raise seed crop even in drought prone tracts of India where rainfall is scanty.

Time of planting and age of seedlings are the two cultural practices which exercise considerable influence on the growth, yield attributes and resultant seed quality of transplanted rice. As rice is highly sensitive to diverse ecological situation, seedling age at transplanting plays a crucial role in realising the potential yield and behaves differently on the basis of the management of the crop and duration of the variety (Kurmi et al., 1993).

Mother crop nutrition brings about manifold changes in the elemental composition of the seed and consequently on the viability and vigour (Austin, 1972).

Some of the enzymes and nutrients also induce the mother plant to absorb more nutrients from the soil for enhanced photosynthetic activity. The seed thus produced will be sound and well filled with reasonable standards of quality. Hence, the response of the strain to applied nutrients either through soil or foliage has to be studied in terms of yield and quality of seed.

Plant growth on sodic soil is adversely affected by high pH, excessive exchangeable sodium, poor physical conditions and imbalance and low availability of plant nutrients (Singh and Sharma, 1993). Increased fertiliser use becomes inevitable as a major means to achieve a successful green revolution. In recent years, however, with increasing pressure to produce high yields of quality seeds from a single crop and higher total yields under intensive cropping systems, concern for sustainable soil management and productivity has emerged out as an issue of vital importance (Aruna, 1994). Addition of organic amendments in various forms will improve the physical and chemical properties of soil and thereby the available land can be potentially utilised for maximising quality seed production per unit area, besides extending the area of cultivation without any constraint.

The pre and post harvest losses of rice during various operations are not fully evaluated so far. The proper

appraisal of these losses through assessing seed shattering will aid to predict this either due to heritability or high productivity through the introduction of high yielding varieties and improved technologies. Besides this a hitherto neglected aspect like seed shattering deserves greater attention to maximise rice production (Rao et al., 1993).

The successful establishment of a crop is the most important factor in determining seed vigour. The prediction of vigour of lots before sowing is one of the prime and chief objectives of valiant effort in many countries, leading to the innovation of vigour tests. Although over 35 years ago, the seed vigour was recognised as a measurable aspect of seed quality, no reliable vigour test has been identified into the official rules of either the ISTA or AOSA (Woodstock, 1973). This is due to the confusion and controversy in employing the vigour tests due to varied factors.

Seed is a biological unit, the moment it attains physiological maturity on the mother plant in the field its storage life starts, with which ageing follows as well. This physiological ageing in seed is accelerated by the hostile environment. The field factors such as plant density per unit area, environmental pollution with chemicals, climatic and edaphic factors and the storage

factors such as seed health due to storage pests and pathogens, seed treating chemicals, containers, storage environment and period of storage affect the ageing of the seeds. Also the facts suggest that some seed volatiles may accelerate the loss of seed vigour and be a cause of seed deterioration in hermitically sealed containers even at sub-zero temperatures (Zhang et al., 1993).

Because of improper production and lack of knowledge and technical knowhow for storage conditions, Indian seed industry often faces the problem of poor viability and short shelf-life of stored seeds.

A knowledge on the competitive role and inter action of agro-ecology and seed crop management techniques in terms of growth, yield attributes and shelf-life will go a long way in tailoring or coining the package of practices for maximising the yield of sound and healthy seed.

To gain an insight on all the above facts, studies were carried out to evaluate,

- i) the influence of season of production and plant density on field performance, resultant seed quality and storability of rice varieties IR 50 and ADT 38,

- ii) the effect of age of seedling and nitrogen levels on the seed yield and quality of rice varieties IR 50 and ADT 38,
- iii) the efficacy of seed hardening treatments on the field performance, seed yield and quality attributes of direct seeded rice (IR 50 and ADT 38),
- iv) the effect of gypsum application in sodic soils on the seed yield, quality and storability of rice varieties IR 50 and ADT 38,
- v) the effect of green manuring and gypsum alone and in combination of green manuring + gypsum on seed yield, quality and storability of rice variety CO 43 in sodic soil.
- vi) the influence of stages of harvest and foliar spraying of chemical nutrients on seed shattering loss and quality of rice variety ADT 38, and
- vii) the vigour status of rice seeds through bioassay.

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REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Earlier work on the effect of season and plant density, age of seedling, pre-sowing hardening treatments and direct seeding, gypsum and green manure amendments under sodic soil, foliar spray with chemicals and their influence on seed shattering loss and seed quality, evolution of volatile compounds during storage, bioassay of seed vigour and viability and vigour of naturally as well as acceleratedly aged seeds are reviewed hereunder.

2.1. Season and plant density on yield attributes and quality

Environmental factors (soil fertility, wet or dry season, solar radiation and temperature during seed development) and crop management (added 'N' fertilizer, age of seeding, method of seeding, plant spacing) affect rice yield and seed quality (Anon, 1995). Research pursuits have proved that production of good quality seed is influenced by varied agro-climatic ecosystems and cultural managements such as season, duration, crop canopy, population density and nitrogen (Padmajarao 1987, 1988 and 1989) in cultivated rice. Rice is generally considered as semiaquatic annual grass, although, in the tropics it can survive as a

perennial. In different growth stages rice responds differently to adverse environmental conditions, soil moisture deficit imposed during the reproductive stage greatly reduced seed yield and quality of cultivar IR 64 under aerobic conditions (Yambao and Ingram, 1988). The incident radiation during the main rice growing season (wet season) is considerably lower (by about 40%) than that in the dry season (Hayashi, 1969).

DeDatta and Zarate (1970) reported highly significant correlation between seed yield and solar radiation during the last 45 days of tropical irrigated rice. Solar radiation at reproductive and ripening stages influenced the seed yield and quality. The seed characteristics as well as some of the chemical constituents of the rice seed can show considerable variations due to changes in agro-climatic and agronomic factors (Yang, 1975; Evans and DeDatta, 1979; Petibskaya, 1984; Parida and Mitra, 1989).

Eagles (1984) reported considerable variation in harvesting and conversion of solar energy due to seasonal variation into biological production in crop species. Cereals like rice belonging to C-3 group of plants are considered to be less efficient in the utilisation of solar radiation due to seasonal variation for both biological and economical yield and seed quality.

Shahu et al., (1989) reported that the duration of the rice from planting to harvest ranged from 81 days in August to 122 days in December planted crops. Yogeeswara Rao (1989) studied the influence of temperature regimes over crop growth periods up to heading (50% flowering) and reported significant increase of dry matter accumulation at heading, seed yield and quality.

Kudo (1975) and Murata (1976) observed the dependence of rice seed yield and quality, the dry matter accumulation at heading and solar radiation available over ripening phase. The productivity index was strongly and positively associated with the dry matter production and accounted for 73.5 per cent.

The changes in rainfall, soil moisture and solar radiation parameters due to seasonal variations were significantly affected the vegetative, reproductive and maturation growth stages of rice as reported by Yosida (1981).

Gill and Shahi (1985), Trivedi and Kwartta (1985) and Joon and Singh (1989) observed significant increase in seed yield in early planted (June 15) rice over normal and late transplanted ones. Delayed planting significantly decreased the yield components and seed yield.

Time and season of planting (a major non-monetary input) influenced seed yield and quality. Maximum seed yield and quality can be achieved by planting the rice crop at the optimum time at any specific location, which may vary from variety to variety (Reddy and Narayana, 1984; Babu, 1987; Anon, 1992 ; Singh et al., 1993).

Singh et al., (1993) observed significant varietal differences in terms of growth ,panicle number per m², panicle weight and seed yield due to season of transplanting and reported linear reduction in seed yield with every 10 days delay in transplanting from July,15 to August,4.

Padmajarao (1990) reported decreased seed quality attributes of rice with prolonged time of planting beyond 1st week of July irrespective of the varieties. Early planting improved the yield and seed quality of rice compared to late planting (Singh et al., 1993).

Rice is grown in India in diverse agro-climatic environments characterized by spatial and temporal variations in rainfall and in any soils of varying water retention capacity. To make efficient use of resources and maximize seed production, variations in population density are needed under these diverse environments (Anon, 1994).

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Agronomic practice that help to increase rice seed production should be environmentally benign. Among the different seed crop management practices, spacing of mother plant plays an important role in quality seed production (Austin, 1972). Seed yield is a complex factor influenced by both external and internal factors. Among the external factors plant density plays a major role (Austin and Longman, 1980). Increasing the plant density is one of the crop management practices adopted for increasing productivity (Savant et al., 1994).

Vegetative as well as productive tillers increased as the spacing between rows increased in rice (Bathkal and Patil, 1970). Shahi et al. (1976) observed more tillers plant⁻¹ and lesser panicles per m² under wider spacing in rice.

Wider spacing induced more number of both total and productive tillers than closer spacing in rice (Carberry et al., 1985).

Variation in spacing resulted in alteration of leaf area index (LAI), which had direct impact on seed yield (Yoshida, 1972).

Shahi et al. (1976) did not observe significant differences in yield of dwarf rice cv. Jaya grown under

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20 x 20, 20 x 15 and 15 x 15 cm spacings with 1 to 4 seedlings hill⁻¹ and reported increased yield in 20 x 20 cm spacing with one seedling hill⁻¹.

Honda (1977) observed differential total number of tillers in five varieties of rice and with an increase in planting density, the number of tillers gradually decreased. Plant population and geometry of planting influences the seed yield in transplanted rice. Increasing the spacing beyond 200 sq. cm hill⁻¹ (20 x 10 cm) is detrimental to seed yield of rice. Closer spacing increases number of total tillers and higher percentage of productive tillers and number of seeds per unit area (Pothiraj et al., 1977).

Increased sowing rate of rice increases number of plants, tillers, panicles per m² and germination (Amarlal 1978).

Srinivasalureddy (1979) reported significant higher seed yield of rice in higher spacing (15 x 10 cm) compared to the lower spacing of 10 x 10 cm due to the production of more number of productive tillers hill⁻¹ and filled seeds panicle⁻¹.

Ibrahim et al., (1980) reported increased tillering, dry matter production and seed yield of rice grown under increased spacing.

Suzuki (1981) observed decreased panicle length, culm length, number primary and secondary branches panicle⁻¹ and number of spikelets panicle⁻¹ under increased plant density. But length of anther and stigma remained unaffected in rice.

Balasubramaniyam and Vaithialingam (1983) reported the negative influence of spacing on plant height and root length and positive influence on number of productive tillers hill⁻¹ and panicle number per m² in rice.

Gangadhariah (1983) and Kaushik and Gautam (1984) observed non-significant effect of spacings on 1000 seed weight in rice.

The number of panicles per m² were higher in a conventional planting at 15 x 10 cm spacing during the wet season in rice and was higher at 15 x 20 cm spacing during dry season (Thangamuthu and Subramaniyan, 1983).

The number of tillers and number of panicle bearing tillers hill⁻¹ and 1000 seed weight decreased with increasing plant density, however, plant height, number of seeds per m² and seed yield were not affected in rice Basumathi -370 raised with different number of seedlings per hill (Ashraf and Mahmood, 1989). Mohammad et al. (1987) and Liou (1987) reported marked decrease in panicle length, number of primary branches and number of seeds on secondary branches in closely spaced rice.

Zhang xian and Huang yong (1990) from their studies in seedlings hill⁻¹ did not observe major changes in rate of seed set, 1000 seed weight, plant height, panicle length and harvest index due to levels of plant density. However, the traits namely, seed yield plant⁻¹, total weight plant⁻¹, panicles plant⁻¹ and quality attributes were found to be unstable under the levels of plant density in rice.

Closer spacing resulted in early flowering in rice due to the production of less number of tillers having restricted growth unlike in wider spacing and increase in spikelet sterility was due to more competition of photosynthates in an unit area as reported by Reddy and Reddy (1992).

Seed yield plant⁻¹ significantly decreased as plant density increased. While the increased seed yield plant⁻¹ was observed under wider spacing in rice (Swan et al., 1993).

The ear-bearing tillers hill⁻¹, 100 seed weight and filled seeds panicle⁻¹ in rice were significantly higher with lower plant density. A slight increase in the return rupee spent was however observed with the lower plant density compared to higher plant density as reported by Kanungo and Roul (1994).

Savant et al. (1994) concluded that the increased number of seedlings hill⁻¹ and number of hills per m² were significantly increased the methane emission and this affected early stages of growth and tiller formation and seed yield in rice.

According to Peltonen and Jarvinen (1995) the increased plant density per m² were significantly decreased the yield and quality parameters like number of seeds panicle⁻¹, panicle yield and dry matter production. They also observed significant interaction between season and plant density for days to flowering, maturity, plant height and seed yield in rice.

Aswathaiah (1977) and Hart and Burton (1985) recorded better germination, vigour and increased root length of seedlings and protein content of the seeds of pearl millet obtained from wider than from closely spaced plants.

The germination per cent, root length and vigour index were significantly higher in sorghum seeds obtained from 45 x 15 cm spacing (Krishnaswamy and Ramaswamy, 1984).

Wider spacing showed significant improvement with regard to length, diameter, weight and number of seeds per cob in Maize (Krishnaveni and Ramaswamy, 1985).

2.2. Age of seedling and nitrogen levels on yield components and seed quality

The world's rising concerns about land degradation, soil erosion, water shortages and environmental pollution translate for rice research. Increasing the input / output efficiency of nutrients, water and labour make possible sustainable crop intensification and continuing reduction in the cost of rice production on agricultural land (Anon, 1993).

Transplanting of rice depends on a farmer's resources, particularly the availability of irrigation water, labour and other farm inputs. Often, the farmers are forced to take up planting with overaged seedlings, due to delay in field preparation caused by erratic rainfall and inadequate water supply. The ideal age of seedlings for transplanting is governed by the duration of varieties and field conditions (Murthy and Sahu, 1979).

Time of planting and age of seedlings are the two cultural practices which exercise considerable influence on the growth, seed yield and quality of transplanted rice (Joon and Singh 1989).

Three to four week old rice seedlings are recommended for transplanting to achieve optimum seed yield and quality

on normal soils (Macalinga and Obordo, 1970), but mortality is high when aged seedlings are transplanted and the extent of mortality varies due to duration of the crop and varieties (Qadar, 1990).

Singh (1987) and Singh and Sharma (1984 and 1993) did not observe significant reduction in productive tillers hill⁻¹, length of panicle and seed yield due to planting of aged seedling in long duration rice variety (CSR-1). In long duration it has sufficient time for completion of vegetative and reproductive stages irrespective of seedling age when compared to short duration variety. They also observed higher number of productive tillers hill⁻¹, larger length of panicle and significant increase in seed yield in the crop raised with aged seedlings due to the application of increased levels of N.

The yield and yield attributes declined significantly with aged seedlings (30, 45 and 60 day old seedlings) and the decline was partly attributed to the production of fewer productive tillers hill⁻¹ and spikelets panicle⁻¹ (Ashraf and Mahmood, 1989).

Swarup and Singh (1989) reported non-significant correlation between the uptake of nutrient and seedling age. However, the recovery of applied N was higher at 60 kg than at 120 and 180 kg N.

Cada and Taleon (1963) observed increase in crop duration with increase in seedling age.

Reddy and Reddy (1992) reported increased number of days to 50 per cent flowering, crop duration and spikelet sterility and low dry matter production, leaf area index and rate of crop growth through planting of aged seedlings.

Kulkarni and Eswari (1994) reported 6.5, 14.5 and 25 days delayed flowering in the crop raised with 40, 50 and 60 day old seedlings, respectively when compared to 30 day old seedlings. The use of 60 day old seedlings resulted in 7 per cent reduction in panicle length, 23 per cent decrease in number of filled seeds panicle⁻¹, 13.7 per cent decrease in seed yield and 36.4 per cent increase of spikelet sterility.

Khishbuchi (1981) and Ganesh and Soundarapandian (1988) observed significant interactions between genotype, environment and age of seedling for the seed yield and yield components.

Kulkarni and Eswari (1994) reported that G x E (linear) interaction was significant for days to 50 per cent flowering, number of seeds panicle⁻¹ and panicle length.

Bassi et al. (1994) reported delayed and quicker emergence of panicle in 20 and 25 day old and 35 - 45 day old seedlings. The genetic differences among the genotypes in the establishment of transplanted seedlings might have caused the differences in panicle emergence and days to flowering.

Mannan and Siddique (1990) observed that the tiller and panicle numbers did not differ significantly with seedling age in CV BR 11. However, in CV BR 22, seedling age was inversely related to tiller and panicle numbers and transplanting of 30 to 60 day old seedlings had no significant effect on seed yield of BR 11 and BR 22.

Number of panicles per m², number of filled seeds panicle⁻¹, panicle length and seed yield were significantly affected by the age of seedling. Among the varieties Gayatri (Long duration) produced significantly higher seed yield over Savitri (Medium duration) (Singh and Sharma, 1993).

Osada et al. (1975) observed premature heading of non-photosensitive rice varieties in the nursery bed due to delayed transplanting (beyond 45 days).

Hou (1978) stated that the decrease in yield due to transplanting of aged seedlings was less in late than in early maturing varieties.

Reddy et al. (1987) reported planting of 60 day old seedlings increased the grain yield in long duration rice variety, while decrease was observed with 90 day old seedling.

The seed yield of rice is directly related to the duration of the variety and was found to decrease with planting of aged seedlings. However, the decrease in yield due to planting of aged seedlings was less in late maturing than in early maturing varieties (Rao and Raju, 1987; Kurmi et al., 1993). They also observed increased crop duration with aged seedlings. However the mainfield duration, number of panicles per m², panicle length, seed weight and seed quality decreased with the increase in seedling age.

Joon and Singh (1989) opined that age of seedlings had a significant effect on seeds panicle⁻¹, panicle per hill⁻¹, 1000 seed weight and seed quality. They reported significant differences among the varieties and higher yield with 60 day old than with 30 and 45 day old seedlings.

Duration of the crop was increased by 14 - 15 days due to planting of aged seedlings in different varieties. The duration progressively increased with progressive increase in the age of the seedlings and attained maximum when 51 day old seedlings were planted (Nayak et al., 1994).

The maximum seed yield was obtained in the crop that received higher dose of fertilizers. The yield attributing characters viz., panicle length, number of panicles per unit area and number of filled seeds panicle⁻¹ were influenced by higher fertility levels (Mohapatra et al., 1990).

Nitrogen use efficiency decreased with each successive increase in N application and this will vary depending upon the age of seedling in rice (Singh and Sharma, 1993).

Increased nitrogen level increased the yield attributes significantly (Kaul et al., 1972). MassodAli (1976) reported that nitrogen favourably effected the number of cobs plant⁻¹. Increasing amounts of nitrogen increased the yield attributes significantly (Buragohain and Kalita, 1985).

Addition of nitrogen at 180 kg ha⁻¹ increased the ear length of pearl millet (Tregubengo et al., 1974). Panda et al. (1974) observed higher grain yield of maize due to increase in cob length.

Increase in the number of grains cob⁻¹ due to the increment in the levels of applied nitrogen have been reported by MassodAli (1976). The grain yield response with increment in nitrogen levels due to improvement in number of grains cob⁻¹ and hundred grain weight has been reported by Narasimhareddy et al. (1988).

Shukla and Wassay (1970) found increased protein accumulation in the seed with split application of nitrogen. Gargo (1978) reported increased accumulation of protein in maize seed due to N application.

Balakrishnan et al. (1994) reported considerable yield reduction in short duration rice varieties with transplanting of 45 days old seedlings compared to 35 days old seedlings.

Ayyasamy et al. (1991) did not observe any alterations in yield attributes and seed yield in the crop raised with 50 days old seedlings of the medium duration rice varieties.

2.3. Seed hardening treatments on seed yield and quality of direct seeded rice.

Direct seeding and transplanting are the two common establishment methods in rice seed production. In direct seeded rice poor plant stand usually develops because of low seed rate, poor germination and early flooding (Sharma et al., 1995).

Seed hardening and high seed rate are necessary in the maintenance of plant population under direct seeding. Direct seeded rice seems to be more suitable in multiple cropping programmes due to early maturation (Thakur, 1993).

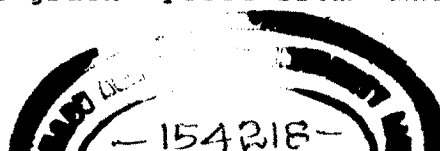
Direct seeding shortens the cropping cycle due to the absence of transplanting shock (Dingkuhn et al., 1990; (Schnier et al., 1990).

Direct sowing of rice, helps in overcoming the labour problem as the labour requirement is less under this conditions. However, production of vigorous seedling and maintenance of adequate population are the major problems under direct seeding. Presowing hardening treatments are the handy tools to overcome this problem (Akram, 1993).

Genkel and Kolotova (1934) suggested a hardening method for enhancing drought resistance in plants by treatment before sowing.

Pogosov (1962) recorded enhanced yield due to pre-soaking of tomato seed in mere water. Pre soaking of seeds in 0.5 to 2.0 per cent potassium phosphate and potassium nitrate solutions for one to four days induced earlier (5days) and higher germination in tomato seeds over control (Ells, 1963).

The response to hardening appears to be much greater when plants experience water stress, either due to shortage of soil water or from high rates of potential transpiration. Zubenko (1959) obtained 40 per cent increase in plant growth and 33 per cent increase in grain yield from maize seeds



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soaked for 24 hours. Dawson (1965) reported similar findings in ragi (*Eleusine Coracana* L.)

Sastry et al. (1969) from their studies concluded that hardening of ragi seeds with Kinins induced drought tolerance. There is evidence that growth regulators such as CCC enable plants to withstand unfavourable conditions. EL-Damaty et al. (1965) pointed out the tolerance of wheat seedlings subjected to CCC (2-chloroethyl trimethyl ammonium chloride) treatment to high water stress due to high salinity or low moisture.

Karivaratharaju et al. (1973) observed increased drought resistance of plants raised by hardened seeds through promotion of deep and extensive root system besides other biochemical influences.

The beneficial effects of water soaking and chemical treatments in inducing growth and yield might be attributed to leaching out of toxic metabolites from the seed and to antifungal and anticatabolic effects of the treatments (Basu et al., 1974).

Balasubramanian (1976) reported the induction of drought resistance by presowing seed treatments due to increased sugar fractions and osmotic pressure of cell sap that helped in uptake of water.

Dimov et al. (1978) observed improvement in germination of capsicum and tomato seeds soaked in potassium nitrate and phosphate.

Venkataraman et al. (1978) reported 0.2 per cent DAP as the optimum dose for presowing hardening for rice, beyond which the germination was impaired considerably.

Mengel et al. (1979) reported increased yield by treating paddy seeds with zinc chelate (6.0 per cent Zn EDTA) before sowing. Similarly seed treatment with zinc chelate (6.0 per cent) gave an increased yield of 763 to 829 kg ha⁻¹ over the control (Sedberry et al., 1979).

Rice seed soaked in potassium chloride (1.0 per cent) registered the highest seed yield over control (Peeran and Natanasabapathy, 1980; Rao et al., 1985).

Hardening of rice seeds with the chemicals like calcium chloride, ferric sulphate, potassium nitrate, sodium chloride, succinic acid, zinc sulphate, adenine, ascorbic acid and gibberellic acid induced more germination, root length, tillers, plant height, dry matter and yield, (Karivaratharaju and Ramakrishnan, 1985).

Soaking the seeds in 0.1 per cent zinc sulphate solution for 4 hours increases the germination percentage of

the seed, plant growth and zinc content of rice plant (Gukova et al., 1986).

Srinivasan and Naidu (1986) reported highest endosperm weight and seedling vigour of the paddy seeds subjected to pre sowing treatment with zinc sulphate solution (5 ppm) for 16 h.

Zia and Yousuf (1986) recommended dipping of sprouted seeds of paddy in one per cent zinc sulphate before sowing for early and uniform emergence.

Nitrate, sulphate, carbonate and chloride of copper presowing seed treatments enhanced the germination energy of paddy by 14 and 12 per cent in the laboratory test and field, respectively and increased the yield by 10 to 12 per cent (Sheudzhen and Rymar, 1987).

Presoaking the seeds of dormant paddy cultivars in ascorbic acid (0.2N), nitric acid (0.2N), potassium nitrate(0.2N) and sulphuric acid (0.2%) for 24 h improves the germination percentage compared to untreated seeds (Tomar et al., 1987).

Rosell et al. (1988) recorded faster germination, earlier flowering and fruiting in tomato, by using the seeds subjected to hot water (60°C) treatment for 2 h prior to

sowing. Rani (1988) recommended soaking of tomato seeds either in 2.0 per cent mixtalol (paras) or calcium oxychloride for 24 h for getting enhanced germination, vigour and field emergence.

Soaking of rice seeds in 3.0 per cent potassium nitrate for 12 h after presoaking in water for 10 h registered higher germination and vigour besides recording increased field emergence and seedling height (Poongothai, 1989 and Manonmani, 1990).

Ramanathan (1980), Singh and Chatterjee (1990) and Narayanasamy et al. (1991) reported increased productive tillers, filled seeds panicle⁻¹ and 12.5 per cent increased seed yield by using the seeds of rice variety TKM 9 hardened with succinic acid 100 ppm. The treatment also increased the 1000 seed weight, root length and dry matter production.

Pre soaking the seeds in CCC at 7500 ppm for 12 h did not improve seedling growth, yield and yield attributes of short duration rice (Balakrishnan et al., 1994).

Shad and DeDatta (1986) and Budhar et al. (1990) reported higher number of panicles sq.m⁻¹, number of filled seeds panicle⁻¹, test weight and seed yield in direct sown rice compared to transplanted crop.

Direct sown short duration rice records higher seed yield when well fertilized and maintained at higher population density level (Yoshida, 1981). Direct seeding enabled to produce more tillers and higher plant biomass by restricting the vegetative growth and duration as against transplanted crop, which experience transplanting shock (Dingkuhn et al., 1990 and Schnier et al., 1990).

Dingkuhn et al. (1991) observed increased yield and yield attributing parameters in well fertilized direct seeded short duration variety (IR 58) over transplanted ones. Whereas in longer duration varieties the yield increase disappeared due to growth delaying effects of transplanting shock. Active and more number of tillers were observed in direct seeded rice than in transplanted rice (Schnier et al., 1990).

Vankeulen and Seligman (1987) reported low and increased N concentrations in the initial and growth stages of transplanted rice. Nitrogen concentration decreases in the transplanted rice after establishment until maturity due to depletion and tissue expansion followed by N dilution and translocation (Schnier et al., 1990 a). They also observed continuous decline of foliar N concentration in transplanted rice. Whereas it was interrupted by a brief recovery due to the split N application in direct seeded rice.

In transplanted rice, canopy photosynthesis was low until 35 DAS due to transplanting shock, whereas in direct seeded rice the linear increase of maximum canopy photosynthesis was observed 20 days earlier than in transplanted rice ending in a maximum at 35 DAS as observed by Dingkuhn et al. (1991).

Mitra et al. (1992) reported that early harvest of direct seeded rice is possible without sacrificing seed yield compared to transplanting as direct seeding shortens the growth duration by 16 days and saves four to five irrigations during the reproductive phase.

The duration of the crop was reduced by about seven days in direct sown crop rather than transplanted one, whereas transplanting gave higher monetary returns than direct seeding. However, both the methods were almost similar in cost: benefit ratio (Thakur, 1993).

Kundu et al. (1993) stated that seed yield did not vary significantly either with method of sowing or transplanting.

Swamy and Murthy (1993) reported that higher productivity and yield of rice cultivar Rasi under rainfed direct sown conditions was due to its drought tolerance capacity and accumulation of more dry matter, resulted in

producing more tillers, panicles per unit area, more filled seeds and less sterility per cent.

Ramamoorthy et al. (1993) reported more number of tillers, number of filled seeds panicle⁻¹ and better quality of the resultant seed in the rice crop raised through direct seeding and subsequent continuous submergence.

Direct seeding of rice at 100 kg ha⁻¹ recorded high yield in semi dry condition. Basal application of N did not influence seed yield, hence N application has to be adjusted depending upon the moisture availability (Rajendran, 1991).

Chau et al. (1994) reported higher number of established seedlings in anaerobically direct seeded rice cultivars compared to dry seeding. Significant differences were also observed for panicle size, spikelet number panicle⁻¹, 1000 seed weight and seed yield.

Direct seeding eliminates labour demands for seed bed preparations, seedling care, pulling of the seedlings and transplanting in the main field. Moreover, in direct seeded rice the growth and yield parameters like number of tillers, leaf area index, panicle length, test weight and grain yield significantly varied due to levels of irrigation and nitrogen management (Prasad et al., 1994).

2.4. Influence of gypsum and green manuring on seed yield and quality of rice in sodic soils.

Salinity in growth medium is a limiting factor of agricultural productivity in arid and semiarid regions, where, the brackish water is the only water resource. The detrimental effect of salinity on biomass production is attributed to osmotic stress and/or the direct effects of the ions on the physiological and biochemical functions of the cells (Greenway and Munns, 1980).

Salinity is known to inhibit uptake of several nutrients such as NO_3^- (Aslam et al., 1984), K^+ and Ca^{2+} (Cramer et al., 1985).

Sodic soils are characterised by high exchangeable sodium in the soil profile, adverse soil physical properties and reduced availability of plant nutrients viz., N, Ca, Zn and Na. Crops grown in these soils suffer nutritional disorder and results in low crop yields. Application of gypsum was reported to reclaim the sodic soils (Swarup, 1985 a).

Green manuring before transplanting the rice substitute the N requirement and also improve the yield in sodic soils (Ghai et al., 1988).

Rice is considered to be a salt sensitive crop (Flowers and yeo, 1981). However, considerable variability for salinity resistance among rice varieties is also apparent (Yeo and Flowers, 1982).

Iwaki (1956) reported reduced germination of rice under 1.0 to 1.5 per cent sodium chloride and nil germination with the concentration more than 2.5 per cent.

Pearson (1961) reported apparent tolerance and high sensitivity of rice to salinity levels during germination and at 1 to 2 leaf stage.

Reduction and stimulation of root growth in 12 rice cultivars due to higher and lower concentrations of sodium chloride was observed by Jones (1980).

Data and Pradhan (1981) reported retarded germination and growth and more depressed root growth than shoot growth in rice seedlings subjected to saline water.

Decreased and delayed germination percentage of rice under higher salt concentration in the growth medium was observed by Eswarareddy and Ramaireddy (1983).

Ansari et al. (1980) and sung (1981) reported normal germination of wheat and barley in the presence of sodium

salts and decreased root and shoot growth with increasing sodium chloride concentration.

Sodic soils are low productive as crop growth is adversely affected by the presence of high amounts of sodium salts. Intensive efforts were made to bring such salt affected soils under rice cultivation and to maximise production by using various amendments, preferably gypsum (Swarup, 1985 b; Oster, 1992).

Chhabra and Abrol (1977) observed that the rice crop itself could reclaim sodic soils and the effect of rice was more biochemical in nature rather than through increased permeability alone. Because of the biological activity of rice roots lowered soil pH and decreased loss of organic matter during the process of leaching.

Several legume species, leaves and cuttings of perennial plants are being used as common green manure to reclaim the sodic soils. These organic amendments not only reclaim the sodic soils but also supply nutrition to crops (Puttaswamygowda et al., 1973, Swarup, 1985 a).

Swarup (1987) reported greater reclamation efficiency of farm yard manure and better crop growth and increased yield in sodic soils.

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YadvinderSingh et al. (1992) stated that the green manure crop after incorporation in the saline soil due to release of organic acids brings about favourable changes in physio chemical properties of alkali soils, which ultimately leads to increased yield and seed quality of rice.

Green leaf manures like Acacia leaves are more effective in reclaiming the sodic soil by lowering the ESP and increasing the exchangeable Ca and Mg, (AnandSwarup, 1988).

Application of gypsum at 20 t ha⁻¹ along with green manure to sodic soil resulted in a marked reduction in soil pH and ESP compared to application of gypsum alone (Swarup, 1987).

Application of gypsum at 25 t ha⁻¹ with frequent flooding and draining followed by green manure application (*Sesbania aculeata* Poir) at 6.5 t ha⁻¹ resulted in considerable improvement in clayey sodic soil characteristics (Krishnamoorthy, 1978 and Palaniappan et al., 1992).

Gupta and Soi (1992) reported decreased pH, EC, ESP and organic acid and increased seed yield of rice under saline soil with the application of gypsum at 15 t ha⁻¹ on the basis of soil pH and leaching.

Paramasivam et al. (1990) reported increased P and K uptake of rice with the combined application of gypsum and pressmud in sodic soil. Green manure in combination with gypsum along with effective supply of Zn from the native as well as applied sources to plants in sodic soils increased the yield as concluded by Anandswarup (1991).

The concentration of essential nutrients such as N, P, K, Fe and Mn were much higher in 30 days old rice plant grown under sodic soil treated with organic amendments (Anandswarup, 1992). He also observed the better availability of nutrition to crop due to enhanced absorption of these essential elements, which resulted in increased yield components and seed yield of rice.

Application of gypsum reclaimed the soil and improved the availability of essential plant nutrients. Green manuring considerably improved organic carbon, available N, P and K status of the soil and enhanced the availability of secondary and micro nutrients in the sodic soils besides increasing the yield and seed quality of rice (Aruna, 1994).

Ghai et al. (1988) reported the equivalent effect of application of green manures like *S. acleata* and *Sesbania Sp* on N uptake of rice to that of application of 122 and 78 kg ha⁻¹ of the chemical nitrogen, respectively.

The incorporation of green leaf manure, *Leucaena* in sodic soil during wet and dry seasons induces higher N uptake throughout the vegetative period of rice which results in higher reproductive effort (Zoyza et al., 1990).

Rice seed yield and its component characters such as plant population, number of tillers, number of panicle bearing tillers and number of total seeds panicle⁻¹ declined, whereas duration of heading and maturity including sterile glumes increased under saline and alkali conditions (Dwivedi et al., 1991).

Krishnamoorthy et al. (1987) reported that salt tolerant rice cultivars Au 1, Co 43 and CSC 1 showed high tolerance to salinity as evidenced by less reduction in growth, tiller number (20 to 46%), leaf area (23 to 45%) and dry matter accumulation (10 to 12%) compared to control.

Soil amendments significantly increased the seed yield of rice and gypsum treatment resulted in more yield and seed quality than other amendments like pyrite and pressmud (Rajkumar et al., 1991).

The favourable effect of green manure on crop growth could be attributed to the enhanced availability of nutrients like N, P, Fe, Mn and Zn and reduction in sodicity due to hydrolysis (Swarup, 1987).

Green manuring before transplantation of rice improved yield and yield components under partial substitution of N requirement of crop (Swarup, 1987; Ghai et al., 1988).

Application of green manure *S. aculeata* to sodic soil enhances rice grain yield (Anandswarup, 1991).

Yadav and Agarwal (1961) demonstrated rice yield increase of 37, 97 and 173 per cent through the application of green manure alone, gypsum alone and both conjointly, respectively.

Application of gypsum and green manure with *Sesbania* in sodic soil increases the rice yield to 3.7 t ha⁻¹ as against 0.92 t ha⁻¹ with N-p-K alone (Shirwal and Despande, 1977).

Incorporation of green manure at 5.6 t ha⁻¹ (or) gypsum at 12 t ha⁻¹ in saline sodic soil, increases the rice yield by 57 and 23 per cent, respectively (Misra, 1976).

Combination of green manure and gypsum or sulphur or lignite fly ash or pressmud or pyrite amendments helped in obtaining increased crop yields and its components in the saline sodic soils (Shetty, 1975; Yavindersingh, 1992).

Arunin et al. (1988) reported an yield of 1.25 t ha⁻¹ in rice crop raised in saline alkali soils incorporated with green manure, *S. Speciosa* compared to 0.4 t ha⁻¹ under control.

The uptake of N, P and K in seed and significant increase in yield components and seed yield of rice were higher under combined application of green manure and gypsum at 100 kg N ha⁻¹ under sodic soil (Aruna, 1994).

Swarup and Singh (1994) observed improvement in seed yield of rice and wheat and decreased pH and ESP of the soil profile under gypsum and FYM applications compared to control.

2.5. Stages of harvest on seed shattering loss and quality

Shedding or shattering of seeds in rice from harvesting to threshing some times causes losses to the tune of 5 to 12 per cent. In majority of the cultivars (68.6%) the shattering loss ranges between 1 to 10 per cent and in the remaining cultivars it has been reported up to 38 per cent (Sahu and Sahu, 1981).

Seed shattering is a heritable character and is controlled by genes. This also changes due to environmental conditions (Choudhary et al., 1980, Rao et al., 1980, Singh

et al., 1980, Ghorai and Pande 1982, and Sardana and Borthakur 1987).

Agrawal et al. (1990) reported significant correlation of panicle length with that of seed number, while seed shattering was independent of panicle length and number of spikelets panicle⁻¹.

Several research workers have studied seed shattering in rice. The different components of pre and post harvest losses of rice during various operations under field practices are not fully evaluated for proper appraisal of total pre and post harvest loss (Varma, 1981, Ali and ojha, 1982, Singh et al 1983, Bhole et al., 1985 and Rao et al., 1993). They have reported that the post harvest losses are more in local varieties when compared to high yielding varieties.

Shands et al. (1967) from their studies on germination responses of barley seeds from different harvesting conditions and storage reported differential influence of date of harvest on germination potential of seeds with later harvests showing successive reductions in germination.

The term field seed deterioration by Glueck et al. (1977) includes the term grain weathering, which means the total physio-chemical deterioration of the seed. Factors

contributing to the weathering include alternate wetting and drying, prolonged exposure to sunlight, insect and bird damage. Weathering symptoms include seed discolouration, seed coat splitting and sprouting in the earhead.

Tekrony et al. (1980) found that in soybean seed vigour declined rapidly with the delay in harvest after harvestable maturity.

Singh and Borikar (1990) observed genetic variability in fourteen parental lines of sorghum harvested at different maturity stages and suggested that 30 to 35 days for early and 35 to 40 days for late genotypes for harvesting after anthesis for maximum germination and vigour.

According to Kameswararao et al. (1991) the seeds of pearl millet had maximum seed longevity when harvested at one week after physiological maturity, which was optimum time of harvest to obtain good quality seeds.

Apparao et al. (1993) evaluated four CMS lines of pearl millet harvested at different stages of maturity and reported that maximum fresh weight and dry matter accumulation occurred at 28 to 35 days after pollination.

2.5.1. Foliar spray of nutrients on seed yield and quality.

Mother crop nutrition greatly influence the seed yield and quality (Roberts, 1972). Singh et al. (1978) reported that foliar application of chemical nutrients was better than other method in improving yield, yield parameters and other desirable quality characters.

The demand for nutrients may vary with the advancement in growth stages, until maturity. Adequate nutrient supply is necessary for maximum growth during the vegetative period. Avoidance of nutrient stress is essential during translocation of nutrients from vegetative to reproductive parts to achieve higher quality seed yields (Munda et al., 1983).

It is a well established fact that plants utilise water soluble nutrients when it is fed through foliage and utilize for better yield and quality in many crops. Foliar application of nutrients and hormones had increased the yield and quality of seeds in many Agricultural and Horticultural crops. According to yoshida et al. (1970) soil or foliar application of Zinc sulphate was as effective as dipping the seedlings before planting in a Zinc oxide suspension for correcting Zn deficiency and Zn has a stimulatory effect on growth and activity of nitrogen fixing organisms (Mishusting and Shilnikova, 1973).

Forno et al. (1975) studied the varietal response to supplemental application of Zn and noticed variation in seed yield of rice varieties.

Foliar application of N and P in the form of diammonium phosphate (DAP) was recommended by Ramachandran et al., (1980) for the improvement of yield in rice.

Venkataswamy and Iruthiyaraj (1980) reported increased yield of seed cotton through foliar spray of DAP.

Application of Zinc plays a role in nucleic acid and protein synthesis and aids in the utilization of phosphorus and nitrogen and increases panicle length and seed formation (Gill and Singh, 1978), while the application of boron helps in lignin and protein synthesis and cell division (Takkar and Randhawa, 1978) in rice.

Zinc had a marked effect in increasing yield of rice by promoting its growth, increasing the number tillers, panicles and well filled seeds and preventing early withering (Dong et al., 1982).

Nandhisa and Mahadevappa (1984) observed positive correlation between 1000 seed weight and seed protein content and an increased seed protein content with increasing levels of nutrition.

Xiong (1987) reported that the spraying of 0.8 to 1.2 ppm boron induces earlier heading in rice by 1 to 5 days, increased pollen fertility from 12.2 to 17.3 per cent 1000 seed weight.

Foliar spray with boron and Zinc increased the total number of pod and seed yield plant⁻¹ over no spray (control) but cytozyme, molybdenum and DAP increased the number of pods plant⁻¹ over both water spray and no spray in soyabean. Cytozyme and DAP were found effective in improving root length too (Sabirahamed, 1989).

Sankarreddi et al. (1983) reported that cytozyme application to soil, seed and the crop had neither favourable nor detrimental effect on yield of rice, groundnut and green gram. However, cytozyme components were claimed to improve seed germination and field emergence and utilization of nutrients in the plant, increased resistance to pest and diseases and thereby increased crop yields (Anonymous, 1980) and hence, yield and quality of various seed crops (Pandita et al., 1983 and Hooda et al., 1985).

According to Sharma (1986) spraying of cytozyme to soyabean plant at four leaf and pre flowering stages in field trial during 1984 and 1985 recorded the highest yield of 11.95 q ha⁻¹ and the magnitude of increase was 6.54 per cent over control. This was mainly attributed to increased number of pods plant⁻¹.

Sabirahamed (1989) reported the influence of foliar spray of cytozyme (1.25 per cent) on pod weight, seed yield, seed weight and germination of soyabean compared to no spray (control) and water spray.

Cytozyme at 0.25 per cent did not significantly influence plant height, productive tillers, number of filled seeds, seed weight and yield in rice (Yasin and Carpuz, 1989).

Ramamoorthy et al. (1990) reported the influence of growth regulators (Cytozyme and Triaccontanol) on rice in reducing the sterility percentage, increasing the 1000-seed weight, seed yield and maintenance of viability and vigour under storage.

2.6. Effect of natural and artificial ageing on viability and vigour of seed in storage.

Maintenance of seed vigour and viability in terms of germination from harvest until planting is important in a seed production programme. Care should be taken at all levels of production, processing and distribution to maintain viability and vigour of the seed.

Most of the orthodox seeds can be stored for several years with minimum loss to viability. However, the

potential storage life of seeds within a given species or variety differs perhaps due to both intrinsic and extrinsic factors. Eventhough the causes for differences in storage life of the same variety are not fully understood, several factors viz., the status (Physical and Physiological) of the seed at the time of storage, the seed moisture, storage temperature and relative humidity; seed mycoflora; the packaging material and seed treatment are reasonably responsible. Besides, the biochemical and physiological changes that occur within seed are also responsible to the loss of viability and vigour potential. In this review attempts have been made to summarise some of the recent developments which have been made on physiological and biochemical changes in respect of the seed deterioration and their relationship to seed senescence and vigour. The various mechanisms involved in the loss of viability and vigour during natrual ageing and/or artifical ageing particularly, in rice have been reviewed hereunder.

The major tropical and subtropical seeds have been classified as good, intermediate and poor storers under ambient conditions of warm humid places. According to this classification, rice seeds are classified as good storer; sunflower as poor storer and maize and cotton as intermediate storers (Delouche et al., 1973).

On the basis of duration of life of seeds under optimal conditions, Ewart (1908) divided the seeds into three biological classes viz., (i) Microbiotic (life span not exceeding three years) (ii) Mesobiotic (life span of three to fifteen years) and (iii) Macrobiotic (life span of fifteen to hundred years). The seeds of many agricultural crops including rice come under the microbiotic group. This classification is obviously dependent upon the knowledge of the optimal conditions of storage for each kind of seed.

Once the seeds reach physiological maturity they undergo irreversible degenerative changes which reduced their survival capacity. The combined effects of this irreversible degenerative changes are known as deterioration or conditions most probably influencing the deterioration, thus an understanding of the mechanisms which control the rate of deterioration might provide ways for curbing deterioration and senescence and could thereby extend the life of the seed.

2.6.1. Physiological changes during seed deterioration.

As seeds age, they maintain germinability for some time and subsequently enter a period of decline during which some seeds completely fail to germinate; while others germinate and grow normally. Kearns and Toole (1939) reported differences in viability among the seeds of same age to heterogeneity of individual seeds within a seed lot.

Among the many physiological manifestations of seed deterioration, the changes in seed colour, delayed germination, decreased tolerance to stress conditions, higher sensitivity to radiation treatments, reduced growth of seedlings, reduced germinability and increased number of abnormal seedlings account for the degenerative changes. Of these responses, reduced germinability has been the most widely accepted single criterion of seed deterioration. All these indications may or may not appear in a single sample of seed and some of them are specific to the mother crop conditions viz; environmental factors, crop management aspects, genotypic variation and species (Toole et al., 1948).

Delay in the full expression of germination of seed is usually the earliest detectable physiological sign of quality loss in the aged seeds (Parkinson, 1948).

Changes in seed colour occur during deterioration. Seeds that are damaged by heat (Zeleny, 1954) or by fungi (Christensen and Kaufmann, 1969), due to changes in climatic conditions during seed maturation or delayed harvest seed lose their natural lusture. In snap beans (Toole et al., 1948), alfalfa and cloves (West and Harris, 1963) and lima beans (Wester, 1970) seeds with off colour had low germinability both under laboratory and field conditions.

Sircar and Biswas (1960) reported that the loss of viability of rice cv. Rupsail seeds within one year. They attributed this to the accumulation of toxic metabolites which inhibit the germination.

Several storage experiments on rice seeds with different cultivars under different storage conditions revealed that the reduction in the germination and seedling vigour was certain but the rate and extent of reduction varied with the cultivars, production and storage conditions and other factors like seed moisture and status of the seed at the time of storage (Dharmalingam, 1978; Agrawal, 1980; Tomar and Singh 1986).

Varietal differences in the seed viability period of rice seeds during storage under different conditions have been reported by several workers (Vijayalakshmi, 1987; Sikder, 1988; Murugesan et al., 1989; Juliano et al., 1990).

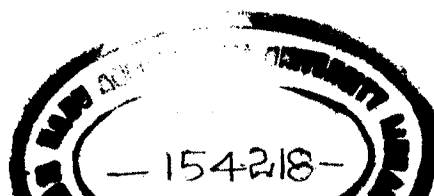
Murugesan et al., (1989) observed higher values for coleoptile length, seedling length, vigour index and dry matter production in medium bold seeds than long slender. Variability in germination and dehydrogenase activity was considerably higher in long slender genotypes than the medium bold genotypes. Higher dehydrogenase activity indicated the potential vigour of stored seeds of medium bold genotypes. Similarly Verma et al., (1990)

evaluated twenty genotypes for seedling vigour and reported positive correlation of germination percentage with that of root length and vigour index.

Seed germination rate and its associated characteristics of rice have been studied by Krishnasamy and Seshu (1989). The path analysis suggested that 100 seed weight acted through a high indirect effect of free amino acid content on germination rate. Further, they also observed, the cultivar differences for germination rate following ageing and under low temperature (20 and 15°C) and moisture (-5 bar., PEG 8000) stresses.

Ray et al., (1990) studied the mechanism of seed deterioration in early (photo-insensitive) and late maturing (photo sensitive) cultivars of rice viz; 'Jaya' and 'Pankaj', respectively under accelerated ageing at 100% RH and 40°C temperature and observed rapid loss of viability in low vigour seeds under accelerated ageing compared to high vigour seeds.

Younis et al., (1990) from their studies on accelerated ageing to predict varietal differences in seed vigour and viability in three rice cultivars reported rapid decline in germinability and seedling growth in Amber 33 compared to Hybrid 2.



Sharma et al., (1990) observed genetic variability among rice varieties and noted long roots with high fresh weight of shoot and higher vigour index in bold seeded varieties. ✓

Shenoy et al., (1990) reported that the various laboratory parameters viz., germination, germination rate and germination under low temperature (15°C) and water stresses (-0.772 MPS using PEG-8000) showed non linear association with field emergence, whereas the amylase activity and germination in nonanoic acid (0.028 g/l) exhibited linear association.

Seshu et al., (1990) reviewed various biometrical parameters in relation to seed vigour in rice and reiterated that seed vigour is recognised as an important seed quality parameter distinct from germinability. They also observed greater tolerance of the dormant seeds for deterioration and significant yield reduction due to poor vigour.

Seshu and Dadlani (1990) observed variable impact of vigour on seed crop performance in different species. In rice, a number of agronomic traits, eco-geographic adaptations, including yield is reported to be significantly affected by seed vigour.

The initial seed quality and storage potential of rice significantly influenced by the plant density and mother crop condition at growth stages. (The storage life of rice seeds had close association with seed borne fungi *Helminthosporium oryzae* and it caused discolouration of seeds with characteristic black streaks on the glume as concluded by Jerlin (1990).) ✓

Ramegowda (1992) reported that the use of aged seed caused rapid decline in germination, root and shoot length, seedling dry matter, vigour index, rate of field emergence. He also observed positive association of field emergence potential of deteriorated seeds with physiological attributes and the chemical constituents of the aged seeds.

2.6.2. Biochemical changes during seed deterioration.

(Seed storage begins immediately after maturity regardless of where or how seeds are held.) During seed development, anabolic processes predominate and bring about a gradual increase in dry matter, including development of embryo and food reserves. Following maturation, biochemical changes continue eventually, catabolic processes predominate and deterioration becomes apparent. Catabolic changes occur more slowly under low temperature and low relative humidity than under high temperature and high relative humidity conditions (Ramegowda, 1992).

Much work has been done on biochemical changes viz., respiratory changes, changes in enzyme activity, food reserves, membrane changes and accumulation of toxic substances associated with seed deterioration (Anderson, 1973, Ray and Gupta, 1979; Ghosh et al., 1981; Krishnasamy and Seshu, 1989; 1990; Ray et al., 1990; Younis et al., 1990; Ramegowda, 1992), to our knowledge on biochemical deterioration of seeds and their relation with seed production conditions and initial vigour is still inconclusive. Hence, an attempt has been made to correlate some of such factors with the differentially deteriorated seeds from storage produced under various mother crop conditions. Various biochemical changes associated with seed senescence have been reviewed here under.

Respiratory metabolism results in the oxidation of food reserves, production of a large number of intermediates which serve as building blocks for synthesis of protoplasmic components like proteins, nucleic acids and lipids and production of biochemical energy in the form of adenosine triphosphate for these reactions.

Seeds of many species have been used to study changes in respiration induced by natural ageing (Mirta et al., 1974; Krishnasamy and Seshu, 1989), accelerated ageing (Abdul-Baki, 1969; Ramegowda, 1992). In most cases, germination and growth tests were made on seeds from the

same seed lot in an attempt to correlate respiratory to physiological changes. However, Sircar, (1970) and Mirta et al., (1974) have studied this phenomenon in the differentially aged seed lots and observed significant decline in the respiration rates and a positive association with germinability of rice seeds.

Jones et al., (1942) investigated changes in proteins of wheat seeds stored for 24 months under conditions which induced direct levels of deterioration. They observed major changes in proteins of deteriorated seeds and increase in aminoacids which resulted from protein degradation. Likewise, Ray and Gupta (1979 a) and Ramegowda (1992) in Rice; Basavarajappa et al., (1991) in corn reported reduction in seed proteins with concomitant increase in aminoacids of deteriorated seeds.

Similarly, reduction in the number of essential aminoacids (Mirta et al., 1974), negative association of aminoacids with germinability (Krishnasamy and Seshu, 1989) and (significant increase in the free aminoacids (Ghosh et al., 1981; Younis et al., 1990; Ramegowda, 1992 in rice; Basavarajappa et al., 1991 in corn) with seed ageing have been reported.) ✓

Krishnasamy and Seshu (1990), Shenoy et al., (1990), Younis et al., (1990) and Ramegowda (1992) in rice; Mukhtar and Laidman (1982) in wheat; Saxena et al., (1985) in sesamum; Ramamoorthy and Karivaratharaju (1989) in tomato and other workers have proved that membrane deterioration is the first stage of ageing or senescence.

Roberts (1973) observed the initial seed deterioration during ageing reduced the enzyme activity, respiration and synthesis of macro molecules. He also reported changes in enzyme activity of various seed lots to accompany the seed deterioration which precedes loss of viability.

Ramegowda (1992) observed rapid decrease in protein content, phosphorus fraction levels, alpha amylase, total dehydrogenase, peroxidase, total nucleic acids and RNA content and increase in electrical conductivity, total soluble sugars, free aminoacids, melanodehyde (MDH) a product of lipid peroxidation and acid soluble-P during ageing and these are related to loss of germinability and seedling vigour of rice seeds.

2.7. Evolution of volatile compounds by seeds and Bioassay of seed vigour

Moisture and temperature have been regarded as the most important factors that cause deterioration of seeds during storage (Priestley, 1986). Therefore, hermetically sealed storage of seeds under low temperature has generally been adopted for prolonging their longevities against moisture and temperature fluctuations occurring in the natural environment. However, seed deterioration has been an inexorable process and has taken place even under the sealed storage of dry seeds at subzero temperatures. The underlying mechanism of inevitable seed deterioration remains obscure. Thus, the best strategy for seed storage to ensure the maximum longevity of seeds is not known. However, it has been noted that some kinds of seeds produced during same period which were enclosed within small aluminium foil bags lost their vigour more quickly at retail shops than those were in bulk. This suggests the involvement of volatile compounds evolved by seeds themselves in the deterioration process (Zhang et al., 1993).

One of the more popular theories has been that loss of viability is due to the accumulation of various substances to toxic levels.

D'Amato and Hoffman-Ostenhof (1956) reviewed a great deal of literature which purported to show that automutagenic substances may accumulate in seeds and may cause loss of viability.

The freshly ground cocoa beans contain various volatile compounds such as isovaleraldehyde, isobutyraldehyde, propionaldehyde, methanol, acetaldehyde, methylacetate and diacetyl and this indicates that dry cocobean seeds may contain various volatile compounds (Bailey, et al., 1962).

West and Harris (1963) evaluated the aqueous extracts of off-colour deteriorated colve seeds and reported the acidic nature of the extract compared to the extract of normal seeds. The extracts of deteriorated seeds contained certain compounds which absorbed light in ultraviolet range. The extract of off-colour seeds also slowed down the germination rate compared to normal seeds.

Bengtsson and Bolund (1964) observed the existence of acetaldehyde, ethanol and hexanal in the form of volatiles from pea seeds obtained by heating to 100°C in water and keeping there for 1 min. In addition Pattee et al., (1969) indentified Pentane, acetaldehyde, methylformate, octane, 2-butanone, acetone, methanol, ethanol, pentanal and hexanal as the volatile components of a slurry raw peanut seeds.

Honing and Rackis (1975) reported that the yields of volatile components in the aqueous slurries of soyabean seeds decreases rapidly from the maturation stage, suggesting that the contents of volatile compounds in seeds would be extremely low when they were completely matured and ripened.

Taylorson (1979) reported the release of volatiles, such as methanol, acetone and ethanol from dry grass seeds during accelerated ageing after ripening by heating at 50°C. These facts imply that even matured dry seeds may contain various volatile compounds and release them during storage.

Rice provides a good example in which most of the potentially toxic compounds which have been investigated were claimed to be responsible at various times for loss of viability, eg. indole acetic acid (IAA) and various other indole derivatives (Sircar and Dey, 1967).

Zhang et al., (1993) reported that accumulation and emanations of volatile compounds in dry seeds of rice as well as the seeds at subzero temperatures.

Fielding and Goldsworthy (1982), has suggested a possible relationship between the content of volatiles and the vigour of seeds. He has also reported that the amounts of thermally-derived volatiles from dry wheat seeds in N₂

gas may give a very sensitive indication of their potential vigour.

The amounts of thermally-derived volatile aldehydes, such as butanal, pentanal and hexanal, released from dry soyabean seeds are significantly correlated with their vigour as reported by Hailstones and Smith (1989).

Wilson and Mc Donald (1986) reported the involvement of volatile compounds evolved from seeds at their deterioration as well as decline/its changes of vigour status of seeds during storage/senescence.

Delouche and Baskin (1973) emphasised that the methods of quantification of the basic causes for seed deterioration should form the most sensitive vigour tests.

Basu et al. (1990) evolved a new and inexpensive seed vigour bioassay method based on the basic principle of exposure of a sensitive test material (Harvest-fresh high-vigour jute seeds) to the gaseous emanations of germinating stock seeds of (wheat) different vigour levels.

Volatile aldehydes constitute as important component of the gaseous emanations (Harman et al., 1982).

Wilson and Mc Donald (1986) reported that the volatile gases produced by the germinating wheat seeds are most likely the products of lipid peroxidation.

Existence of vigour in natural or artificially aged seeds remains the same (Basu et al., 1990). They also indicated that besides the volatile aldehydes (product of lipid peroxidation) the other growth inhibiting substances from germinating medium-vigour wheat seeds were responsible for the reduction in growth of jute seedlings.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

With a view to realise the objectives, enumerated earlier, the following field experiments were carried out during Kharif 1992 and Rabi 1993 seasons at Agricultural Research Station(ARS), Tamil Nadu Agricultural University, Bhavanisagar with short (IR 50) and medium duration (ADT 38 and CO 43) rice cultivars and was repeated during Kharif 1994. The weather conditions prevailed during the cropping periods are furnished in Annexure I.

3.1. MATERIALS

The seeds of three rice cultivars IR 50, ADT 38 and CO 43 obtained from the Breeder seed increase scheme, Agricultural Research Station, Bhavanisagar formed the materials for the study. The characteristic features of the cultivars are given in Annexure II.

The seeds were first dried to a moisture content around 12 per cent and then graded by adopting "Salt floatation technique".

In a 20 litre capacity plastic bucket 15 litres of 20 per cent sodium chloride solution of 1.08 specific gravity was taken and in this the seeds of each cultivar were poured

separately, stirred thoroughly and allowed to settle down. The sinkers which are the denser fraction of seeds settled down at the bottom of the bucket were collected after draining the salt solution and utilised for raising the nursery. The lighter fraction constituting the 'Floaters' was rejected.

Seedlings of IR 50 and ADT 38 were raised in one cent nursery in required numbers. The healthy and vigour^{ous} seedlings of IR 50 and ADT 38 were alone pulled on 25 and 30 days after sowing, respectively were used for transplanting in the main field. The recommended agronomic and plant protection measures were adopted for all the experiments.

The seeds were harvested at physiological maturity and observations were made in five plants selected at random in each treatment for all the experiments studied.

3.2 METHODS

Experiment I: Season of production and plant density on seed yield and quality and storage potential of the resultant seeds.

Field trials were laid out in the Agricultural Research Station, TNAU, Bhavanisagar during Kharif 1992 and Rabi 1993 and Kharif 1994 (Plate 1).

PLATE 1. GENERAL VIEW OF EXPERIMENTAL FIELD



The experimental details are furnished below.

Experimental design : Randomised Block design

Replication : Four

Treatmental details

Spacings (cm)	Plant population ha^{-1}	Abbreviations
10 x 10	10,00,000	D ₁
12.5 x 10	8,00,000	D ₂
15 x 10	6,66,666	D ₃
20 x 10	5,00,000	D ₄
15 x 15	4,44,444	D ₅

Seasons

Kharif	1992	SI
Rabi	1993	SII
Kharif	1994	SIII

Plot size : 4.0 x 4.0 m

Manures and manuring

100 : 50 : 50 kg ha^{-1} of N, P and K. Nitrogen was applied in the form of urea in three splits viz., 50 per cent basal, 25 per cent each at active tillering and panicle initiation stages. Entire phosphorus and potash were applied basally in the form of superphosphate and muriate of potash, respectively at the time of last ploughing. The seeds were harvested at physiological maturity and the

following field and laboratory observations / estimations were recorded.

3.2.1. FIELD OBSERVATIONS

3.2.1.1. Days to initiation of flowering

The day on which the first spikelets in the panicle of the population came to flowering was recorded as days to first flowering.

The following observations were recorded in five plants selected at random in each treatment for item 3.2.1.2 to 3.2.1.11 and the mean worked out and recorded.

3.2.1.2. Number of tillers

Total number of tillers hill⁻¹ at maturity were counted and recorded as whole number.

3.2.1.3. Number of productive tillers

Productive tillers hill⁻¹ in number at maturity were counted and recorded as whole number.

3.2.1.4. length of Panicle

Length of panicle without peduncle was measured from the culm base to tip of the panicle after harvest and expressed in cm.

3.2.1.5. weight of Panicle

Weight of panicle was recorded after harvest using electronic balance and expressed in g.

3.2.1.6. Days to maturity

The number of days required for the plant population to attain physiological maturity after sowing was recorded based on the physical appearance of seed colour.

3.2.1.7. Number of good seeds

Individual earheads were threshed manually. The good seeds panicle⁻¹ were separated from the bulk, counted and recorded in whole number.

3.2.1.8. Awned seeded earhead percentage

The earheads of each treatment were separately observed for the occurrence of awns in the seed at the time

of physiological maturity and the mean percentage was computed based on the total earheads.

3.2.1.9. Seed yield

The panicles harvested from each treatmental plots were threshed separately, cleaned free of chaff and inert matter, dried and then weighed. The seed yield of the plots were computed to hectare and expressed in kg ha⁻¹.

3.2.1.10. Seed Recovery percentage

The harvested seeds from individual treatment after cleaning were graded using 14/64" x 3/4" oblong sieve. The percentage of recovery was calculated by using the following formula:

$$\text{Seed recovery \%} = \frac{\text{Weight of seeds retained in } 14/64" \times 3/4" \text{ sieve}}{\text{Weight of total seed}}$$

With the graded seed the following determinations were made.

3.2.1.11. 1000 seed weight

The 1000 seed weight in respect to each treatment was determined by recording the mean weight of eight samples and expressed in g. (Anon, 1985).

3.3.1. MEASURE OF VIABILITY AND VIGOUR

3.3.1.1. Speed of germination

Seedling emergence from the seeds sown in the sand bench were recorded daily from 3rd day of sowing until complete germination. The mean rate of emergence was worked out by the following formula (Heydecker, 1962).

$$SG = \frac{x_1}{y_1} + \frac{x_2}{y_2} + \dots + \frac{x_n}{y_n}$$

Where, SG : Speed of germination,

$x_1 + x_2 + \dots + x_n$: daily germination count and

$y_1 + y_2 + \dots + y_n$: Corresponding day of germination

3.3.1.2. Germination

Germination test was conducted using roll towel medium (Anon, 1985). A total number of 4 x 100 seeds were taken at random from each treatment and placed in paper roll towel medium and allowed to germinate at $25 \pm 2^\circ\text{C}$ and 90 ± 2 per

cent relative humidity. After 14 days, the seedlings were evaluated and the normal seedlings produced were counted and expressed as germination percentage.

3.3.1.3. Root length

At the end of the germination test, ten normal seedlings from each replication were carefully removed at random and length of root was measured from the crown base to the tip of the primary root and the mean value was calculated and expressed in cm.

3.3.1.4. Vigour Index

The vigour indices were computed as whole number by adopting the following formula (Abdul - Baki and Anderson, 1973).

Vigour Index = Germination(%) x Mean root length of seedlings.

3.3.1.5. Dry matter production

The seedlings used for growth measurements from each replication were air dried first and then in a hot air oven maintained at $85^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for 24 h and cooled in a desiccator for 45 minutes and the mean dry weight of the seedlings was expressed in mg seedling⁻¹.

3.4.1. BIOCHEMICAL STUDIES

3.4.1.1. Seed leachate tests

Fifty seeds taken at random were sterilized with 0.05 per cent $HgCl_2$ for 5 min and then washed thoroughly with distilled water. After removal of surface water the seeds were soaked in 50 ml of distilled water for 16 hours at $30 \pm 1^\circ C$ and decanted. The leachate thus obtained was used for the following tests.

3.4.1.1.1. Electrical Conductivity (EC) (Presley, 1958)

The EC of seed steep water was measured in an Elico type CM-82 conductivity bridge with a cell constant of 1.0. The readings were taken in duplicate and the mean value expressed in dSm^{-1} .

3.4.1.1.2. Sugar Content (Somogyi, 1952)

To one ml of the seed leachate, one ml. of copper reagent was added in a test tube and boiled for 15 min. After cooling in running water one ml. of Nelson's arsenomolybdate reagent was added and volume made upto 10 ml with distilled water. The colour complex developed was measured with an ERMA photoelectric colorimeter (Model AE - 11) using

red filter (620 nm). The OD values were referred to a glucose standard curve and expressed in $\mu\text{g } 50 \text{ seeds}^{-1}$ 50 ml^{-1} of distilled water.

3.4.1.1.3. Free Aminoacids (Ching and Ching, 1964)

One ml of 0.2 per cent ninhydrin was added to one ml of seed leachate and boiled for 15 min. in boiling water bath. Then it was cooled in running water and diluted to 10 ml. The intensity of colour developed was read against a leucine standard in ERMA photo-electric colorimeter (Model AE - 11) and expressed in $\mu\text{g. } 50 \text{ seeds}^{-1}$ 50 ml^{-1} of distilled water.

3.4.1.2. Protein Content (Ali - Khan and youngs, 1973)

One hundred mg of ground meal was taken in a 50 ml ployethylene screw-cap bottle and 25 ml of 1 N sodium hydroxide was added. The mixture was shaken for 30 min. at a wrist action shaker to disperse the protein. Then 10 ml of the suspension was poured into a graduated test tube and used as a blank to compensate for the differences in the amount of natural pigments extracted. To the remaining suspension in the bottle, 0.25 ml of 10 per cent copper sulphate solution was added and the bottle was reshaken for 5 min., to develop the colour complex. The sample solution was then poured into a separate test tube and along with its

blank left overnight to allow the dispersed material to settle down. After centrifugation for 10 min. the optical density (O.D.) of the clear supernatant solution was measured in an ERMA photoelectric colorimeter (Model AE.11) using a red filter (620 nm) with suitable blank. From the mean O.D. value, the protein percentage for each treatment was calculated as follows;

$$\text{Protein \%} = 3.78 + (61.6 \times \text{O.D. value})$$

3.4.1.3. Alpha-amylase Activity (Simpson and Naylor, 1962)

Two grams of agar shreds and one gram of potato starch were mixed together in water to form a paste and the volume made upto 100 ml. The homogenous solution of agar starch mixture after boiling was poured into sterilised petridishes and allowed to settle in the form of a gel after cooling.

The pre-soaked (8 h) and half cut paddy seeds (with their half endosperm and embryo portion intact) were placed in the petridishes in such a way that the endospermic part remained in contact with agar-starch gel. The dishes were closed and kept in dark at 30°C. After 24 h, the dishes were uniformly poured with potassium iodide solution (0.44 g iodine crystal + 20.008 g potassium iodide in 500 ml. distilled water) and excess solution was drained off after few minutes. The diameter of halo (clear) zone formed around the seed was measured in mm and reported as alpha

amylase activity. The vigorous seeds formed large halo zone than seeds possessing low vigour.

3.5.1.1. STORAGE POTENTIAL OF RESULTANT SEED

Bulk seeds obtained from population dynamics experiment conducted during Kharif 1992 and Rabi 1993 were cleaned, graded and dried to a moisture content of around 12.0 per cent. Then, the seeds were treated with thiram 75 per cent WDP at 4 g kg⁻¹ of seed and packed in cloth bag and stored under ambient conditions of temperature and relative humidity. The following seed quality determinations were made initially (P₀) and subsequently once in three months over a period of 15 months (P₃, P₆, P₉, P₁₂ and P₁₅) as detailed in 3.3.1.

- 3.5.1.1.1. Speed of germination
- 3.5.1.1.2. Germination
- 3.5.1.1.3. Root length
- 3.5.1.1.4. Vigour index
- 3.5.1.1.5. Dry matter production

The following biochemical studies were also made as detailed in 3.4.1.

- 3.5.1.1.6. Electrical conductivity
- 3.5.1.1.7. Sugar content
- 3.5.1.1.8. Free aminoacids

3.5.1.1.9. Protein content

3.5.1.1.10. Alpha-amylase activity

3.5.1.1.11. Seed health test (Anon, 1985)

A total number of 4 x 100 seeds were taken at random from each treatment and placed in sterilised petridishes each provided with three layers of moistened filter paper and incubated in near ultraviolet lamp for 7 days. After the incubation period, the fungal colonies were observed under the stereomicroscope and the number of seeds affected by *Helminthosporium oryzae* fungi was counted and expressed in percentage.

3.5.1.2. ACCELERATED AGEING TEST (Woodstock and Feeley, 1965)

The seeds obtained from population dynamics experiment conducted during Kharif, 1994 alone were subjected to accelerated ageing test after their initial evaluation at $40 \pm 1^{\circ}\text{C}$ temperature and 98 ± 2 per cent Relative Humidity for 12 days and the following observations were made with the aged seeds as detailed in 3.3.1 and 3.4.1.

3.5.1.2.1. Speed of germination

3.5.1.2.2. Germination

3.5.1.2.3. Root length

3.5.1.2.4. Vigour index

- 3.5.1.2.5. Dry matter production
- 3.5.1.2.6. Electrical conductivity
- 3.5.1.2.7. Sugar content
- 3.5.1.2.8. Free aminoacids
- 3.5.1.2.9. Protein content
- 3.5.1.2.10. Alpha - amylase activity
- 3.5.1.2.11. Seed health test as detailed in 3.5.1.1.11.

Experiment. 2:

3.2.2. Age of seedling and nitrogen levels on seed yield and quality and storage potential of resultant seeds.

A field trial with the rice cultivars IR50 and ADT 38 was conducted during Kharif 1992. The experimental details are furnished below.

Design : Factorial Randomised Block design
Replication : Three
Treatmental details

Seedling age	Abbreviations
20 days	A ₁
30 days	A ₂
40 days	A ₃
50 days	A ₄
60 days	A ₅

Nitrogen levels

Control (Recommended dose)	N ₁
25 kg ha ⁻¹ in addition to control	N ₂
50 kg ha ⁻¹ in addition to control	N ₃
75 kg ha ⁻¹ in addition to control	N ₄

Plot size : 5 x 4 m
 Spacing : 15 x 10 cm for IR50
 20 x 10 cm for ADT 38

The seeds were harvested at physiological maturity and the following field and laboratory evaluations were made.

Field observations as detailed in 3.2.1 and 3.3.1..

- 3.2.2.1. Days to initiation of flowering
- 3.2.2.2. Number of tillers hill⁻¹
- 3.2.2.3. Number productive tillers hill⁻¹
- 3.2.2.4. Length of panicle
- 3.2.2.5. Weight of panicle
- 3.2.2.6. Days of maturity
- 3.2.2.7. Number of good seeds panicle⁻¹
- 3.2.2.8. Awned seeded earhead percentage
- 3.2.2.9. Seed yield
- 3.2.2.10. Seed recovery percentage
- 3.2.2.11. 1000 seed weight

- 3.2.2.12. Speed of germination
- 3.2.2.13. Germination
- 3.2.2.14. Root length
- 3.2.2.15. Vigour index
- 3.2.2.16. Dry matter production

BIOCHEMICAL STUDIES as detailed in 3.4.1.

- 3.2.2.17. Electrical conductivity
- 3.2.2.18. Sugar content
- 3.2.2.19. Free aminoacids
- 3.2.2.20. Protein content
- 3.2.2.21. Alpha-amylase activity
- 3.2.2.22. Seed health test as detailed in 3.5.1.1.11.

**3.2.2.b. ACCELERATED AGEING TEST (Woodstock and Feeley,
1965)**

For assessing the storage potential, accelerated ageing test was adopted. The following quality evaluations were made as detailed in 3.5.1.2.

- 3.2.2b.1. Speed of germination
- 3.2.2b.2. Germination
- 3.2.2b.3. Root length
- 3.2.2b.4. Vigour index
- 3.2.2b.5. Dry matter production

- 3.2.2b.6. Electrical conductivity
- 3.2.2b.7. Sugar content
- 3.2.2b.8. Free aminoacids
- 3.2.2b.9. Protein content
- 3.2.2b.10. Alpha-amylase activity
- 3.2.2b.11. Seed health test as detailed in 3.5.1.1.11.

Experiment 3:

3.2.3. Seed hardening treatments on yield and quality and storage potential of direct seeded rice.

The bulk seeds of the cultivars IR 50 and ADT 38 were cleaned and graded as detailed in 3.1 and dried to a moisture content of 12 per cent. The seeds were then divided into four equal portions in each cultivar and subjected to the following seed hardening treatments before sowing. The seed to water ratio adopted was 1:1.

Hardening treatments	Abbreviations
Dry seed (control)	T ₀
Water soaking	T ₁
Potassium chloride (kcl) - 1.0%	T ₂
Potassium di-hydrogen	
Phosphate (KH ₂ Po ₄) - 0.5 per cent	T ₃

The seeds were first soaked in water for 10 h and then soaked in the aforesaid chemical solutions for 12 h. After

soaking, the seeds were dried initially under shade and subsequently during the early hours of the day to bring down to its original moisture content.

With the hardened seeds a direct seeded field experiment was conducted during Kharif 1992 season using factorial randomised block design with five replications. The plot size adopted was 5 x 4 m. The hardened seeds after treating with thiram 4 g kg⁻¹ were broadcasted at the rate of 100 kg ha⁻¹ and after 10 days of seeding thinning was done to maintain uniform plant density. All the other recommended agronomic and plant protection measures were adopted throughout the crop period.

The following field (3.2.3.) and laboratory (3.2.3b) observations were recorded.

3.2.3.1. Days to initial emergence

The number of days taken from sowing to commence emergence was recorded.

3.2.3.2. Field emergence percentage

The emergence of seedlings on 15th day of sowing was counted and the percentage of emergence was calculated based on the total number of seeds sown and recorded.

The following field observations were also recorded as detailed in 3.2.1.

- 3.2.3.3. Days to initiation of flowering
- 3.2.3.4. Number of tillers hill⁻¹
- 3.2.3.5. Number of productive tillers hill⁻¹
- 3.2.3.6. Length of panicle
- 3.2.3.7. Weight of panicle
- 3.2.3.8. Days to maturity
- 3.2.3.9. Number of good seeds panicle⁻¹
- 3.2.3.10. Awned seeded earhead percentage
- 3.2.3.11. Seed yield
- 3.2.3.12. Seed recovery percentage
- 3.2.3.13. 1000 seed weight

The seeds harvested from each treatment were cleaned, dried and graded. Then the seeds were stored under ambient storage conditions, in fresh gada cloth bags after treating with thiram at 4 g kg⁻¹ of seed.

Before storing and subsequently at trimonthly intervals upto fifteen months, samples were drawn and the following quality evaluations were made as detailed in 3.3.1. and 3.4.1.

- 3.2.3b.1. Speed of germination
- 3.2.3b.2. Germination

- 3.2.3b.3. Root length
- 3.2.3b.4. Vigour index
- 3.2.3b.5. Dry matter production
- 3.2.3b.6. Electrical conductivity
- 3.2.3b.7. Sugar content
- 3.2.3b.8. Free aminoacids
- 3.2.3b.9. Protein content
- 3.2.3b.10. Alpha-amylase activity
- 3.2.3b.11. Seed health test as detailed in 3.5.1.1.11.

Experiment 4:

3.2.4. Levels of gypsum application in sodic soils on seed yield and quality and storage potential of resultant seed

An experiment was conducted with rice cultivars IR 50 and ADT 38 during Rabi 1993 under sodic sandy clay loam soil of Typic Natru Stalf. The initial soil characteristics are given in Annexure III.

The experimental details are furnished below.

Design : Factorial Randomised Block design

Replications : Five

Treatments (On the basis of gypsum requirement)

Gypsum application

Abbreviations

Control (No amendment)

T₀

1200 kg ha⁻¹

T₁

2400 kg ha ⁻¹		T ₂
3600 kg ha ⁻¹		T ₃
Plot size	:	4 x 4 m

The entire quantity of gypsum was applied along with FYM @ 10 t ha⁻¹ in one dose 10 days before transplanting.

The following field (3.2.4) and laboratory (3.2.4 b) observations were recorded.

3.2.4.1. Plant density m⁻²

The number of seedlings established per m² after 15 days of transplanting was observed and recorded.

The following field observations were recorded as detailed in 3.2.1.

- 3.2.4.2. Days to initiation of flowering
- 3.2.4.3. Number of tillers hill⁻¹
- 3.2.4.4. Number of productive tiller hill⁻¹
- 3.2.4.5. Length of panicle
- 3.2.4.6. Weight of panicle
- 3.2.4.7. Days to maturity
- 3.2.4.8. Number of good seeds panicle⁻¹
- 3.2.4.9. Awned seeded earhead percentage
- 3.2.4.10. Seed yield

3.2.4.11. Seed recovery percentage

3.2.4.12. 1000 seed weight

The seeds obtained from each treatment were dried to safe moisture content (12.0 per cent). Then the seeds were treated with thiram 4 g kg⁻¹ and stored in cloth bags under ambient conditions. The following observations were recorded initially and at trimonthly intervals upto fifteen months as detailed in 3.3.1. and 3.4.1.

3.2.4b.1. Speed of germination

3.2.4b.2. Germination

3.2.4b.3. Root length

3.2.4b.4. Vigour index

3.2.4b.5. Dry matter production

3.2.4b.6. Electrical conductivity

3.2.4b.7. Sugar content

3.2.4b.8. Free aminoacids

3.2.4b.9. Protein content

3.2.4b.10. Alpha-amylase activity

3.2.4b.11. Seed health test as detailed in 3.5.1.1.11.

Experiment 5:

3.2.5. Green manuring and gypsum application in sodic soils on the seed yield and quality and storage potential of resultant seed

A field trial was laid out during Rabi 1993 with rice

cv.Co 43 in the sodic sandy clay loam soil type of Typic Natru Stalf. The soil characteristics are given in Annexure IV. The experimental details are furnished below.

Design : Factorial Randomised Block design.

Replication : Four

Treatments	Abbreviations
Control (No amendment)	F ₀
Green manure - (Sesbania aculeata) @ 10 t ha ⁻¹	F ₁
Green manure (S. acculeata) @ 10 t ha ⁻¹ + gypsum @ 3.4 t ha ⁻¹ on the basis of gypsum requirement	F ₂
Green leaf manure (Pongamia glabra) @ 10 t ha ⁻¹	F ₃
Gypsum alone @ 3.4 t ha ⁻¹	F ₄
Green leaf manure (Pongamia glabra) @ 10 t ha ⁻¹ + gypsum @ 3.4 t ha ⁻¹	F ₅
plot size	: 4 x 4 m

The green manure crop, *Sesbania aculeata* (N 3.2%, P 0.44% and K 1.34% on dry weight basis) was cut on 45th day after sowing and incorporated into the soil. Moisture content of green manure crop was 70.4 per cent.

Pongamia glabra (N 2.82 %, P 0.25 %, K 0.18 %) was the green leaf manure (leaves and small twigs) used in the experiment. The green and green leaf manure materials were

collected, incorporated into the soil and allowed to decompose for a period of seven days. The gypsum was applied basally and then the 30 days old rice seedlings was transplanted.

The following field observations were recorded as detailed in 3.2.1.

- 3.2.5.1. Plant density / m² as detailed in 3.2.4.1.
- 3.2.5.2. Days to initiation of flowering
- 3.2.5.3. Number of tillers hill⁻¹
- 3.2.5.4. Number of productive tillers hill⁻¹
- 3.2.5.5. Length of panicle
- 3.2.5.6. Weight of panicle
- 3.2.5.7. Number of good seeds panicle⁻¹
- 3.2.5.8. Days to maturity
- 3.2.5.9. Awned seeded earhead percentage
- 3.2.5.10. Seed recovery percentage
- 3.2.5.11. 1000 seed weight

The resultant seeds from each treatment were dried, graded and treated with thiram at 4 g kg⁻¹ and stored in cloth bags under ambient conditions. Before storing and at trimonthly intervals the seed samples were drawn for the following quality estimations.

MEASURE OF VIABILITY AND VIGOUR as detailed in 3.3.1.

- 3.2.5b.1. Speed of germination
- 3.2.5b.2. Germination
- 3.2.5b.3. Root length
- 3.2.5b.4. Vigour index
- 3.2.5b.5. Dry matter production

BIOCHEMICAL STUDIES as detailed in 3.4.1.

- 3.2.5b.6. Electrical conductivity
- 3.2.5b.7. Sugar content
- 3.2.5b.8. Free aminoacids
- 3.2.5b.9. Protein content
- 3.2.5b.10. Alpha-amylase activity
- 3.2.5b.11. Seed health test as detailed in 3.5.1.1.11.

Experiment. 6:

3.2.6. Stages of harvest and foliar spray of nutrients on seed yield and quality

A field trial was laidout during Rabi season 1993 adopting factorial randomised block design set in four replications with cv. ADT 38. The details of the treatments are furnished below.

Foliar spray chemicals**Abbreviations**

Control (No spray)

F₀

Diammonium phophate 2.0 per cent at

50 per cent flowering	F ₁
Cytozyme 0.5 per cent at	
50 per cent flowering	F ₂
Water at physiological maturity	F ₃

Stages of Harvest

At physiological maturity	H ₁
3rd day after physiological maturity	H ₂
6th day after physiological maturity	H ₃
9th day after physiological maturity	H ₄
12th day after physiological maturity	H ₅
Plot size	: 5 x 4 m

Foliar spray was given in the evening hours.

The following observations were recorded from the twentyfive panicles selected at random in each treatment.

- 3.2.6.1. Length of panicle as detailed in 3.2.1.4.
- 3.2.6.2. Number of good seeds panicle⁻¹ as detailed in 3.2.1.7
- 3.2.6.3. Seed shattering percentage

Seed shattering percentage was worked out by following uniform fall method (Sahu and Sahu 1981).

- 3.2.6.5. Seed Recovery percentage as detailed in 3.2.1.10.
- 3.2.6.6. 1000 seed weight as detailed in 3.2.1.11.

MEASURE OF VIABILITY AND VIGOUR as detailed in 3.3.1.

- 3.2.6.7. Speed of germination
- 3.2.6.8. Germination
- 3.2.6.9. Root length
- 3.2.6.10. Vigour index
- 3.2.6.11. Dry matter production

BIOCHEMICAL STUDIES as detailed in 3.4.1.

- 3.2.6.12. Electrical conductivity
- 3.2.6.13. Sugar content
- 3.2.6.14. Free aminoacids
- 3.2.6.15. Protein content
- 3.2.6.16. Alpha-amylase activity
- 3.2.6.17. Seed health test as detailed in 3.5.1.1.11.

Experiment 7:**3.2.7. Bioassay of seed vigour**

A laboratory experiment was conducted during 1995 with rice cultivars IR 50 and ADT 38 seeds of different vigour levels as a stock and harvest-fresh high-vigour pearl millet seeds as bioassay material to predict the vigour status as well as the effect of major volatile components emanating from the germinating medium and low vigour rice seeds on the seedling growth of pearl millet. The experimental details are furnished below.

Rice seeds of different vigour levels were obtained by subjecting the freshly harvested seeds to accelerated ageing at $40 \pm 1^{\circ}\text{C}$ temperature and 98 ± 2 per cent relative humidity for 6 and 12 days. After the respective periods of ageing, an approximate vigour rating of high vigour (harvest - fresh), medium vigour (6 days aged) and low vigour (12 days aged) was given based on the viability assessed through standard germination (Plate 2&3) and membrane integrity through electrical conductivity test.

Vigour levels of rice	Abbreviations
(Artificially aged)	
High - vigour (Harvest - fresh)	HV
Medium - vigour (aged for 6 days)	MV
Low - vigour (aged for 12 days)	LV
Blank (without stock material)	B

Rice seeds produced in different seasons were utilized for the following experiment. Seeds with varying vigour levels were obtained by natural ageing under ambient storage conditions. The details are furnished below.

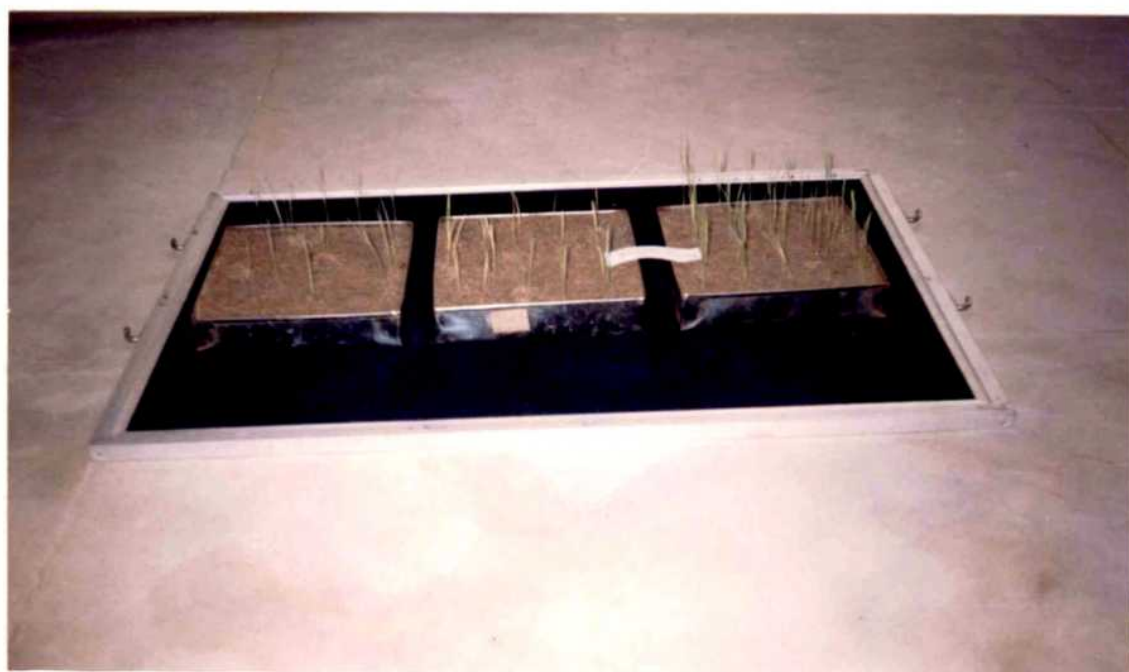
Vigour levels of rice	Abbreviations
(Naturally aged)	
High - vigour (Harvest - fresh seeds produced in Rabi 95)	HV

PLATE 2. VIGOUR RATING BASED ON GERMINATION OF RICE SEEDS**NATURALLY AGED SEEDS**

High Vigour

Medium Vigour

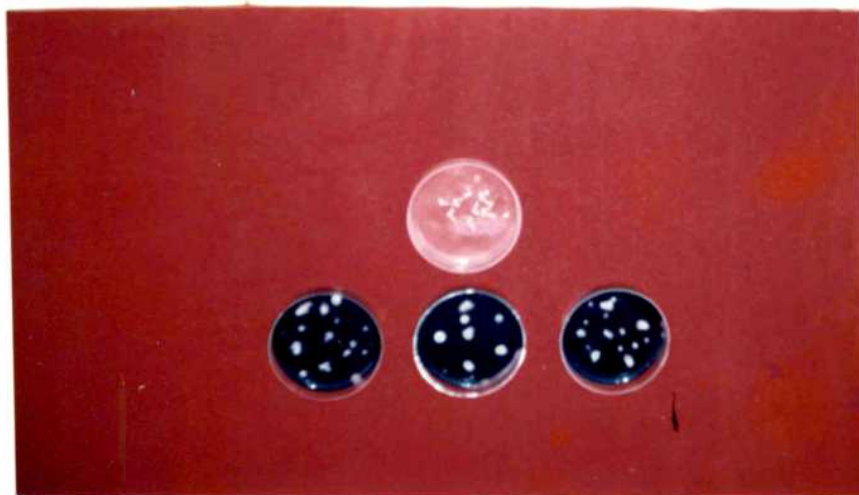
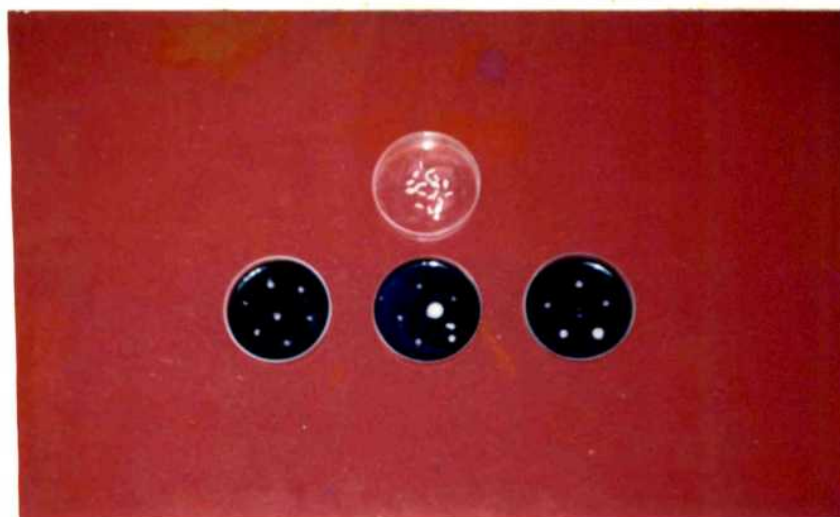
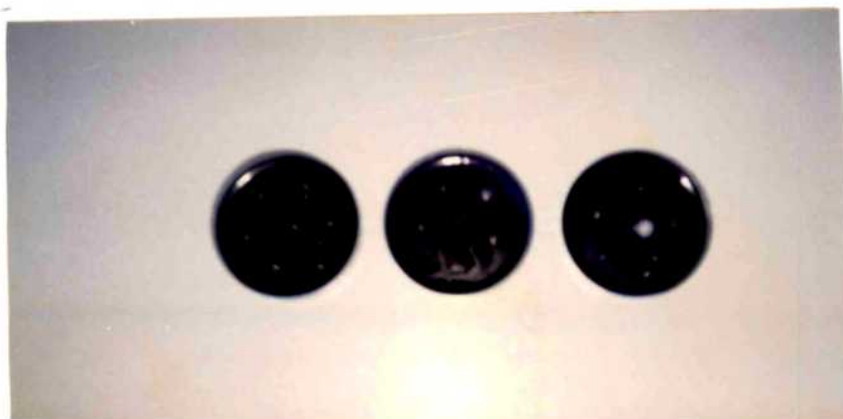
Low Vigour

ACCELERATEDLY AGED SEEDS

Low Vigour

Medium Vigour

High Vigour

PLATE 3. VIGOUR RATING BASED ON ALPHA AMYLASE ACTIVITY**HIGH VIGOUR****MEDIUM VIGOUR****LOW VIGOUR**

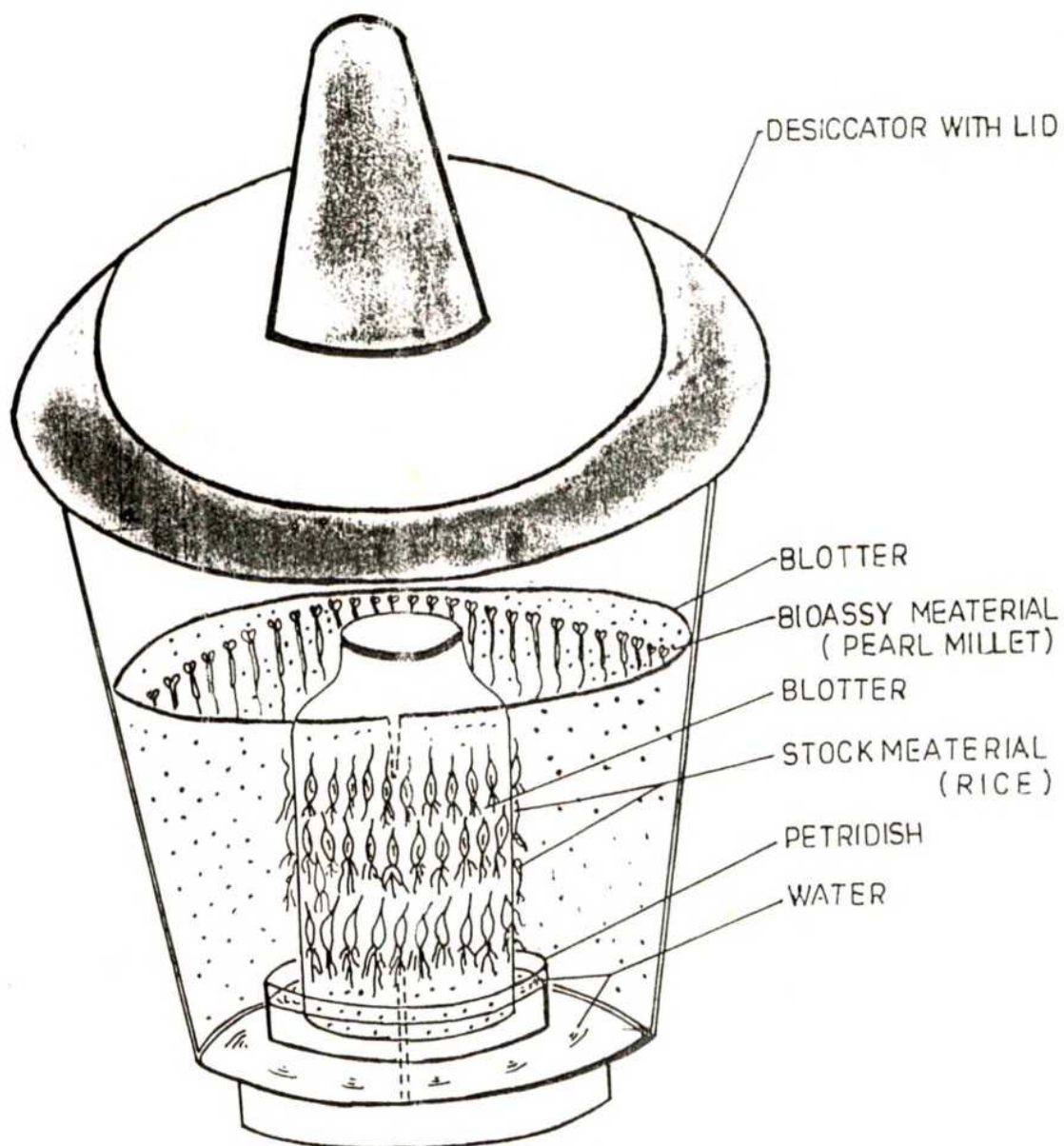
Medium-vigour (9 month - old, produced in Kharif 1994)	MV
Low - vigour (15 month old, produced in Rabi 1994)	LV
Blank (without stock material)	B

After obtaining the differentially aged seeds from the ambient storage conditions, the vigour status of the seeds lots were confirmed through standard germination and membrane integrity test as explained elsewhere.

Then, a seed sample of 500 g from each vigour ratings were stored in the deep freeze at 10°C till used it was for the completion of bioassay experiment.

Rice seeds of different vigour levels and high - vigour seeds of pearl millet were germinated simultaneously in an air - tight 2.30 litre capacity (outside diam. 16 cm, height 16 cm) desiccator (Fig.1). Rice seeds of different vigour levles were placed on a moist blotter (20 cm x 13 cm), which was wrapped on the outer surface of an empty 250 ml capacity glass bottle (outside diam of 5 cm, height 14.5 cm). Before placing on the blotter, rice seeds were sterilized with 0.05 per cent mercuric chloride solution for 30 min. followed by thorough washing and imbibition in distilled water for 2 hr. Pearl millet seeds for each treatment were placed in one row on a moist blotting paper

FIG:1. THE EXPRIMENTAL SET-UP FOR THE BIOASSAY OF SEED VIGOUR



(size 44.5 cm x 15.5 cm) in a straight line leaving a margin of 2.5 cm from the upper edge of the blotter.

High - vigour seeds of pearl millet were used for the bioassay. The pearl millet seeds germinate very quickly and it is possible to record seedling growth after 48 hr which would coincide with the major phase of volatile gas production by stock material. The small seeds (100 seed weight 60 mg) are characterized by their uniformity and rapidity in germination and high sensitiveness to the gaseous emanations of stock seeds of rice. The harvest - fresh pearl millet seed, after collection were dried to a moisture content of 8.0 per cent and stored in small glass vials at -10°C in a refrigerator prior to their use in the bioassay to ensure steady supply of high - vigour bioassay material whenever required.

The blotter with the pearl millet seeds was introduced into the desiccator in such a way that the inner wall of the desiccator was uniformly lined by the blotting paper sheet. 30 ml of water was added to the bottom of the desiccator so that about 1 cm of the blotter with pearl millet seeds could be covered by the standing water to ensure adequate moisture supply to the germinating pearl millet seeds. The glass bottles containing the blotter with rice seeds of different

vigour status were carefully placed inside the desiccator on a 6.5 cm dia petridish containing 30 ml of water for the germinating rice seeds.

The desiccators were then securely closed by glass lids which were lined / pasted with vasseline for air - tight close. There was also a blank set (control) in which only pearl millet seeds were placed.

The desiccators were kept in a temperature controlled room at $23 \pm 1^{\circ}\text{C}$ and after 48 hr, the germination percentage and seedling growth of rice and pearl millet were recorded. The experiments were repeated thrice for both the rice cultivars (IR 50 and ADT 38) separately. Mean seedling length of rice and pearl millet were computed on the basis of germination per cent.

The following observations were recorded as detailed in 3.3.1.

- 3.2.7.1. Germination
- 3.2.7.2. Root length
- 3.2.7.3. Shoot length

The shoot length was measured from the base of the culm to the tip of the primary leaf and expressed in mm.

3.2.7.4. Root / shoot ratio

The ratio between root and shoot length was calculated and recorded.

3.2.7.5. Vigour index

3.2.8. Statistical computation

The data of field experiments and laboratory tests were analysed by the 'F' test for significance following the methods described by Panse and Sukhatme (1985). Wherever necessary the values recorded in percentage were transformed into angular values (Arcsine) before carrying out statistical analysis. The critical differences (CD) were calculated at 5 per cent probability.

RESULTS

CHAPTER IV

RESULTS

4.1. Influence of Season and plant density on Seed Yield and quality

Days to initiation of flowering

The days to initiation of flowering differed significantly due to varieties, season and densities (Table 1). The variety V₂ took more number of days (56.9) for initiation of flowering compared to V₁ (41.9). Among the seasons the crop raised in Kharif '94 (S III) took more number of days (52.2) for initiation of flowering compared to 47.8 and 48.3 days, respectively of the crops raised in Kharif 92 (SI) and Rabi 1993 (SII) seasons.

Except a slight variation in higher plant densities (D₁ and D₂), the days to initiation of flowering did not vary much due to plant densities in both the varieties.

None of the interactions influenced the initiation of flowering significantly, except the interaction between varieties and seasons. The interactions V₂ x SIII and V₂ x SII took more number of days (58.8 and 56.7) and it was less in V₁ x SII (39.8) and V₁ x SI (40.2) followed by V₁ x SIII (45.6) and V₂ x SI (48.0).

Table 1. Influence of season of production and plant density on days to initiation of flowering

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	37.8	38.5	44.8	40.2	52.8	56.0	58.3	55.7	48.0
D2	40.0	39.8	45.3	41.7	54.8	56.5	58.0	56.4	49.1
D3	41.0	40.0	46.0	42.3	55.3	57.0	57.3	57.1	49.7
D4	41.0	40.5	45.8	42.4	56.8	56.8	58.3	57.6	50.0
D5	41.3	40.0	46.3	42.5	57.0	57.3	58.0	57.9	50.2
Mean	40.2	39.8	45.6		55.3	56.7	58.8		
Mean				41.9				56.9	
Season Mean	SI	SII	SIII						
	47.8	48.3	52.2						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	0.88	0.54	0.62		0.68	NS	NS	NS	

Number of tillers

Number of tillers plant⁻¹ at harvest increased significantly due to plant densities (Table 2). The plant density of D₄ and D₅ induced higher tillers (10.6 and 10.7) compared to D₁ (8.7). None of the other treatments, varieties and their interactions influenced the tiller number plant⁻¹.

Number of productive tillers

The number of productive tillers plant⁻¹ at harvest differed significantly due to density of planting (Table 3, Fig. 2). Among the plant densities, D₅ induced more number of productive tillers (9.5) followed of D₄ (9.4), while it was less in D₁ (7.4). None of the other factors and interactions influenced the productive tillers plant⁻¹.

Length of panicle

Length of panicle differed significantly due to varieties, seasons and plant densities (Table 4). Between the varieties V₂ (ADT 38) recorded the lengthiest panicle (21.0 cm), compared to 19.9 cm recorded by V₁ (IR 50). Among the seasons, the crop raised in SI (20.52 cm) followed by SII (19.94 cm) recorded lengthier panicles, while it was

Table 2. Influence of season of production and plant density on number of tillers plant⁻¹

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	9.5	8.3	8.3	8.7	11.8	8.3	9.0	8.7	8.7
D2	9.3	8.3	8.3	8.6	10.0	9.0	8.8	9.3	9.0
D3	11.0	10.5	9.5	10.3	10.8	8.8	9.8	9.8	10.1
D4	10.5	11.3	10.0	10.6	11.8	9.5	10.3	10.5	10.6
D5	10.2	11.0	9.5	10.4	12.5	10.5	10.9	10.9	10.7
Mean	10.2	9.9	9.1		10.8	9.2	9.5		
Mean				9.7					9.8

Season mean	V1				V2			
	SI	SII	SIII	Mean	SI	SII	SIII	Mean
	10.5	9.6	9.3					
CD (P=0.05)	NS	NS	1.29	NS	NS	NS	NS	NS

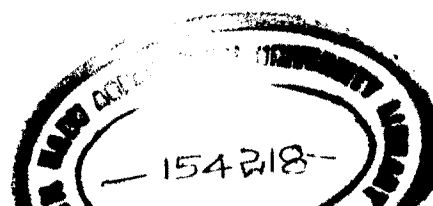


Table 3. Influence of season of production and plant density on number of productive tillers plant⁻¹

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	7.8	7.0	7.0	7.3	7.8	6.8	7.8	7.4	7.4
D2	7.3	7.3	7.5	7.3	8.0	8.8	8.2	8.2	7.8
D3	9.0	9.5	8.0	8.8	9.3	7.8	8.8	8.6	8.7
D4	9.8	9.8	8.8	9.5	10.3	8.5	9.3	9.3	9.4
D5	9.5	10.5	8.3	9.4	10.8	9.5	8.3	9.5	9.5
Mean	8.7	8.8	7.9		9.4	8.1	8.4		
Mean				8.5				8.6	
Season Mean	SI	SII	SIII						
	9.6	8.9	8.2						
	V	S	D		VxS	VxD	SxD	VxSxD	
CD(P=0.05)	NS	NS	1.02		NS	NS	NS	NS	

Table 4. Influence of season of production and plant density on length of panicle (cm)

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	19.00	18.30	17.92	18.41	18.70	18.40	18.40	18.50	18.50
D2	19.80	19.28	18.93	19.38	20.53	20.60	19.80	20.29	19.80
D3	20.60	20.55	19.05	20.07	22.10	23.25	20.28	21.86	21.00
D4	21.78	20.65	20.32	20.91	23.20	23.05	21.80	22.68	21.80
D5	21.40	20.93	20.48	20.93	22.30	21.18	22.23	21.90	21.40
Mean	20.52	19.94	19.34		21.40	21.30	20.49		
Mean	19.90				21.00				
Season Mean	SI	SII	SIII						
	21.0	20.6	20.0						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	0.46	0.50	0.75		NS	0.60	NS	1.60	

Fig.2 Influence of plant density on number of productive tillers and good seeds

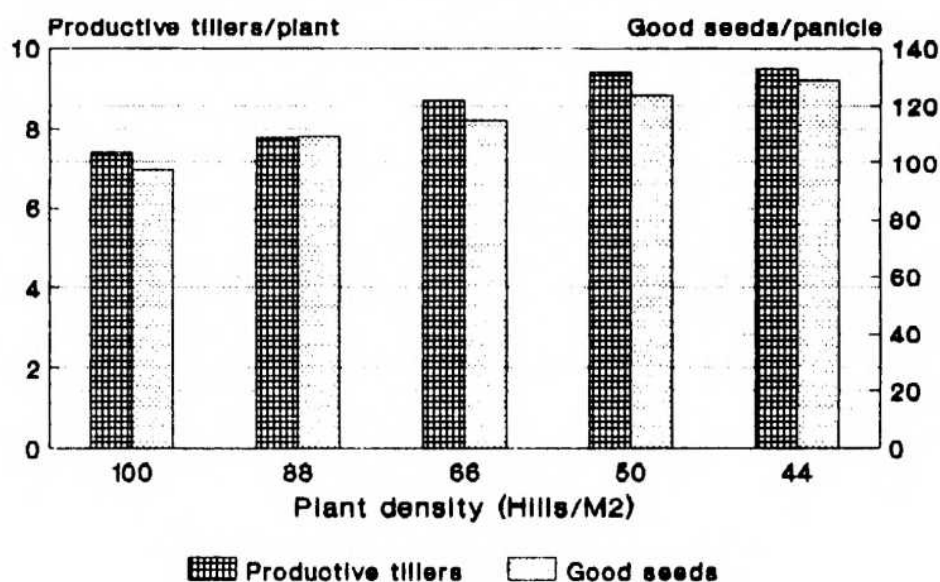
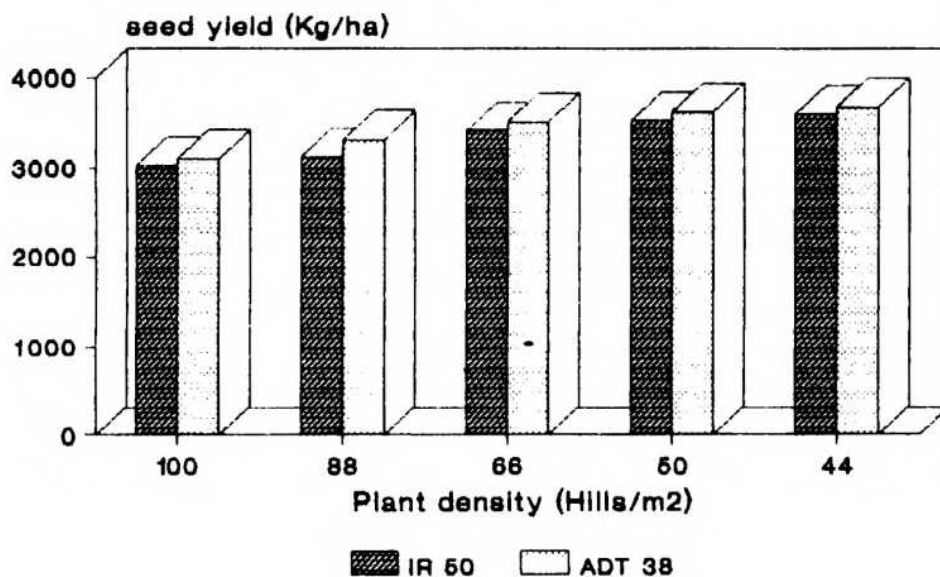


Fig.3 Influence of plant density and variety on seed yield



shorter in SIII (19.34 cm). Wider plant density (D_4) significantly increased the panicle length by 15.1 per cent over D_1 (18.5 cm) by recording a maximum length of 21.8 cm and it was closely followed by D_5 (21.4 cm) compared to other plant densities.

The interaction between varieties and plant densities was significant. The variety V_2 in D_4 and V_1 in D_5 recorded lengthiest panicle of 22.68 and 20.93 cm, respectively compared to other interactions.

Weight of panicle

Significant differences were observed in weight of panicle due to plant densities (Table 5). Among the plant densities D_5 recorded higher panicle weight of 2.54 g followed by D_4 (2.41 g), while D_1 recorded the less weight of 1.84 g. The percentage increase of weight of panicles of D_5 over D_1 was 27.6.

The interaction between varieties x seasons was significant. The variety V_2 at SIII and V_1 at SII had the highest values (2.36 and 2.34 g) followed by V_2 at SI and V_1 at SII (2.24 and 2.16 g). V_1 and V_2 at D_1 , D_2 and D_3 had lesser influence on panicle weight as compared to former interactions.

Table 5. Influence of season of production and plant density on weight of panicle (g)

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	2.03	1.80	1.75	1.86	1.80	1.76	1.93	1.83	1.84
D2	1.83	1.95	1.87	1.88	2.00	1.80	2.21	2.00	1.94
D3	2.25	2.02	1.95	2.07	2.03	1.90	2.47	2.13	2.10
D4	2.65	2.45	2.05	2.38	2.60	2.10	2.59	2.43	2.41
D5	2.93	2.57	2.19	2.56	2.75	2.20	2.58	2.51	2.54
Mean	2.34	2.16	1.96		2.24	1.95	2.36		
Mean				2.10				2.20	
Season Mean	SI	SII	SIII						
	2.30	2.10	2.20						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	NS	NS	0.27		0.29	NS	NS	NS	

Days to maturity

Number of days to maturity differed significantly due to varieties and seasons (Table 6). Between the varieties the medium duration variety (V2) took 132.0 days to attain physiological maturity compared to 104 days by short duration variety (V1). Among the seasons, the days to maturity decreased by 1.6 and 1.2 days in SII and SI, respectively compared to SIII. The densities of planting did not influence the days to maturity.

The interactions between varieties x seasons, varieties x densities and seasons x densities were significant. The variety V₂ in SII and SIII took more number of days for attaining physiological maturity followed by V₂ in SI and V₂ at D₂ and D₁. While the densities D₁, D₂, D₃, D₄ and D₅ did not alter the days to attainment of physiological maturity of V₁. In SIII the plants under D₁ took lesser number of days to attain maturity as compared to other seasons and plant densities.

Number of good seed

Number of good seeds panicle⁻¹ significantly increased due to plant densities (Table 7, Fig. 2). The plant density at D₅ (120.8) followed by D₄ (124.1) recorded higher number of good seeds panicle⁻¹, while it was lower in D₁ (97.5).

Table 6. Influence of season of production and plant density on days to maturity

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	104.0	105.0	102.8	103.9	132.8	134.0	129.8	132.2	118.0
D2	103.5	105.0	103.8	104.1	131.0	135.5	131.0	132.5	118.3
D3	105.8	104.0	105.0	104.9	130.50	133.0	132.0	131.8	118.4
D4	106.3	106.0	104.8	105.7	130.8	132.8	132.3	131.9	118.8
D5	106.5	106.0	105.8	106.0	130.8	132.0	131.5	131.4	118.7
Mean	105.2	105.2	104.4		131.2	133.5	131.3		
Mean				104.9					132.0
Season Mean	SI	SII	SIII						
	118.2	119.4	117.8						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	1.95	0.56	NS		0.87	0.94	1.38	NS	

Table 7. Influence of season of production and plant density on number of good seed panicle⁻¹

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	99.5	92.0	90.3	93.9	110.0	96.0	96.0	101.0	97.5
D2	113.3	106.5	101.0	106.9	109.0	107.0	107.8	112.0	109.4
D3	124.5	114.0	118.3	118.9	114.0	103.0	115.5	110.0	114.5
D4	127.0	120.0	116.5	121.2	127.5	130.0	132.0	127.0	124.1
D5	131.5	121.8	120.5	124.6	140.3	132.0	126.0	133.0	128.8
Mean	119.2	110.9	109.3		120.0	116.0	114.0		
Mean	113.2				116.7				
Season Mean	SI	SII	SIII						
	119.6	113.5	111.7						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	NS	NS	13.41	NS	NS	NS	NS	NS	

Awne*d* seeded ear

Percentage of awne*d* seeded ears significantly differed due to varieties, seasons and plant densities (Table 8). In V_2 the percentage of occurrence of awne*d* seeded ears was higher (2.9%) compared to V_1 (0.7%).

Among the seasons, SI (54.2%) followed by SII (42.9%) recorded higher percentage of awne*d* seeds compared to SIII (1.1%). In the plant densities, D_3 recorded more number of awne*d* seeded ears (3.2%) followed by D_4 (2.5%), while the occurrence of awne*d* seeded ears was less in D_1 (0.5%).

The interaction of varieties x seasons, densities x seasons and seasons x densities were significant.

Seed yield

Seed yield differed significantly due to varieties, seasons and plant densities (Table 9, Fig. 3). Between the varieties V_2 recorded higher seed yield (3448 kg ha⁻¹) compared to V_1 (3335 kg ha⁻¹). Among the seasons the crop raised in SI and SIII recorded more seed yield (3530 and 3361 kg ha⁻¹) compared to SII (3286 kg ha⁻¹). The seed yield increase in SI and SIII was 6.9 and 2.2 per cent over SII.

Table 8. Influence of season of production and plant density on awned seeded ears (%)

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	0.30	0.08	0.10	0.16	1.2	0.8	0.6	0.9	0.5
D2	0.70	0.55	0.20	0.48	1.9	1.4	1.0	1.4	0.9
D3	1.00	0.93	0.30	0.74	3.4	2.8	1.8	2.7	1.7
D4	1.43	1.00	0.35	0.93	5.1	4.2	2.6	4.0	2.5
D5	1.73	1.18	0.25	1.05	6.8	5.6	3.8	5.4	3.2
Mean	1.03	0.75	0.24		3.7	3.00	2.00		
Mean	0.7				2.9				
Season Mean	SI	SII	SIII						
	2.4	1.9	1.1						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	0.94	0.42	0.67		0.42	0.54	0.67	NS	

Table 9. Influence of season of production and plant density on seed yield (kg ha⁻¹)

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	3126	2984	2940	3017	3260	2966	3064	3096	3057
D2	3056	3148	3170	3125	3428	3198	3290	3305	3215
D3	3620	3216	3405	3414	3650	3396	3500	3516	3465
D4	3706	3410	3461	3526	3770	3525	3588	3628	3577
D5	3748	3525	3510	3594	3930	3488	3678	3698	3646
Mean	3450	3256	3298		3608	3315	3424		
Mean	3335				3448				
Season Mean	SI	SII	SIII						
	3530	3286	3361						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	47.8	58.5	75.6		NS	NS	NS	NS	

Among the densities D_5 recorded higher seed yield (3698 kg ha⁻¹) followed by D_4 (3628 kg ha⁻¹) compared to other plant densities, while D_1 recorded the lesser yield of 3057 kg ha⁻¹. The percentage increase of seed yield in the lesser densities of D_4 and D_5 compared to D_1 ranged from 5 to 1.9.

Seed Recovery

Seed recovery percentage differed significantly due to varieties and plant densities (Table 10). Between the varieties V_2 recorded the highest seed recovery of 71.4 per cent compared to V_1 (68.0%). Among the plant densities D_4 (75.0%) followed by D_5 (73.8%) recorded higher seed recovery compared to other plant densities, while, D_1 recorded the least recovery of 62.9 per cent.

1000 seed weight

Significant differences were observed in 1000 seed weight due to varieties, seasons and plant densities (Table 11, Fig. 4). Between the varieties V_2 recorded higher 1000 seed weight of 22.3 g compared to V_1 (21.8 g). Among the seasons SIII followed by SI recorded higher 1000 seed weight of 22.4 and 22.1 g, respectively, while SII recorded the lower seed weight of 21.7 g. Among the plant densities D_4 followed by D_5 recorded higher seed weight of

Table 10. Influence of season of production and plant density on seed recovery (%)

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	65.2	62.8	62.8	63.6	54.3	66.5	65.8	62.2	62.9
D2	64.8	62.3	63.0	63.3	73.7	69.2	67.2	70.0	66.7
D3	69.1	67.0	68.6	68.2	73.9	70.8	69.0	71.2	69.7
D4	73.8	69.6	72.1	71.8	83.0	76.8	74.7	78.2	75.0
D5	74.4	70.4	72.6	72.5	72.0	77.2	76.1	75.1	73.8
Mean	69.5	66.4	67.8		71.4	72.1	70.6		
Mean	68.0				71.4				
Season Mean	SI	SII	SIII						
	70.5	69.3	69.2						
	V	S	D	V x S	V x D	S x D	V x S x D		
CD(P=0.05)	2.30	NS	3.64	NS	NS	NS	NS	NS	

Table 11. Influence of season of production and plant density on 1000 seed weight (g)

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	21.45	21.26	21.67	21.46	23.62	20.90	22.54	22.35	21.90
D2	20.59	21.24	21.86	21.23	22.91	21.80	22.51	22.4	21.80
D3	21.23	22.40	21.80	21.81	23.76	21.60	22.71	22.69	22.30
D4	22.59	21.85	21.71	22.05	23.74	21.70	22.96	22.79	23.00
D5	22.10	22.24	22.68	22.34	23.82	21.93	23.10	22.95	22.70
Mean	21.60	21.80	21.94		22.57	21.59	22.76		
Mean	21.80				22.3				
Season Mean	SI	SII	SIII						
	22.1	21.7	22.4						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	0.66	0.81	1.0		NS	NS	NS	NS	

23.0 and 22.7 g, respectively compared to other densities, while D₁ recorded the least weight of 21.9 g.

Speed of germination

The speed of germination of seeds differed significantly due to varieties, seasons and plant densities (Table 12). Irrespective of population densities and seasons the speed of germination of the seeds from V₁ was found to be earlier compared to the seeds from V₂. Among the densities the seeds from D₄ germinated earlier compared to the seeds from other densities. The speed of germination was lower in the seeds from D₁. Among the seasons, the seeds produced in SIII showed higher speed of germination compared to that from SII and SI.

Germination

Seasons and plant densities significantly influenced the germination potential of the seed (Table 13, Fig. 4). Irrespective of other factors the seeds produced in SIII recorded higher mean germination of 93.0 per cent, followed by SII (88.3%), while the seeds from SI recorded the least germination of 88.2 per cent and it was on a par with SII. Among the plant densities the seeds obtained from D₅, D₄ and D₃, being on par, recorded higher germination (91.2, 90.8 and 90.1%, respectively) over D₁ (88.0%) and D₂ (88.6%).

Table 12. Influence of season of production and plant density on speed of germination of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	27.43	26.20	30.53	28.10	26.60	23.60	28.60	26.30	27.20
D2	27.40	26.38	30.80	28.20	28.10	24.80	28.40	27.10	27.60
D3	30.10	27.00	31.80	29.60	28.80	24.20	29.20	27.40	28.50
D4	30.05	27.60	31.60	29.80	28.00	25.00	30.80	27.90	28.80
D5	30.75	28.20	32.23	30.40	29.10	24.60	31.60	28.40	29.50
Mean	29.20	27.10	31.40		28.10	24.40	29.70		
Mean				29.20					27.50
Season Mean	SI	SII	SIII						
	28.70	26.00	30.60						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	0.895	1.10	1.42		NS	NS	NS	NS	

Table 13. Influence of season of production and plant density on germination (%) of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	87.0 (68.9)	88.0 (69.7)	90.0 (71.6)	88.3 (70.0)	87.0 (68.9)	88.0 (69.7)	88.0 (69.7)	87.7 (69.5)	88.0 (69.7)
D2	88.5 (70.2)	89.5 (71.1)	89.3 (70.9)	89.1 (70.7)	88.0 (69.7)	86.0 (68.0)	86.0 (68.0)	88.0 (69.7)	88.6 (70.3)
D3	87.0 (68.9)	88.0 (69.7)	94.0 (75.8)	89.7 (71.3)	88.5 (70.2)	88.0 (69.7)	88.0 (69.7)	90.5 (72.1)	90.1 (71.7)
D4	89.5 (71.1)	90.0 (71.6)	95.0 (77.1)	91.5 (73.1)	87.5 (69.3)	87.0 (68.9)	87.0 (68.9)	90.2 (71.8)	90.8 (72.3)
D5	88.0 (69.7)	90.0 (71.6)	95.0 (77.1)	91.7 (73.4)	89.0 (70.6)	88.0 (69.7)	88.0 (69.7)	90.7 (72.2)	91.2 (72.7)
Mean	88.4 (70.1)	89.1 (70.7)	92.7 (74.3)	90.0 (71.6)	88.0 (69.7)	87.40 (69.2)	87.40 (69.2)	89.4 (71.0)	

Season Mean

(Figures in parenthesis are arcsine values)									
Season Mean	SI	SII	SIII						
	88.2 (69.8)	88.3 (70.0)	93.0 (74.8)						
CD(P=0.05)	V NS	S 1.55	D 2.0	V x S NS	V x D NS	S x D NS	V x S x D NS		

Fig.4 Influence of plant density on seed weight , germination and dry matter production

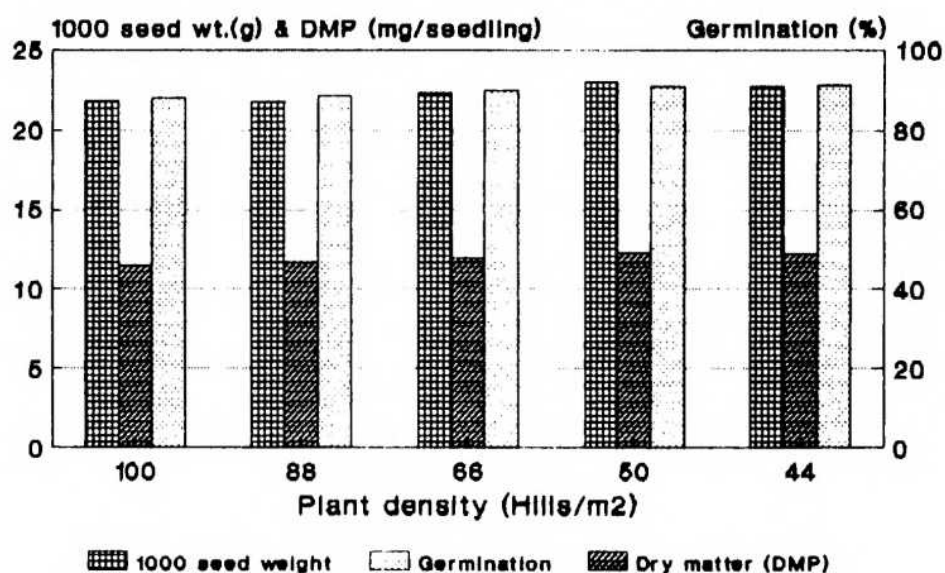
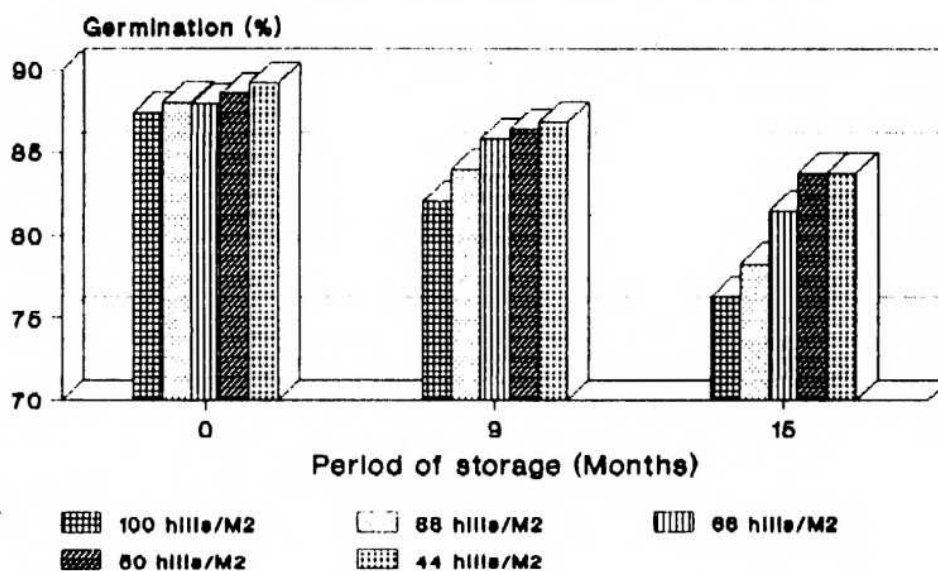


Fig.5 Influence of plant density and storage period on germination of seeds



Root length

The root length differed significantly due to seasons of sowing and plant densities (Table 14). Irrespective of other factors the seeds obtained from SIII recorded lengthier root (20.8 cm) than those seeds from SI and SII (19.7 and 19.0 cm, respectively). Among the plant densities the seeds obtained from D₅, D₄ and D₃, being on par, recorded lengthier roots (20.9, 20.5 and 20.3 cm, respectively) compared D₁ (18.7 cm) and D₂ (18.9 cm). The differences due to varieties and the interaction between varieties x seasons, varieties x densities and densities x seasons were not significant.

Vigour Index

The vigour potential differed significantly due to varieties, seasons and plant densities (Table 15). The seeds of V₂ recorded higher vigour (1814) than V₁ (1732). Among the seasons the seeds obtained from SIII recorded the maximum vigour (1912) compared to SII and SI (1666 and 1739, respectively). Irrespective of other factors the resultant seeds from lesser plant densities significantly increased the vigour index. The seeds from D₅ followed by D₄ recorded the maximum vigour index of 1918 and 1876, respectively as compared to other densities, while the seeds from D₁ recorded the least vigour of 1642. In general the vigour

Table 14. Influence of season of production and plant density on root length (cm) of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	17.60	16.80	19.65	18.02	18.10	19.20	20.45	19.23	18.70
D2	18.30	17.20	19.40	18.30	19.00	18.80	20.43	19.40	18.90
D3	19.30	18.60	20.80	19.57	21.58	20.20	21.00	20.92	20.30
D4	21.70	18.80	21.00	20.50	19.68	19.80	21.78	20.42	20.50
D5	21.40	19.40	21.20	20.67	20.63	20.65	22.38	21.23	20.90
Mean	19.66	18.16	20.41		19.78	19.73	21.20		
Mean	19.40				20.30				
Season Mean	SI	SII	SIII						
	19.70	19.00	20.80						
CD(P=0.05)	V	S	D		V x S	V x D	S x D	V x S x D	
	NS	1.30	1.68		NS	NS	NS	NS	

Table 15. Influence of season of production and plant density on vigour index of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	1530	1480	1764	1592	1580	1690	1804	1691	1642
D2	1616	1540	1728	1628	1664	1598	1856	1699	1664
D3	1674	1632	1748	1685	1715	1778	2092	1862	1774
D4	1942	1639	1995	1858	1903	1778	1998	1893	1876
D5	1926	1476	2014	1895	1844	1840	2139	1941	1918
Mean	1737	1607	1850		1741	1726	1974		
Mean	1732				1814				
Season Mean	SI	SII	SIII						
	1739	1666	1912						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	35.01	42.88	55.36		60.65	78.30	NS	NS	

decreased with increase in the population density.

The interactions between varieties x seasons and varieties x plant densities were significant. The seeds of V₂ produced in SIII recorded the maximum vigour index of 1974 followed by the seeds of V₁ produced in the same season (1850) over other interactions. In the interaction of varieties x plant densities the seeds of V₂ from D₅ recorded the maximum vigour index of 1941 followed by the seeds of V₁ from D₅ (1895) over other interactions.

Dry matter production

The dry matter production of seeds differed significantly due to varieties, seasons and plant densities (Table 16, Fig. 4). Irrespective of seasons and plant densities the seeds of V₂ recorded maximum dry matter (12.1 mg) than the seeds of V₁ (11.8 mg). Among the seasons of planting, the seeds obtained from SIII and SI, being on par, recorded maximum dry matter of 12.4 and 12.3 mg, respectively over SII (11.1 mg).

In the population densities the seeds from D₄ (12.3 mg) followed by D₅ (12.2 mg) recorded higher dry matter compared to other plant densities, while the seeds from D₁ recorded the least dry matter of 11.5 mg.

Table 16. Influence of season of production and plant density on dry matter production of (mg seedling⁻¹) resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	11.80	10.03	12.10	11.31	12.10	10.60	12.36	11.69	11.50
D2	11.42	10.42	12.23	11.36	12.60	11.10	12.26	11.99	11.70
D3	12.16	11.36	12.41	11.98	12.70	10.90	12.40	12.00	12.00
D4	12.32	11.74	12.32	12.13	13.00	11.60	12.50	12.39	12.30
D5	12.24	11.46	12.48	12.06	12.90	11.80	12.45	12.38	12.20
Mean	11.99	11.00	12.31		12.66	11.20	12.39		
Mean	11.80				12.10				
Season Mean	SI	SII	SIII						
	12.30	11.10	12.40						
	V	S	D		V x S	V x D	S x D	V x S x D	
CD(P=0.05)	0.201	0.246	0.317		NS	NS	NS	NS	

Electrical conductivity

The mean electrical conductivity values of seed leachates differed significantly due to seasons and plant densities (Table 17). Among the seasons of production, the seeds obtained from SIII recorded minimum EC (53.7 dSm^{-1}) over SII (96.3 dSm^{-1}) and SI (80.7 dSm^{-1}). The resultant seeds from lower plant densities recorded significantly lower EC values irrespective of seasons of sowing. The seeds from D_5 and D_4 recorded the lowest EC values of 73.5 and 74.1 dSm^{-1} , respectively, while the leachate from the seeds of D_1 recorded higher EC value of 85.4 dSm^{-1} .

None of the interactions except varieties x seasons showed significant influence on EC. The EC of the seeds of V_2 and V_1 produced in SIII recorded the lowest values of 46.3 and 61.1 dSm^{-1} , respectively compared to other interactions.

Sugar content

The mean sugar values of the seed leachates showed significant differences due to varieties, seasons and plant densities (Table 18). Irrespective of other factors the seeds of the variety V_1 recorded lower sugar value ($3.5 \mu\text{g}$) than the seeds from V_2 ($3.8 \mu\text{g}$). Among the seasons of production, the seeds from SIII and SI being on par recorded

Table 17. Influence of season of production and plant density on electrical conductivity of (dSm⁻¹) resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	83.6	107.0	73.4	88.0	92.8	106.0	49.4	82.8	85.4
D2	82.3	70.0	64.0	72.1	85.0	103.0	47.6	78.5	75.3
D3	86.2	96.0	58.1	80.1	78.8	98.0	48.2	74.9	77.5
D4	72.9	98.0	55.4	75.4	77.0	95.0	42.8	71.6	74.1
D5	72.0	92.5	56.7	73.8	75.80	97.5	43.5	72.2	73.5
Mean	79.4	92.7	61.1		81.9	99.9	46.3		
Mean				77.7					76.0
Season Mean	SI	SII	SIII						
	80.7	96.3	53.7						
	V	S	D		VxS	VxD	SxD	VxSxD	
CD(P=0.05)	NS	6.0	5.2		8.5	NS	NS	NS	

Table 18. Influence of season of production and plant density on sugar content (μg) of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	3.14	4.64	3.39	3.72	3.62	4.16	3.54	3.78	3.75
D2	3.39	4.36	3.43	3.73	3.59	4.30	3.42	3.77	3.75
D3	2.97	3.92	3.16	3.35	4.10	3.98	3.44	3.84	3.6
D4	2.86	3.52	3.20	3.19	3.86	3.90	3.31	3.67	3.4
D5	2.80	3.89	3.12	3.27	3.72	4.00	3.25	3.66	3.5
Mean	3.03	4.07	3.30		3.78	4.10	3.39		
Mean	3.50								3.80
Season Mean	SI	SII	SIII						
	3.40	4.10	3.30						
	V	S	D		VxS	VxD	SxD	VxSxD	
CD(P=0.05)	0.080	0.098	0.127		0.139	0.180	0.220	NS	

minimum sugar values (3.3 and 3.4 μg , respectively) compared to SII (4.1 μg). The resultant seeds from lower plant density levels recorded lower sugar values irrespective of varieties and seasons. The seeds from D_4 , D_5 and D_3 being on par, recorded the lowest sugar values of 3.4, 3.5 and 3.6 μg , respectively as against 3.75 (μg) recorded by both D_1 and D_2 .

The interactions between varieties x seasons, varieties x plant densities and plant densities x seasons were significant. The seeds of V_1 produced in SI and SIII recorded lowest sugar content of 3.03 and 3.30 μg . The seeds of V_1 from D_4 and D_5 recorded the lowest values of 3.19 and 3.27 μg , respectively. The seeds produced in SI and SIII at D_5 and in SIII at D_3 recorded the lowest values of 2.80, 3.12 and 3.16 μg , respectively.

Aminoacids

The mean aminoacid values of seed leachates differed significantly due to varieties, seasons and plant densities (Table 19). Irrespective of other factors the seeds of V_1 recorded lower aminoacids (1.8 μg) than the seeds from V_2 (2.1 μg). Among the seasons the seeds obtained from SIII recorded minimum aminoacids (1.7 μg). The aminoacids decreased from the seeds obtained from lower densities (1.8 μg) to that higher densities (2.1 μg), irrespective of

Table 19. Influence of season of production and plant density on aminoacids (μg) of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	1.92	2.02	1.64	1.87	2.24	2.35	1.94	2.18	2.00
D2	1.99	2.14	1.51	1.88	2.18	2.42	2.00	2.20	2.10
D3	1.80	2.02	1.38	1.73	2.10	2.25	1.93	2.10	1.90
D4	1.82	1.98	1.43	1.75	2.00	2.16	1.80	1.99	1.90
D5	1.77	1.92	1.32	1.67	2.10	2.10	1.74	1.98	1.80
Mean	1.86	2.02	1.46		2.12	2.26	1.88		
Mean				1.80					2.10
Season Mean	SI	SII	SI	SIII					
	2.00	2.10	1.70						
	V	S	D		VxS	VxD	SxD	VxSxD	
CD(P=0.05)	0.042	0.052	0.067		0.074	NS	NS	NS	

varieties and seasons.

None of the interactions except, varieties x seasons showed significant differences in the aminoacids content of the leachates. The leachates of the seeds of V₁ produced in SIII and S1 and that of V₂ produced in SIII recorded the lower aminoacids values.

Protein content

The mean protein content of seeds differed significantly due to varieties, seasons and plant densities (Table 20,). The seeds obtained from V₂ recorded higher protein content (10.2%) than that from V₁ (8.8%). Among the seasons of production, the seeds obtained from SIII recorded maximum protein content of 10.4 per cent compared to SII (8.5%) and SI (9.7%). The resultant seeds from lower plant densities recorded significantly higher protein content irrespective of varieties and seasons. The seeds from D₅ recorded the highest protein content of 10.0 per cent followed by D₄ (9.8%) and D₃ (9.6%), while D₁ recorded the lowest protein content of 9.0 per cent.

None of the interactions except varieties x seasons of production showed significant influence on the protein content of seeds. The seeds of V₂ produced in SIII and SI recorded the maximum protein values (11.45 and 10.22%,

Table 20. Influence of season of production and plant density on protein content (%) of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	8.96	7.14	9.12	8.41	9.65	8.45	10.70	9.60	9.00
D2	9.21	7.26	9.28	8.58	9.83	8.53	10.90	9.75	9.20
D3	8.87	8.43	9.49	8.93	10.45	9.10	11.38	10.31	9.60
D4	9.38	8.37	9.35	9.03	10.83	9.40	11.75	10.66	9.80
D5	9.56	8.64	9.41	9.20	10.35	9.30	12.50	10.72	10.00
Mean	9.20	7.97	9.33		10.22	8.96	11.45		
Mean				8.80					10.20
Season Mean	SI	SII	SIII						
	9.70	8.50	10.40						
	V	S	D		VxS	VxD	SxD	VxSxD	
CD(P=0.05)	0.113	0.139	0.179		0.197	NS	0.311	NS	

respectively) over the other respective interactions.

Alpha amylase activity

The mean values of alpha amylase activity of the seeds significantly influenced due to varieties, seasons and plant densities (Table 21). Between the varieties the seeds obtained from V₁ recorded higher alpha amylase activity (10.9 mm) than the seeds from V₂ (10.2 mm). Among the seasons the seeds obtained from SIII followed by SI recorded the maximum alpha amylase activity of 11.5 and 10.7 mm, while the activity was less in SII (9.6 mm). The resultant seeds from lower levels of plant densities recorded significantly higher alpha amylase activity irrespective of varieties and seasons. Alpha amylase activity steadily decreased from lower (D₅) to higher densities (D₁).

Except the interaction of varieties x seasons none of the interactions showed significant differences in alpha amylase activity. The seeds of V₁ and V₂ produced in SIII recorded higher alpha amylase activity compared to other interactions.

Fungal infection

The fungal infection per cent differed significantly due to varieties and seasons (Table 22). Irrespective of

Table 21. Influence of season of production and plant density on alpha amylase activity of (mm) resultant seeds

Treatments	V1					V2					Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	SI	SII	Mean
D1	10.80	9.24	10.60	10.21	9.65	8.45	10.70	9.60	9.60	9.90	
D2	10.20	9.16	11.15	10.17	9.83	8.53	10.90	9.75	10.00		
D3	11.38	10.61	11.78	11.25	10.45	9.10	11.38	10.31	10.80		
D4	11.55	11.21	11.83	11.53	10.83	9.40	11.75	10.66	11.10		
D5	11.48	10.75	12.10	11.44	10.35	9.30	12.50	10.72	11.10		
Mean	11.08	10.19	11.49		10.22	8.96	11.45				
Mean				10.90				10.20			
Season Mean	SI	SII	SIII								
	10.70	9.60	11.50								
	V	S	D		VxS	VxD	SxD	VxSxD			
CD(P=0.05)	0.201	0.246	0.317	0.348	NS	NS	NS	NS	NS	NS	

Table 22. Influence of season of production and plant density on fungal infection (%) of resultant seeds

Treatments	V1				V2				Mean
	SI	SII	SIII	Mean	SI	SII	SIII	Mean	
D1	3.38	4.00	2.40	3.26	2.30	3.00	1.50	2.30	2.80
D2	3.13	5.25	3.10	3.83	2.00	3.30	1.30	2.20	3.00
D3	2.88	3.50	1.98	2.78	1.10	2.00	1.10	1.40	2.10
D4	1.38	3.50	2.00	2.29	1.40	2.50	1.20	1.70	2.00
D5	1.75	4.00	2.13	2.63	1.70	3.00	1.00	1.90	2.30
Mean	2.50	4.05	2.32		1.70	2.80	1.20		
Mean				3.00					1.90
Season Mean	SI	SII	SIII	SIII					
	2.10	3.40	1.80						
	V	S	D		VxS	VxD	SxD	VxSxD	
CD(P=0.05)	0.260	0.318	NS	NS	NS	NS	NS		

other factors the seeds from V2 recorded lesser fungal infection (1.9%) compared to the seeds from V1 (3.0%). Among the seasons of production the seeds from SIII (1.8%) and SI (2.1%) being on par, recorded less fungal infection compared to SII (3.4%). The plant density does not reveal any significant difference in fungal invasion irrespective of varieties and seasons.

None of the interactions showed significant difference in fungal infection per centage.

STORAGE STUDIES

The resultant seeds obtained from Kharif 1992 and Rabi 1993 seasons were alone subjected to storage studies.

Speed of germination

The speed of germination of the stored seeds differed significantly due to periods of storage, varieties, seasons and plant densities (Table 23).

With the increase in the period of storage the speed of germination decreased from 27.4 (P_0) to 21.5 (P_5) irrespective of varieties, seasons and population densities.

Between the varieties V_1 recorded highest mean speed of germination of 27.9 and the lowest was by V_2 (23.0)

Table 23. Influence of season, plant density and periods of storage on speed of germination of resultant seeds

	P0						P1					
	V1			V2			V1			V2		
	SI	SII		SI	SII		SI	SII		SI	SII	
D1	27.43	26.20		26.60	23.60		26.40	25.60		27.00	23.40	
D2	27.40	26.38		28.10	24.80		27.20	26.00		27.80	23.90	
D3	30.10	27.00		28.00	25.00		31.20	28.90		27.40	24.60	
D4	30.05	27.60		28.00	25.00		31.20	28.90		27.40	24.60	
D5	30.75	28.20		29.10	24.60		30.40	27.60		28.40	24.90	

Table 23. (contd...)

		P2				P3			
		V1		V2		V1		V2	
	SI	SII	SI	SII	SI	SII	SI	SII	SI
D1	26.20	24.70	24.60	20.80	25.20	24.00	21.00	18.60	
D2	27.80	26.00	25.40	21.60	26.40	25.40	22.80	19.80	
D3	30.20	27.20	27.20	23.10	29.00	26.80	26.00	22.40	
D4	31.30	28.40	26.80	23.00	30.80	27.20	25.10	22.20	
D5	29.50	28.30	27.60	23.80	29.60	27.40	26.20	22.60	

Table 23. (contd....)

		P4				P5			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1	24.10	22.80		16.40	16.40	23.00	19.60	13.60	12.60
D2	25.80	24.60		17.90	17.20	23.80	21.40	16.20	15.80
D3	28.20	25.80		22.60	20.20	27.40	24.20	20.80	18.60
D4	30.20	26.70		23.40	19.90	29.60	25.40	21.60	19.00
D5	30.00	27.00		23.80	21.00	29.20	25.80	22.60	20.20

Table 23. (contd...)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	25.9	27.1	27.4	28.2	28.6	27.4	28.7	26.1	28.7	26.2
P1	26.1	26.8	27.9	27.9	27.3	27.2	28.3	26.1	28.2	26.1
P2	24.2	25.8	27.2	27.3	26.4	26.2	27.6	24.7	28.0	24.3
P3	22.6	24.7	26.3	26.4	24.5	24.9	26.1	28.7	27.0	22.8
P4	20.3	22.2	24.3	25.4	23.5	23.1	24.2	22.1	26.3	20.0
P5	18.1	20.4	23.3	24.0	21.8	21.5	22.8	20.2	24.6	18.4
Mean	22.9	24.5	26.0	26.5	25.4		26.3	23.8	27.9	23.0
SI	23.7	25.6	27.6	28.1	26.3	26.3				
SII	22.0	23.4	24.4	25.0	24.4	23.8				
V1	25.0	26.3	28.2	29.0	27.2	27.9	28.4	25.8		
V2	20.7	22.7	23.9	24.1	23.5	23.0	24.1	21.8		

Significant factors

P	S	V	D	PxV
0.70	0.47	0.50	0.75	1.16

irrespective of other factors. In the seasons the speed of germination was higher in SI (26.3) compared to SII (23.8). All the density recorded higher speed compared to D_1 . Among the densities D_4 and D_3 recorded higher speed of germination (26.5 and 26.0) compared to other densities.

Except, varieties x periods, the other interactions were not significant. The speed of germination at P_0 of V_1 and V_2 was 28.7 and 26.2, respectively, which decreased to 24.6 and 18.4 after 15 months of storage (P_5).

Germination

The germination potential differed significantly among periods of storage, seasons and plant densities (Table 24, Fig. 5).

The mean germination percentage, irrespective of varieties, seasons and densities decreased with increase in the storage period from 87.9 (P_0) to 83.1 per cent (P_5).

Between the seasons, the seeds from SI maintained higher germination potential of 85.6 per cent over periods of storage compared to SII (84.8%). Among the densities the germination potential of the seeds from higher densities declined faster compared to those seeds from lower densities. The seeds from D_5 , D_4 and D_3 maintained

Table 24. Influence of season, plant density and periods of storage on germination (%) of resultant seeds

		P0			P1		
		V1			V2		
		SI	SII	SI	SII	SI	SII
D1	87 (68.9)	88 (69.7)	87 (69.3)	88 (68.7)	86 (68.0)	86 (69.7)	86 (68.0)
D2	89 (70.6)	89 (70.6)	88 (69.7)	86 (68.0)	88 (69.7)	89 (70.6)	96 (78.5)
D3	87 (68.9)	88 (69.7)	87 (68.9)	88.00 (69.7)	88 (69.7)	88 (69.7)	88 (69.7)
D4	89 (70.6)	90 (71.6)	88 (69.7)	87 (68.9)	90 (71.6)	86 (68.0)	84 (66.4)
D5	90 (71.6)	90 (71.6)	89 (70.6)	88 (69.7)	90 (71.6)	90 (71.6)	88 (69.7)

(Figures in parenthesis are arcsine values)

Table 24. (contd...)

	P2			P3		
	V1	V2	V1	V2	V1	V2
D1	84 (66.4)	82 (64.9)	86 (68.0)	84 (66.4)	82 (64.9)	84 (66.4)
D2	86 (68.0)	84 (66.4)	88 (69.7)	88 (68.0)	82 (64.9)	86 (68.0)
D3	86 (68.0)	86 (68.0)	88 (69.7)	90 (71.6)	84 (66.4)	86 (68.0)
D4	88 (69.7)	90 (71.6)	86 (68.0)	87 (68.9)	88 (69.7)	84 (66.4)
D5	88 (69.7)	86 (68.0)	88 (69.7)	88 (69.7)	87 (68.9)	88 (69.7)

(Figures in parenthesis are arcsine values)

Table 24. (contd....)

		P4				P5			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		80 (63.4)	78 (62.0)	80 (63.4)	78 (62.0)	78 (62.0)	75 (60.0)	76 (60.7)	76 (60.7)
D2		82 (64.9)	78 (62.0)	82 (64.9)	82 (64.9)	79 (62.7)	76 (60.7)	80 (63.4)	78 (62.0)
D3		84 (66.4)	82 (64.9)	84 (66.4)	84 (66.4)	82 (64.9)	80 (63.4)	82 (64.9)	82 (64.9)
D4		86 (68.0)	86 (68.0)	86 (68.0)	84 (66.4)	83 (65.7)	84 (66.4)	84 (66.4)	84 (66.4)
D5		86 (68.0)	85 (67.2)	86 (68.0)	85 (67.2)	84 (66.4)	84 (66.4)	85 (67.2)	82 (64.9)

(Figures in parenthesis are arcsine values)

Table 24. (contd...) Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	87.4 (69.2)	88.0 (69.7)	87.9 (69.6)	88.5 (70.1)	89.2 (70.8)	88.2 (69.9)	88.2 (69.9)	88.2 (69.9)	88.7 (70.4)	88.5 (70.2)
P1	86.3 (68.3)	88.5 (70.2)	88.0 (69.7)	87.5 (69.3)	89.0 (70.6)	87.9 (69.7)	88.2 (69.9)	87.5 (69.3)	88.2 (69.9)	87.7 (69.5)
P2	84.0 (66.4)	86.5 (68.4)	87.5 (69.3)	87.2 (69.1)	87.5 (69.3)	86.5 (68.4)	86.8 (68.7)	86.3 (68.3)	86.0 (68.0)	87.2 (69.1)
P3	82.0 (64.9)	84.0 (66.4)	85.8 (67.9)	86.4 (68.4)	86.8 (68.7)	85.0 (67.2)	85.5 (67.6)	84.5 (66.8)	84.4 (66.7)	85.5 (67.6)
P4	79.0 (62.73)	81.5 (64.5)	83.5 (66.0)	85.8 (67.9)	85.5 (67.6)	83.1 (65.7)	83.8 (66.3)	82.3 (65.1)	82.7 (65.4)	83.1 (65.7)
P5	76.3 (60.9)	78.3 (62.2)	81.5 (64.5)	83.8 (66.3)	83.8 (66.3)	80.7 (63.9)	81.4 (64.5)	80.1 (63.5)	80.5 (63.8)	81.0 (64.2)
Mean	82.5 (65.3)	84.5 (66.8)	85.7 (67.8)	86.5 (68.4)	87.0 (68.9)	85.6 (67.7)				
SI	83.1 (65.73)	85.0 (67.2)	85.9 (68.0)	86.6 (68.5)	87.5 (69.3)	85.6 (67.7)				
SII	81.9 (68.75)	83.9 (66.3)	85.5 (67.6)	86.4 (68.4)	86.4 (68.4)	84.8 (67.1)				
V1	82.1 (65.0)	83.6 (66.1)	85.2 (67.4)	87.6 (69.4)	87.0 (68.9)	85.1 (67.29)				
V2	82.9 (65.6)	85.3 (67.0)	86.2 (68.2)	85.4 (67.8)	86.9 (68.8)	85.4 (67.5)				
Significant factors	P	S	D	PxD	VxD	(Figures in parenthesis are arcsine values)				
CD ($P=0.05$)	0.96	0.58	0.64	1.3	1.29					

germination potential above certification standard (80%) over a period of 15 months. While the germination of the seeds of D_2 and D_1 declined below certification standard after a period of 9 and 6 months, respectively.

The interactions between periods x varieties and varieties x densities were significant. The germination potential at P_0 of D_4 and D_2 , was 88.5 and 88.0 per cent and at P_1 of D_2 and D_3 was 88.5 and 88.0 per cent, respectively. In the latter interaction the seeds from V_1 at D_4 and D_5 recorded maximum germination (87.6 and 87.0%), that significantly declined to 82.1 and 82.9 per cent in V_1 and V_2 at D_1 , respectively.

Root length

The root length differed significantly due to periods of storage and densities (Table 25).

Among the densities, D_4 and D_5 (20.1 and 20.1 cm) recorded lengthier roots compared to other densities. In all the densities the root length decreased with increase in the period of storage from 19.3 (P_0) to 16.2 cm (P_5).

Irrespective of other factors the reduction in root length was lower in V_1 compared to V_2 over periods of storage.

Table 25. Influence of season, plant density and periods of storage on root length (cm) of resultant seeds

	P0						P1					
	V1			V2			V1			V2		
	SI	SII		SI	SII		SI	SII		SI	SII	
D1	17.60	16.80		18.10	19.20		17.20	17.00		17.80	19.65	
D2	18.30	17.20		19.00	18.80		19.60	17.80		18.60	20.60	
D3	19.30	18.60		21.58	20.20		20.40	19.40		20.40	19.40	
D4	21.70	18.80		19.68	19.80		20.98	19.23		19.60	21.80	
D5	21.40	19.40		20.63	20.65		22.40	20.30		21.40	19.20	

Table 25. (contd...)

		P2				P3			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		16.80	16.23	16.20	18.20	15.60	15.40	15.78	17.00
D2		18.60	17.00	18.00	19.40	17.80	16.60	17.38	18.20
D3		20.70	20.40	19.40	18.75	20.20	20.00	18.35	19.00
D4		22.00	20.80	20.00	20.60	21.85	19.90	19.80	19.80
D5		21.80	21.00	20.65	19.58	21.00	20.80	19.70	19.20

Table 25. (contd....)

		P4						P5					
		V1			V2			V1			V2		
		SI	SII		SI	SII		SI	SII		SI	SII	
D1	14.80	14.00		13.20	15.40		12.60	11.83		10.55	11.60		
D2	16.95	15.20		16.40	17.60		15.78	13.60		13.00	13.60		
D3	19.40	19.60		18.60	18.20		17.60	18.40		17.20	17.40		
D4	20.60	20.00		19.00	19.25		19.40	19.20		18.20	18.80		
D5	20.40	19.20		19.20	18.60		18.98	20.10		18.60	18.40		

Table 25. (contd....)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	17.9	18.3	19.9	20.2	20.3	19.3	19.7	19.0	18.9	19.8
P1	18.0	19.1	20.1	20.6	20.8	19.7	19.9	19.5	19.5	19.9
P2	16.7	18.3	19.8	20.9	20.8	19.3	19.4	19.2	19.5	19.0
P3	15.9	17.6	19.6	20.3	20.3	18.7	18.8	18.6	18.9	18.5
P4	14.4	16.5	19.0	19.7	19.4	17.8	17.9	17.7	18.0	17.6
P5	11.6	14.0	17.6	18.9	19.0	16.2	16.2	16.3	16.7	15.7
Mean	15.8	17.3	19.3	20.1	20.1		18.6	18.4	18.6	18.4
SI	15.4	17.5	19.5	20.3	20.5	18.6				
SII	16.1	17.1	19.2	19.9	19.7	18.4				
V1	15.5	17.0	19.6	20.4	20.6	18.6	19.1	18.2		
V2	16.0	17.6	19.1	19.8	19.6	18.4	18.2	18.6		

Significant factors

	P	D	PxD	PxV	DxV	SxV
CD ($P = 0.05$)	0.61	0.52	0.70	0.84	0.44	0.81

In the interactions of varieties x seasons and varieties x densities were significant. The seeds from V₁ at SI (19.1 cm) and V₁ at D₅ (20.6 cm) recorded lengthier roots compared to other interactions irrespective of storage periods.

Vigour index

Significant differences were observed due to storage periods, varieties, seasons and their interactions (Table 26, Fig. 6).

Irrespective of the varieties, seasons and densities the vigour index values decreased from 1724 (P₁) to 1308 (P₅) over periods of storage. Between the varieties V₁ recorded the highest mean vigour index value of 1587 and the lowest (1566) by the seeds of V₁.

The seeds from SI maintained high vigour (1594), irrespective of varieties, densities and storage periods than the seeds from SII (1560).

Among the densities D₅ followed by D₄ recorded higher vigour index of 1742 and 1727 over periods of storage compared to D₃ (1650), D₂ (1463) and D₁ recorded the lowest vigour of 1230. In the interaction of varieties x periods, the vigour index values of both the varieties decreased with

Table 26. Influence of season, plant density and periods of storage on vigour index of resultant seeds

		P0						P1					
		V1			V2			V1			V2		
		SI	SII	SI	SI	SII	SI	SI	SII	SI	SI	SII	SI
D1	1530	1480	1580	1690	1480	1462	1566	1702					
D2	1616	1540	1664	1598	1724	1566	1674	1854					
D3	1674	1632	1715	1778	1796	1707	1795	1707					
D4	1942	1639	1903	1778	1890	1728	1686	1831					
D5	1926	1476	1844	1840	2016	1786	1926	1690					

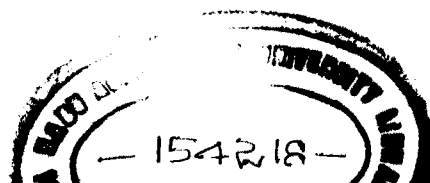


Table 26. (contd...)

		P2				P3			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1	1412	1328		1361	1532	1280	1232	1263	1394
D2	1598	1428		1584	1640	1460	1360	1495	1565
D3	1780	1754		1708	1688	1738	1680	1652	1634
D4	1936	1872		1692	1728	1896	1751	1684	1658
D5	1918	1806		1724	1719	1806	1810	1685	1668

Table 26. (contd...)

		P4				P5			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		1184	1092	1030	1201	982	885	763	882
D2		1394	1186	1312	1443	1248	1034	1014	1062
D3		1630	1608	1562	1529	1443	1472	1376	1426
D4		1772	1720	1596	1613	1610	1612	1492	1580
D5		1754	1632	1652	1582	1596	1688	1562	1510
Mean		1547	1448	1430	1474	1376	1338	1241	1292

Table 26. (contd...)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	1570	1613	1745	1755	1840	1704	1740	1669	1675	1734
P1	1553	1705	1751	1784	1830	1724	1755	1693	1716	1733
P2	1398	1560	1724	1809	1806	1659	1681	1638	1681	1638
P3	1292	1470	1676	1754	1739	1586	1596	1576	1596	1577
P4	1127	1334	1582	1687	1661	1478	1489	1468	1501	1455
P5	869	1095	1423	1575	1578	1308	1300	1316	1355	1267
Mean	1230	1463	1650	1727	1742	1577	1594	1560	1587	1566
SI	1284	1484	1668	1744	1789	1594				
SII	1319	1442	1633	1711	1696	1560				
V1	1279	1431	1660	1782	1785	1587	1633	1542		
V2	1324	1495	1640	1673	1699	1566	1555	1578		

Significant factors

	P	S	V	D	PxS	PxV	PxD	SxV	SxD
CD (P=0.05)	60.22	38.7	50.2	40.48	70.12	76.87	77.31	64.0	61.11

Fig.6 Influence of plant density and storage period on vigour index

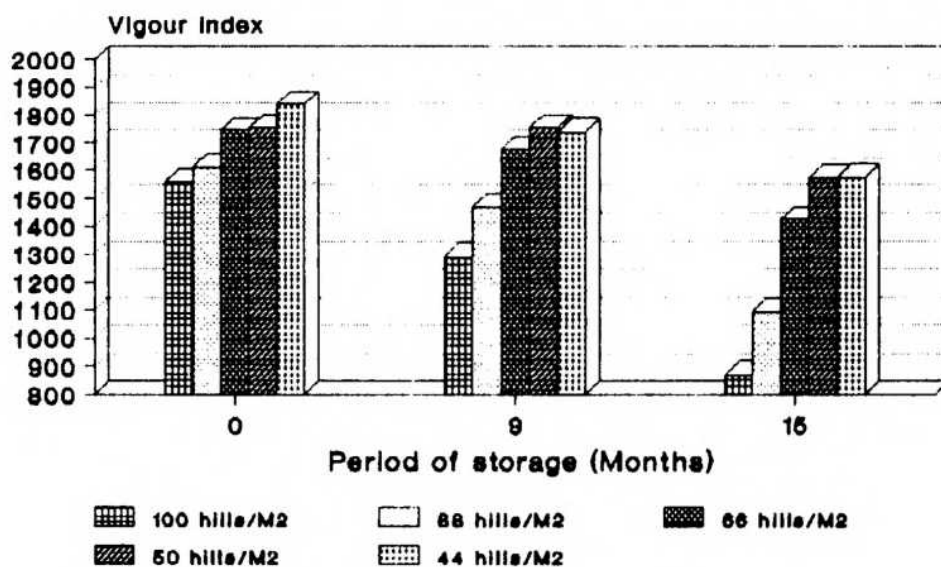
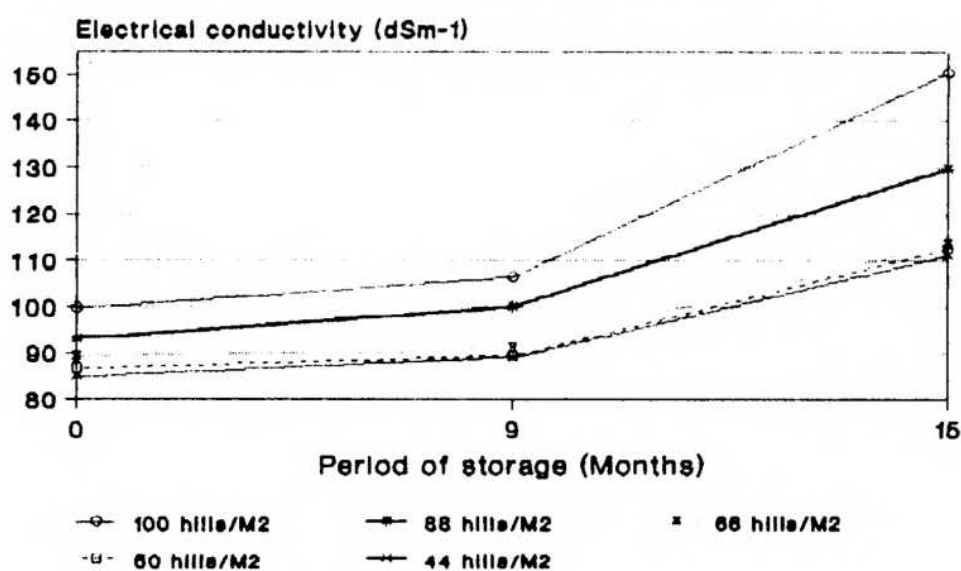


Fig.7 Influence of plant density and storage period on EC of seeds



increase in the period of storage. Similar trend was observed with seasons x densities.

Dry matter production

Dry matter production differed significantly due to periods, seasons and densities (Table 27).

The dry matter decreased with increase in the period of storage from 13.9 (P_1) to 10.0 mg (P_5) irrespective of varieties, seasons and densities.

In the seasons the seeds from SI recorded higher dry matter (12.4 mg) than SII (10.7 mg) over periods of storage. At the end of the storage period of 15 months the mean dry weight of seedlings was higher with the seeds from D_3 (13.0 mg), D_4 and D_5 (12.0 mg) followed by D_2 and D_1 (10.5 and 10.2 mg, respectively).

Electrical conductivity

Significant differences in electrical conductivity values were observed due to periods of storage, varieties, seasons, densities and their interactions (Table 28, Fig. 7).

Table 27. Influence of season, plant density and periods of storage on dry matter production (mg seedling⁻¹) of resultant seeds

	P0						P1					
	V1			V2			V1			V2		
	SI	SII		SI	SII		SI	SII		SI	SII	
D1	11.80	10.30		12.10	10.60		10.60	10.20		11.90	10.70	
D2	11.42	10.42		12.60	11.10		11.20	10.60		12.80	11.30	
D3	12.16	11.36		12.70	10.90		13.20	11.80		12.60	11.40	
D4	12.32	11.71		13.00	11.60		12.83	12.30		13.20	11.50	
D5	12.24	11.46		12.90	11.80		13.40	12.60		13.00	12.13	

Table 27. (contd...)

		P2				P3			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1	11.00	9.80		10.90	9.90	10.40	9.20	10.20	9.20
D2	10.80	10.35		11.60	10.60	10.60	9.60	11.40	10.40
D3	14.00	12.00		12.15	11.00	13.20	11.60	11.80	10.80
D4	13.60	12.10		12.80	11.20	14.00	11.80	12.60	11.00
D5	13.20	12.80		13.10	11.80	13.60	12.20	12.80	11.40

Table 27. (contd....)

		P4						P5					
		V1			V2			V1			V2		
		SI	SII		SI	SII		SI	SII		SI	SII	
D1	9.60	8.10		9.60	8.40		8.20	7.53		8.40	7.60		
D2	9.20	8.50		11.00	10.00		8.40	8.43		10.20	9.40		
D3	12.40	10.90		11.60	10.10		11.60	9.85		10.80	10.00		
D4	13.60	11.00		12.20	10.80		12.90	10.43		11.00	10.20		
D5	13.00	11.80		12.40	11.20		11.35	10.28		11.40	10.63		

Table 27. (contd...)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	11.2	11.4	11.8	12.2	11.2	11.5	12.0	11.1	11.2	11.9
P1	10.9	12.0	21.3	12.5	12.8	13.9	16.1	11.6	15.7	12.0
P2	10.4	10.8	12.3	12.4	12.8	11.7	12.3	11.2	12.0	11.5
P3	9.5	10.4	11.9	12.3	12.4	11.3	12.1	10.6	11.6	11.0
P4	10.0	9.5	10.7	11.7	12.1	10.8	11.4	10.2	10.8	10.7
P5	9.1	8.7	10.1	11.7	12.1	10.8	11.4	10.2	10.8	10.7
Mean	10.2	10.5	13.0	12.0	12.0		12.4	10.7	11.9	11.2
SI	10.6	10.9	15.2	12.7	12.5	12.4				
SII	9.8	10.0	10.9	11.2	11.7	10.7				
V1	10.1	10.1	14.7	12.3	12.2	11.9	13.0	10.8		
V2	10.2	10.8	11.3	11.7	12.0	11.2	11.8	10.6		

Significant factors

	P	S	D
CD(P=0.05)	1.04	1.20	1.90

Table 28. Influence of seasons, plant density and periods of storage on electrical conductivity (dSm⁻¹) of resultant seeds

	P0						P1					
	V1			V2			V1			V2		
	SI	SII		SI	SII		SI	SII		SI	SII	
D1	83.60	96.20		92.80	106.00		84.20	98.60		91.70	107.00	
D2	82.30	102.00		85.00	103.00		82.60	108.40		81.80	102.7	
D3	76.60	96.00		78.80	98.00		76.00	95.00		79.50	97.10	
D4	72.90	98.00		77.00	95.00		69.80	96.20		79.40	95.20	
D5	72.00	92.50		75.80	97.50		73.20	90.40		96.80	95.80	

Table 28. (contd...)

		P2						P3					
		V1			V2			V1			V2		
		SI	SII		SI	SII		SI	SII		SI	SII	
D1	84.60	99.30		95.60	116.40		88.60	108.60		102.80	126.00		
D2	83.00	107.80		87.40	109.00		86.30	112.40		90.80	114.20		
D3	75.40	94.80		81.20	100.80		77.20	97.60		85.60	104.60		
D4	67.20	96.40		80.00	98.40		70.20	99.60		84.80	102.80		
D5	74.00	90.00		82.60	99.60		75.60	91.30		86.20	103.20		

Table 28. (contd....)

		P4			P5		
		V1			V2		
		SI	SII		SI	SII	
D1	96.20	120.20	120.80	140.20	124.00	138.60	160.40 178.60
D2	88.00	119.40	104.20	128.60	104.20	126.20	138.20 150.40
D3	79.60	99.80	92.80	116.00	82.00	114.20	122.00 136.20
D4	73.60	104.30	90.40	109.20	85.60	123.60	112.40 128.20
D5	77.80	93.60	92.00	112.60	88.40	118.40	116.80 120.60

Table 28. (contd....)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	99.7	93.2	89.4	86.7	85.1	90.9	80.5	101.2	89.3	92.4
P1	90.0	95.3	87.2	86.4	84.8	88.7	77.8	99.6	84.9	92.5
P2	90.6	96.8	89.3	85.6	86.1	89.7	81.1	98.3	87.3	92.1
P3	106.3	100.1	91.2	89.4	89.1	95.4	84.7	106.0	90.8	100.0
P4	119.4	110.1	97.0	94.4	103.0	103.0	91.6	114.4	95.3	110.7
P5	150.4	129.8	113.6	112.5	111.1	123.5	113.4	133.5	110.4	136.4
Mean	109.4	104.4	94.6	92.5	91.7		88.2	108.8	93.0	104.0
SI	100.1	93.1	84.4	86.0	82.4	88.2				
SII	118.7	115.6	104.8	104.0	101.0	108.8				
V1	101.4	100.3	88.8	88.9	85.7	93.0	81.0	105.0		
V2	117.3	108.5	100.5	97.7	96.1	104.0	95.4	112.7		

Significant factors

	P	V	S	D	PxV	PxD	VxS	VxD
CD (P=0.05)	2.07	1.92	0.86	1.36	2.94	2.46	2.42	2.86

The electrical conductivity increased gradually with increase in the storage period from 88.7 (P_1) to 123.5 dSm^{-1} (P_5). Between the varieties the increase was lesser in V_1 compared to V_2 irrespective of seasons and periods of storage. Among the densities, D_5 recorded the lower electrical conductivity value (91.7 dSm^{-1}) followed by D_4 (92.5 dSm^{-1}) and the maximum value was observed in D_1 (109.4 dSm^{-1}) over periods of storage.

In the interactions, the seeds from V_1 at SI and D_5 recorded lesser electrical conductivity values over periods of storage than others.

Sugar content

The sugar content in the seed leachates of the stored seeds differed significantly due to periods of storage, varieties, seasons and densities (Table 29).

With the increase in the period of storage the sugar content increased from 3.8 μg (P_0 and P_1) to 5.0 μg (P_5), irrespective of varieties, seasons and densities. Between the varieties, the seeds from V_2 recorded lower sugar content (4.2 μg) while, it was higher in V_1 (4.7 μg) irrespective of other factors. In the seasons, the seeds from SI recorded lower sugar content of 4.1 μg compared to SII (4.8 μg).

Table 29. Influence of season, plant density and periods of storage on sugar content (µg) of resultant seeds

	P0				P1			
	V1		V2		V1		V2	
	SI	SII	SI	SII	SI	SII	SI	SII
D1	3.14	4.64	3.62	4.16	3.24	4.70	3.70	4.20
D2	3.39	4.36	3.59	4.30	3.50	4.40	3.62	4.38
D3	2.97	3.92	4.10	3.98	2.84	3.89	4.14	4.10
D4	2.86	3.52	3.86	3.90	2.90	3.72	3.97	3.92
D5	2.80	3.89	3.72	4.00	3.15	3.84	3.80	3.98

Table 29. (contd....)

		P2			P3		
		V1			V2		
		SI	SII	SII	SI	SII	SII
		SI	SII	SII	SI	SII	SII
D1	4.00	5.10	4.10	4.50	4.86	6.20	4.34 4.84
D2	4.10	5.60	3.80	4.26	4.68	6.40	4.00 4.40
D3	3.26	4.15	4.10	4.20	3.52	4.74	4.20 4.26
D4	3.11	3.98	3.86	3.87	3.63	4.88	3.91 3.90
D5	3.22	3.90	3.72	3.80	3.80	4.68	3.80 3.76

Table 29. (contd....)

		P4			P5		
		V1			V2		
		SI	SII		SI	SII	
D1	5.72	7.80	4.72	5.10	6.84	8.90	5.10 5.95
D2	5.90	7.10	4.20	4.78	6.76	8.76	4.48 5.28
D3	4.00	5.00	4.36	4.30	4.96	5.90	4.52 4.64
D4	4.10	5.28	4.10	3.98	5.00	6.20	4.24 4.21
D5	4.21	5.64	3.90	3.86	5.11	6.38	4.16 4.18

Table 29. (contd...)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	3.9	3.9	3.7	3.6	3.6	3.8	3.4	4.1	3.6	3.9
P1	4.0	3.9	3.8	3.7	3.7	3.8	3.5	4.1	3.7	4.0
P2	4.1	4.5	4.1	3.8	3.6	4.0	3.8	4.3	4.0	4.0
P3	4.7	4.9	4.5	4.1	4.0	4.4	4.1	4.8	4.7	4.2
P4	5.8	5.5	4.4	4.4	4.4	4.9	4.5	5.3	5.5	4.3
P5	6.8	6.3	5.0	4.9	5.0	5.6	5.1	6.1	6.5	4.7
Mean	4.9	4.9	4.2	4.1	4.1				4.7	4.2
SI	4.4	4.4	3.9	3.8	3.8	4.1				
SII	5.4	5.3	4.6	4.3	4.3	4.8				
V1	5.3	5.4	4.2	4.1	4.2	4.7	4.1	5.2		
V2	4.5	4.3	4.2	4.0	3.9	4.2	4.1	4.3		

Significant factors

	P	V	S	D	PxV	PxS	PxD	VxS	VxD	SxD
CD ($P=0.05$)	0.24	0.13	0.11	0.17	0.28	0.26	0.22	0.19	0.20	0.08

Among the densities, D_4 and D_5 recorded the lowest sugar of 4.1 μg followed by D_3 (4.2 μg) than D_1 and D_2 (4.9 μg).

Aminoacids

The aminoacids in the seed leachate differed significantly due to periods of storage, seasons and densities (Table 30).

The amount of aminoacids in the leachate increased from 1.90 μg (P_0) to 4.0 μg (P_5) over periods of storage. In the seasons, SI and SII recorded lowest and highest mean aminoacids of 2.5 and 2.8 μg , respectively. Among the densities, the increase of aminoacids was lesser in D_5 followed by D_4 and D_3 , while it was higher in D_2 .

The interactions between periods of storage x varieties, periods x seasons, periods x densities and varieties x seasons were significant.

Protein content

Significant differences were observed due to periods, varieties, seasons, densities and their interactions (Table 31, Fig. 8).

Table 30. Influence of season, plant density and periods of storage on aminoacids (µg) of resultant seeds

		P0				P1			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		1.92	2.02	2.24	2.35	2.10	2.23	2.39	2.52
D2		1.99	2.14	2.18	2.42	2.00	2.13	2.20	2.56
D3		1.80	2.02	2.10	2.25	2.00	1.95	2.27	2.40
D4		1.82	1.98	2.00	2.16	1.86	1.92	2.10	2.42
D5		1.77	1.92	2.10	2.10	1.98	2.00	2.30	2.30

Table 30. (contd...)

		P2				P3			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		2.36	2.44	2.70	2.88	2.85	3.10	3.12	3.50
D2		2.10	2.18	2.61	2.97	2.40	2.84	3.25	3.37
D3		1.90	2.10	2.42	2.76	2.21	2.63	2.92	3.10
D4		1.94	1.96	2.35	2.62	2.28	2.41	2.81	2.90
D5		1.88	1.93	2.40	2.70	2.10	2.52	2.60	2.71

Table 30. (contd....)

	P4						P5					
	V1			V2			V1			V2		
	SI	SII		SI	SII		SI	SII		SI	SII	
D1	3.83	3.93		3.94	4.20		4.62	5.00		5.20	5.81	
D2	3.60	3.76		4.10	4.32		4.45	4.73		4.80	5.91	
D3	2.75	3.10		3.51	3.93		3.49	4.17		4.20	4.85	
D4	2.80	2.97		3.55	3.41		3.22	3.70		4.10	4.61	
D5	2.62	3.10		3.41	3.26		3.77	3.41		4.31	4.49	

Table 30. (contd....)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	2.0	2.0	1.8	1.8	1.8	1.9	1.6	2.1	1.9	1.8
P1	2.2	2.2	2.1	1.9	1.9	2.0	2.1	2.0	2.1	2.0
P2	2.4	2.2	2.2	2.1	2.2	2.2	2.1	2.3	2.3	2.1
P3	2.9	2.7	2.5	2.5	2.5	2.6	2.4	2.7	2.7	2.5
P4	3.6	3.7	3.0	2.9	2.7	3.2	3.0	3.3	3.0	3.3
P5	4.0	4.5	4.0	4.0	4.0	4.0	3.7	4.2	3.8	4.2
Mean	2.8	2.9	2.6	2.5	2.4		2.5	2.8	2.6	2.7
SI	2.7	2.7	2.5	2.4	2.3	2.5				
SII	2.9	3.0	2.7	2.7	2.5	2.8				
V1	2.8	2.8	2.6	2.5	2.5	2.6	2.6	2.7		
V2	2.9	2.9	2.6	2.5	2.4	2.7	2.5	2.9		

Significant factors

	P	S	D	PxV	PxS	PxD	SxV
CD ($P=0.05$)	0.17	0.06	0.09	0.18	0.18	0.12	0.10

Table 31. Influence of season, plant density and periods of storage on protein content (%) of resultant seeds

	P0						P1					
	V1			V2			V1			V2		
	SI	SII		SI	SII		SI	SII		SI	SII	
D1	8.96	7.14		9.62	8.46		8.71	7.00		9.58	8.50	
D2	9.21	7.26		9.40	8.50		9.46	7.34		9.46	8.48	
D3	8.87	8.43		9.86	9.20		9.09	8.56		9.80	9.10	
D4	9.38	8.37		10.20	9.64		9.62	8.85		10.00	9.70	
D5	9.56	8.64		9.95	9.52		9.38	9.09		10.20	9.56	

Table 31. (contd...)

		P2				P3			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		8.66	6.84	9.36	8.20	7.78	6.00	9.12	7.80
D2		9.52	7.26	9.40	8.32	8.99	6.86	9.24	8.10
D3		9.20	8.62	9.72	9.00	9.11	8.40	9.70	8.92
D4		9.55	8.90	9.90	9.66	9.20	8.20	9.84	9.46
D5		9.20	9.14	10.00	9.42	8.90	8.86	9.88	9.32

Table 31. (contd....)

		P4			P5		
		V1			V2		
		SI	SII	SII	SI	SII	SII
D1	6.82	5.10	8.76	7.10	5.94	4.21	8.10 6.20
D2	7.95	5.94	9.00	7.80	6.92	5.00	8.36 7.10
D3	8.80	7.81	9.64	8.76	8.01	6.96	8.42 8.14
D4	8.91	8.90	9.80	9.32	8.21	8.10	9.68 8.98
D5	8.62	8.26	9.72	9.26	8.45	7.90	9.54 8.84

Table 31. (contd....)

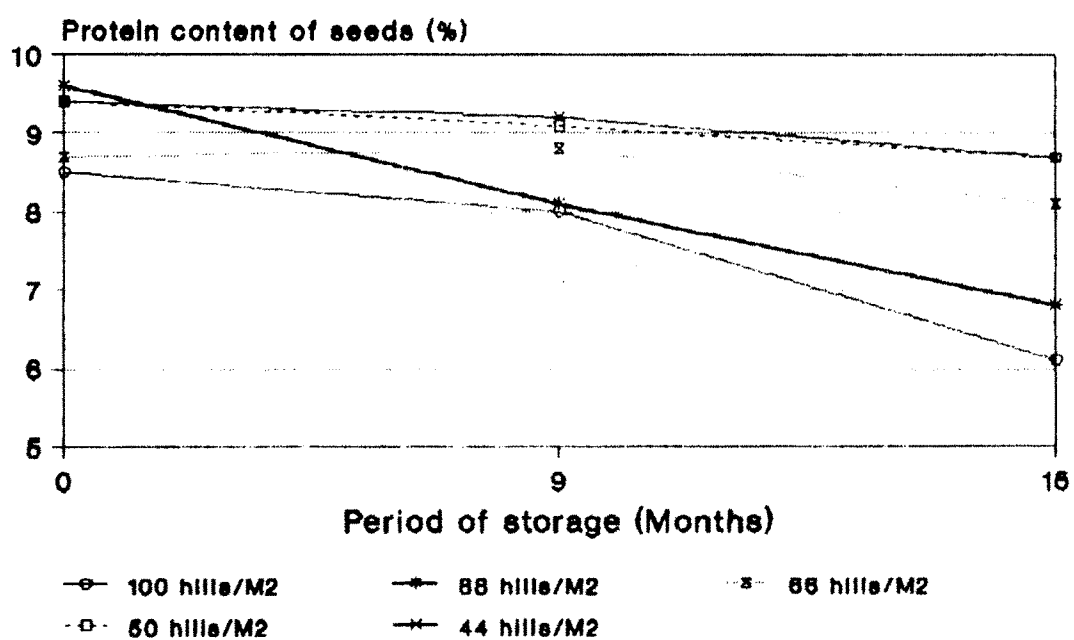
Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	8.5	8.6	9.1	9.4	9.4	9.0	9.5	8.5	8.6	9.4
P1	8.5	8.7	9.1	9.5	9.6	9.1	9.5	8.6	8.7	9.5
P2	8.6	8.6	9.0	9.3	9.5	9.0	9.4	8.6	8.7	9.3
P3	8.0	8.1	8.8	9.1	9.2	8.7	9.2	8.2	8.2	9.1
P4	6.9	7.7	8.8	9.2	9.0	8.3	8.8	7.8	7.7	8.9
P5	6.1	6.8	8.1	8.7	8.7	7.7	8.3	7.1	7.0	8.4
Mean	7.8	8.1	8.8	9.2	9.2		9.1	8.1	8.2	9.1
SI	8.5	8.9	9.3	9.5	9.5	9.1				
SII	7.1	7.3	8.4	9.0	9.0	8.1				
V1	7.1	7.6	8.4	8.8	8.9	8.2	8.7	7.6		
V2	8.4	8.6	9.3	9.7	9.6	9.1	9.5	8.7		

Significant factors

	P	V	S	D	PxV	PxD	SxV	SxD	VxD
CD (P=0.05)	0.28	0.07	0.08	0.13	0.18	0.20	0.12	0.15	0.11

Fig.8 Influence of plant density and storage period on protein content



The protein content decreased gradually with increase in the period of storage from 9.0 (P_0) to 7.7 per cent (P_5). The mean protein content of the varieties irrespective of periods, seasons and densities were 8.2 per cent (V_1) and 9.1 per cent (V_2). In the seasons, the decrease in protein content was higher in SII compared to SI over periods of storage. Among the population densities the reduction in protein content was less in D_4 and D_5 (9.2%) followed by D_3 (8.8%), while the decrease was little faster in the seeds from D_2 (8.1%) and D_1 (7.8%).

Alpha amylase activity

The alpha amylase activity of the seeds decreased from 10.2 (P_1) to 9.0 mm (P_5) over periods of storage (Table 32). Between the varieties the seeds from V_1 recorded higher alpha amylase activity (10.3 mm) than V_2 (9.2 mm). In the seasons SI registered higher activity (10.0 mm) compared to SII (9.5 mm).

Fungal infection

The fungal infection per cent differed significantly due to periods of storage, varieties, seasons and their interactions (Table 33).

Table 32. Influence of season, plant density and periods of storage on alpha amylase activity (mm) of resultant seeds

		P0			P1		
		V1			V2		
		SI	SII	SII	SI	SII	SII
D1	10.80	9.24	9.65	8.45	10.60	9.30	9.70
D2	10.20	9.16	9.83	8.53	10.70	9.40	9.90
D3	11.38	10.61	10.45	9.10	11.40	10.70	10.40
D4	11.55	11.21	10.83	9.40	11.80	11.30	10.90
D5	11.48	10.75	10.35	9.30	11.60	10.90	10.40

Table 32. (contd...)

		P2				P3			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		10.20	9.10	9.65	8.45	9.80	8.00	9.45	8.30
D2		10.40	9.10	9.83	9.25	10.00	8.20	9.68	9.10
D3		11.50	10.60	10.38	9.30	11.60	10.20	10.80	9.43
D4		12.00	10.40	10.93	9.40	11.60	10.20	10.80	9.38
D5		11.80	10.80	10.45	9.30	11.20	10.30	10.30	9.38

Table 32. (contd...)

		P4				P5			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1	8.23	7.50	9.00	8.10	7.80	6.90	8.20	7.60	
D2	9.40	8.00	9.20	8.95	8.20	7.40	8.70	7.95	
D3	10.80	9.80	10.13	9.00	10.60	9.60	9.85	8.85	
D4	11.20	9.90	10.15	9.30	11.00	9.30	10.10	9.00	
D5	11.00	10.00	10.80	9.10	10.80	9.40	9.95	8.90	

Table 32. (contd....)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	9.5	9.4	10.3	10.7	10.5	10.1	10.5	9.6	10.6	9.5
P1	9.5	9.8	10.5	10.9	10.5	10.2	10.7	9.7	10.7	9.7
P2	9.4	9.6	10.4	10.7	10.6	10.1	10.6	9.6	10.7	9.6
P3	8.9	9.2	10.1	10.5	10.3	9.8	10.0	9.5	10.4	9.2
P4	8.2	8.9	9.9	10.3	10.2	9.5	9.6	9.3	10.1	9.0
P5	7.5	8.1	9.8	9.9	9.8	9.0	9.1	8.8	9.5	8.5
Mean	8.8	9.2	10.2	10.5	10.3		10.1	9.5	10.3	9.2
SI	9.0	9.2	10.7	10.9	10.8	10.1			10.7	9.6
SII	8.7	9.2	9.7	10.0	9.8	9.5			10.0	8.9
V1	9.4	9.7	10.7	11.1	10.8	10.3	10.7	10.0		
V2	8.2	8.7	9.7	9.8	9.8	9.2	9.6	8.9		

Significant factors

	P	S	V	D	PxS	PxD	SxD	VxD
CD (P = 0.05)	0.31	0.22	0.12	0.18	0.36	0.31	0.26	0.35

Table 33. Influence of season, plant density and periods of storage on fungal infection (%) of resultant seeds

	P0						P1					
	V1			V2			V1			V2		
	SI	SII		SI	SII		SI	SII		SI	SII	
D1	3.38	4.00		2.30	3.00		4.30	5.00		2.50	3.50	
D2	3.13	5.25		2.00	3.30		3.30	5.20		3.00	3.00	
D3	2.88	3.50		1.10	2.00		3.70	5.30		1.50	2.50	
D4	1.38	3.50		1.40	2.50		1.70	4.20		1.10	2.50	
D5	1.75	4.00		1.70	3.00		2.10	3.90		2.00	3.00	

Table 33. (contd...)

		P2				P3			
		V1		V2		V1		V2	
		SI	SII	SI	SII	SI	SII	SI	SII
D1		4.70	5.60	3.50	4.50	5.30	6.70	5.00	6.50
D2		4.00	5.40	3.50	4.50	5.70	6.00	4.50	6.50
D3		3.30	4.90	2.50	3.50	4.70	5.60	3.50	5.00
D4		2.70	4.33	2.00	3.00	3.50	4.90	3.00	4.00
D5		4.20	3.90	3.10	3.50	4.60	5.00	4.00	4.00

Table 33. (contd...)

		P4			P5		
		V1			V2		
		SI	SII	SII	SI	SII	SII
D1	6.90	8.70	6.50	8.00	8.30	10.10	8.00 9.50
D2	7.30	7.30	6.50	8.50	8.50	9.70	7.50 10.00
D3	5.80	6.90	5.00	6.50	7.00	8.60	6.00 7.50
D4	5.70	6.60	4.50	5.00	7.20	8.60	5.00 6.50
D5	6.80	5.70	5.00	4.50	7.40	8.00	5.50 6.00

Table 33. (contd....)

Interactions

	D1	D2	D3	D4	D5	Mean	SI	SII	V1	V2
P0	3.1	3.4	2.4	2.1	2.6	2.7	2.1	3.4	3.3	2.1
P1	3.8	3.6	5.8	2.5	3.0	3.7	2.5	4.9	3.9	3.6
P2	4.7	4.0	3.4	3.4	3.9	3.9	3.4	4.4	4.3	3.5
P3	6.0	5.4	4.7	4.0	4.7	5.0	4.4	5.5	5.2	4.7
P4	7.7	7.2	6.1	5.6	5.6	6.5	6.0	6.9	6.8	6.1
P5	9.0	8.9	7.2	6.8	6.7	7.7	7.0	8.4	8.3	7.1
Mean	5.7	5.4	4.9	4.1	4.4		4.2	5.6	5.3	4.5
SI	5.1	4.8	3.9	3.4	4.1					
SII	6.4	6.1	6.0	4.7	4.8					
V1	6.1	5.9	5.2	4.5	4.8		4.7	5.9		
V2	5.4	5.0	4.7	3.6	4.1		3.8	5.3		

Significant factors

	P	V	S	D
CD ($P=0.05$)	0.53	0.38	0.38	0.61

In general, the fungal infection increased with increase in the storage period. With the increase in the storage period the fungal infection increased from 2.7 to 7.7 per cent, irrespective of varieties, seasons and densities.

Among the varieties and seasons V₂ and SI recorded lower fungal infection percentages (4.5 and 4.2%) than V₁ and SII (5.3 and 5.6%). Throughout the storage period the seeds from D₄ and D₁ registered lower and higher fungal infection, respectively.

Accelerated ageing on seed quality

The resultant seeds obtained from the Kharif 1994 season after its initial evaluation were subjected to accelerated ageing for 12 days to predict its storability.

Speed of germination

The speed of germination due to varieties and densities differed significantly due to accelerated ageing (Table 34). The seeds from lower densities of D₅ and D₄ registered highest speed of germination of 23.1 and 28.9, respectively after ageing than those seeds from other densities. Between the varieties the rate of germination of the seeds of V₁ was higher (22.3) compared to V₂ (20.6)

Table 34. Influence of season and plant density on speed of germination, germination (%) and root length (cm) of resultant seeds after accelerated ageing

	Speed of Germination			Germination (%)			Root length (cm)		
	VI	V2	Mean	VI	V2	Mean	V1	V2	Mean
D1	20.70	19.20	19.90	42 (40.4)	38 (38.1)	40.00 (39.2)	13.80	14.20	14.00
D2	20.50	19.00	19.80	46 (42.7)	40 (39.2)	43.00 (41.0)	14.50	15.50	15.00
D3	22.60	20.50	21.60	52 (46.1)	55 (47.9)	53.30 (46.9)	17.40	18.20	17.80
D4	23.90	21.90	22.90	53 (46.9)	56 (48.5)	54.70 (47.7)	16.90	19.13	18.00
D5	23.80	22.40	23.10	55 (47.9)	53 (46.7)	54.20 (47.4)	18.00	18.60	18.30
Mean	22.30	20.60		49.70 (44.8)	48.30 (44.0)		16.12	17.13	

(Figures in parenthesis are arcsine values)

V	D	VxD	V	D	VxD	V	D	VxD
CD(P=0.05) 0.373	0.590	NS	NS	2.47	3.49	0.809	1.28	NS

irrespective of densities.

Germination

The germination potential of the aged seeds differed significantly due to densities (Table 34). Among the population densities the germination potential of the seeds from D_1 and D_2 , reduced drastically after ageing compared to the seeds from D_3 , D_4 and D_5 . In the densities the seeds from lower densities of D_5 and D_4 , recorded higher germination after ageing. The decline in germination from lower (D_5) to higher (D_1) densities ranged from 3.0 to 14.7 per cent irrespective of varieties.

The interaction between varieties x density levels revealed that the seeds of V_2 at D_4 and D_3 and V_1 at D_5 maintained highest germination of 56, 55 and 55 per cent, respectively after ageing, while the least was recorded by the seeds of V_2 at D_1 (38%).

Root length

Accelerated ageing induced significant variations in the root length, among the varieties and density levels (Table 34). Their interaction was not significant. In the varieties V_2 recorded longer roots of 17.13 cm while, the shortest was in V_1 (16.12 cm). Among the density levels D_5

and D₄ recorded lengthier roots of 18.30 and 18.00 cm, respectively compared to D₁ (14.00 cm) irrespective of varieties.

Vigour index

The vigour index values due to varieties, density levels and their interactions differed significantly due to accelerated ageing (Table 35). The seeds of the varieties V₂ recorded the higher vigour of 847 than V₁ (808). Among the density levels D₅ followed by D₄ recorded higher vigour index values of 990 and 981 and lower by D₁ (560).

In the interaction of varieties x densities, V₂ at D₄ and D₅ registered maximum vigour of 1070 and 1017 followed by V₁ at D₅ (993) and V₂ at D₅ (986).

Dry matter production

Dry matter production differed significantly due to density levels (Table 35). The seeds from D₅, D₄ and D₃ recorded the dry matter production 9.45, 9.15 and 9.10 mg, respectively on par with each other and significantly higher than D₁ (7.48 mg) and D₂ (8.00 mg).

Electrical conductivity

The electrical conductivity values significantly

Table 35. Influence of season and plant density on vigour index, dry matter production (mg Seedling^{-1}) and electrical conductivity (dSm^{-1}) of resultant seeds after accelerated ageing

	Vigour Index				Dry matter production (mg seedling^{-1})				Electrical conductivity (dSm^{-1})			
	VI	V2	Mean	VI	V2	Mean	VI	V2	Mean	V1	V2	Mean
D1	580	540	560	7.13	7.83	7.48	79.60	68.60	74.10			
D2	668	623	645	8.10	7.90	8.00	78.90	69.00	74.00			
D3	905	1017	961	9.20	9.00	9.10	77.40	67.30	72.40			
D4	893	1070	981	8.90	9.40	9.15	75.00	65.40	70.20			
D5	993	986	990	9.30	9.60	9.45	74.60	64.00	69.00			
Mean	808	847		8.53	8.75		77.10	66.90				
	V	D	VxD	V	D	VxD	V	D	VxD			
CD(P=0.05)	25.43	40.21	50.87	NS	0.39	NS	1.21	1.92	NS			

varied due to varieties and density levels (Table 35). Between the varieties the aged seeds of V_2 recorded higher EC value of 77.1 dSm^{-1} compared to V_1 (66.9 dSm^{-1}). Among the population densities the aged seeds from lower densities of D_5 , D_4 and D_3 recorded lower EC values compared to those from higher densities of D_2 and D_1 .

Sugar content

Significant differences in sugar content existed among the density levels due to accelerated ageing however, the varietal differences and their interaction were not significant (Table 36). Among the density levels higher sugar exudation in the leachate was observed in the higher density levels of D_1 ($7.55 \text{ } \mu\text{g}$) and D_2 ($7.73 \text{ } \mu\text{g}$) compared to lower densities of D_4 ($6.45 \text{ } \mu\text{g}$), D_5 ($6.48 \text{ } \mu\text{g}$) and D_3 ($6.96 \text{ } \mu\text{g}$).

Aminoacids

Significant differences were observed in amino acid content among the varieties and density levels, while their interactions were not significant (Table 36). The seed leachate of V_1 and V_2 registered the lowest and highest aminoacid values of 5.79 and $6.65 \text{ } \mu\text{g}$, respectively, after accelerated ageing. After ageing, the increase of amino acid content was least in D_5 and D_4 (5.88 and $5.95 \text{ } \mu\text{g}$)

Table 36. Influence of season and plant density on sugar content (μg) and aminoacids (μg) of resultant seeds after accelerated ageing

	Sugar content (μg)			Aminoacids (μg)		
	VI	V2	Mean	V1	V2	Mean
D1	7.17	7.94	7.55	6.31	7.33	6.82
D2	7.45	8.00	7.73	5.94	6.91	6.43
D3	6.80	7.12	6.96	5.64	6.43	6.04
D4	6.50	6.40	6.45	5.70	6.19	5.95
D5	6.63	6.32	6.48	5.35	6.41	5.88
Mean	6.90	7.16		5.79	6.65	
	V	D	VxD	V	D	VxD
CD(P=0.05)	NS	0.333	NS	0.125	0.197	NS

followed by D₃ (6.04 µg), while it was highest in D₁ (6.82 µg) and D₂ (6.43 µg).

Protein content

Protein content differed significantly due to density levels (Table 37). Among the density levels D₃ and D₄ registered the highest protein content of 8.28 and 8.23 per cent respectively after ageing followed by D₂ (7.70%). The density levels of D₁ and D₂ recorded the lowest protein content of 6.54 and 6.84 per cent, respectively.

The interaction between the varieties x density levels was significant. Protein content of aged seeds of V₂ at D₃ and D₄ and V₁ at D₄ were the highest, compared other interactions.

Alpha amylase activity

Alpha amylase activity of the aged seeds differed significantly due to varieties, density levels and their interactions (Table 37). Between the varieties the aged seeds from V₂ recorded higher activity (7.16 mm) compared to the seeds from V₁ (6.76 mm). Among the density levels D₄ and D₃ registered the highest alpha amylase activity (7.80 and 7.60 mm) compared to D₁ and D₂ (6.00 and 6.10 mm).

Table 37. Influence of season and plant density on protein content (%), alpha amylase activity (nm) and fungal infection of resultant seeds after accelerated ageing

	Protein content (%)				Alpha amylase (nm)				Fungal infection (%)			
	VI	V2	Mean	VI	V2	Mean	VI	V2	Mean	VI	V2	Mean
D1	6.84	6.24	6.54	5.90	6.10	6.00	5.60	5.70	5.70	5.60	5.70	5.70
D2	6.95	6.72	6.84	6.20	6.00	6.10	6.20	5.80	6.00	6.20	5.80	6.00
D3	7.80	7.60	7.70	7.10	7.50	7.30	5.30	5.90	5.60	5.30	5.90	5.60
D4	8.10	8.35	8.23	7.80	7.80	7.80	4.90	5.20	5.10	4.90	5.20	5.10
D5	7.95	8.60	8.28	6.80	8.40	7.60	5.10	4.90	5.00	5.10	4.90	5.00
Mean	7.53	7.50		6.76	7.16		5.40	5.50		5.40	5.50	
V		D	VxD	V	D	VxD	V	D	VxD	V	D	VxD
CD(P=0.05)	NS	0.19	0.27	0.25	0.40	0.56	NS	NS	NS	NS	NS	NS

Fungal infection

The percentage of fungal load of the aged seeds did not differ significantly due to varieties, density levels and their interactions (Table 37).

4.2. Influence of age of seedling and levels of nitrogen on seed yield and quality.

Days to initiation of flowering

Days to initiation of flowering did not differ significantly due to varieties, nitrogen levels and their interactions, except age of seedlings (Table 38). In general highest age groups took more number of days for initiation of flowering. Among the age groups A₂ took lesser number of days of 48.0 for the initiation of flowering followed by A₁ (48.1), while A₃ took the maximum number of days (52.6) compared to other age groups.

Number of tillers

The number of tillers plant⁻¹ at harvest differed significantly due to nitrogen levels (Table 39). The increased levels of nitrogen increased the tiller number compared to the recommended dose of fertilizers irrespective of varieties and age groups and were on par with each other.

Table 38. Influence of age of seedling and nitrogen levels on days to initiation of flowering

[illegible]

Table 39. Influence of age of seedling and nitrogen levels on number of tillers plant⁻¹

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	10.7	11.0	10.7	10.3	10.6	10.3	10.7	11.0	10.7	10.8	10.7
A2	11.0	11.3	12.0	11.6	11.5	10.6	10.7	10.7	10.0	10.5	11.0
A3	10.0	11.0	12.3	11.4	11.2	10.0	10.6	11.7	10.7	10.8	11.0
A4	8.7	9.3	10.0	9.8	9.4	9.7	9.7	10.3	10.3	10.0	9.7
A5	7.3	7.6	6.7	7.0	7.2	8.6	8.3	8.7	9.0	8.7	7.9
Mean	9.5	10.1	10.3	10.0		9.9	10.0	10.5	10.1		
Mean	10.0					10.1					
Nitrogen Mean											

Number of productive tillers

The number of productive tillers plant⁻¹ at harvest differed significantly due to age of the seedlings (Table 40, Fig. 9). Among the age groups A₂ recorded higher number of productive tillers (9.4) followed by A₃ (9.3) and were on par with each other. While A₅ recorded the lower number of productive tillers (5.9) compared to all the other age groups.

Length of panicle

Length of panicle differed significantly due to varieties and age of seedlings (Table 41). Between the varieties V₂ recorded lengthier panicle (21.6 cm) than V₁ (19.7 cm) irrespective of age of planting and nitrogen levels.

Among the age groups A₂ followed by A₃ recorded lengthier panicles of 22.0 and 21.5 cm compared to other age groups. The plants under A₅ recorded shorter panicle of 19.9 cm.

The nitrogen levels and none of the interactions showed significant influence on the panicle length.

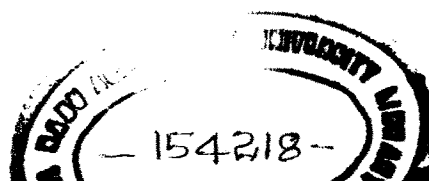


Table 40. Influence of age of seedling and nitrogen levels on number of productive tillers plant⁻¹

Age of seedling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	9.0	9.0	8.6	9.0	8.9	8.0	8.3	10.0	9.3	8.9	8.9
A2	9.3	9.7	10.0	9.6	9.6	9.0	9.0	9.7	9.0	9.2	9.4
A3	8.3	9.3	10.7	9.3	9.4	8.3	9.7	9.7	8.6	9.1	9.3
A4	6.0	7.4	8.3	8.0	7.4	7.6	8.7	8.7	8.3	8.3	7.9
A5	5.0	5.6	4.7	5.3	5.2	6.3	7.0	6.7	6.3	6.6	5.9
Mean	7.5	8.2	8.5	8.3		7.9	8.5	8.9	8.3		
Mean					8.1					8.4	
Nitrogen Mean			N1	N2	N3	N4					
			7.7	8.4	8.6	8.3					
		A	N	V	AxN	AxV	NxV	AxNxV			
CD(P=0.05)		0.917	NS	NS	NS	NS	NS	NS	NS	NS	

Table 41. Influence of age of seedling and nitrogen levels on length of panicle (cm)

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	20.4	20.0	20.6	20.5	20.4	21.6	21.5	21.8	21.6	21.7	21.0
A2	20.8	21.5	21.8	20.9	21.3	22.4	22.6	23.0	22.5	22.6	22.0
A3	19.6	20.2	21.6	21.4	20.5	22.0	22.4	22.9	22.3	22.4	21.5
A4	18.4	19.0	19.2	18.8	18.9	20.8	21.4	21.6	21.0	21.2	21.0
A5	17.6	17.5	18.0	17.4	17.6	19.6	20.4	20.8	20.3	20.2	19.9
Mean	19.4	19.6	20.2	19.6		21.3	21.7	22.0	21.5		
Mean	19.7					21.6					
Nitrogen Mean	N1	N2	N3	N4							
	20.3	20.6	21.1	20.6							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	0.758	NS	1.200	NS	NS	NS	NS	NS	NS		

Fig.9 Influence of seedling age on days to maturity, productive tillers and good seeds

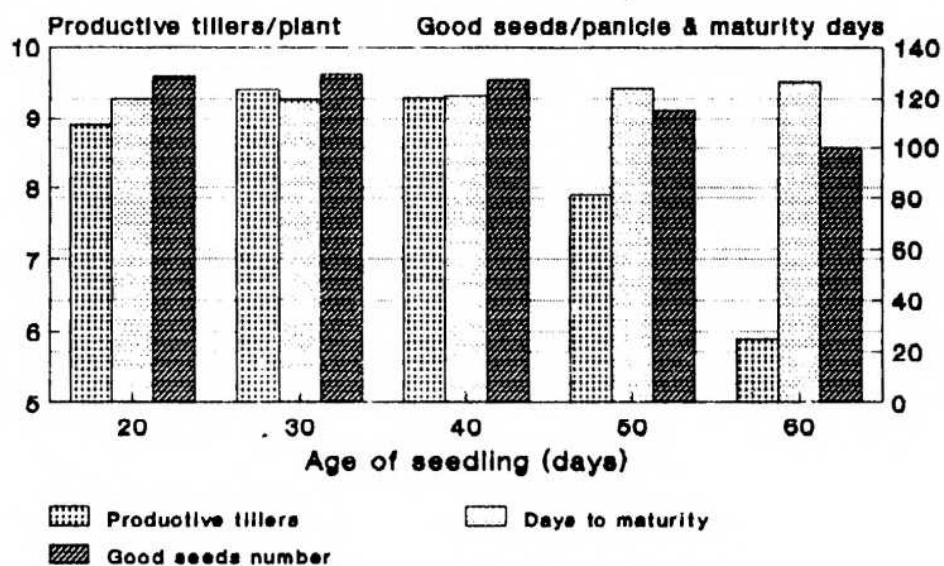
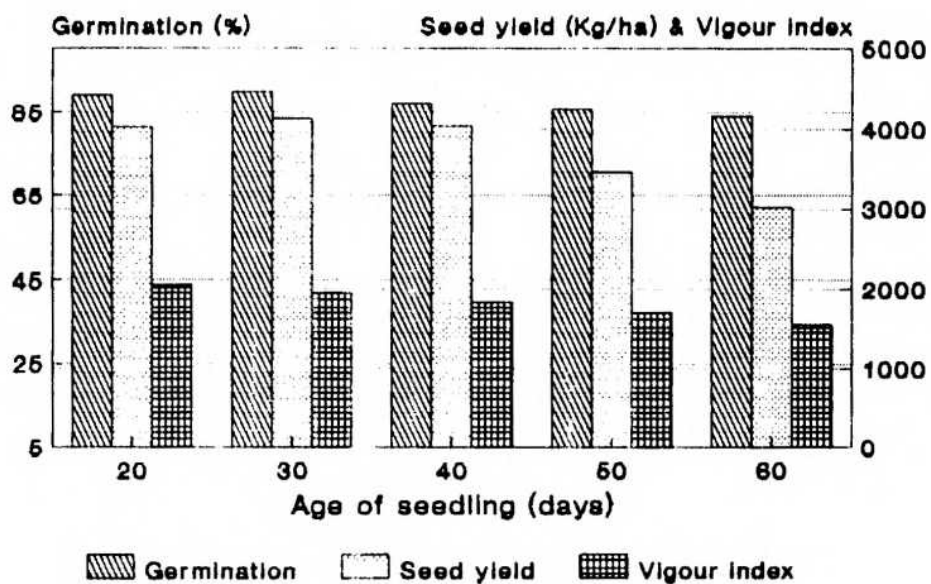


Fig.10 Influence of seedling age on seed yield, germination and vigour Index



Weight of the panicle

The weight of the panicle was significantly influenced due to varieties, nitrogen levels and age of the seedlings (Table 42). Irrespective of other factors V₂ recorded the maximum panicle weight of 2.5 g compared to V₁ (2.4 g). Among the nitrogen levels N₂, N₁ and N₃ being on par, recorded higher panicle weight (2.54, 2.52 and 2.50 g, respectively) than N₄ (2.49 g). In the age groups A₂ and A₃ recorded the maximum panicle weight of 2.6 g, while A₁ recorded the minimum weight of 2.1 g.

None of the interactions, except varieties x age groups showed significant difference in panicle weight. The varieties V₁ and V₂ at A₂ and V₂ at A₃ recorded the maximum panicle weight (2.6 g).

Days to maturity

Significant differences were observed for days to maturity due to varieties, levels of nitrogen and age of the seedlings (Table 43, Fig. 9). Between the varieties V₂ took more number of days (135.7) to attain physiological maturity compared to V₁ (108.1) and the difference between the varieties was 27.6 days. Among the nitrogen levels the plants grown under N₃ and N₄ took less number of days for maturity (121.4 and 121.6) compared to the plants grown

Table 42. Influence of age of seedling and nitrogen levels on weight of panicle (g)

Age of seedling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	2.50	2.60	2.60	2.40	2.50	2.55	2.60	2.50	2.64	2.57	2.50
A2	2.40	2.60	2.70	2.60	2.60	2.74	2.71	2.64	2.63	2.68	2.60
A3	2.30	2.50	2.70	2.60	2.50	2.61	2.66	2.69	2.54	2.63	2.60
A4	2.10	2.30	2.50	2.40	2.30	2.47	2.43	2.44	2.36	2.42	2.40
A5	1.80	1.90	2.00	1.90	1.90	2.23	2.30	2.23	2.25		2.10
Mean	2.30	2.40	2.50	2.40		2.52	2.54	2.50	2.49		
Mean					2.40					2.5	
Nitrogen Mean											

Table 43. Influence of age of seedling and nitrogen levels on days to maturity

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	104.0	103.0	104.0	105.0	103.9	135.3	134.7	135.0	136.0	135.2	119.6
A2	105.0	104.0	104.0	104.0	104.2	134.3	134.0	133.6	133.6	133.9	119.0
A3	109.0	107.0	107.0	107.0	107.2	136.0	135.0	134.3	134.6	135.0	121.2
A4	113.0	112.0	109.0	109.0	110.7	137.6	135.6	135.6	136.0	136.5	123.6
A5	115.0	116.0	114.0	113.0	114.5	138.6	138.3	137.3	137.6	138.0	126.2
Mean	109.1	108.3	107.6	107.5		136.4	135.7	135.2	135.6		
Mean	108.1					135.7					
Nitrogen Mean	N1	N2	N3	N4							
	122.7	122.0	121.4	121.6							
	A	N	V	AxN	AxV	NxV	AxNxV				
	0.610	0.546	0.386	1.221	0.863	NS	NS	NS			
CD(P=0.05)											

under N_1 (122.7 days).

As the age of the seedlings increased, the days to maturity also increased simultaneously. The seedlings planted at A_2 took less number of days to attain maturity by 5.7 and 5.2 per cent, respectively compared to other age groups, while the seedlings planted at A_3 took maximum number of days (126.2) for the attainment of maturity.

The interaction between varieties $\times$ age of the seedlings and age of the seedlings $\times$ nitrogen levels were significant. The variety V_1 at all the age groups took less number of days for the attainment of maturity compared to other interactions. In the interaction of age groups $\times$ nitrogen levels N_2 at A_1 took less number of days for maturity compared to other interactions.

Number of good seeds

Number of good seeds panicle⁻¹ differed significantly due to varieties and age of seedlings (Table 44, Fig. 9). The variety V_2 recorded higher number of good seeds panicle⁻¹ (126.8) compared to V_1 (113.2).

Among the age groups the seedlings of A_2 , A_1 and A_3 being on par, recorded higher number of good seeds panicle⁻¹

Table 44. Influence of age of seedling and nitrogen levels on number of good seed panicle⁻¹

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	122	124	120	126	123.0	134	138	135	132	135	129.0
A2	118	122	120	122	120.5	138	140	139	138	139	129.7
A3	115	119	122	120	119.0	128	135	138	134	134	126.5
A4	108	112	114	113	111.8	117	118	120	119	118	114.9
A5	93	91	92	90	91.7	108	106	112	105	108	99.8
Mean	111.2	113.5	113.9	114.2		125	127	129	126		
Mean	113.2					126.8					
Nitrogen Mean						N1	N2	N3	N4		
						118.1	120.4	121.4	120.1		
						A	N	V	AxN	AxV	AxNxV
CD(P=0.05)						3.331	NS	2.107	NS	4.711	NS

(129.7, 129 and 126.5) compared to that of A₅ (99.8) and A₄ (114.9).

The interaction of varieties x age of seedlings was significant. The variety V₂ at A₂ and A₁ recorded higher number of good seeds panicle⁻¹ compared to other interactions.

Awned seeded ear

The occurrence of awned seeded ears differed significantly due to varieties, nitrogen levels and age of the seedlings (Table 45). Between the varieties the percentage of occurrence of awned seeded ears was higher in V₂ (4.5%) than V₁ (0.6%). Among the nitrogen levels N₄ and N₃ induced more number of awned ear heads (3.1 and 2.8%) compared N₂ (2.3%) and N₁ (1.9%). Among the age of the seedlings A₄ and A₅ recorded increased number of awned panicles (3.1 and 3.0%) compared to the other age groups.

The interaction between varieties x age of the seedlings was significant. The variety V₂ at A₄ and A₅ had the highest percentage (5.4 and 5.39%) of awned panicles compared to other interactions.

Table 45. Influence of age of seedling and nitrogen levels on awned seeded ear (%)

Age of seedling	V1					V2					Mean	
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	N1	N4
A1	0.00	0.00	0.20	0.10	0.1	2.53	2.50	2.80	3.33	2.79	1.4	1.4
A2	0.20	0.20	0.50	1.10	0.5	3.90	4.23	4.77	4.60	4.38	2.4	2.4
A3	0.00	0.50	0.50	1.00	0.5	3.33	3.86	5.33	5.70	4.56	2.5	2.5
A4	0.20	0.50	1.00	1.40	0.8	4.37	5.23	6.13	5.90	5.41	3.1	3.1
A5	0.30	0.60	0.70	1.20	0.7	4.03	5.20	5.83	6.50	5.39	3.0	3.0
Mean	0.14	0.35	0.60	1.00		3.63	4.21	4.97	5.21			
Mean	0.6											4.5
Nitrogen Mean	N1	N2	N3	N4								
	1.9	2.3	2.8	3.1								
	A	N	V	AxN	AxV	NxV	AxNxV					
CD(P=0.05)	0.35	0.32	0.22	NS	0.50	NS	NS	NS	NS			

Seed yield

Seed yield (kg ha^{-1}) varied significantly due to varieties and age of seedlings (Table 46, Fig. 10). The variety V_2 recorded the maximum seed yield of 4022 kg ha^{-1} compared to V_1 (3437 kg ha^{-1}). Among the age of the seedlings, the lesser age groups viz., A_2 , A_3 and A_1 recorded higher seed yield of 4118, 4036 and 4070 kg ha^{-1} compared to 3450 and 3019 kg ha^{-1} recorded by A_4 and A_5 . The yield increase of the lower age groups (A_2 , A_3 and A_1) ranged between 14.5 to 26.7 per cent over A_5 .

Seed Recovery

Seed recovery differed significantly due to varieties and age of seedlings (Table 47), whereas the nitrogen levels did not influence the recovery percentage. The variety V_2 recorded the highest recovery per cent of 78.0 compared to V_1 (67.6%). Among the age groups A_2 and A_3 recorded maximum seed recovery percentage (77.7 and 76.7%) over A_5 (61.7%) and it was followed by A_1 and A_4 (76.1 and 71.7%). The increase in seed recovery percentage among the age groups ranged from 1 to 16 per cent irrespective of varieties.

None of interactions showed significant difference in seed recovery percentage.

Table 46. Influence of age of seedling and nitrogen levels on seed yield (kg ha⁻¹)

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	3895	3920	3880	3906	3900	4086	4108	4291	4074	4140	4020
A2	3916	3978	4065	4021	3995	4165	4208	4325	4286	4241	4118
A3	3641	3790	3912	3876	3804	4112	4266	4385	4310	4268	4036
A4	2862	2930	2986	2876	2914	3916	3988	4056	3984	3986	3450
A5	2512	2580	2604	2592	2572	3410	3453	3516	3484	3466	3019
Mean	3365	3440	3490	3454		3938	4005	4115	4028		
Mean	3437					4022					
Nitrogen Mean	N1	N2	N3	N4							
	3652	3722	3802	3741							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	189.15	NS	119.62	NS	267.5	NS	NS	NS	NS		

Table 47. Influence of age of seedling and nitrogen levels on seed recovery (%)

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	72.4	71.4	72.8	71.3	72.0	80.4	80.7	80.0	79.7	80.2	76.1
A2	73.0	74.0	74.6	74.2	74.0	80.6	81.3	82.4	81.8	81.5	77.7
A3	70.2	71.6	73.4	72.8	72.0	81.0	81.2	82.0	81.5	81.4	76.7
A4	63.5	65.0	66.2	66.8	65.4	76.4	78.0	79.5	78.2	78.0	71.7
A5	52.5	54.0	55.5	56.0	54.5	68.2	69.0	69.8	68.4	68.9	61.7
Mean	66.3	67.2	68.5	68.2		77.3	78.0	78.7	77.9		
Mean	67.6										78.0

Nitrogen Mean	N1	N2	N3	N4							
	71.8	72.6	73.6	73.1							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	3.457	NS	2.186	NS	NS	NS	NS	NS	NS		

1000 Seed Weight

The seed weight did not differ due to varieties, nitrogen levels, age of the seedlings and their interactions (Table 48). However, among the age groups A₂ recorded numerical increase in seed weight compared to other age groups.

Speed of germination

Speed of germination differed due to varieties and age of the seedlings (Table 49). Irrespective of other factors the seeds collected from V₁ recorded higher rate of germination (29.2) compared to V₂ (27.8). Among the age of the seedlings A₁ and A₂ recorded the maximum speed of germination of 30.7 and 30.0, respectively compared to other age groups and it was minimum in A₃ (25.5).

The nitrogen levels and none of the interactions except the interaction of varieties x age of the seedlings showed significant difference in the speed of germination of the resultant seeds. The variety V₁ at A₁ and A₂ recorded higher values (32.2 and 31.1) for speed of germination compared to other interactions.

Table 48. Influence of age of seedling and nitrogen levels on 1000 seed weight (g)

Age of seedling	V1				V2				Mean	
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean
A1	22.40	22.00	22.40	22.30	22.30	22.00	22.10	22.30	21.53	21.98
A2	23.10	22.90	23.40	21.60	22.80	22.60	23.00	23.80	23.20	23.15
A3	20.50	21.60	21.60	21.30	21.20	22.40	22.67	22.77	22.43	22.57
A4	18.50	19.10	19.50	18.30	18.80	20.53	20.80	21.57	21.17	21.02
A5	16.30	17.20	16.90	16.90	16.80	19.50	20.23	20.43	19.57	19.93
Mean	20.10	20.70	20.80	20.10		21.42	21.61	22.13	21.75	
Mean					20.40					21.70
Nitrogen Mean						N1	N2	N3	N4	
						20.70	21.20	21.50	21.00	
	A	N	V			AxN	AxV	NxV	AxNxV	
CD(P=0.05)	NS	NS	NS	NS		NS	NS	NS	NS	

Table 49. Influence of age of seedling and nitrogen levels on speed of germination of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	31.60	32.40	32.00	32.60	32.20	29.60	29.00	29.80	29.13	29.38	30.70
A2	30.40	31.20	31.80	32.90	31.10	28.50	29.00	30.23	29.60	29.33	30.00
A3	29.80	30.20	30.90	30.00	30.20	27.40	27.83	28.50	28.00	27.93	29.00
A4	26.40	27.20	27.80	27.00	27.00	26.67	26.43	27.20	26.63	26.73	26.80
A5	24.70	25.10	24.80	26.00	25.20	25.20	26.00	25.80	26.40	25.85	25.50
Mean	28.60	29.20	29.50	29.30		27.47	27.65	28.31	27.95		
Mean	29.20					27.80					
Nitrogen Mean	N1	N2	N3	N4							
	28.00	28.40	28.90	28.60							
CD(P=0.05)	A	N	V	AxN	AxV	NxV	AxNxV				
	0.592	NS	0.374	NS	0.837	NS	NS	NS	NS	NS	

Germination

Germination per cent differed significantly due to nitrogen levels and age of the seedlings (Table 50, Fig. 10). Among the age groups the seeds from A₂ and A₁ recorded the maximum germination of 89.9 and 89.0 per cent, respectively compared to other age groups and it was minimum in A₅ (84.0%). In the levels of nitrogen F₃ and F₄, being on par, recorded higher germination (87.8 and 87.7%) over F₂ (86.7%) and F₁ (86.1%).

Except the interaction of varieties x age of seedlings, the other interactions were not significant. The seeds of the varieties from A₁ and A₂ recorded higher germination compared to A₃, A₄ and A₅.

Root length

Except age of the seedlings the root length did not differ significantly due to varieties, levels of nitrogen and their interactions (Table 51). The seeds obtained from the crops planted with different age of seedlings revealed that the seeds from A₂ and A₁, being on par recorded lengthier roots (21.9 and 21.4 cm, respectively) compared to other age groups, while A₅ recorded the shortest root length of 17.9 cm.

Table 50. Influence of age of seedling and nitrogen levels on germination (%) of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	90 (71.6)	92 (73.6)	90 (71.6)	88 (69.7)	90.0 (71.6)	88 (69.7)	86 (68.0)	88 (69.7)	90 (71.6)	88.0 (69.7)	89.0 (70.6)
A2	88 (69.7)	90 (71.6)	90 (71.6)	92 (73.6)	90.0 (71.6)	89 (70.6)	90 (71.6)	90 (71.6)	89 (70.6)	89.8 (71.4)	89.9 (71.5)
A3	84 (66.4)	86 (68.0)	86 (68.0)	88 (69.7)	86.0 (68.0)	86 (68.0)	87 (68.9)	90 (71.6)	88 (69.7)	87.7 (69.5)	86.8 (68.7)
A4	84 (66.4)	84 (66.4)	86 (68.0)	85 (67.2)	84.8 (67.1)	86 (68.0)	86 (68.0)	88 (69.7)	86 (68.0)	86.3 (68.3)	85.5 (67.6)
A5	82 (64.9)	81 (64.2)	84 (66.4)	86 (68.0)	83.30 (65.9)	84 (66.4)	85 (67.2)	86 (68.0)	84 (66.4)	84.7 (67.0)	84.0 (66.4)
Mean	85.6 (67.7)	86.7 (68.6)	87.2 (69.1)	87.8 (69.6)	86.9 (68.8)	86.6 (68.5)	86.6 (68.5)	88.4 (70.1)	87.0 (68.9)		
Mean										87.2 (69.1)	
(Figures in parenthesis are arcsine values)											
Nitrogen Mean	N1	N2	N3	N4							
	86.1	86.7	87.8	87.7							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	1.22	1.09	NS	NS	1.73	NS	NS	NS			

Table 51. Influence of age of seedling and nitrogen levels on root length (cm) of resultant seeds

Age of seedling	V1					V2					Mean	
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	Mean	
A1	22.60	23.00	23.20	22.80	22.90	21.80	15.58	21.57	20.93	19.97	21.40	
A2	24.10	22.00	22.60	21.80	22.00	21.13	21.73	22.43	22.03	21.83	21.90	
A3	20.60	21.20	21.40	20.60	21.00	20.53	21.30	21.30	21.87	21.25	21.10	
A4	19.20	19.60	19.50	18.60	19.20	19.53	20.50	20.17	19.73	19.98	19.60	
A5	16.50	17.80	17.60	18.20	17.50	18.63	18.80	19.00	20.13	19.14	17.90	
Mean	20.10	20.70	20.90	20.40		20.33	19.58	20.89	20.94			
Mean	20.50										20.40	
Nitrogen Mean	N1	N2	N3	N4								
	20.20	20.10	20.90	20.60								
	A	N	V	AxN	AxV	NxV	AxNxV					
CD(P=0.05)	0.58	NS	NS	NS	NS	NS	NS	NS	NS	NS		

Vigour Index

Vigour index differed significantly due to nitrogen levels and age of the seedlings (Table 52, Fig. 10). Among the nitrogen levels, vigour index ranged from 1851 (N_3) to 1751 (N_1). In the age groups A_1 and A_2 recorded highest vigour index of 2051 and 1957, respectively compared to others age groups.

The interactions between varieties x nitrogen levels and variety x age of the seedlings were significant. The varieties V_1 at N_2 and V_2 at N_3 and N_4 recorded the maximum vigour index of 1885, 1883, and 1833, respectively compared to other interactions. The variety V_1 at A_1 and A_2 recorded higher vigour index of 2174 and 1968 compared to other interactions.

Dry matter production

The dry matter production differed significantly due to varieties and age of the seedlings (Table 53). The seedlings of V_2 recorded maximum dry matter production (12.1 mg) than those from V_1 (11.5 mg). Among the age of seedlings, the seed obtained from A_2 and A_1 , being on par recorded maximum dry matter (12.6 and 12.5 mg, respectively), while it was minimum in A_3 (10.3 mg).

Table 52. Influence of age of seedling and nitrogen levels on vigour index of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	2034	2447	2075	2140	2174	1918	1926	1982	1886	1928	2051
A2	1882	1980	2005	2006	1968	1834	1926	2025	1996	1945	1957
A3	1729	1825	1841	1813	1802	1806	1798	1944	1936	1871	1837
A4	1614	1646	1678	1582	1630	1676	1754	1830	1702	1740	1685
A5	1437	1528	1496	1466	1482	1580	1564	1634	1646	1606	1544
Mean	1739	1885	1820	1802		1763	1794	1883	1833		
Mean	1811					1818					
Nitrogen Mean	N1	N2	N3	N4							
	1751	1839	1851	1817							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	51.91	46.42	NS	NS	73.41	65.66	NS				

Table 53. Influence of age of seedling and nitrogen levels on dry matter production (mg seedling⁻¹) of resultant seeds

Age of seedling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	12.80	13.10	12.90	13.00	13.00	12.03	11.90	12.23	12.40	12.14	12.50
A2	12.40	11.80	12.60	12.00	12.20	12.77	13.00	13.23	12.90	12.98	12.60
A3	11.80	11.80	11.90	11.70	11.80	12.00	12.40	12.73	12.23	12.34	12.10
A4	11.40	11.00	11.20	10.80	11.10	11.80	11.50	12.20	12.03	11.88	11.50
A5	9.20	9.60	9.40	9.50	9.40	10.90	11.23	11.60	11.03	11.19	10.30
Mean	11.50	11.50	11.60	11.40		11.90	12.00	12.40	12.12		
Mean					11.50					12.10	
Nitrogen Mean			N1	N2	N3	N4					
			11.70	11.80	12.00	11.70					
		A	N	V	AxN	AxV	NxV	AxNxV			
CD(P=0.05)		0.28	NS	NS	0.18	NS	0.39	NS	NS	NS	

None of the interactions except varieties x age of the seedlings exhibited significant influence on dry matter production. The variety V_1 at A_1 and V_2 at A_2 recorded maximum dry matter production (13.0 and 12.6 mg, respectively) compared to other interactions.

Electrical conductivity

The electrical conductivity of the seed leachates differed significantly due to varieties, levels of nitrogen and age of the seedlings (Table 54). Between the varieties the seeds obtained from V_1 recorded lower electrical conductivity value (52.7 dSm^{-1}) than the seeds from V_2 (67.8 dSm^{-1}). Among the levels of nitrogen the seeds obtained from N_3 and N_2 , being on par, recorded minimum EC values of 59.7 and 60.0 dSm^{-1} , respectively compared to N_1 (60.6 dSm^{-1}), and N_4 (60.6 dSm^{-1}). In the seedling age groups the resultant seeds from A_2 and A_1 recorded lowest EC values of 55.2 and 57.6 dSm^{-1} , respectively, while the seeds from A_3 recorded higher EC value of 45.6 dSm^{-1} .

The interactions between varieties x age of the seedlings and levels of nitrogen x age of the seedlings were significant. The variety V_1 at A_2 and A_1 recorded the lowest EC values of 49.0 and 51.5 dSm^{-1} , respectively

Table 54. Influence of age of seedling and nitrogen levels on electrical conductivity (dSm⁻¹) of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	51.40	50.80	51.80	52.00	51.50	63.50	63.20	64.00	63.80	63.62	57.60
A2	49.60	48.80	48.40	49.20	49.00	62.60	60.40	61.00	61.20	61.30	55.20
A3	52.60	51.20	51.50	52.00	51.80	70.50	68.50	67.60	69.30	68.98	60.40
A4	54.20	54.60	53.70	54.20	54.20	71.60	70.40	69.77	70.50	70.57	62.40
A5	56.60	57.20	55.40	58.40	56.90	73.80	74.60	73.20	75.63	74.31	65.60
Mean	52.90	52.50	52.50	53.20		68.40	67.42	67.11	68.09		60.60
Mean	52.70					67.80					
Nitrogen Mean	N1	N2	N3	N4							
	60.60	60.00	59.70	60.60							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	0.36	0.33	0.23	0.73	0.52	NS	NS	NS			

compared to other interactions. In the interactions of nitrogen x age groups N_2 , N_3 at A_2 recorded lowest EC values.

Sugar content

The sugar exudation in the seed leachate differed significantly due to varieties and age of the seedlings (Table 55). Between the leachates of V_1 and V_2 the leachate of V_2 showed lower sugar value (2.8 μg) than the leachate of V_1 (3.0 μg). Among the age of the seedlings, the leachates from A_1 and A_2 recorded lower sugar values of 2.6 and 2.6, respectively compared to other age groups. The leachate of the seeds from A_5 recorded the highest value of 3.4 μg .

Aminoacids

The aminonacids of the seed leachates differed significantly due to varieties, nitrogen levels and age of the seedlings (Table 56). The seed leachate of the varieties V_1 recorded lower aminoacids (1.5 μg) while, it was higher in the leachates of V_2 (1.9 μg). Among the levels of nitrogen the leachates of N_3 and N_4 recorded minimum value of 1.6 μg compared to N_2 (1.7 μg) and N_1 (2.0 μg). The seeds raised from A_2 and A_3 recorded lower aminoacid values of 1.2 and 1.5 μg .

Table 55. Influence of age of seedling and nitrogen levels on sugar content (μg) of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	2.69	2.60	2.68	2.60	2.64	2.39	2.60	2.50	2.63	2.52	2.60
A2	2.72	2.79	2.60	2.59	2.68	2.67	2.53	2.40	2.54	2.53	2.60
A3	2.92	2.96	2.80	2.85	2.89	2.87	2.73	2.77	2.60	2.74	2.80
A4	3.15	3.20	2.08	3.22	3.16	3.13	2.97	2.87	3.00	2.99	3.10
A5	3.48	3.51	3.27	3.39	3.41	3.33	3.37	3.23	3.30	3.31	3.40
Mean	2.99	3.01	2.89	2.93		2.88	2.84	2.75	2.81		
Mean	3.00										2.80

Nitrogen Mean			N1	N2	N3	N4					
			3.00	2.90	2.90	2.90					
		A	N	V	AxN	AxV	NxV	AxNxV			
CD(P=0.05)		0.10	NS	0.07	NS	NS	NS	NS	NS		

Table 56. Influence of age of seedling and nitrogen levels on aminoacids (µg) of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	1.55	1.46	1.30	1.32	1.41	3.32	1.33	1.05	1.00	1.68	1.50
A2	1.48	1.30	1.25	1.67	1.30	1.30	1.25	1.11	0.92	1.15	1.20
A3	1.56	1.35	1.45	1.36	1.43	1.70	1.80	1.60	1.53	1.56	1.50
A4	1.73	1.59	1.84	1.83	1.71	2.30	2.10	2.15	2.20	2.19	2.00
A5	1.98	1.89	1.88	1.86	1.90	2.96	3.10	2.85	2.70	2.91	2.40
Mean	1.66	1.52	1.54	1.47		2.32	1.92	1.75	1.68		
Mean	1.50					1.90					
Nitrogen Mean			N1	N2	N3	N4					
			2.00	1.70	1.60	1.60					
		A	N	V	AxN	AxV	NxV	AxNxV			
CD(P=0.05)		0.07	0.07	0.05	NS	0.11	NS	NS	NS		

In the interaction of varieties x age of the seedlings, the leachate from V₂ and V₁ at A₂ recorded the lower amino acid values followed by V₁ at A₁ and A₃, V₂ at A₃ and A₁ over other respective interactions.

Protein content

The mean protein content of the seeds differed significantly due to varieties and age of seedlings (Table 57). The seeds of the varieties V₂ recorded higher protein content (10.0%) than the seeds from V₁ (9.5%). Among the age of the seedlings, the seeds from A₂, A₁ and A₃, being on par recorded maximum protein content (10.2, 10.0 and 10.0%, respectively) compared to A₅ (8.9%) and A₄ (9.6%).

Except the interaction between varieties x age of the seedlings, the other interactions were not significant. The seeds from V₂ at A₂, A₃ and A₁, being on par, recorded the maximum protein content (10.61, 10.42 and 10.28%, respectively) over other respective interactions.

Alpha amylase activity

The alpha amylase activity of seeds significantly differed due to varieties and age of the seedlings (Table 58). Between the varieties the seeds from V₁

Table 57. Influence of age of seedling and nitrogen levels on protein content (%) of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	9.84	9.94	9.80	9.90	9.87	10.20	10.43	10.50	10.00	10.28	10.00
A2	9.76	9.81	9.97	9.84	9.84	10.50	10.37	10.80	10.76	10.61	10.20
A3	9.70	9.75	9.82	9.80	9.76	10.20	10.43	10.71	10.35	10.42	10.00
A4	9.10	9.22	9.36	9.35	9.25	9.63	9.83	10.18	9.97	9.90	9.60
A5	8.58	8.76	8.92	8.85	8.78	8.97	9.13	9.19	9.00	9.07	8.90
Mean	9.39	9.49	9.57	9.55		9.90	10.04	10.27	10.02		
Mean	9.50										10.00
Nitrogen Mean	N1	N2	N3	N4							
	9.60	9.80	9.90	9.80							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	0.37	NS	0.24	NS	0.53	NS	NS	NS	NS		

Table 58. Influence of age of seedling and nitrogen levels on alpha amylase activity (nm) of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	12.10	12.90	13.00	12.50	12.63	10.90	11.10	11.00	10.80	10.95	11.80
A2	12.00	12.40	13.00	12.60	12.50	11.00	10.90	11.20	10.80	10.98	11.70
A3	11.20	11.20	11.80	11.40	11.40	10.53	10.70	10.90	10.63	10.69	11.00
A4	10.50	10.40	10.80	10.50	10.55	9.80	9.70	9.90	9.80	9.80	10.20
A5	9.20	9.00	9.40	9.00	9.16	8.63	8.50	8.80	8.63	8.64	8.90
Mean	11.00	11.18	11.61	11.20		10.17	10.18	10.36	10.13		
Mean	11.20					10.20					
Nitrogen	Mean	N1	N2	N3	N4						
		10.60	10.70	11.00	10.70						
		A	N	V	AxN	AxV	NxV	AxNxV			
CD(P=0.05)		0.34	NS	0.22	NS	0.48	NS	NS	NS		

recorded higher alpha amylase activity (11.2 mm) than the seeds from V₂ (10.2 mm). Among the age of seedlings the seeds obtained from A₁ and A₂, being on par recorded maximum alpha amylase activity (11.8 and 11.7 mm), while it was minimum in A₅ (8.9 mm).

The interaction between varieties x age of the seedlings was significant, while the other interactions were not significant. The seeds from V₁ at A₁ and A₂, being on par recorded higher alpha amylase activity followed by V₂ at A₁ and A₂ and V₁ at A₃ over other respective interactions.

Fungal infection

The fungal infection per cent of the seeds differed significantly due to varieties levels of nitrogen and age of the seedlings (Table 59). The seeds obtained from V₂ recorded less fungal infection (1.1%) compared to those seeds from V₁ (2.1%). Among the levels of nitrogen N₁, N₂ and N₃ recorded less fungal infection (1.5, 1.6 and 1.6%, respectively) compared to N₄ (1.8%). Among the age groups A₁ and A₂ recorded less fungal infection (0.8 and 0.9%) followed by A₃ (1.5%) and A₄ (2.0%) over A₅ (2.5%).

Except the interaction between varieties x age of the seedlings, the other interactions were not significant. In the interaction between varieties x age of seedlings V₂ at

Table 59. Influence of age of seedling and nitrogen levels on fungal infection (%) of resultant seeds

Age of seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	1.20	0.80	1.00	0.60	0.90	0.80	0.80	0.80	0.17	0.64	0.80
A2	1.00	1.20	0.80	1.30	1.08	0.87	0.67	0.63	1.03	0.80	0.90
A3	1.80	2.00	1.73	2.13	1.92	0.90	0.97	1.17	1.37	1.10	1.50
A4	2.43	2.60	2.90	3.20	2.78	1.17	0.97	1.56	1.50	1.30	2.00
A5	3.50	3.97	3.83	4.63	3.98	1.63	1.70	1.50	1.83	1.67	2.80
Mean	1.99	2.11	2.05	2.37		1.07	1.02	1.13	1.18		
Mean	2.10					1.10					
Nitrogen Mean	N1	N2	N3	N4							
	1.50	1.60	1.60	1.80							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	0.19	0.17	0.12	NS	0.27	NS	NS	NS	NS		

A₁ and A₂ recorded less fungal infection followed by V₁ at A₁ and A₂ and V₂ at A₁ over other respective interactions.

Accelerated ageing on Seed quality

The resultant seeds of the above experiment were subjected to accelerated ageing test for 12 days for assessing its storage potential.

Speed of germination

The speed of germination of aged seeds differed significantly due to levels of nitrogen and age of the seedlings (Table 60). Irrespective of the age of the seedlings the speed of germination among the nitrogen levels ranged from 20.1 (N₃) to 18.7 (N₁). Among the seedling age groups, the seeds from A₂ and A₃ recorded higher speed of germination of 21.6 and 20.6, respectively after ageing compared to other age groups. Except, the interaction between varieties x age groups, others were not significant. The aged seeds of V₁ at A₂, V₂ at A₃ and V₁ at A₁ recorded the maximum speed of germination of 23.0, 21.6 and 20.3, respectively compared to other interactions.

Table 60. Influence of age of seedling and nitrogen levels on speed of germination of resultant seeds after accelerated ageing

Age of Seedling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	19.40	20.20	21.60	20.00	20.30	17.50	18.00	17.60	18.10	17.80	19.10
A2	20.90	22.50	24.90	23.80	23.00	19.80	20.40	21.00	20.10	20.10	21.60
A3	18.80	19.20	20.60	19.50	19.60	20.80	20.70	21.40	23.70	21.50	20.60
A4	17.20	17.80	18.50	18.00	17.90	19.40	19.20	20.60	19.80	19.70	18.80
A5	16.40	15.80	17.50	18.50	17.10	16.40	17.00	17.60	16.80	16.90	17.00
Mean	18.70	19.10	20.60	20.00		18.60	18.80	19.50	19.90		
Mean					19.61						19.25
Nitrogen mean	N1	N2	N3	N4							
	18.70	19.00	20.10	20.00							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	0.59	0.53	NS	NS	0.84	NS	NS	NS			

Germination

The mean germination of the aged seeds differed significantly due to age of the seedlings and the interaction between varieties x age of the seedlings (Table 61, Fig. 11).

The aged seeds of A_2 and A_3 recorded higher germination (48.1 and 46.5%) than the seeds from A_5 and A_4 (33.3 and 41.6%, respectively).

In the interaction, the seeds from V_1 and V_2 at A_2 recorded the maximum germination compared to A_5 and other interactions.

Root length

Except, age groups, the varieties, levels of nitrogen and the interactions were not significant (Table 62). Among the age groups A_3 and A_2 , being on par, recorded lengthier roots (18.5 and 18.3 cm) compared to other age groups, while in A_5 the reduction was higher.

Vigour index

Vigour index of aged seeds differed significantly due to age groups (Table 63). Among the age groups A_3 followed

Table 61. Influence of age of seedling and levels of nitrogen on germination (%) of resultant seeds after accelerated ageing

Age of Seedling	V1					V2					Mean	
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	Mean	
A1	44.30 (41.70)	48.00 (43.90)	44.30 (41.70)	43.00 (41.00)	44.90 (42.10)	38.00 (38.10)	42.00 (40.40)	46.00 (42.70)	40.00 (39.20)	41.50 (40.10)	43.20 (41.10)	
A2	48.00 (43.90)	52.00 (46.20)	53.00 (46.70)	50.30 (45.20)	50.80 (45.50)	42.00 (40.40)	45.00 (42.10)	48.00 (43.90)	46.00 (42.70)	45.30 (42.30)	48.10 (43.90)	
A3	42.00 (40.40)	45.00 (42.10)	43.30 (41.20)	44.00 (41.60)	43.60 (41.30)	45.00 (42.10)	48.00 (43.90)	50.00 (45.00)	54.00 (47.30)	49.30 (44.60)	46.50 (46.50)	
A4	37.00 (37.50)	39.00 (38.70)	38.30 (38.20)	40.30 (39.40)	38.70 (33.70)	43.00 (41.00)	42.00 (40.40)	45.00 (42.10)	48.00 (43.90)	44.50 (41.80)	41.60 (40.10)	
A5	32.00 (34.50)	31.00 (33.80)	33.30 (35.20)	29.00 (32.60)	31.30 (34.00)	35.00 (36.30)	32.00 (34.50)	38.00 (38.10)	35.30 (36.50)	35.20 (36.40)	33.30 (33.30)	
Mean	40.70 (39.60)	43.00 (41.00)	42.50 (40.70)	41.30 (40.00)		40.60 (39.60)	41.80 (40.30)	45.40 (42.40)	44.80 (42.00)			
Mean					41.80 (40.30)					43.20 (41.10)		

(Figures in parenthesis are arcsine values)				
Nitrogen mean	N1	N2	N3	N4
	40.10 (39.29)	42.40 (40.51)	43.90 (41.50)	43.10 (41.03)
CD(P=0.05)	A	N	V	AxN
	2.16	NS	NS	NS
				AxN
				NS

Fig.11 Influence of seedling age on germination,EC and protein of aged seed

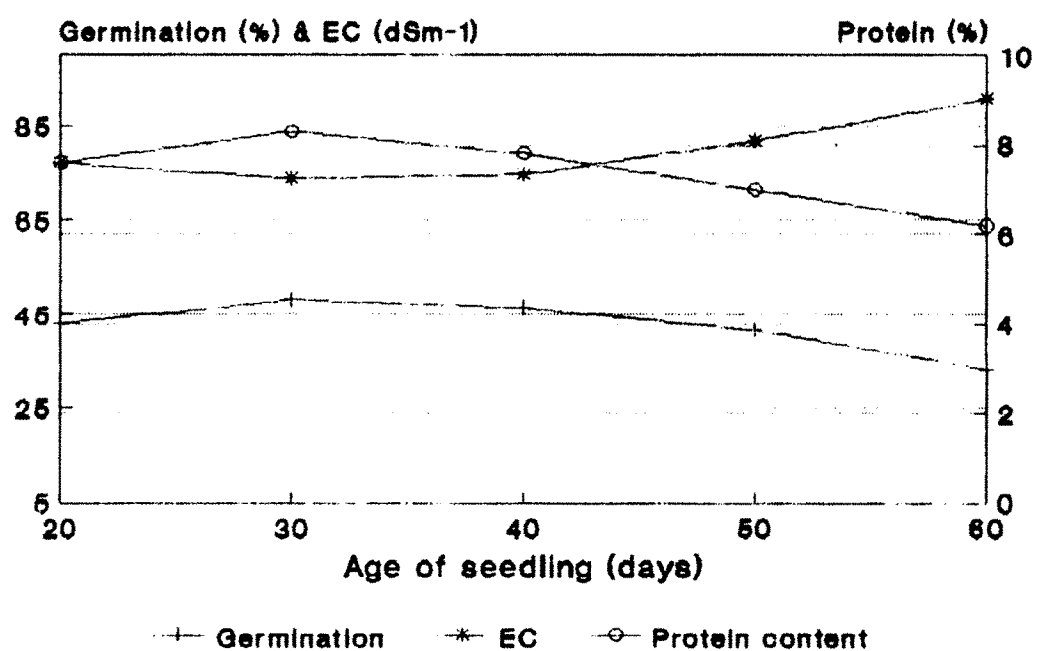


Table 62. Influence of age of seedling and levels of nitrogen on root length (cm) of resultant seeds after accelerated ageing

Age of Seed-ling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	17.40	18.20	16.80	16.90	17.40	16.40	16.40	16.80	16.00	16.30	16.90
A2	18.60	20.22	19.10	18.50	19.10	17.20	17.00	17.60	18.20	17.50	18.30
A3	17.80	18.50	19.20	19.00	18.60	19.00	19.40	19.80	18.60	18.30	18.50
A4	16.40	16.10	17.00	16.80	16.60	18.20	18.60	18.20	19.70	18.40	17.50
A5	15.60	15.40	16.40	15.80	15.80	16.50	16.80	16.20	16.60	16.50	16.20
Mean	17.20	17.70	17.80	17.50		17.40	17.70	17.80	17.50		
Mean					17.50					17.40	
Nitrogen mean	N1	N2	N3	N4							
	17.30	17.70	17.80	17.50							
CD(P=0.05)	A	N	V	AxN	AxV	NxV	AxNxV				
	1.33	NS	NS	NS	NS	NS	NS				

Table 63. Influence of age of seedling and levels of nitrogen on vigour index of resultant seeds after accelerated ageing

Age of Seedling	V1				V2				Mean	
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean
A1	766	874	814	894	837	631	645	533	608	604
A2	892	998	1050	941	970	728	765	845	839	794
A3	749	832	826	851	814	858	932	990	1004	946
A4	607	633	640	671	639	783	780	824	388	819
A5	498	447	545	458	487	568	538	621	728	614
Mean	702	756	776	763		714	732	762	813	
Mean					750					755
Nitrogen mean	N1	N2	N3	N4						
	708	745	769	788						
CD(P=0.05)	A	N	V	AxN	AxV	NxV	AxNxV			
	31.38	NS	NS	40.10	28.42	NS	NS			

by A₂ recorded maximum vigour index values of 927 and 890 than other age groups. The aged seeds of A₅ recorded the minimum vigour of 593.

The interactions between varieties x age groups and nitrogen levels x age groups were significant.

Dry matter production

The aged seeds of the resultant seeds from different levels of nitrogen and age groups differed significantly in respect to dry matter production (Table 64). The seed from N₃ and N₄ being on par, recorded the maximum dry matter of 8.5 and 8.4 mg as against 8.1 mg recorded by the seeds from N₁ and N₂ over a period of 12 days of ageing. Among the age groups A₂ followed by A₃ recorded the maximum dry matter production of 9.3 and 9.1 mg than other age groups, while A₅ recorded the minimum value of 6.9 mg.

The interactions between varieties x levels of nitrogen, varieties x age groups and levels of nitrogen x age groups were significant.

Electrical conductivity

The mean electrical conductivity (EC) of the leachates of the aged seeds varied significantly due to varieties and

Table 64. Influence of age of seedling and levels of nitrogen on dry matter production (mg seedling⁻¹) of resultant seeds after accelerated ageing

Age of Seed-ling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	9.20	8.60	9.10	8.50	8.80	7.60	8.00	7.80	7.50	7.70	8.30
A2	9.10	9.60	10.20	10.30	9.80	8.30	8.60	9.10	9.30	8.80	9.30
A3	8.50	8.80	9.20	9.50	9.00	9.40	8.90	9.20	9.30	9.10	9.10
A4	6.80	7.10	7.80	8.10	7.50	8.50	8.00	8.40	7.80	8.20	7.80
A5	6.30	6.10	6.80	6.80	6.50	7.70	6.90	7.20	7.30	7.30	6.90
Mean	8.00	8.00	8.60	8.60		8.20	8.10	8.30	8.20		
Mean	8.30					8.20					
Nitrogen mean	N1	N2	N3	N4							
	8.10	8.10	8.50	8.40							
CD(P=0.05)	A	N	V	AxN	AxV	NxV	AxNxV				
	0.19	0.18	NS	0.40	0.28	0.25	NS				

age groups (Table 65, Fig. 11). The aged seeds from V_1 registered lower electrical conductivity of 72.0 dSm^{-1} than the seeds from V_2 (85.91 dSm^{-1}).

Among the age groups the seeds from A_2 (73.8 dSm^{-1}) and A_3 (74.8 dSm^{-1}) being on par, recorded minimum EC values compared to other age groups, while A_5 recorded the maximum value of 90.7 dSm^{-1} .

The interaction between varieties x age groups was significant, while the other interactions were not significant.

Sugar content

The mean sugar values of the seed leachate of the aged seeds varied significantly due to varieties, levels of nitrogen and seedling age groups (Table 66). Between the varieties the aged seeds of V_1 recorded higher sugar content of ($6.81 \text{ } \mu\text{g}$) compared to V_2 ($7.7 \text{ } \mu\text{g}$). Among the nitrogen levels N_3 and N_2 , being on par, recorded minimum sugar values (7.0 and $7.1 \text{ } \mu\text{g}$) compared to other levels. Among the age groups A_2 recorded the minimum sugar value of $6.0 \text{ } \mu\text{g}$ followed by A_1 ($6.21 \text{ } \mu\text{g}$) and A_3 ($6.3 \text{ } \mu\text{g}$) and were on par with each other, while A_5 recorded the maximum value of $9.8 \text{ } \mu\text{g}$.

Table 65. Influence of age of seedling and levels of nitrogen on electrical conductivity (dSm^{-1}) of resultant seeds after accelerated ageing

Age of Seedling	V1				V2				Mean	
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean
A1	65.80	63.40	65.00	66.40	65.10	88.60	89.20	88.50	90.60	89.20
A2	66.20	65.30	63.20	62.60	64.30	84.20	85.40	82.30	81.20	83.30
A3	70.60	70.60	69.40	68.30	69.70	83.40	81.00	79.00	76.00	79.80
A4	76.40	75.80	75.20	76.30	75.90	90.50	86.90	85.50	88.00	87.80
A5	84.00	83.60	86.00	85.40	84.70	98.00	92.30	99.20	97.40	96.70
Mean	72.60	71.80	71.70	71.80		89.00	87.00	86.90	87.80	
Mean					72.00					85.90
Nitrogen mean	N1	N2	N3	N4						
	80.80	79.40	79.30	79.80						
	A	N	V	AxN	AxV	NxV	AxNxV			
CD(P=0.05)	4.38	NS	2.77	NS	6.20	NS	NS	NS		

Table 66. Influence of age of seedling and levels of nitrogen on sugar content (μg) of resultant seeds after accelerated ageing

Age of Seed-ling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	5.20	5.00	5.30	5.20	5.10	7.10	7.00	7.40	7.60	7.20	6.20
A2	5.30	5.10	4.90	5.20	5.10	6.90	7.00	6.40	6.80	6.70	6.00
A3	6.80	6.90	5.90	6.50	6.50	6.40	6.00	5.80	6.40	6.10	6.30
A4	8.00	7.50	7.40	7.80	7.60	8.50	7.20	7.90	8.60	8.00	7.90
A5	9.20	9.60	9.80	9.40	9.50	9.70	10.20	9.60	10.40	10.00	9.80
Mean	6.90	6.80	6.60	6.80		7.70	7.40	7.40	7.90		
Mean					6.81						7.70
Nitrogen mean	N1	N2	N3	N4							
	7.30	7.10	7.00	7.40							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	0.23	0.21	0.15	0.46	0.33	NS	NS	NS			

The interactions between varieties x age groups and levels of nitrogen x age groups were significant

Aminoacids

The aminoacid content of the aged seeds varied significantly due to varieties, levels of nitrogen and age groups (Table 67). The aged seeds of V₂ recorded lesser amino acid content of (7.0 µg) than the seeds of V₁ (7.8 µg). Among the nitrogen levels N₄ and N₃ registered minimum aminoacids (7.2 and 7.3 µg) compared to N₁ (7.6 µg) and N₂ (7.5 µg), irrespective of varieties and age groups. In the age groups the seeds from A₁ and A₂ recorded the lower aminoacids (6.6 and 6.6 µg) compared to other age groups, while A₅ recorded the highest value of 8.6 µg.

The interactions between varieties x age groups and levels of nitrogen x age groups were significant.

Protein content

The protein content of the seeds differed significantly due to levels of nitrogen and age groups (Table 68 ;Fig.11). Among the nitrogen levels, the seeds from N₃ recorded higher protein content (7.7%) than the seeds from N₁ (7.3%), N₄ (73.%) and N₂ (7.4%).

Table 67. Influence of age of seedling and levels of nitrogen on aminoacids (μg) of resultant seeds after accelerated ageing

Age of Seedling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	7.32	7.11	7.00	7.10	7.10	6.30	5.90	6.00	5.80	6.20	6.60
A2	7.10	6.80	6.90	6.80	6.90	6.40	6.30	6.20	6.10	6.20	6.60
A3	8.20	7.80	7.50	7.60	7.70	6.70	6.80	6.60	6.50	6.60	7.20
A4	8.60	8.50	8.20	8.20	8.40	7.70	7.90	7.60	7.40	7.60	8.00
A5	9.10	9.20	8.90	8.40	8.90	8.20	8.10	8.10	8.20	8.20	8.60
Mean	8.60	7.90	7.70	7.60		7.10	7.00	6.90	6.80		
Mean					7.80						7.00
Nitrogen mean	N1	N2	N3	N4							
	7.60	7.50	7.30	7.20							
	A	N	V	AxN	AxV	NxV	AxNxV				
CD(P=0.05)	0.08	0.07	0.05	0.15	0.11	NS	0.22				

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Table 68. Influence of age of seedling and levels of nitrogen on protein content (%) of resultant seeds after accelerated ageing

Age of Seedling	V1				V2				Mean	
	N1	N2	N3	N4	Mean	N1	N2	N3		N4
A1	8.20	8.40	8.10	7.90	8.10	7.10	7.30	6.90	7.00	7.60
A2	7.90	8.40	8.50	8.30	8.30	7.80	8.00	8.60	8.40	8.30
A3	7.10	7.40	7.80	7.20	7.40	8.00	7.90	8.70	7.90	7.80
A4	6.80	6.80	7.10	6.60	6.80	6.80	7.20	7.60	7.50	7.00
A5	6.30	6.40	6.50	6.40	6.40	6.20	5.90	6.40	5.80	6.20
Mean	7.30	7.50	7.60	7.30		7.20	7.30	7.70	7.30	
Mean					7.50					7.40
Nitrogen mean	N1	N2	N3	N4						
	7.30	7.40	7.70	7.30						
CD(P=0.05)	A	N	V	AxN	AxV	NxV	AxNxV			
	0.17	0.15	NS	0.34	0.24	NS	NS			

Among the age groups the seeds from A₂ followed by A₃ recorded higher protein content (8.2 and 8.1%) compared to other age groups, while A₅ recorded the minimum value of 6.0 per cent.

The interactions between varieties x age groups and levels of nitrogen x age groups were significant.

Alpha amylase activity

The alpha amylase activity of the aged seeds differed significantly due to varieties, levels of nitrogen and age groups (Table 69). The seeds from V₂ and V₁ registered highest and lowest alpha amylase activity of 7.1 and 6.4 mm, respectively. Among the nitrogen levels, the aged seeds of N₃ and N₄ being on par, recorded maximum activity of 7.1 and 7.0 mm compared to N₁ (6.4 mm) and N₂ (6.7 mm). Among the age groups the seeds from A₂ and A₃ recorded maximum alpha amylase activity of 7.8 and 7.4 mm than the seeds from A₅ (5.0 mm).

The interactions between varieties x age groups and levels of nitrogen x age groups were significant.

Table 69. Influence of age of seedling and levels of nitrogen on alpha amylase activity (mm) of resultant seeds after accelerated ageing

Age of Seedling	V1					V2					Mean
	N1	N2	N3	N4	Mean	N1	N2	N3	N4	Mean	
A1	7.20	7.60	7.50	7.30	7.40	6.60	6.80	6.60	6.30	6.30	6.90
A2	7.50	7.80	8.40	8.90	8.20	6.90	7.40	7.80	8.00	7.50	7.80
A3	6.20	6.00	6.80	7.50	6.60	7.60	8.10	8.60	8.20	8.10	7.40
A4	5.70	6.00	5.80	5.50	5.80	7.20	7.50	8.20	7.90	7.70	6.70
A5	3.40	3.90	4.60	4.40	4.10	5.80	5.20	6.20	5.40	5.70	5.00
Mean	6.00	6.30	6.60	6.70		6.80	7.00	7.50	7.20		
Mean	6.40										7.10
Nitrogen mean	N1	N2	N3	N4							
	6.40	6.70	7.10	7.00							
	A	N	V	AxN	AxV	NxV	AxNxV				
	0.24	0.22	0.15	0.48	0.32	NS	NS	NS			
	CD(P=0.05)										

Fungal infection

Fungal infection percentage of the aged seeds differed significantly due to varieties and age groups (Table 70). Between the varieties V_1 recorded higher percentage of fungal activity (7.7%) compared to V_2 (5.2%). The seeds obtained from A2 and A3 recorded lesser fungal activity of 4.0 and 4.5 per cent compared to other age groups, while A5 recorded the maximum fungal infection per cent (7.0%). Nitrogen levels did not reveal any significant difference in fungal invasion irrespective of varieties and age of seedlings.

The interactions between varieties x age groups and nitrogen levels x age groups were significant.

4.3. Presowing seed hardening on yield and quality of direct seeded rice

Days to emergence

Days to emergence differed significantly due to seed hardening treatments (Table 71). All the treatments induced early emergence compared to control (T_0) irrespective of varieties. The seeds of T_1 and T_2 recorded early initial emergence by 2.6 and 2.8 days, respectively compared to T_1 (3.4) and T_0 (4.4). The reduction in days for initial

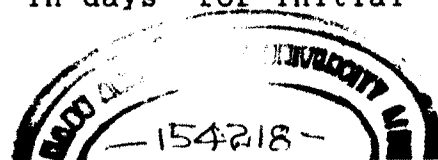


Table 70. Influence of age of seedling and levels of nitrogen on fungal infection (%) of resultant seeds after accelerated ageing

Age of Seed-ling	V1				V2				Mean		
	N1	N2	N3	N4	Mean	N1	N2	N3		N4	Mean
A1	6.40	6.80	7.50	6.50	6.80	4.40	4.00	4.80	5.00	4.60	5.70
A2	5.80	5.00	4.40	4.80	5.00	4.50	4.20	3.80	3.50	4.00	4.50
A3	7.60	8.20	7.40	7.50	7.70	4.80	4.60	4.20	4.50	4.50	6.10
A4	8.50	9.00	9.70	9.50	9.20	5.80	5.50	6.40	6.00	6.00	7.60
A5	10.40	9.70	9.20	9.80	9.80	6.50	7.20	6.80	7.50	7.00	8.40
Mean	7.80	7.80	7.60	7.60		5.20	5.10	5.20	5.30		
Mean					7.70					5.20	
Nitrogen mean	N1	N2	N3	N4							
	6.50	6.50	6.40	6.50							
	A	N	V	AxN	AxV	NxV	AxNxV				
	0.34	NS	0.22	0.69	0.49	NS	NS				
CD(P=0.05)											

emergence among the treatments ranged from 1 to 1.8, irrespective of varieties.

Field emergence

The field emergence differed significantly due to treatments (Table 71). Irrespective of varieties all the treatments registered increased percentage of field emergence compared to T_0 . The treatments T_2 and T_3 recorded the highest field emergence of 86.0 and 84.9 per cent, respectively and the lowest was by T_0 (75.5%).

Days to initiation flowering

All the treatment significantly induced early flowering irrespective of varieties (Table 71). The plants of T_3 and T_2 took minimum days of 48.00 and 48.9 for flowering, while the plants under T_0 took the maximum of 50.7 days. Among the varieties V_1 took lesser days of 40.8 compared to V_2 (57.0). The response of the varieties to various treatments was not significant.

Number of tillers

Number of tillers plant⁻¹ varied significantly due to treatments (Table 72). All the treatments irrespective of the varieties recorded increased number of tillers compared

Table 71. Influence of seed hardening treatments on days to initial emergence, field emergence (%) and days to initiation of flowering of direct seeded rice

Treatments	Days to initial emergence			Field emergence (%)			Days to initiation flowering		
	VI	V2	Mean	VI	V2	Mean	VI	V2	Mean
To	4.5	4.3	4.4	75.0	76.0	75.5	42.6	58.8	50.7
T1	3.3	3.5	3.4	82.0	84.0	83.0	39.8	56.0	47.9
T2	2.5	3.0	2.8	86.0	86.0	86.0	40.8	57.0	48.9
T3	2.5	2.8	2.6	84.0	86.0	84.9	40.0	56.0	48.0
Mean	3.2	3.4		81.8	83.0		40.8	57.0	
V		T	VxT	V	T	VxT	V	T	VxT
CD(P=0.05)	NS	0.755	NS	NS	3.28	NS	0.574	0.811	NS

to control (T_0). Among the treatments T_2 (10.9) followed by T_3 (10.6) recorded highest number of tillers and the lowest by T_0 (8.5).

Number of productive tillers

Number of productive tillers plant⁻¹ differed significantly due to treatments (Table 72, Fig. 12). All the treatments irrespective of varieties induced more number of productive tillers compared to control (T_0). Among the treatments T_2 and T_3 recorded maximum number of tillers (9.8) followed by T_1 (8.5) and the least was in T_0 (6.1). The percentage increase due to treatments over control ranged from 28 (T_1) to 38 (T_2 and T_3).

Length of panicle

Panicle length differed significantly due to treatments and varieties (Table 72). Irrespective of the varieties, all the treatments induced longer panicle length (20.6 cm) compared to T_0 (18.20 cm). Among the treatments T_3 registered the highest panicle length of 21.0 cm followed by T_2 (20.95 cm) and T_1 (19.75 cm) and the lowest in T_0 (18.20 cm). Within the varieties V_2 registered lengthier panicle of 20.40 cm, while it was shorter in V_1 (19.55 cm). The response of the varieties to different treatments did not vary significantly.

Table 72. Influence of seed hardening treatments on number of tillers and productive tillers per plant and length of panicle (cm) of direct seeded rice

Treatments	No. of tillers plant ⁻¹			No. of productive tillers plant ⁻¹			Length of panicle (cm)		
	VI	V2	Mean	VI	V2	Mean	V1	V2	Mean
To	8.0	9.0	8.5	6.0	6.2	6.1	17.80	18.60	18.20
T1	9.0	9.8	9.4	8.6	8.4	8.5	19.20	20.30	19.75
T2	11.0	10.8	10.9	9.8	9.8	9.8	20.40	21.50	20.95
T3	10.8	10.4	10.6	10.0	9.6	9.8	20.80	21.20	21.00
Mean	9.7	10.0		8.6	8.5		19.55	20.40	
V	T	VxT	V	T	VxT	V	T	VxT	
NS	1.30	NS	NS	0.98	NS	0.584	0.826	NS	
CD(P=0.05)									

Weight of panicle

The panicle weight differed significantly due to treatments and varieties (Table 73). All the treatments irrespective of varieties recorded increased panicle weight compared to control (T_0). Among the treatments, T_3 recorded more weight (2.43 g) followed by T_2 (2.38 g) and T_1 (2.03 g) and the less was recorded by T_0 (1.76 g). Between the varieties V_2 proved to be the best by recording maximum panicle weight of 2.22 g compared to V_1 (2.08 g). The percentage increase in panicle weight due to treatments over control ranged from 13.3 g (T_1) to 27.6 g (T_3).

Days to maturity

The days to maturity varied significantly due to treatments and varieties (Table 73). On an average T_3 and T_2 registered less number of days (115.3 and 115.6) for maturity followed by T_1 (116) compared to T_0 (121.0). Between the varieties V_1 and V_2 recorded less and more number of days (104.0 and 130.0) for maturity. The response of the varieties to treatments was not significant.

Number of good seeds

Number of good seeds panicle⁻¹ differed significantly due to treatments and varieties (Table 73, Fig. 12). All

Table 73. Influence of seed hardening treatments on weight of panicle (g), days to maturity and No. of good seeds ear⁻¹ of direct seeded rice

Treatments	Weight of panicle (g)			Days to maturity			No. of good seeds ear ⁻¹		
	VI	V2	Mean	VI	V2	Mean	V1	V2	Mean
To	1.70	1.82	1.76	107.0	135.0	121.0	78.0	88.0	83.0
T1	1.96	2.10	2.03	103.0	129.0	116.0	92.0	102.0	97.0
T2	2.30	2.46	2.38	103.0	128.0	115.6	108.0	116.0	112.0
T3	2.36	2.50	2.43	103.0	128.0	115.3	106.0	112.0	109.0
Mean	2.08	2.22		104.0	130.0		96.0	104.5	

V	T	VxT	V	T	VxT	V	T	VxT
CD(P=0.05)	0.090	0.128	NS	0.882	1.25	NS	3.66	5.17
								NS

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Fig.12 Influence of seed hardening on productive tillers, good seeds and seed yield

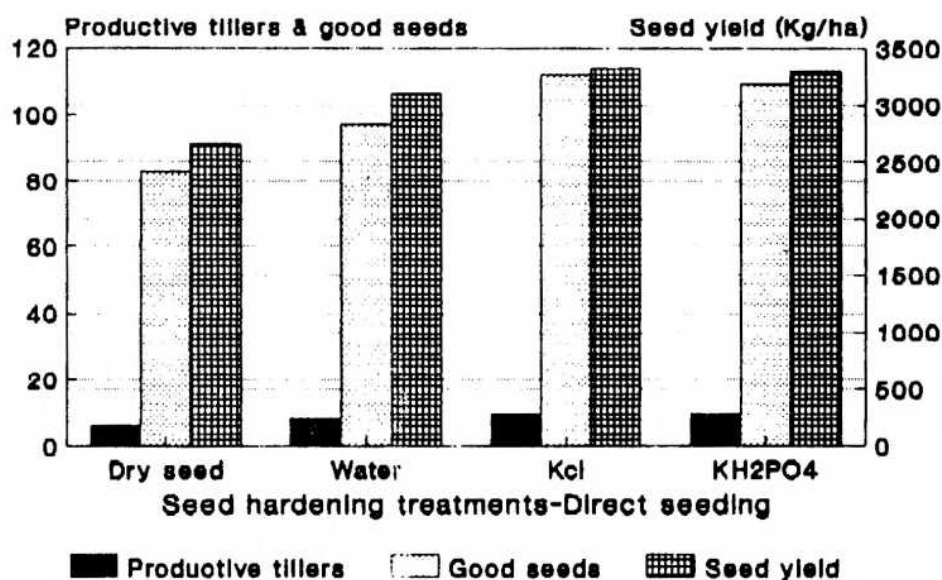
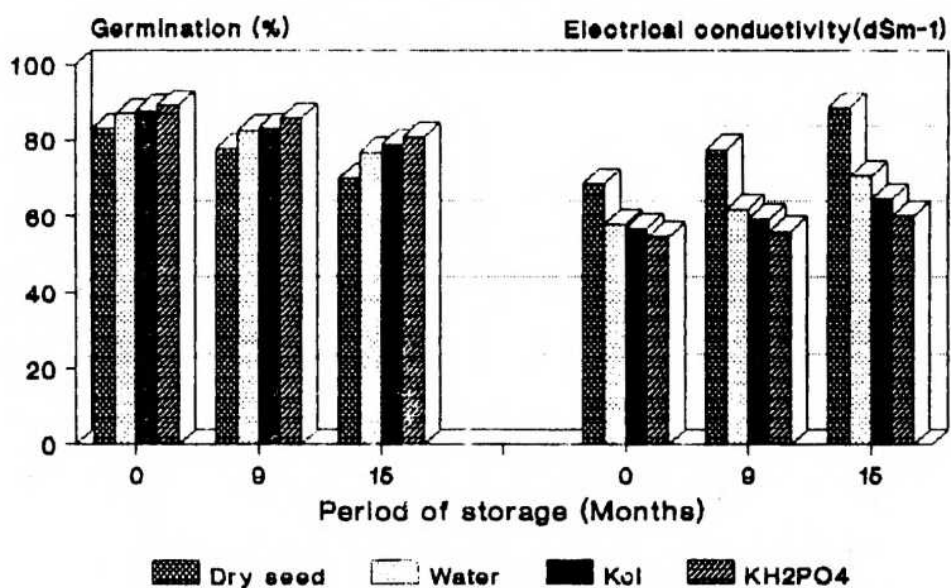


Fig.13 Influence of seed hardening and storage period on germination and EC



the treatments irrespective of varieties recorded more number of good seeds panicle⁻¹ compared to control (T₀). Among the treatments T₂ followed by T₃ registered the highest number of 112.0 and 109.0 good seeds panicle⁻¹ and the least was by T₁ (97.0). The varieties V₂ and V₁ recorded maximum and minimum good seed panicle⁻¹ (104.5 and 96.0). The percentage increase of good seeds panicle⁻¹ due to treatments over control ranged from 14.4 (T₁) to 25.9 (T₂).

Awned seeded ear

Occurrence of awned seeded ears differed significantly due to treatments and varieties (Table 74). All the treatments induced more number of awned seeded ears compared to control (T₀). Among the treatments T₁ (1.0%) registered lowest per cent of awned seeded ears and the highest was by T₂ (2.72%), while T₀ registered the minimum value of 0.24 per cent. Within the varieties V₁ registered the lowest per cent of awned ears (0.96%) compared to V₂ (1.7%).

Seed yield

The seed yield differences among the treatments and varieties were significant (Table 74, Fig. 12). All the treatments irrespective varieties recorded higher seed yield compared to control (T₀). On an average the treatment T₂

Table 74. Influence of seed hardening treatments on awned seeded ear (%) and seed yield kg ha⁻¹ of direct seeded rice

Treatments	Awed seeded ear (%)			Seed yield kg ha ⁻¹		
	VI	V2	Mean	VI	V2	Mean
To	0.10	0.40	0.24	2527	2774	2650
T1	0.42	1.60	1.00	3024	3186	3105
T2	2.84	2.60	2.72	3248	3410	3329
T3	0.50	2.20	1.35	3210	3382	3296
Mean	0.96	1.70		3002	3188	
	V	T	VxT	V	T	VxT
CD	0.624	1.36	NS	50.81	71.87	NS

recorded the maximum seed yield of 3329 kg ha^{-1} followed by T_3 (3296 kg ha^{-1}) and the minimum by T_0 (2650 kg ha^{-1}). Between the varieties V_2 proved to be the best by recording the maximum seed yield of 3188 kg ha^{-1} compared to V_1 (3002 kg ha^{-1}). The response of the individual varieties did not vary significantly due to treatments. The percentage increase in seed yield due to treatments over control ranged from 14.7 (T_1) to 20.4 (T_2).

Seed recovery

Seed recovery per cent differed significantly due to treatments, varieties and their interactions (Table 75). All the treatments recorded higher recovery percentage compared to control (T_0). Among the treatments the highest recovery was recorded in T_2 (71.4%) and the lowest in T_0 (58%). The increase in seed recovery percentage due to treatments ranged from 3.1 to 22.6 irrespective of varieties. Between the varieties V_2 , registered the highest recovery percentage of 68.0 and the lowest was in V_1 (64.8%). The response of the varieties varied markedly for the treatments. The varieties V_1 (70.2%) and V_2 (72.6%) responded well for the treatment T_2 , while the variety V_2 responded only for T_3 (71.2%).

Table 75. Influence of seed hardening treatments on seed recovery (%) and 1000 seed weight (g) of direct seeded rice

Treatments	Seed Recovery (%)			1000 Seed Weight (g)		
	VI	V2	Mean	V1	V2	Mean
To	56.2	59.8	58.0	17.80	18.60	18.20
T1	63.6	68.5	66.0	20.40	20.80	20.60
T2	70.2	72.6	71.4	21.80	22.40	22.10
T3	69.0	71.2	70.1	21.60	22.10	21.85
Mean	64.8	68.0		20.40	20.98	27.80

V	T	VxT	V	T	VxT
CD(P=0.05)	0.39	0.55	0.78	0.44	0.63
					NS

1000 seed weight

The differences in 1000 seed weight due to varieties and treatments were significant (Table 75). The resultant seeds from all the treatments recorded higher seed weight compared to untreated control (T_0). The treatments T_2 and T_3 recorded higher seed weight of 22.40 and 22.10 g and were on par. However, it distinctly differed from T_1 (20.80 g) and T_0 (18.60 g). The differences in seed weight among the varieties have not appeared prominent, however, the varieties V_2 , recorded the highest seed weight of 20.98 g compared to V_1 (20.40 g). The response of the varieties did not vary significantly due to treatments.

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Speed of germination

Speed of germination differed significantly due to periods of storage, varieties and treatments (Table 76). The speed of germination decreased concomitantly from 28.6 (P_0) to 22.6 (P_5) with increase in the storage period irrespective of varieties and treatments. Between the varieties the seeds obtained from V_2 maintained higher speed of germination (26.7) than those seeds from V_1 (25.7) over a period of 15 months of storage. Among the treatments, the seeds from T_2 and T_3 , being on par, recorded higher speed of

Table 76. Influence of seed hardening treatments and periods of storage on speed of germination of resultant seeds of direct seeded rice.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	26.8	27.6	27.2	25.6	27.0	26.3	23.8	25.6	24.7	21.0	24.2	22.6	19.8	21.6	20.7	17.0	18.6	17.8	23.2
T1	28.0	29.6	28.8	28.4	28.6	28.5	27.9	27.0	27.4	26.2	26.0	26.1	25.0	25.3	25.2	22.6	23.0	22.8	26.5
T2	27.8	30.3	29.5	28.0	29.2	28.6	27.6	28.5	28.1	27.0	27.4	27.2	26.1	26.0	26.1	24.4	24.8	24.6	27.4
T3	28.4	30.2	29.3	27.6	29.9	28.8	28.0	29.2	28.6	27.4	28.0	27.7	26.4	25.0	25.7	24.9	25.7	25.3	27.4
Mean	27.8	29.4		27.4	28.7		26.8	27.6		25.4	26.4		24.3	24.5		22.9	23.4		
Mean	28.6		28.1			27.2			25.9			24.4						22.6	

Variety mean	V1	V2						
	25.7	26.7						
P	V	T	PxV	PxT	VxT	PxVxT		
CD(P=0.05)	0.70	0.41	0.58	NS	NS	NS	NS	

Table 77. Influence of Seed hardening treatments and periods of storage on germination (%) of resultant seeds of direct seeded rice.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	84 (66.4)	83 (65.7)	83.5 (66.6)	83 (65.7)	82 (64.9)	82.5 (65.3)	82 (64.9)	81 (64.2)	81.5 (64.5)	78 (62.0)	78 (62.0)	78 (62.0)	74 (59.3)	75 (60.0)	74.5 (59.7)	70 (56.8)	70 (56.8)	70 (56.8)	78.3 (62.2)
T1	88 (69.7)	86 (68.0)	87.0 (68.9)	88 (69.7)	85 (67.2)	86.5 (68.4)	89 (70.6)	86 (68.0)	87.5 (69.3)	84 (66.4)	81 (64.2)	82.5 (65.3)	79 (62.7)	82 (64.9)	80.5 (63.8)	78 (62.0)	76 (60.7)	77.0 (61.3)	83.5 (66.0)
T2	88 (69.7)	88 (69.7)	88.0 (69.7)	89 (70.6)	88 (69.7)	88.5 (70.2)	90 (71.6)	88 (69.7)	89.0 (70.6)	85 (67.2)	82 (64.9)	83.5 (66.0)	80 (63.4)	82 (64.9)	81.0 (64.2)	80 (63.4)	78 (62.4)	79.0 (62.7)	84.8 (67.1)
T3	90 (71.6)	89 (70.6)	89.5 (71.1)	90 (71.6)	89 (70.6)	89.5 (71.1)	90 (71.6)	90 (71.6)	90.0 (71.6)	88 (69.7)	84 (66.4)	86.0 (68.0)	84 (66.4)	84 (66.4)	84.0 (66.4)	82 (64.9)	80 (63.4)	81.0 (64.2)	86.6 (68.5)
Mean	87.5 (69.3)	86.5 (68.4)	87.0 (68.9)	87.5 (69.3)	86.0 (68.0)	86.8 (68.9)	87.8 (69.6)	86.3 (68.3)	87 (68.9)	83.8 (66.3)	81.3 (64.4)	82.5 (65.3)	79.0 (62.7)	80.8 (64.0)	80.0 (63.4)	77.3 (61.6)	75.9 (60.6)	76.8 (61.2)	

(Figures in parenthesis are arcsine values)

Variety Mean V1 V2
 84.0 82.0
 (66.4) (64.9)

P V T PxV Pxt Vxt PxtT
 CD(P=0.05) 1.5 0.88 1.2 NS NS NS NS

germination (27.4) over T_0 (23.2). The interactions between the periods of storage, varieties and treatments were not significant.

Germination

The germination potential of the seeds differed significantly due to periods of storage, varieties and treatments (Table 77, Fig. 13.). The mean germination percentage of seeds decreased progressively from P_0 (87.0) to P_5 (76.8) with increase in the storage period irrespective of varieties and treatments. The seeds from V_1 maintained higher germination (87.0%) than the seeds from V_2 (82.0%) over a period of 15 months of storage irrespective of other factors. The seeds from all the treatments maintained germination above certification standard (80.0%) up to 15 months, while the seeds from control declined below the standard after sixth month of storage irrespective of periods and varieties.

Root length

The root length differed significantly due to seed hardening treatments (Table 78). The mean root length decreased from 17.3 cm (P_0) to 14.1 cm (P_5) with the increase in the period of storage irrespective of varieties and treatments. Among the treatments, the seeds obtained

Table 78. Influence of seed hardening treatments and periods of storage on root length (cm) of resultant seeds of direct seeded rice.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	15.7	14.6	15.1	16.2	14.0	15.1	15.8	14.5	15.1	14.6	13.8	14.2	13.2	12.0	12.6	10.8	10.4	10.6	13.8
T1	17.6	16.8	17.2	17.4	17.6	17.5	17.0	18.2	17.6	16.2	17.4	16.8	14.8	16.2	15.5	12.5	13.8	13.1	16.2
T2	18.2	19.0	18.6	18.6	18.4	18.5	18.9	19.0	18.9	18.1	18.0	18.0	17.3	17.2	17.2	16.1	15.6	15.8	17.8
T3	18.8	16.4	18.6	19.0	18.2	18.6	20.2	18.8	19.5	19.4	17.9	18.6	18.6	17.0	17.8	17.2	16.7	16.9	18.3
Mean	17.3	17.2		17.8	17.1		17.9	17.6		17.1	16.7		15.9	15.6		14.1	14.1		
Mean	17.3			17.4				17.8		16.9			15.7					14.1	

Variety mean V1 V2

16.82 16.41

P V T PrV PrVt PrVt

CD(P=0.05) NS NS 2.9 NS NS NS NS

from T₃ and T₂, being on par, produced longer roots (18.3, 17.8 cm) followed by T₁ (16.2 cm) compared T₀ (13.8 cm).

Vigour index

The mean vigour index of seeds decreased concomitantly from 1517 (P₀) to 1093 (P₅) with increase in the period of storage irrespective of varieties and treatments (Table 79). The seeds obtained from V₁ recorded maximum vigour (1421) than the seeds from V₂ (1360) over a period of 15 months. The resultant seeds from treatments irrespective of varieties maintained higher vigour over 15 months period of storage compared to control. The seeds from T₃ followed by T₂ recorded the maximum vigour index values of 1588 and 1520, respectively as against 1088 by the seeds from T₀.

The interactions between periods of storage x treatments and varieties x treatments were significant. The seeds from T₂ and T₃ at all periods of storage recorded maximum vigour index over T₀. The latter interaction revealed that the seeds from V₁ at T₃ recorded the maximum vigour index followed by V₂ at T₃ over other respective interactions.

Dry matter production

The mean dry matter production of seeds decreased linearly from 10.9 mg (P₀) to 7.9 mg (P₅) with increase in

Table 79. Influence of seed hardening treatments and periods of storage on vigour index of resultant seeds of direct seeded rice.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	1327	1211	1269	1344	1148	1246	1296	1175	1236	1138	1076	1107	990	886	938	756	722	739	1088
T1	1548	1445	1497	1532	1496	1514	1514	1567	1541	1360	1409	1385	1214	1280	1247	982	1048	1015	1359
T2	1602	1672	1637	1656	1610	1638	1702	1692	1697	1538	1476	1507	1418	1376	1397	1280	1216	1248	1520
T3	1692	1638	1665	1710	1602	1656	1818	1696	1757	1766	1504	1605	1562	1394	1478	1402	1236	1362	1522
Mean	1542	1492		1560	1467		1582	1528		1436	1366		1296	1234		1105	1080		
Mean	1517			1514			1558			1401			1265			1093			

Variety mean	V1		V2		P	V	T	PrV	PrT	VxT	PrVxT
	V1	V2	V1	V2							
	1421	1360									
CD(P=0.05)	33.48	19.3	27.3	NS	66.8	38.5	NS				

the storage period irrespective of varieties and treatments (Table 80). Among the treatments, the seeds obtained from T_3 and T_2 , being on par, recorded maximum dry matter production (11.0 and 11.7 mg, respectively) followed by T_1 (9.4 mg) compared to T_0 (7.3 mg).

Electrical conductivity

The mean electrical conductivity values of seed leachates increased progressively from 59.5 dSm^{-1} (P_0) to 71.1 dSm^{-1} (P_5) with increase in the storage period irrespective of varieties and treatments (Table 81, Fig. 13). The seeds obtained from V_2 recorded lower electrical conductivity value of 58.6 dSm^{-1} than those seeds from V_1 (69.2 dSm^{-1}) over a storage period of 15 months. Among the treatments the leachates of the seeds of T_4 and T_3 recorded lesser EC values (56.3 and 59.5 dSm^{-1}) compared to T_2 (62.5 dSm^{-1}) and T_0 (77.2 dSm^{-1}) over periods of storage.

The interactions between periods x varieties, periods x treatments and varieties x treatments were not significant.

Sugar content

The mean sugar content of seed leachates increased linearly from 2.8 μg (P_0) to 7.4 μg (P_5) with increase in

Table 81. Influence of seed hardening treatments and periods of storage on electrical conductivity (dSm⁻¹) of resultant seeds of direct seeded rice.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	72.4	64.6	68.5	74.8	66.0	70.4	77.6	70.2	73.9	82.2	73.0	77.6	88.6	79.2	83.9	93.4	84.6	89.0	77.2
T1	63.4	52.3	57.9	63.6	53.2	58.4	65.2	55.6	60.4	67.4	56.4	61.9	71.2	60.4	65.8	76.4	64.8	70.6	62.5
T2	62.9	51.0	57.0	62.4	50.4	56.4	64.2	52.0	58.1	65.6	53.2	59.4	68.4	55.0	61.7	70.8	58.2	64.5	59.5
T3	59.3	49.8	54.6	58.2	48.2	53.2	61.2	49.3	55.25	61.8	50.6	56.2	63.4	52.6	58.0	65.6	54.8	60.2	56.3
Mean	64.5	54.5		64.8	54.5		67.0	56.8		69.3	58.3		72.9	61.8		76.6	65.8		
Mean	59.5			59.6			62.0			63.8			67.4			71.1			

Variety mean	V1	V2																	
	69.2	58.6																	
P	V	T	PxV	PxT	VxT	PxVxT													
CD(P=0.05)	3.66	2.11	2.99	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

the storage period irrespective of varieties and treatments (Table 82). The seeds obtained from V_2 recorded lower sugar content (4.99 μg) than the seeds from V_1 (4.34 μg) over a period of 15 months of storage. The resultant seeds from the treatments T_3 and T_2 , being on par, recorded significantly lower sugar values (3.9 and 4.1 μg , respectively) compared to T_0 (5.9 μg) irrespective of periods of storage and varieties.

The interactions between periods x varieties and periods x treatments were significant. At all periods of storage, the seeds from V_1 , recorded lower sugar values compared to V_2 . The seed leachates of the seeds from T_3 at P_1 , T_3 at P_0 and T_3 at P_2 recorded lowest sugar values of 2.5, 2.5 and 3.0 μg .

Aminoacids

The mean aminoacid values of seed leachates increased progressively from 1.89 μg (P_0) to 5.24 μg (P_5) with increase in the period of storage irrespective of varieties and treatments (Table 83). The seeds from V_1 recorded lower aminoacids (3.08 μg) than the seeds from V_2 (3.20 μg) over a period of 15 months irrespective of treatments. Among the treatments, the seeds from T_3 and T_1 being on par recorded minimum aminoacids (2.92 and 2.93 μg , respectively) followed by T_2 (2.95 μg) over T_0 (3.76 μg).

P0		P1			P2			P3			P4			P5			Mean		
V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean		
T0	2.9	3.1	3.0	3.2	4.1	3.7	4.2	5.2	4.7	5.9	6.6	6.2	7.7	8.2	7.9	9.8	10.5	10.1	5.9
T1	2.7	2.8	2.7	2.9	3.2	3.0	3.4	4.6	4.0	4.2	5.2	4.7	5.6	6.4	6.0	7.2	8.7	7.9	4.8
T2	2.6	2.7	2.7	2.7	2.9	2.8	3.2	3.8	3.2	4.1	4.8	4.5	4.7	5.6	5.1	5.1	6.5	5.8	4.1
T3	2.5	2.5	2.5	2.5	2.5	2.5	2.9	3.1	3.0	3.9	4.3	4.1	5.6	5.4	5.5	5.4	6.4	5.9	3.9
Mean	2.7	2.8		2.8	3.3		3.4	4.2		4.5	5.2		5.6	6.4		6.9	8.0		
Mean	2.8			3.0				3.8			4.9			6.1				7.4	

Variety	mean	V1	V2
4.34	4.99		
P	V		
	T	PV	PVT
			PVVT
0.3	0.17	0.25	0.42
		0.6	
CD(P=0.05)		NS	NS

The interactions between periods x varieties, periods x treatments and varieties x treatments were significant.

Protein content

The mean protein content of the seeds decreased simultaneously from 8.67 (P_0) to 6.38 per cent (P_5) with increase in the storage period irrespective of varieties and treatments (Table 84). The resultant seeds from V_2 recorded higher protein content (8.14%) than the seeds of V_1 (7.81%) over a period of 15 months irrespective of treatments. Among the treatments, the seeds from T_3 and T_2 being on par, recorded significantly higher protein content of 8.88 and 8.82, per cent, respectively compared to 7.98 in T_1 and 6.25 in T_0 , irrespective of storage periods.

The interactions between periods x treatments and varieties x treatments were significant. At all periods of storage T_3 (except at P_3 and P_5) recorded maximum protein content followed by T_2 compared to T_0 . In the other interactions the seeds from V_1 and V_2 at T_3 recorded maximum protein content over other interactions.

Alpha amylase activity

The alpha amylase activity of the seeds progressively

Table 84. Influence of seed hardening treatments and periods of storage on protein content (%) of resultant seeds of direct seeded rice.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	7.16	7.66	7.41	7.20	7.80	7.49	6.80	7.33	7.06	5.90	6.80	6.35	4.80	5.70	5.25	3.45	4.10	3.77	6.25
T1	8.46	9.10	8.80	8.35	9.24	8.79	8.10	9.09	8.55	7.60	8.20	7.90	7.20	7.80	7.48	6.10	6.54	6.32	7.98
T2	9.20	9.26	9.22	9.30	9.36	9.33	9.22	9.30	9.26	8.90	8.99	8.94	8.10	8.60	8.35	7.60	7.96	7.78	8.82
T3	9.36	9.21	9.28	9.50	9.45	9.47	9.52	9.41	9.46	9.10	9.14	9.11	8.60	8.20	8.40	7.86	7.50	7.68	8.98
Mean	8.55	8.81		8.59	8.96		8.41	8.76		7.88	8.18		7.18	7.58		6.25	6.53		
Mean	8.67			8.77			8.87			8.02			7.37					6.38	

Variety mean V1 V2
7.81 8.14

P V T PrV PrT PrVT PrVIT
0.17 0.09 0.14 NS 0.34 0.19 NS

CD(P=0.05)

decreased from 10.4 mm (P_1) to 7.2 mm (P_5) with increase in the storage period irrespective of varieties and treatments (Table 85). The seeds obtained from V_2 recorded higher alpha amylase activity (9.42 mm) than the seeds of V_1 (8.90 mm) over a storage period of 15 months. The resultant seeds from all the treatments recorded significantly increased alpha amylase activity irrespective of periods of storage. Among the treatments the seeds from T_3 and T_2 recorded higher activity (10.6 and 10.1 mm) compared to T_0 (6.8 mm).

The interactions between periods x treatments and varieties x treatments were significant.

Fungal infection

After the initial evaluation, the stored seeds from different treatments, were tested for fungal infection. The mean fungal infection percentage progressively increased from 0.80 per cent (P_0) to 3.50 per cent (P_5) with increase in the period of storage (Table 86). Among the two varieties, the seeds from V_2 recorded minimum fungal infection of 1.92 per cent compared to 2.28 per cent in V_1 . The seeds received from T_3 and T_2 treatments being on par, registered less fungal infection (1.4 and 1.6%) compared to the seeds from T_0 (3.3%).

Table 85. Influence of seed hardening treatments and periods of storage on alpha amylase activity (nm) of resultant seeds of direct seeded rice.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	8.4	9.0	8.7	8.2	9.1	8.7	7.1	8.0	7.6	6.2	7.0	6.6	5.0	5.9	5.4	3.8	4.2	3.9	6.8
T1	9.7	10.2	9.9	10.1	10.6	10.4	9.4	10.1	9.8	8.8	9.4	9.1	7.9	8.6	8.3	6.3	7.4	6.9	9.1
T2	10.9	11.3	11.2	11.0	11.5	11.3	10.2	11.0	10.6	9.7	10.5	10.1	8.9	9.8	9.4	8.2	9.0	8.6	10.1
T3	10.8	10.2	10.5	11.5	11.3	11.4	11.1	10.8	10.9	10.8	10.2	10.6	10.2	10.6	10.4	9.3	9.8	9.6	10.6
Mean	10.6	10.3		10.2	10.6		9.5	9.9		8.9	9.3		8.0	8.7		6.9	7.6		
Mean	10.2			10.4				9.6			9.1			8.4				7.2	

Variety mean		V1	V2						
		8.90	9.42						
	P	V	T	PxV	PxT	VxT	PxVxT		
CD(P=0.05)	0.24	0.14	0.2	NS	0.48	0.28	NS		

Table 86. Influence of seed hardening treatments and periods of storage on fungal infection (%) of resultant seeds of direct seeded rice.

	P0		P1		P2		P3		P4		P5		Mean						
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean							
T0	1.20	1.64	1.40	2.60	1.80	2.20	3.00	2.50	2.80	4.30	3.20	3.80	4.50	3.80	4.20	5.60	5.00	5.30	3.30
T1	0.60	1.00	0.80	1.80	2.60	1.90	2.10	2.20	2.10	2.80	2.50	2.70	2.70	2.65	2.700	3.00	3.50	3.30	2.24
T2	0.60	0.60	0.60	2.00	1.00	1.50	1.80	1.10	1.50	1.73	0.90	1.30	2.10	1.20	1.70	3.00	2.50	2.80	1.60
T3	0.40	0.40	0.40	1.40	0.60	1.00	1.50	0.80	1.20	1.50	1.00	1.30	1.90	1.38	1.60	2.50	2.80	2.70	1.40
Mean	0.70	0.93		1.95	1.35		2.10	1.65		2.61	1.90		2.71	2.56		3.53	3.45		
Mean	0.80			1.65			1.90			2.26			2.60			3.50			

Variety mean		V1	V2								
		2.28	1.92								
P	V	T	PxV	PxT	VxT	PxVxT					
CD(P=0.05)	0.52	0.3	0.42	NS	NS	NS	NS	NS	NS	NS	NS

4.4 Levels of gypsum application in sodic soil on seed yield and quality

Plant population

The application of different levels of gypsum and varieties significantly influenced the plant population/m² (Table 87). The plant population increased with increase in the levels of gypsum application from 40.5 (T₁) to 63.5 (T₃) compared to T₀ (30.5). Among the gypsum levels T₃ (3600 kg ha⁻¹ of gypsum) maintained the maximum plant population of 63.5, while, it was not uniform in other levels and the lowest was in control (30.5). Between the varieties V2 responded well for gypsum application and maintained higher average population of 48.5 compared to V1 (45.0).

Days to initiation flowering

The levels of gypsum, varieties and their interactions on days to initiation of flowering was significant (Table 87). In general as the dose of gypsum increased the days to flowering decreased. Among the different doses of gypsum T₃ induced earlier flowering (52 days) followed by T₂ (55.8) and T₁ (59.0). The plants under control took more number of days (64.3) for the initiation of flowering. Between the varieties V₁ took less number of days (49.6) for initiation of flowering compared to V2 (65.9).

Treatments	Plant population/m ²			Days to initiation of flowering			No. of tillers plant ⁻¹		
	VI	V2	Mean	VI	V2	Mean	V1	V2	Mean
To	28	33	30.50	56	73	64.30	5	7	5.90
T1	39	42	40.50	53	66	59.00	7	9	7.80
T2	51	54	52.50	47	65	55.80	10	11	10.40
T3	62	65	63.50	43	61	52.00	12	13	12.50
Mean	45.0	48.5		49.6	65.9		8.60	9.70	

	V	T	VxT	V	T	VxT	V	T	VxT
CD(P=0.05)	1.88	2.66	NS	1.10	1.56	2.20	1.10	1.54	NS

There was uniformity in respect to varietal response to gypsum application. Both the varieties responded well for higher dose (T3) of gypsum application.

Number of tillers

Number of tillers plant⁻¹ differed significantly due to levels of gypsum and varieties. Their interactions were not significant (Table 87). Tiller number plant⁻¹ increased with the increase in the dose of gypsum application from 7.8 (T1) to 12.5 (T3). Gypsum application at higher level (T3) recorded the maximum tillers plant⁻¹, while it was minimum in T0 (5.9).

Between the varieties V₂ recorded more number of tillers compared to V₁ irrespective of gypsum application. In the varieties V₂ responded well for gypsum application than V₁.

Number of productive tillers

Number of productive tillers plant⁻¹ varied significantly due to application of gypsum and varieties (Table 88, Fig. 14). Among the gypsum levels the maximum productive tillers of 8.6 was recorded in T₃, which was on par with T₂ (7.8) and it was minimum in T₀ (3.0). In the two varieties tried V₂ recorded the maximum number of

productive tillers (6.7) compared to V₁ (5.4) irrespective of gypsum application.

Length of panicle

The length of panicle varied significantly due to levels of gypsum and varieties (Table 88). In the levels of gypsum T₃ recorded higher panicle length of 19.9 cm, followed by T₂ (18.5 cm), while T₀ recorded the lowest length of 15.7 cm. The percentage increase in panicle length due to levels of gypsum over control ranged from 7.6 to 21.0. Between the varieties V₂ recorded higher panicle length of 18.0 than V₁ (17.5 cm).

Weight of panicle

Panicle weight differed significantly due to levels of gypsum and varieties (Table 88). All the levels of gypsum irrespective of varieties registered increased panicle weight over control (T₀). Among the gypsum levels, T₃ recorded more weight (2.40 g), while it was less in T₀ (1.56 g). The percentage increase in panicle weight due to levels of gypsum over control ranged from 15.7 to 35.0. In the varieties V₂ recorded higher panicle weight (2.05 g) than V₁ (1.86).

Table 88. Influence of levels of gypsum in sodic soil on number of productive tillers plant⁻¹, length of panicle (cm) and weight of panicle (g)

Treatments	No. of productive tillers plant ⁻¹			Length of panicle (cm)			Weight of panicle (g)		
	VI	V2	Mean	VI	V2	Mean	V1	V2	Mean
To	3	3	3.00	15.40	16.00	15.70	1.36	1.75	1.56
T1	4	6	4.80	16.80	17.20	17.00	1.80	1.90	1.85
T2	7	9	7.80	18.20	18.80	18.50	1.94	2.10	2.02
T3	8	9	8.60	19.60	20.20	19.90	2.35	2.46	2.40
Mean	5.40	6.70		17.50	18.00		1.86	2.05	
V		T	VxT	V	T	VxT	V	T	VxT
CD(P=0.05)	1.11	1.58	NS	0.512	0.724	NS	0.155	0.219	NS

Fig.14 Influence of gypsum in sodic soil on productive tillers, good seeds and seed yield

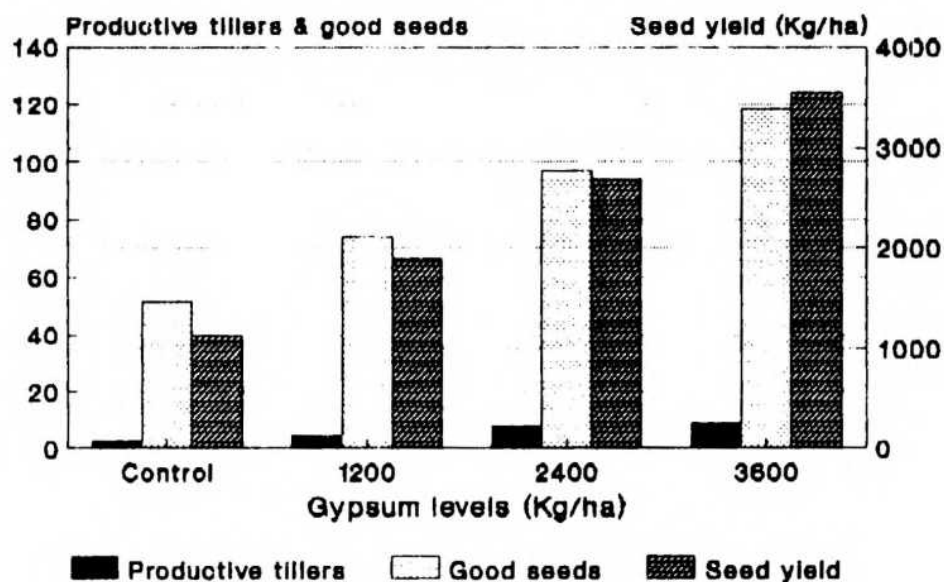
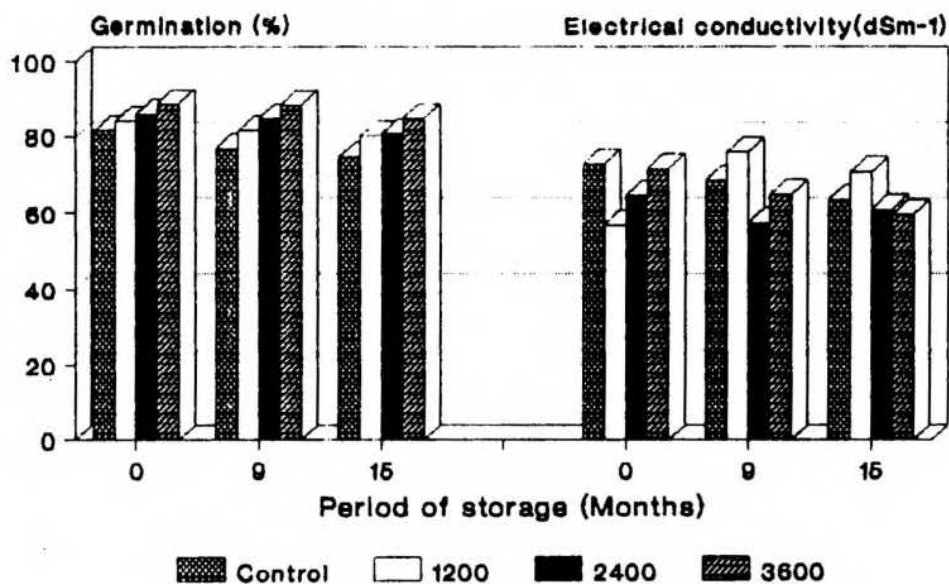


Fig.15 Influence of gypsum levels and storage period on germination and EC



Days to maturity

Significant differences were observed in days to maturity due to levels of gypsum, varieties and their interactions (Table 89). Among the levels of gypsum T_3 (122.3 days) recorded minimum number of days to maturity and the plants under control took maximum days (135). The decrease in days to maturity over control ranged from 5.5 (T_1) to 13.2 (T_3) among the levels of gypsum. Between the varieties V_1 registered lowest number of days (112.2) compared to V_2 (144.2) for days to maturity. Both the varieties responded well for gypsum application and the response to higher dose (T_3) was prominent.

Number of good seeds

The number of good seeds panicle⁻¹ varied significantly due to levels of gypsum and varieties (Table 89, Fig. 14). All the gypsum levels recorded higher number of good seeds panicle⁻¹ irrespective of varieties compared to control. The increase in number of good seeds due to gypsum levels over control ranged from 22.7 (T_1) to 67.1 (T_3). Among the gypsum levels T_3 recorded the highest number of good seeds panicle⁻¹ (118.4) followed by T_2 (97.0) and the lowest in T_1 (74.0). Between the varieties V_2 recorded more number of good seeds (89.0) compared to V_1 (81.3).

Table 89. Influence of levels of gypsum in sodic soil on days to maturity, number of good seeds panicle⁻¹ and awned seeded ear (%)

Treatments	Days to maturity			No. of good seeds panicle ⁻¹			Awed seeded ear (%)		
	VI	V2	Mean	VI	V2	Mean	V1	V2	Mean
To	119	153	135.50	48	55	51.30	0.00	0.20	1.10
T1	114	146	130.00	70	79	74.00	0.00	0.60	0.30
T2	110	141	125.20	92	102	97.00	0.50	1.20	0.85
T3	107	138	122.30	116	122	118.40	0.80	1.80	1.30
Mean	112.20	144.20		81.30	89.00	0.64	0.95		
V		T	VxT	V	T	VxT	V	T	VxT
CD(P=0.05)	0.68	0.96	1.36	3.39	4.80	NS	0.11	0.15	0.22

Awned seeded ear

Production of awned seeded ears varied significantly due to levels of gypsum, varieties and their interactions (Table 89). Application of increased levels of gypsum concomitantly increased the occurrence of awned ear percentage over control (T_0). Among the levels of gypsum lowest occurrence of awned ears was recorded in T_0 (0.10%) and T_1 (0.30%), whereas it was highest in T_3 (1.30%). Between the varieties minimum occurrence of awns was recorded in V_1 (0.64%) than V_2 (0.95%). The differences in the occurrence of awned ear percentage among the varieties appeared prominent due to the increased levels of gypsum. The treatment T_3 in V_1 and V_2 and T_2 in V_2 recorded highest percentage of awned ears compared to other interactions and control.

Seed yield

The seed yield differed significantly due to the levels of gypsum and varieties (Table 90, Fig. 14). All the levels of gypsum irrespective of varieties registered more seed yield compared to control (T_0), however, higher level of gypsum (T_3) increased the seed yield by 68 per cent by recording 3552 kg ha⁻¹ over control (1135 kg ha⁻¹). Among the gypsum levels T_3 recorded the maximum seed yield of 3552 kg ha⁻¹ compared to other levels and control. The seed

yield increase among the gypsum levels over control ranged from 40.3 (T_1) to 68.0 per cent (T_3). Between the varieties V_2 responded well for gypsum application and recorded the maximum seed yield of 2397 kg ha⁻¹ compared to V_1 (2246 kg ha⁻¹).

Seed recovery

Seed recovery per cent differed significantly due to gypsum levels, varieties and their interactions (Table 90). Irrespective of the varieties, all the levels of gypsum increased the seed recovery per cent compared to control (T_0). Among the gypsum levels the maximum recovery was recorded in T_3 (76.7%), followed by T_2 (68.3%) and the minimum was by T_0 (34.5%). The increase in seed recovery percentage due to gypsum application ranged from 5.0 (T_1) to 57.8 (T_3) irrespective of varieties compared to T_0 . Within the varieties V_2 recorded highest recovery of 59.7 per cent compared to V_1 (56.1%). The response of the varieties differed significantly for the levels of gypsum. Both the varieties responded well for T_3 and recorded increased recovery of 73.8 and 79.6 per cent respectively, over the other respective interactions and control.

1000 seed weight

The 1000 seed weight differed significantly due to

Table 90. Influence of levels of gypsum in sodic soil on seed yield (kg ha⁻¹), seed recovery (%) and 1000 seed weight (g)

Treatments	Seed Yield (kg ha ⁻¹)			Seed Recovery (%)			1000 Seed Weight (g)		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
To	1074	1196	1135	33.60	35.40	34.50	16.80	17.30	17.10
T1	1820	1984	1902	50.40	53.80	52.10	17.60	18.20	17.90
T2	2616	2775	2696	66.50	70.00	68.30	18.88	19.10	19.10
T3	3472	3632	3552	73.80	79.60	76.70	20.40	21.00	20.70
Mean	2246	2397		56.10	59.70		18.42	18.90	
V		T	VxT	V	T	VxT	V	T	VxT
CD(P=0.05)	28.27	39.98	NS	0.80	1.12	1.59	0.20	0.29	NS

levels of gypsum and varieties (Table 90). The seed weight increased prominently due to the application of higher level of gypsum (T_3) compared to other levels and control (T_0). Among the gypsum levels T_3 recorded maximum seed weight of 20.7 g, followed by T_2 (19.0 g), while the minimum by T_0 (17.1 g). The treatment T_3 recorded 17.4 per cent increased seed weight over T_0 . Between the varieties though the differences in seed weight was not higher, the variety V_2 recorded higher seed weight (18.9 g) than V_1 (18.42 g).

STORAGE STUDIES

Speed of germination

Speed of germination of the stored seeds differed significantly due to periods of storage, varieties and levels of gypsum (Table 91). The speed of germination of stored seeds decreased progressively from P_1 (25.0) to P_5 (22.8) irrespective of varieties and levels of gypsum. Among the varieties V_2 recorded higher value for speed of germination (24.6) over a period of 15 months compared to V_1 (23.6) irrespective of storage periods and levels of gypsum. All the levels of gypsum maintained higher speed of germination compared to control (T_0). Among the levels T_3 recorded the highest speed of germination of 29.2 followed by T_2 (26.7), T_1 (22.2) and the lowest by T_0 (18.4) irrespective period of storage.

Table 92. Influence of levels of gypsum application in sodic soil and periods of storage on germination (%) of resultant seeds

P0			P1			P2			P3			P4			P5			Mean
V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	82	81	81.5	82	82.0	80	81	80.5	76	78	77.0	76	77	76.5	74	75	74.5	78.8
	(64.9)	(64.2)	(64.5)	(64.9)	(64.9)	(63.4)	(64.2)	(63.8)	(60.7)	(62.0)	(61.3)	(60.7)	(61.3)	(61.0)	(59.3)	(60.8)	(59.7)	(62.5)
T1	86	83	84.2	85	84.5	83	82	82.5	82	81	81.5	81	79	80.0	79	78	80.2	82.3
	(68.0)	(65.7)	(66.6)	(67.2)	(66.4)	(66.8)	(65.7)	(65.3)	(64.9)	(64.2)	(64.5)	(64.2)	(62.7)	(63.4)	(62.7)	(62.0)	(63.6)	(65.1)
T2	87	85	86.0	86	86.0	85	85	85.0	86	84	85.0	82	82	82.0	81	81	80.7	84.1
	(68.9)	(67.2)	(68.0)	(68.0)	(68.0)	(67.2)	(67.2)	(67.2)	(68.0)	(66.4)	(67.2)	(64.9)	(64.9)	(64.9)	(64.2)	(64.2)	(63.9)	(66.5)
T3	90	88	89.0	90	90.1	89	90	89.5	89	88	88.5	86	87	86.5	84	86	85.0	87.0
	(71.6)	(69.7)	(70.6)	(71.6)	(71.6)	(70.6)	(71.6)	(71.1)	(70.6)	(69.7)	(70.2)	(68.0)	(68.9)	(68.4)	(66.4)	(68.0)	(67.2)	(69.6)
Mean	86.0	84.0	85.8	85.5	84.3	84.4	83.3	82.8	83.3	82.8	81.2	81.2	81.1		79.5	80.6		
	(68.0)	(66.4)	(67.9)	(67.6)	(66.7)	(66.7)	(65.9)	(65.5)	(65.9)	(65.5)	(64.3)	(64.3)	(64.2)		(63.1)	(63.9)		
Mean		85.3		85.6		84.4		83.0		81.3		81.3					80.1	
		(68.3)		(67.7)		(66.7)		(65.7)		(64.4)		(64.4)					(63.5)	

Variety mean

V1

V2

83.3

83.1

CD(P=0.05)

1.72

MS

0.99

MS

MS

MS

The interactions between periods x varieties, periods x levels of gypsum and varieties x levels of gypsum were not significant.

Germination

The germination potential of the stored seeds differed significantly due to periods of storage and levels of gypsum (Table 92, Fig. 15). With the increase in period of storage from P_0 (85.3%) to P_5 (80.1%) the germination per cent decreased progressively, however the decrease was less in the seeds obtained from higher levels of gypsum compared to that of T_0 . All the levels of gypsum maintained more than 80.0 per cent germination compared to 78.8 per cent in control (T_0) over a period of 15 months irrespective of varieties. The interaction effects were not significant.

Root length

The periods of storage, varieties and the levels of gypsum significantly influenced the root length of seeds, however, their interactions were not significant (Table 93). The mean root length of the stored seeds decreased from 18.7 (P_1) to 16.9 cm (P_5) with increase in the period of storage. Among the varieties the seeds from V_2 recorded maximum length of 18.6 cm compared to V_1 (17.8 cm) irrespective of periods of storage and levels of gypsum. Among the levels

Table 93. Influence of levels of gypsum application in sodic soil and periods of storage on root length (cm) of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	16.8	17.1	17.0	16.2	17.2	16.7	16.3	17.0	16.7	16.0	16.5	16.3	14.9	15.8	15.4	14.0	14.5	14.3	16.1
T1	17.5	18.0	17.8	17.9	18.4	18.2	17.6	18.2	17.9	17.2	17.8	17.5	16.9	17.0	17.0	15.8	16.0	15.9	17.4
T2	18.2	19.2	18.7	19.0	19.5	19.3	19.2	19.9	19.6	19.0	19.5	19.3	18.5	19.5	19.0	17.9	18.4	18.2	19.1
T3	19.9	20.8	20.3	19.6	21.2	20.4	19.9	21.5	20.7	19.8	21.2	20.5	19.2	21.2	20.2	18.4	20.0	19.2	20.2
Mean	18.1	18.8		18.2	19.1		18.3	19.1		18.0	18.7		17.4	18.7		16.5	17.2		
Mean	18.5			18.7			18.7			18.4			17.9			16.9			

Variety mean V1 V2
17.8 18.6

P V T PrV PrT VtT PrVtT
cd(P=0.05) 0.87 0.50 0.71 NS NS NS NS NS

of gypsum, T_3 (20.2 cm) followed by T_2 (19.1 cm) recorded lengthier roots compared to T_1 (17.4 cm) and T_0 (16.1 cm). In all the levels of gypsum the root length decreased with increase in period of storage, but the decrease was less in T_3 and T_2 over other levels and control.

Vigour index

The vigour index differed significantly due to periods of storage and levels of gypsum (Table 94). With the increase in the storage period the vigour index values decreased from 1602 (P_1) to 1352 (P_5) irrespective of varieties and levels of gypsum.

Among the levels of gypsum T_3 (1774) followed by T_2 (1590) recorded the highest mean vigour index value (1423) compared to T_0 (1266) irrespective of period of storage and varieties.

Dry matter production

Dry matter production differed significantly due to periods, varieties, levels of gypsum and their interactions except, the interaction of periods x varieties (Table 95).

The dry matter decreased with increase in the period of storage irrespective of varieties, levels of gypsum from

Table 94 Influence of levels of gypsum application in sodic soil and periods of storage on vigour index of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	1378	1386	1382	1329	1410	1370	1304	1369	1337	1224	1288	1256	1156	1217	1187	1036	1088	1062	1266
T1	1470	1485	1478	1514	1546	1530	1470	1492	1481	1410	1442	1426	1360	1369	1365	1248	1272	1260	1423
T2	1566	1622	1594	1688	1678	1673	1632	1684	1658	1594	1628	1611	1518	1574	1546	1440	1481	1460	1590
T3	1772	1836	1804	1764	1908	1836	1772	1936	1854	1725	1866	1796	1652	1818	1735	1538	1710	1624	1774
Mean	1547	1581		1569	1636		1555	1620		1488	1556		1422	1495		1316	1388		
Mean	1564			1602			1588			1522			1458					1352	

Variety mean		V1	V2
		1526	1542
P	V	T	PxV
PxV	VxT	PxT	PxVxT
CB(P=0.05)	170.2	NS	138.1
		NS	NS
		NS	NS

Table 95. Influence of levels of gypsum application in sodic soil and periods of storage on dry matter production (mg seedling⁻¹) of resultant seeds.

P0	P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	9.8	10.7	10.3	9.4	10.6	10.0	9.3	10.6	10.0	9.1	10.2	9.7	8.6	9.3	9.0	9.4
T1	10.3	11.2	10.8	10.6	11.4	11.0	10.4	11.6	11.0	10.3	11.4	10.9	10.0	10.8	10.4	10.6
T2	10.9	11.5	11.2	11.2	11.2	11.2	11.5	11.4	11.5	11.2	11.0	11.1	10.8	10.4	10.6	11.0
T3	11.7	12.2	11.9	12.0	12.3	12.2	12.2	12.5	12.4	12.0	12.2	12.1	11.6	12.0	11.8	12.0
Mean	10.7	11.4		10.8	11.4		10.9	11.5		10.7	11.3		10.2	10.7		10.1
Mean	11.0			11.1			11.2			10.9			10.5			9.8

Variety mean V1 V2
10.5 11.0

P V T PrV PrT PrVT
0.17 0.09 0.14 NS 0.33 0.19 NS

300

300

11.2 mg (P_2) to 9.8 mg (P_5). Between the varieties V_2 recorded higher dry matter (11.0 mg) than V_1 (10.5 mg) irrespective of gypsum application over 15 months of storage.

Among the treatments T_3 recorded higher dry weight (12.0 mg) followed by T_2 (11.0 mg) compared to T_0 (9.4 mg). At the end of the storage period of 15 months the mean dry matter production was higher in T_3 (11.4 mg) followed by T_2 (10.2 mg) compared to T_0 (7.7 mg).

Electrical conductivity

The electrical conductivity in the seed leachate of stored seeds differed significantly due to periods, varieties and levels of gypsum (Table 96, Fig. 15).

The electrical conductivity increased gradually with the progressive increase in the storage period from 65.5 (P_0) to 69.4 dSm^{-1} (P_5) irrespective of varieties and treatments. Between the varieties V_2 recorded the minimum conductivity of 62.9 (dSm^{-1}) compared to V_1 (71.2 dSm^{-1}) over periods of storage.

Among the treatments T_3 recorded the lower electrical conductivity (57.6 dSm^{-1}) followed by T_2 (64.4 dSm^{-1}) than T_0 (76.3 dSm^{-1}) over periods of storage.

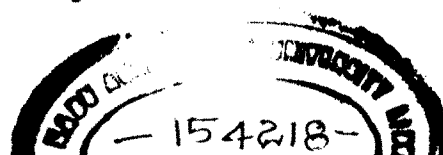


Table 96. Influence of levels of gypsum application in sodic soil and periods of storage on electrical conductivity (dSm⁻¹) of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	75.8	69.6	72.8	76.3	71.0	73.7	74.5	72.2	73.4	78.1	73.8	76.0	86.6	75.8	81.2	86.8	75.4	81.1	76.3
T1	73.1	64.2	68.7	73.6	64.8	69.2	74.1	65.1	69.6	75.0	66.4	70.7	76.4	67.5	72.0	75.6	67.7	71.7	70.3
T2	68.6	58.6	63.6	67.5	59.1	63.3	68.0	60.0	64.0	68.8	60.6	64.7	69.6	61.8	65.6	68.8	60.7	64.8	64.4
T3	61.5	52.6	57.1	61.0	52.0	56.5	61.2	52.8	57.0	61.6	53.2	57.4	62.4	54.0	58.2	60.6	50.8	59.7	57.6
Mean	69.7	61.3		69.6	61.8		69.4	62.5		70.9	63.2		72.3	64.8		75.0	63.7		
Mean	65.5			65.7			66.0			67.1			69.3			69.4			

Variety mean V1 V2
71.2 62.9

P V T PrV PrT PrVT
CD(P=0.05) 0.54 0.31 0.44 NS 1.08 0.62 NS

Except the interaction between periods x varieties, the other interactions were not significant. Irrespective of storage periods the seeds of V2 at T3 recorded less electrical conductivity values than others.

Sugar content

The sugar content in the seed leachates of the stored seeds differed significantly due to varieties, levels of gypsum and their interactions, except the interaction between periods x varieties (Table 97).

The sugar values of the varieties over periods of storage irrespective of gypsum treatment did not vary widely.

Among the levels of gypsum T₃ recorded the lowest sugar of 3.0 µg followed by T₂ (3.6 µg) and the highest by T₀ (5.3 µg) irrespective storage periods and varieties. In all the periods T₃ recorded the lowest sugar content in the leachate than T₀. In both the varieties T₃ recorded the lowest sugar value, while the highest was by T₀.

Table 97. Influence of levels of gypsum application in sodic soil and periods of storage on sugar content (µg) of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	4.60	4.25	4.43	4.72	4.31	4.51	4.80	4.5	4.65	5.10	4.91	5.00	5.81	6.00	5.90	6.90	7.20	7.05	5.30
T1	3.95	3.70	3.85	4.00	3.67	3.83	4.10	3.70	3.90	4.30	3.90	4.10	4.90	4.61	4.75	5.60	5.27	5.43	4.30
T2	3.10	3.20	3.15	3.20	3.31	3.25	3.10	3.40	3.25	3.23	3.83	3.53	3.50	4.00	3.75	4.10	4.90	4.50	3.60
T3	2.70	2.80	2.74	2.80	2.76	2.75	2.86	2.65	2.76	2.90	2.80	2.85	3.10	3.22	3.15	3.80	4.06	3.90	3.00
Mean	3.59	3.49		3.68	3.50		3.70	3.56		3.88	3.86		4.33	4.46		5.10	5.34		
Mean	3.50			3.60			3.60			3.90			4.40					5.20	

Variety mean V1 V2
4.10 4.00

P V T PrV PrT PrVt PrVt
MS 0.09 0.12 NS 0.30 0.17 NS

Aminoacids

The aminoacids in the seed leachate of stored seeds varied significantly due to periods of storage, varieties, levels of gypsum and their interactions except periods x varieties (Table 98).

The amount of aminoacids in the leachate increased from 3.7 μg (P_0) to 8.1 μg (P_5) with the increase in the period of storage irrespective of varieties and treatments. Between the varieties V_1 recorded the lowest value of 4.9 μg compared to 5.7 μg in V_2 over periods of storage irrespective of treatments.

Among the levels of gypsum T_3 recorded the lower amino acid content (4.1) followed by T_2 (4.9 μg) than T_0 (7.5 μg) over periods of storage. In all the periods T_3 recorded the lowest amino acid content (2.5 μg) than the other levels. The other interactions revealed that V_1 and V_2 at T_3 and V_1 at T_2 registered the lowest values than the other respective interactions.

Protein content

The protein content of stored seeds varied significantly due to storage periods, varieties, levels of gypsum and their interactions except the interaction between

Table 98. Influence of levels of gypsum application in sodic soil and periods of storage on aminoacids (μg) of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	4.83	5.20	5.00	6.10	6.61	6.40	7.00	7.99	7.50	7.91	8.10	8.00	8.51	9.00	8.80	9.00	9.54	9.30	7.50
T1	2.41	4.33	3.90	3.60	4.80	4.20	4.21	5.60	4.90	4.77	6.20	5.50	5.71	6.90	6.40	8.21	3.40	8.90	5.60
T2	2.98	3.72	3.40	3.10	3.95	3.60	3.91	4.50	4.20	4.41	4.74	4.80	4.90	5.20	5.10	7.81	8.12	8.00	4.90
T3	2.10	2.91	2.50	2.33	3.20	2.80	3.00	5.40	4.20	3.50	4.61	4.10	4.00	5.01	4.50	6.10	6.45	6.30	4.10
Mean	3.33	4.04		3.78	4.64		4.53	5.87		5.15	5.91		5.79	6.52		7.78	8.38		
Mean	3.70			4.30			5.20			5.60			6.20					8.10	

Variety mean V1 V2

4.90 5.70

P V T PrV PrT VxT PrVxT

CD(P=0.05) 0.30 0.12 0.17 NS 0.42 0.24 NS

periods x varieties (Table 99).

The mean protein content of seeds decreased with increase in the period of storage from 7.9 (P₀) to 6.8 per cent (P₀) irrespective of varieties and treatments. Among the treatments T₃ recorded the maximum protein content of 9.6 per cent followed by T₂ (8.0%) and T₀ recorded the minimum of 5.8 per cent. Between the varieties, the seeds from V₁ recorded higher protein (7.7%) than V₁ (7.5%) over periods of storage irrespective treatments.

Throughout the storage period T₃ recorded the highest protein content followed by T₂ compared to T₀. In both the varieties the protein content of seeds increased significantly with the increase in levels of gypsum irrespective of storage period.

Alpha amylase activity

The alpha amylase activity of the stored seeds differed significantly due to periods of storage and levels of gypsum, however the varieties and their interactions were not significant (Table 100).

The alpha amylase activity decreased progressively from 8.8 (P₀) to 7.1 mm (P₅) over periods of storage. Among the levels of gypsum maximum alpha amylase activity was

Table 99. Influence of levels of gypsum application in sodic soil and periods of storage on protein content (%) of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	6.20	6.80	6.51	5.96	6.71	6.33	5.80	6.61	6.21	5.22	6.50	5.85	4.80	5.92	5.40	3.91	4.81	4.40	5.80
T1	7.10	7.40	7.30	7.20	7.20	7.20	7.10	7.30	7.20	6.91	7.10	7.00	6.60	6.80	6.70	5.80	6.10	6.00	6.90
T2	8.43	8.30	8.40	8.32	8.41	8.40	8.40	8.35	8.40	8.21	8.20	8.20	8.05	8.12	8.10	7.60	7.60	7.60	8.10
T3	9.70	9.50	9.60	9.83	9.71	9.80	9.90	9.80	9.90	9.70	9.71	9.70	9.61	9.52	9.60	9.20	9.10	9.20	9.60
Mean	7.86	8.00		7.83	8.00		7.80	8.02		7.51	7.88		7.27	7.59		6.63	6.90		
Mean		8.00				7.90		7.90			7.70			7.45				6.80	

Variety	mean	V1	V2	P	V	T	PxV	PxT	VxT	PxVT
		7.50	7.70							
				0.12	0.07	0.09	NS	0.23	0.13	NS

Table 100. Influence of levels of gypsum application in sodic soil and periods of storage on alpha amylase activity (nm) of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	7.2	7.8	7.5	7.1	7.6	7.4	6.8	7.9	7.4	4.4	7.9	6.2	6.1	6.3	6.2	4.5	5.2	4.9	6.6
T1	8.1	8.6	8.4	8.2	8.7	8.5	8.6	8.6	8.6	7.9	8.2	8.1	7.2	7.9	7.6	6.6	6.8	6.7	8.0
T2	8.9	9.3	9.1	9.0	9.4	9.2	9.0	9.2	9.1	9.7	9.0	8.9	8.2	8.6	8.4	7.5	7.9	7.7	8.7
T3	9.8	10.8	10.3	9.0	10.0	9.5	8.5	10.3	9.4	9.0	10.0	9.5	8.5	10.5	9.5	8.0	9.8	8.9	9.5
Mean	8.5	9.1		8.3	8.9		8.2	9.0		7.5	8.5		7.5	8.3		6.6	7.4		
Mean	8.8			8.7					8.5		8.2			7.9				7.1	

Variety mean	V1	V2																	
	8.1	8.2																	
P			PxV																
CD(P=0.05)	0.71	NS	0.58	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

recorded in T_3 (9.5) followed by T_2 (8.7 mm), while the minimum was in T_0 (6.6 mm) irrespective of storage periods and varieties.

Fungal infection

The fungal infection per cent of stored seeds differed significantly due to periods of storage, levels of gypsum and the interaction of periods x levels of gypsum (Table 101).

The fungal activity increased from 0.61 (P_0) to 2.90 per cent (P_5) with increase in the period of storage, irrespective of varieties and treatments. Among the levels of gypsum the seeds from T_3 and T_2 recorded lower fungal activity of 0.7 and 0.9 per cent, respectively than those from T_1 (1.30%) and T_0 (1.90%). Throughout the storage period the seeds obtained from higher levels of gypsum (T_3 and T_2) recorded lower fungal invasion than control (T_0).

4.5. Green Manuring and gypsum application in sodic soil on seed yield and quality

Plant population

Plant population/m² differed significantly due to soil amendments (Table 102). Among the treatments the plant

Table 101. Influence of levels of gypsum application in sodic soil and periods of storage on fungal infection (%) of resultant seeds.

	P0			P1			P2			P3			P4			P5			Mean
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	
T0	0.80	1.10	0.95	1.00	1.40	1.20	1.20	1.20	1.20	1.50	1.40	1.45	2.60	2.30	2.45	4.20	4.50	4.35	1.90
T1	0.80	0.90	0.86	0.30	0.80	0.55	0.80	0.90	0.85	1.00	0.90	0.95	1.80	1.40	1.60	3.00	3.10	3.00	1.30
T2	0.30	0.60	0.45	0.40	0.50	0.45	0.40	0.40	0.40	0.60	0.60	0.60	1.20	1.00	1.10	2.50	2.10	2.31	0.90
T3	0.10	0.20	0.16	0.20	0.20	0.25	0.30	0.40	0.35	0.40	0.50	0.45	1.00	1.00	1.00	1.80	2.00	1.90	0.70
Mean	0.50	0.70		0.50	0.75		0.68	0.73		0.88	0.85		1.65	1.43		2.88	2.93		
Mean	0.61			0.63			0.70			0.87			1.54					2.90	

Variety mean	V1	V2										
	1.20	1.20										
P	V	T	PxV	PxT	VxT	PxVxT						
CD(P=0.05)	0.18	NS	0.16	NS	0.36	NS	NS	NS	NS	NS		

population varied between 36 to 60. The treatment F_2 maintained maximum population (60) followed by F_3 (58) and F_4 (56), while it was minimum in F_0 (36).

Days to initiation flowering

Days to initiation flowering differed significantly due to treatments (Table 102). Among the treatments control recorded maximum of 63 days for initiation of flowering compared to other treatments. Days to initial flowering in control was on par with F_3 (62). Among the treatments F_2 took less number of days (58.0) for the initiation of flowering. The difference in the attainment of initial flowering among the treatments ranged between 1 and 5 days.

Number of tillers

Number of tillers plant⁻¹ differed significantly due to treatments (Table 102). Among the treatments F_2 recorded the maximum tiller number of 13, which was on par with F_4 and F_3 (12 and 12), while it was minimum in F_0 (6). The percentage increase in tiller number of the treatment F_2 was 53.8 over F_0 .

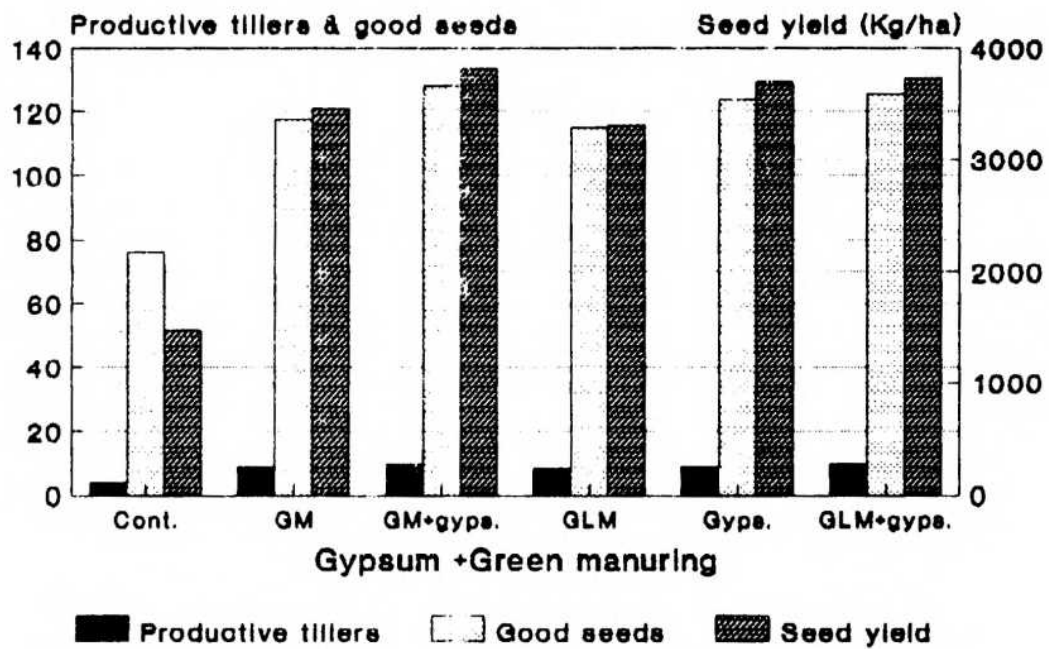
Number of productive tillers

Number of productive tillers plant⁻¹ differed significantly due to treatments (Table 102, Fig. 16). The

Table 102. Influence of green manuring and levels of gypsum on plant population / m², days to initiation of flowering, number of tillers plant⁻¹, number of productive tillers plant⁻¹, length of panicle (cm) and weight of panicle (g).

Treatments	Plant population/ m ²	Days to initiation flowering	No. of tillers plant ⁻¹	No. of productive tillers plant ⁻¹	Length of Panicle (cm)	Weight of panicle (g)
F0	36	63	6	4	16.85	1.86
F1	55	61	10	9	18.60	2.20
F2	60	58	13	10	19.80	2.60
F3	53	62	9	8	18.00	2.15
F4	56	60	12	9	19.20	2.48
F5	58	60	12	10	19.30	2.50
Mean	53	62	10.30	8.30	18.63	2.30
CD(P=0.05)	4.96	1.59	2.36	2.42	0.90	0.14

Fig.16 Influence of gypsum + green manuring on productive tillers, good seeds and seed yield



productive tillers was higher in F_2 (10) and F_5 (10) followed by F_1 (9.0) and F_4 (9), while it was lower in F_0 (4). The percentage increase in number of productive tillers among the treatments ranged between 50 and 60 over control

Length of panicle

Significant differences were observed among the treatments for length of panicle (Table 102). Higher panicle length was observed in F_2 (19.80 cm) followed by F_5 (19.30 cm) and F_4 (19.20 cm) and it was lower in F_0 (16.85 cm). The length of panicle among the treatments varied from 16.85 (F_0) to 19.30 cm (F_5).

Weight of panicle

The amendments induced significant differences in the weight of panicle (Table 102). The treatment F_2 recorded higher panicle weight of (2.60 g) which was on par with F_5 (2.50 g) and F_4 (2.48 g), while it was lower in F_0 (1.86 g). The treatments F_1 and F_3 recorded intermediary weight of 2.20 and 2.15 g, respectively.

Days to maturity

Significant differences were observed among the treatments for days to maturity due to treatments

(Table 103). All the treatments reduced the number of days required to attain physiological maturity compared to control (T_0). On an average F_2 took 140 days to attain maturity followed by F_4 (141) and F_5 (141) than T_0 (155).

Number of good seeds

The number of good seeds ear⁻¹ at harvest differed significantly due to treatments (Table 103, Fig. 16). The increase in number of good seeds was gradual in all the treatments and varied between 76 (F_0) and 128 (F_2). The highest number of good seeds was registered in F_2 (128) followed by F_5 (126), and F_4 (124), than F_0 (76).

Awne seeded ear

Awne seeded ears did not differ significantly due to treatments (Table 103). However F_4 recorded a numerical increase in the production of awne seeded ears compared to others treatments and control.

Seed yield

The seed yield differences among the treatments were significant (Table 103, Fig. 16). All the treatments recorded more seed yield compared to untreated control (T_0). On an average the treatment F_2 recorded the maximum seed

Table 103. Influence of green manuring and levels of gypsum on days to maturity, number of good seeds ear⁻¹, aw ned seeded ear (%), seed yield (kg ha⁻¹), seed recovery (%) and 1000 seed weight (g).

Treatments	Days to Maturity	No. of good seeds ear ⁻¹	Aw ned seeded ear (%)	Seed Yield (kg ha ⁻¹)	Seed Recovery (%)	1000 seed wt (g)
F0	155	76	0.00	1480	40.90	17.45
F1	142	118	0.00	3460	70.20	21.40
F2	140	128	0.20	3820	81.40	22.60
F3	143	115	0.00	3300	75.80	20.85
F4	141	124	0.30	3700	80.20	22.07
F5	141	126	0.15	3740	80.80	22.18
Mean	143.3	114.5	0.11	3250	72.50	21.10
CD(P=0.05)	1.00	9.77	NS	50.87	0.90	0.49

yield of 3820 kg ha⁻¹ followed by F₅ (3740 kg ha⁻¹) and F₄ (3700 kg ha⁻¹) and the minimum by F₀ (1480 kg ha⁻¹). The percentage increase in seed yield over control due to treatments ranged from 55.2 (F₃) to 61.3 (F₂).

Seed recovery

Seed recovery per cent differed significantly due to treatments (Table 103). All the treatments recorded higher recovery percentage compared to control (T₀). Among the treatments the highest value was recorded by F₂ (81.4%) and the lowest was by F₀ (40.9%). The other treatments viz., F₅ (80.8%), F₄ (80.2%), F₁ (76.2%) and F₃ (75.8%) recorded intermediary values. The increase in seed recovery percentage due to treatments ranged from 34.9 (F₃) to 40.5 (F₂) over control (F₀).

1000 seed weight

The differences in 1000 seed weight among the treatments were significant (Table 103). The resultant seeds from all the treatments recorded higher seed weight compared to untreated control (F₀). The seed weight of the treatments F₂ (32.8 g), F₅ (31.2 g) and F₄ (30.7) were on a par, however distinctly differed from control F₀ (22.6 g),

F₃ (29.0 g) and F₁ (29.5 g). The percentage increase in seed weight due to treatments ranged from 22.0 (F₃) to 31.1 over control (F₀).

STORAGE STUDIES

Storage studies were carried out with the resultant seeds obtained from green manure and gypsum treatments. Significant differences were noticed among treatments and periods of storage for speed of germination, seed germination, root length, vigour index, dry matter production, electrical conductivity, sugar content, amino acids, alpha amylase activity, protein content and fungal infection per cent.

The interactions between periods and treatments for vigour index, dry matter production and electrical conductivity were significant.

Speed of germination

The speed of germination of seeds decreased progressively from 29.2 (P₁) to 26.6 (P₅) with increase in the storage period irrespective of treatments (Table 104). All the treatments irrespective of storage period registered higher speed of germination compared to control (T₀) over a period of fifteen months. Among the treatments F₂ recorded

Table 104. Influence of green manuring, levels of gypsum and periods of storage on speed of germination and germination (%) of resultant seeds

Treat- ments	Speed of germination							Germination (%)						
	P0	P1	P2	P3	P4	P5	Mean	P0	P1	P2	P3	P4	P5	Mean
F0	22.60	22.50	21.50	20.80	19.60	18.40	20.90	85 (67.2)	85 (67.2)	84 (66.4)	82 (64.9)	81 (64.2)	79 (62.7)	82.60 (65.4)
F1	29.50	30.00	30.10	29.70	29.00	26.30	29.10	90 (71.6)	90 (71.6)	89 (70.6)	87 (68.9)	86 (68.0)	86 (68.0)	88.00 (69.7)
F2	31.80	32.40	32.60	32.20	31.80	31.50	32.10	94 (75.8)	94 (75.8)	93 (74.7)	91 (72.5)	90 (71.6)	88 (69.7)	91.80 (73.4)
F3	29.00	28.70	27.90	27.10	26.20	25.60	27.40	88 (69.7)	89 (70.6)	88 (69.7)	86 (68.0)	85 (67.2)	83 (65.7)	86.60 (68.5)
F4	30.70	30.60	30.80	30.50	29.80	29.20	30.30	91 (72.5)	92 (73.6)	92 (73.6)	90 (71.6)	88 (69.7)	88 (69.2)	89.80 (71.4)
F5	31.20	31.00	30.20	29.70	29.00	28.60	29.90	91 (72.5)	91 (72.5)	90 (71.6)	88 (69.7)	87 (68.9)	86 (68.0)	89.00 (70.6)
Mean	29.10	29.20	28.90	28.30	27.60	26.60		89.60 (71.2)	90.30 (71.9)	89.30 (70.9)	89.00 (70.6)	86.00 (68.0)	85.00 (67.2)	

	F	P	FxP	F	P	FxP
CD (P=0.05)	1.14	1.14	NS	1.42	1.42	NS

Fig.17 Influence of gypsum and green manuring on germination in storage

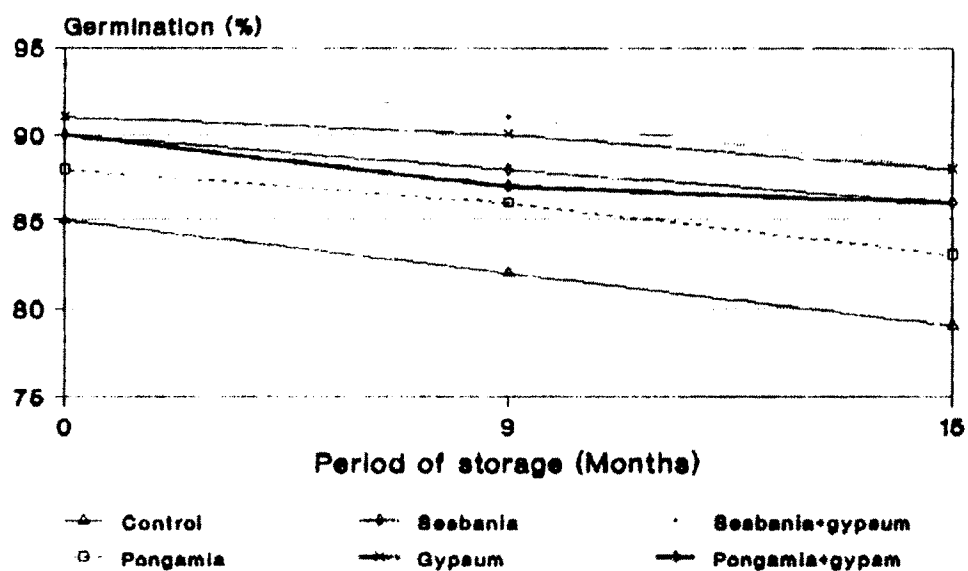
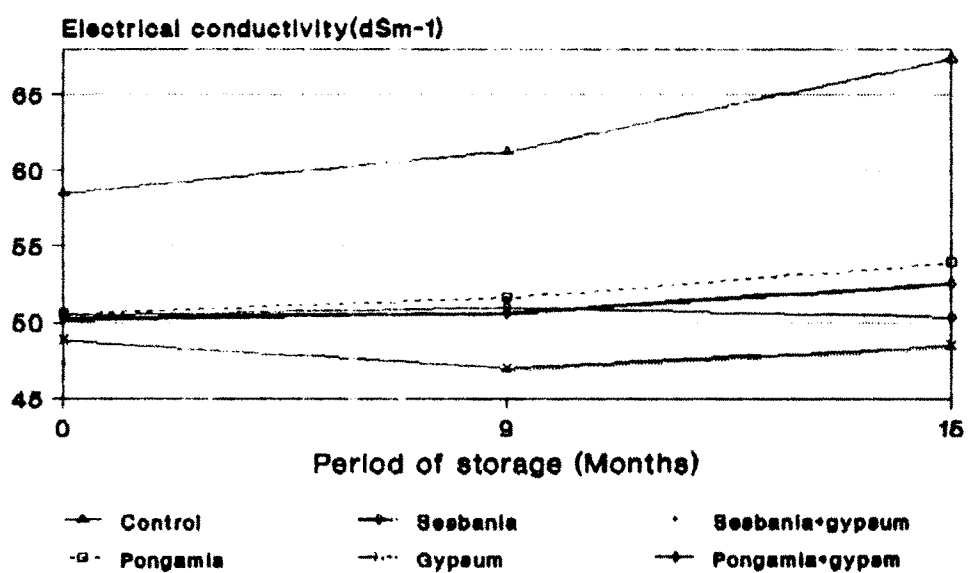


Fig.18 Influence of gypsum and green manuring on EC in storage



the highest speed of germination of 32.1 followed by F_4 (30.3) and the lowest by in control (20.9).

Germination

The mean germination percentage of seeds decreased concomitantly from 90.3 (P_1) to 84.0 per cent (P_5) with increase in the storage period and there after a slight increase in germination per cent was noticed in P_4 and P_5 irrespective of treatments (Table 104, Fig. 17). Among the treatments F_2 recorded the highest germination of 91.8 per cent followed by F_4 (89.8%) and F_1 (88.0%) and the lowest by F_0 (82.6%) over periods of storage.

Root length

The mean root length of the seeds decreased progressively from 20.80 (P_0) to 19.43 cm (P_5) with increase in the storage period irrespective of treatments (Table 105). The resultant seeds from F_2 significantly recorded longer root length (22.76 cm) followed by F_4 and F_5 (21.74 and 21.62 cm, respectively) as against 17.04 cm recorded by the seeds of F_0 .

Vigour index

The mean vigour index of seeds decreased concomitantly from 1889 (P_1) to 1647 (P_5) with increase in the storage

Table 105. Influence of green manuring, levels of gypsum and periods of storage on root length (cm) and vigour index of resultant seeds

Treat- ments	Root length (cm)							Vigour Index						
	P0	P1	P2	P3	P4	P5	Mean	P0	P1	P2	P3	P4	P5	Mean
F0	17.58	17.18	17.63	17.15	16.73	15.83	17.04	1478	1462	1466	1410	1344	1248	1401
F1	20.60	20.43	20.83	21.00	20.40	19.63	20.48	1854	1836	1852	1827	1744	1646	1793
F2	22.40	22.82	22.98	23.23	22.83	22.30	22.76	2095	2143	2150	2111	2052	1962	2086
F3	19.80	19.53	19.18	18.82	18.23	17.65	18.89	1742	1825	1690	1670	1548	1470	1634
F4	21.80	22.23	21.98	21.78	21.53	21.10	21.74	1964	2019	2024	1963	1892	1827	1952
F5	22.60	22.43	22.15	21.55	20.78	20.13	21.62	2058	2047	1190	1892	1810	1729	1920
Mean	20.80	20.77	20.78	20.59	20.10	19.43		1865	1889	1861	1803	1732	1647	

	F	P	FxP	F	P	FxP
CD (P=0.05)	0.18	0.18	NS	11.25	11.25	22.30

period irrespective treatments (Table 105). The resultant seeds from the treatments F_2 and F_4 registered maximum vigour of 2086 and 1952, respectively followed by F_5 (1920) and F_1 (1793) as against 1401 and 1634 recorded by the seeds from F_0 and F_3 , respectively.

The interaction between periods x treatments was significant. The seeds from F_2 at all periods of storage recorded maximum vigour over other treatments. The remaining interactions revealed that the seeds from P_0 and P_1 at F_5 , recorded the maximum vigour of 2058 and 2047 followed by P_2 at F_4 (2024) over other respective interactions.

Dry matter production

The mean dry matter production of seeds decreased linearly from 12.2 (P_0) to 10.9 mg (P_5) with increase in the storage period irrespective of treatments (Table 106). Among the treatments the seeds from F_2 (13.3 mg) and F_4 (12.5 mg) recorded the maximum dry matter production as against the seeds from T_0 (10.3 mg) over a period of fifteen months. The interaction between periods x treatments was significant.

Table 106. Influence of green manuring, levels of gypsum and periods of storage on dry matter production (mg seedling⁻¹) and electrical conductivity (dSm⁻¹) of resultant seeds

Treat- ments	Dry matter production (mg seedling ⁻¹)							Electrical conductivity (dSm ⁻¹)						
	P0	P1	P2	P3	P4	P5	Mean	P0	P1	P2	P3	P4	P5	Mean
F0	11.00	10.90	10.70	10.50	9.80	8.70	10.30	58.50	59.20	60.20	61.20	63.70	67.40	61.70
F1	12.10	11.60	11.80	11.60	10.90	10.60	11.40	50.20	49.80	49.60	50.60	51.20	52.50	50.60
F2	12.80	13.40	13.90	13.80	13.20	12.80	13.30	47.30	46.30	46.40	46.80	47.70	48.30	47.10
F3	11.60	11.40	11.20	11.00	10.60	10.00	11.10	50.60	51.50	50.10	51.60	52.80	53.90	51.90
F4	12.40	12.60	12.80	12.50	12.20	11.70	12.50	48.80	47.50	47.30	47.00	47.80	48.40	47.80
F5	12.60	12.30	12.50	12.10	11.60	11.20	12.10	50.50	50.40	50.50	51.00	52.10	50.30	48.90
Mean	12.20	12.10	12.20	11.90	11.90	10.90		50.90	50.80	50.70	51.40	52.30	53.50	

	F	P	FxP	F	P	FxP
CD (P=0.05)	0.22	0.22	0.54	0.32	0.32	0.77

Electrical conductivity

The mean electrical conductivity values of seed leachates increased progressively from 50.7 (P_2) to 53.5 dSm^{-1} (P_5) with increase in the storage period, however in the initial storage period a slight reduction in the EC value was observed from 50.9 (P_0) to 50.7 dSm^{-1} (P_2) irrespective of treatments (Table 106, Fig. 18). Among the treatments the seeds obtained from F_2 (47.1 dSm^{-1}) followed by F_4 (47.8 dSm^{-1}) and F_5 (48.9 dSm^{-1}) recorded minimum EC values compared to F_0 (61.7 dSm^{-1}). The interaction between periods x treatments was significant.

Sugar content

The mean sugar values of seed leachates increased linearly from 2.76 (P_0) to 4.04 μg (P_5) with increase in the storage period irrespective of treatments (Table 107). The resultant seeds from the treatments recorded significantly lower sugar values irrespective of storage period compared to control (F_0). The seeds from F_4 , F_5 and F_1 recorded the lowest sugar values of 2.64, 2.72 and 2.81 μg , respectively as against 7.00 μg recorded by F_0 .

Table 107. Influence of green manuring, levels of gypsum and periods of storage on sugar content (μg) and aminoacids (μg) of resultant seeds

Treat- ments	Sugar content (μg)							Aminoacids (μg)						
	P0	P1	P2	P3	P4	P5	Mean	P0	P1	P2	P3	P4	P5	Mean
F0	3.95	4.10	4.31	4.81	5.90	7.00	5.05	4.63	5.10	5.81	6.62	8.00	9.60	6.63
F1	2.60	2.65	2.45	2.60	2.88	3.50	2.81	3.00	3.10	3.38	3.73	4.21	4.80	3.70
F2	2.35	2.40	2.38	2.55	2.70	3.30	3.11	2.35	2.40	2.62	3.24	3.82	4.65	3.18
F3	2.73	2.60	2.80	3.11	3.30	3.85	3.06	2.80	2.74	2.91	3.10	4.00	4.91	3.41
F4	2.50	2.46	2.40	2.50	2.70	3.19	2.64	2.61	2.55	2.63	2.81	3.91	4.62	3.81
F5	2.45	2.51	2.41	2.56	2.94	3.41	2.72	2.70	2.74	2.84	2.88	4.12	5.10	3.40
Mean	2.76	2.78	2.79	3.02	3.40	4.04		3.02	3.11	3.37	3.73	4.68	5.61	

	F	P	FxP	F	P	FxP
CD (P=0.05)	0.55	0.55	NS	0.46	0.44	NS

Aminoacids

The mean aminoacid values of the seed leachates increased concomitantly from 3.02 (P_0) to 5.61 μg (P_5) with increase in the storage period irrespective of treatments (Table 107). The resultant seeds from all the treatments recorded significantly lower aminoacid values irrespective of periods of storage. The seeds from F_2 , F_3 and F_4 recorded the lower aminoacid values of 3.18, 3.40 and 3.41 μg compared to F_0 (6.63 μg).

Protein content

Though, the mean protein content of seeds was nonsignificant it decreased over periods of storage from 9.60 (P_2) to 8.74 per cent (P_5), however, a gradual increase was observed in the initial period from 9.45 (P_0) to 9.60 per cent (P_5) (Table 108). Among the treatments, irrespective of storage period, F_2 and F_4 recorded significantly higher protein content of 10.38 and 9.98 per cent than F_0 (7.30%).

Alpha amylase activity

The mean alpha amylase activity of seeds progressively decreased from 10.8 (P_0 and P_1) to 9.3 mm (P_5) with increase in the storage period irrespective of treatments

Table 108. Influence of green manuring, levels of gypsum and periods of storage on protein content (%) and alpha amylase (nm) of resultant seeds

Treat- ments	Protein content (%)							Alpha amylase (nm)						
	P0	P1	P2	P3	P4	P5	Mean	P0	P1	P2	P3	P4	P5	Mean
F0	7.60	7.56	7.40	7.18	6.60	5.40	7.30	8.30	8.30	8.10	7.60	6.90	5.40	7.40
F1	9.50	9.40	9.56	9.40	9.23	8.90	9.50	10.40	10.30	10.20	10.0	9.50	8.80	9.90
F2	10.40	10.60	10.83	10.69	10.39	10.10	10.38	12.50	12.60	12.50	12.40	12.00	11.60	12.30
F3	9.20	9.34	9.20	9.18	8.93	8.50	9.14	9.80	9.60	9.40	9.10	8.60	8.00	9.10
F4	9.80	10.10	10.21	10.10	9.79	9.50	9.98	11.60	11.80	12.00	11.80	11.40	11.80	11.60
F5	10.20	10.40	10.44	10.40	10.22	10.00	9.79	12.20	12.00	12.10	11.90	11.60	11.20	11.80
Mean	9.45	9.56	9.60	9.49	9.19	8.74		10.80	10.80	10.70	10.50	10.00	9.30	

Protein content (%)				Alpha amylase (nm)			
F	P	FxP		F	P	FxP	
CD (P=0.05)	0.56	NS	NS	0.39	0.39	NS	NS

(Table 108). Among the treatments F_2 , F_3 and F_4 recorded higher alpha amylase activity (12.3, 11.8 and 11.6 mm) than F_0 (7.4 mm) over a period of fifteen months.

Fungal infection

The mean fungal invasion per cent increased gradually from 0.1 (P_0) to 2.3 per cent (P_5) with increase in the period of storage, irrespective of treatments (Table 109). Within the treatments, the fungal activity was less in F_2 (0.3%) followed by F_1 , F_4 and F_3 (0.50%) compared to F_0 (1.90%), over a period of 15 months of storage.

4.6. Stages of harvest and foliar spray of nutrients on shattering and quality of seed

Number of seeds earhead⁻¹

The number of seeds earhead⁻¹ differed significantly due to stages of harvest and foliar sprays, however their interactions were not significant (Table 110). As the maturity stage increased the seed number earhead⁻¹ decreased. Among the harvesting stages H_1 recorded higher number of seeds earhead⁻¹ (121.7) followed by H_2 (121.9) compared to other stages, while H_3 recorded the minimum of (107.6).

Table 109. Influence of green manuring, levels of gypsum and periods of storage on fungal infection (%) of resultant seeds

Treat- ments	Fungal infection (%)						
	P0	P1	P2	P3	P4	P5	Mean
F0	0.53	0.80	0.80	1.20	2.50	4.80	1.90
F1	0.00	0.00	0.00	0.20	0.80	1.80	0.50
F2	0.00	0.00	0.00	0.10	0.50	1.40	0.30
F3	0.00	0.00	0.30	0.30	1.40	2.30	0.70
F4	0.00	0.10	0.10	0.50	1.20	2.00	0.50
F5	0.00	0.00	0.00	0.30	0.80	1.60	0.50
Mean	0.10	0.20	0.20	0.40	1.20	2.30	

	F	P	FxP
CD (P=0.05)	0.71	0.71	NS

Among the foliar spray treatments F_1 recorded maximum number of seeds earhead⁻¹ (125.1) followed by F_2 (117.5) compared to other treatments, while F_0 recorded the minimum number of 114.7.

Seed shattering

The seed shattering per cent differed significantly due to stages of harvest, foliar spray treatments and their interactions (Table 110, Fig. 19).

Seed shattering loss gradually increased with increase in the stage of harvest from H_1 and H_2 (2.7 and 2.7%) to H_3 (6.7%).

Among the foliar spray treatments seed shattering loss ranged from 3.1 (F_2) to 5.1 per cent (F_0) irrespective of stages of harvest.

The interaction between stages x foliar spray treatments was significant. The stage H_1 at F_2 and H_2 at F_2 recorded the lowest seed shattering loss (2.0 and 2.1%, respectively).

Table 110. Influence of stages of harvest and spraying of nutrients on number of seeds earhead⁻¹ and seed shattering (%)

Stages of Harvest	No. of seeds earhead ⁻¹					Seed Shattering (%)				
	F0	F1	F2	F3	Mean	F0	F1	F2	F3	Mean
H1	118.0	126.0	125.0	117.7	121.7	3.2	2.6	2.0	2.9	2.7
H2	120.0	128.0	123.7	116.0	121.9	3.4	2.4	2.1	8.0	2.7
H3	115.0	126.0	117.3	111.3	117.4	4.6	2.6	2.7	3.9	3.5
H4	112.0	125.0	113.3	101.7	113.0	5.8	3.6	3.4	4.8	4.4
H5	108.7	120.3	108.3	93.0	107.6	8.6	5.6	5.0	7.6	6.7
Mean	114.7	125.1	117.5	107.9		5.1	3.4	3.1	4.5	
CD(P=0.05)	5.22	4.68	NS			0.33	0.30	0.66		

Fig.19 Influence of harvesting stage and nutrient spray on shattering loss

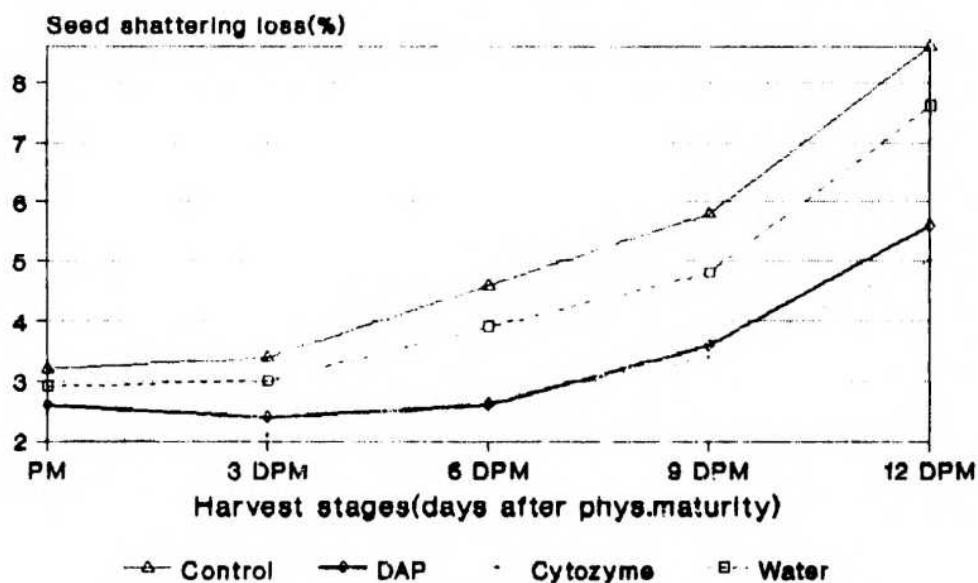
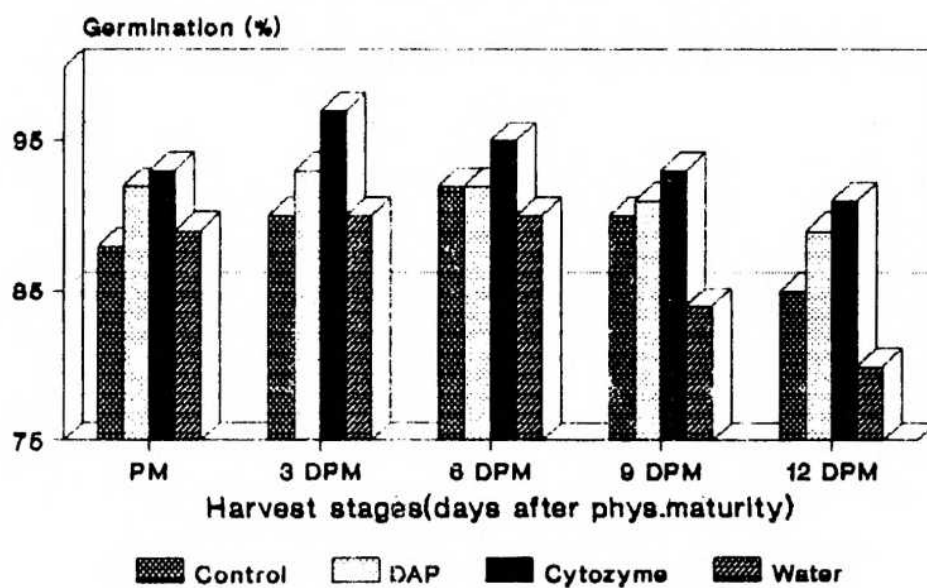


Fig.20 Influence of harvesting stage and nutrient spray on germination



Seed recovery

The seed recovery per cent differed significantly due to stages of harvest and foliar spray treatments (Table 111).

As the stage of harvest increased the recovery percentage decreased. Among the stages of harvest, H_1 , H_2 and H_3 on par recorded the highest seed recovery of 74.3, 74.3 and 74.2 per cent, respectively compared to H_4 (73.5% and H_5 (73.0%).

Among the foliar spray treatments F_2 (75.0%) followed by F_1 and F_3 (73.9 and 73.7%) recorded maximum recovery compared to F_0 (72.9%).

1000 seed weight

The 1000 seed weight due to the stages of harvest, foliar spray treatments and their interactions were not significant (Table 111).

Speed of germination

The stages of harvest and foliar spray treatments differed significantly in respect of speed of germination (Table 112).

Table 111. Influence of stages of harvest and spraying of nutrients on seed recovery (%) and 1000 seed weight (g)

Stages of Harvest	Seed Recovery (%)					1000 Seed Weight (g)				
	F0	F1	F2	F3	Mean	F0	F1	F2	F3	Mean
H1	73.6	74.5	75.2	74.0	74.3	21.8	22.1	22.3	21.9	22.0
H2	74.1	73.7	75.4	74.2	74.3	22.0	22.2	22.4	21.9	22.1
H3	73.3	74.1	75.2	74.1	74.2	21.9	22.4	22.3	21.7	22.1
H4	72.1	73.6	74.8	73.5	73.5	21.4	22.5	22.2	21.4	21.9
H5	71.5	73.5	74.3	72.6	73.0	16.7	22.0	21.2	21.1	20.3
Mean	72.9	73.9	75.0	72.0		22.2	22.1	21.6	20.8	
		H	F	HxF		H	F	HxF		
CD(P=0.05)		0.70	0.63	NS		NS	NS	NS		

The speed of germination decreased gradually with increase in the stage of harvest from 30.9 (H_2) to 29.6 (H_5). The decline in the speed of germination was rapid from H_4 to H_5 . Among the foliar spray treatments irrespective of stages of harvest the mean speed of germination ranged between 29.4 (F_3) and 31.5 (F_2).

Germination

Germination per cent differed significantly due to stages of harvest and foliar treatments (Table 112, Fig. 20). Among the stages of harvest H_1 , H_2 and H_3 recorded more than 90 per cent germination. In the foliar spray treatments the seeds from F_2 and F_1 recorded the maximum germination of 93.7 and 91.4 per cent, compared to other treatments and control (F_0).

Root length

The root length did not differ significantly due to stages of harvest, foliar spray treatments and their interactions (Table 113).

Vigour index

The vigour index values differed significantly due to stages of harvest, foliar spray treatments and their

Table 112. Influence of stages of harvest and spraying of nutrients on speed of germination and germination (%) of resultant seeds

Stages of Harvest	Speed of germination					Germination (%)				
	F0	F1	F2	F3	Mean	F0	F1	F2	F3	Mean
H1	29.6	31.0	31.4	29.3	30.3	88 (69.7)	92 (73.6)	93 (74.7)	89 (70.6)	90.4 (72.0)
H2	30.4	31.6	31.8	29.7	30.9	90 (71.6)	93 (74.7)	97 (80.0)	90 (71.6)	92.40 (74.0)
H3	30.1	31.0	31.5	29.8	30.6	92 (73.6)	92 (73.6)	95 (77.1)	90 (71.6)	92.3 (73.9)
H4	19.5	30.8	31.6	29.6	30.4	90 (71.6)	91 (72.5)	93 (74.7)	84 (66.4)	89.5 (71.1)
H5	28.7	30.0	31.0	28.6	29.6	85 (67.2)	89 (70.6)	91 (72.5)	80 (63.4)	86.3 (68.3)
Mean	29.7	30.9	31.5	29.4		89.0 (70.6)	91.4 (73.0)	93.7 (75.5)	86.5 (68.4)	

(Figures in parenthesis are arcsine values)

	H	F	HxF	H	F	HxF
CD(P=0.05)	0.45	0.40	NS	2.02	1.81	NS

Table 113. Stages of harvest and spraying of nutrients on root length (cm) and vigour index of resultant seeds

Stages of Harvest	Root length (cm)					Vigour Index				
	F0	F1	F2	F3	Mean	F0	F1	F2	F3	Mean
H1	19.20	19.83	19.90	19.10	19.50	1690	1794	1852	1702	1760
H2	19.43	20.07	19.67	19.10	19.57	1764	1842	1891	1719	1804
H3	19.53	19.13	19.87	18.50	19.26	1785	1804	1862	1664	1779
H4	19.40	19.73	18.90	18.97	19.25	1720	1765	1814	1570	1717
H5	18.90	19.83	19.57	18.40	19.18	1606	1744	1802	1472	1656
Mean	19.29	19.72	19.58	18.81		1713	1790	1844	1625	
	H	F	HxF	H	F	HxF				
CD(P=0.05)	NS	NS	NS	22.96	20.53	45.9				

interactions (Table 113). The vigour index values decreased from 1804 (H_2) to 1656 (H_3) among the stages of harvest, irrespective of foliar spray treatments.

Among the foliar spray treatments F_2 recorded the highest mean vigour index value of 1844 followed by F_1 (1790) irrespective of stages of harvest, while the lowest by F_3 (1625).

The seeds subjected to F_2 harvested at physiological maturity (H_1) and three days after physiological maturity (H_2) recorded the maximum vigour index values of 1852 and 1891, respectively.

Dry matter production

Dry matter production varied significantly due to stages of harvest and foliar spray treatments, while their interactions were not significant (Table 114).

The dry matter production values decreased from 12.50 (H_2) to 11.96 mg (H_3) among the stages of harvest. Among the foliar spray treatments the seeds from F_2 registered the maximum dry matter production of 12.63 mg followed by F_1 (12.30 mg) and the minimum by F_3 (12.21 mg) and F_0 (12.24 mg).

Table 114. Stages of harvest and spraying of nutrients on dry matter production (mg seedling⁻¹) and electrical conductivity (dSm⁻¹) of resultant seeds

Stages of Harvest	Dry matter production (mg seedling ⁻¹)					Electrical conductivity(dSm ⁻¹)				
	F0	F1	F2	F3	Mean	F0	F1	F2	F3	Mean
H1	12.34	12.50	12.65	12.41	12.48	53.60	49.20	48.40	50.80	50.50
H2	12.40	12.54	12.70	12.35	12.50	50.20	48.50	47.80	50.60	49.30
H3	12.32	12.50	12.73	12.28	12.46	51.60	49.70	49.20	57.30	50.40
H4	12.21	12.37	12.65	12.11	12.34	52.40	50.20	49.80	52.80	57.30
H5	11.93	11.58	12.41	11.90	11.96	54.60	57.60	57.00	56.20	53.40
Mean	12.24	12.30	12.63	12.21		52.50	49.90	49.20	52.30	

	H	F	HxF	H	F	HxF
CD(P=0.05)	0.14	0.13	NS	0.90	0.80	NS

Electrical conductivity

Electrical conductivity values of the seed leachates differed significantly due to stages of harvest and foliar spray treatments and their interactions were not significant (Table 114). Electrical conductivity of the leachates increased gradually with increase in the stage of harvest. Among the stages of harvest H_2 recorded the lowest value of 49.3 dSm^{-1} and the highest was recorded in the leachate of H_5 (53.4 dSm^{-1}) irrespective foliar spray treatments. Among the foliar spray treatments the electrical conductivity ranged between 49.2 (F_2) and 52.5 dSm^{-1} (F_0) irrespective of stages of harvest.

Sugar content

The sugar content of the seed leachates differed significantly due to the stages of harvest and foliar spray treatments, while, their interactions were not significant (Table 115).

There was a steady increase of the sugar content in the seed leachate from 3.46 (H_2) to $4.01 \text{ } \mu\text{g}$ (H_5) as the stage of harvest increased. The mean sugar content in the foliar spray treatments ranged between 3.47 (F_1) and $3.83 \text{ } \mu\text{g}$ (F_3) irrespective of the stages of harvest.

Table 115. Stages of harvest and spraying of nutrients on sugar content (μg) and aminoacids (μg) of resultant seeds

Stages of Harvest	Sugar content (μg)					Aminoacids (μg)				
	F0	F1	F2	F3	Mean	F0	F1	F2	F3	Mean
H1	3.65	3.40	3.32	3.60	3.49	1.96	1.84	1.80	2.00	1.90
H2	3.55	3.30	3.35	3.62	3.46	2.00	1.90	1.92	1.94	1.94
H3	3.71	3.38	3.42	3.75	3.57	2.02	1.90	1.98	2.10	2.00
H4	3.90	3.50	3.66	3.94	3.75	2.88	2.26	2.30	2.56	2.50
H5	4.14	3.78	3.90	4.22	4.01	3.55	2.90	2.85	3.25	3.10
Mean	3.79	3.47	3.53	3.83		2.50	2.20	2.20	2.40	

	H	F	HxF	H	F	HxF
CD(P=0.05)	0.09	0.08	NS	0.24	0.16	NS

Aminoacids

The amino acid content of the seed leachates varied significantly due to the stages of harvest and foliar spray treatments, while, their interactions were not significant (Table 115).

With the delay in harvest the free aminoacids in the seed leachates increased gradually from 1.90 (H₁) to 3.1 µg (H₅). The quantity of aminoacids in the foliar sprays ranged between 2.2 µg (F₁ and F₂) and 2.5 µg (F₀). Among the foliar spray treatments the seed leachates of F₁ and F₂ recorded the minimum values of 2.2 and 2.2 µg.

Protein content

The protein content of the seeds varied significantly due to stages of harvest and foliar spray treatments while, their interactions were not significant (Table 116). As the stage of harvest increased beyond H₂, the seed protein content decreased gradually and reached the minimum at H₅. Among the stages of harvest H₂ and H₅ recorded maximum (9.54%) and minimum (9.22 %) values. The mean protein content irrespective of stages of harvest was highest in F₂ (9.54%) followed by F₁ (9.50%), while the lowest was recorded by F₃ (9.28%) and F₀ (9.29%), respectively.

Table 116. Stages of harvest and spraying of nutrients on protein content (%) and alpha amylase activity (nm) of resultant seeds

Stages of Harvest	Protein (%)				Alpha amylase (nm)					
	F0	F1	F2	F3	Mean	F0	F1	F2	F3	Mean
H1	9.35	9.48	9.50	9.27	9.40	11.60	11.90	12.10	11.77	11.84
H2	9.49	9.61	9.65	9.40	9.54	11.80	12.23	12.40	11.90	12.08
H3	9.30	9.58	9.60	9.42	9.48	11.90	12.30	12.30	11.80	12.07
H4	9.20	9.50	9.62	9.14	9.37	11.53	12.10	12.20	11.10	11.73
H5	9.12	9.31	9.30	9.16	9.22	11.20	11.97	11.90	11.10	11.54
Mean	9.29	9.50	9.54	9.28		11.61	12.10	12.18	11.53	

	H	F	HxF	H	F	HxF
CD(P=0.05)	0.07	0.07	NS	0.27	0.24	0.55

Alpha amylase activity

The alpha amylase activity of the seeds differed significantly due to stages of harvest, foliar spray treatments and their interactions (Table 116). Among the stages of harvest higher alpha amylase activity was observed in H₂ (12.08 mm) followed by H₃ (12.07 mm) and H₁ (11.84 mm) while, the lowest activity was observed in H₅ (11.54 mm) irrespective of foliar spray treatments. The mean alpha amylase activity among the foliar spray treatments ranged between 12.18 mm and 11.53 mm (F₃) irrespective of the stages of harvest.

Fungal infection

The fungal load differed significantly due to stages of harvest, foliar sprays treatments and their interactions (Table 117). The fungal load on seeds increased with increase in the stage of harvest. Among the foliar spray treatments, the seeds from F₁ recorded the lowest fungal infection (1.60%) than the seeds from other treatments. In the interaction of harvesting stages x foliar spray treatments, higher percentage of fungal activity was found in the seeds harvested at H₅ in F₀ (5.8%) and F₃ (4.9%) and H₄ in F₀ (3.2%).

Table 117. Stages of harvest and spraying of nutrients on fungal infection (%) of resultant seed

Stages of Harvest	Fungal infection (%)			
	F0	F1	F2	F3
				Mean
H1	1.60	1.00	1.40	0.67
H2	1.90	0.80	1.40	1.20
H3	2.10	1.50	1.50	2.00
H4	3.20	1.80	1.80	2.60
H5	5.80	2.90	3.10	4.90
Mean	2.91	1.60	1.84	2.27

	H	F	HxF
CD(P=0.05)	0.29	0.26	0.58

4.7. BIOASSAY OF SEED VIGOUR

Natural ageing on seed quality of rice (stock material)

Germination

The mean germination percentage differed significantly due to varieties and vigour levels (Table 118, Fig. 21).

Between the varieties, V_2 recorded higher germination (84.0%) than V_1 (82.0%). Among the vigour categories the high vigour seeds recorded 94.7 per cent germination compared to medium vigour (81.0%) and low vigour seeds (73.3%).

Root length

The root length of seedlings differed significantly due to varieties and vigour status (Table 118).

In general root length decreased with decrease in the vigour status of the seeds irrespective of varieties. Between the varieties, V_2 recorded lengthier roots (38.7 mm) than V_1 (31.8 mm).

Among the vigour status, the root length was higher in high vigour seeds (48.0 mm) followed by medium (34.6 mm) and low vigour (23.0 mm) seeds.

Shoot length

The shoot length varied significantly due to vigour status. The varieties and interactions were not significant (Table 118).

In the vigour status, highest shoot length (17.9 mm) was recorded by high vigour seeds followed by medium (11.5 mm) and low vigour seeds (8.4 mm).

Root / Shoot ratio

The root / shoot ratio differed significantly due to varieties and vigour levels and their interactions were not significant (Table 118).

The variety V₂, recorded higher ratio of 5.7 than V₁ (2.8).

Among the vigour levels, the root / shoot ratio ranged between 3.1 (HV) and 2.7 (MV).

Vigour index

Vigour index values differed significantly due to varieties and vigour levels and their interactions were not

Fig.21 Germination of stock and bioassay materials in bioassay study

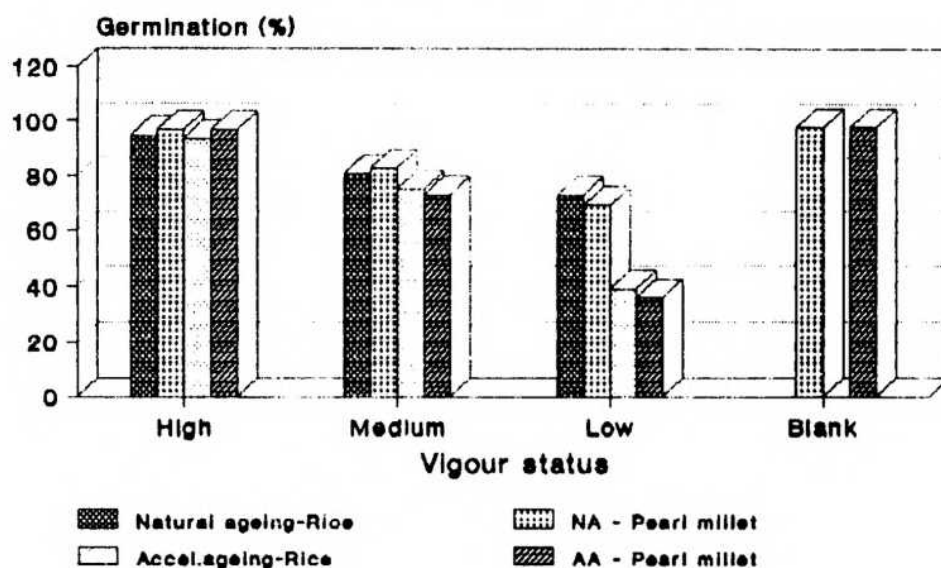
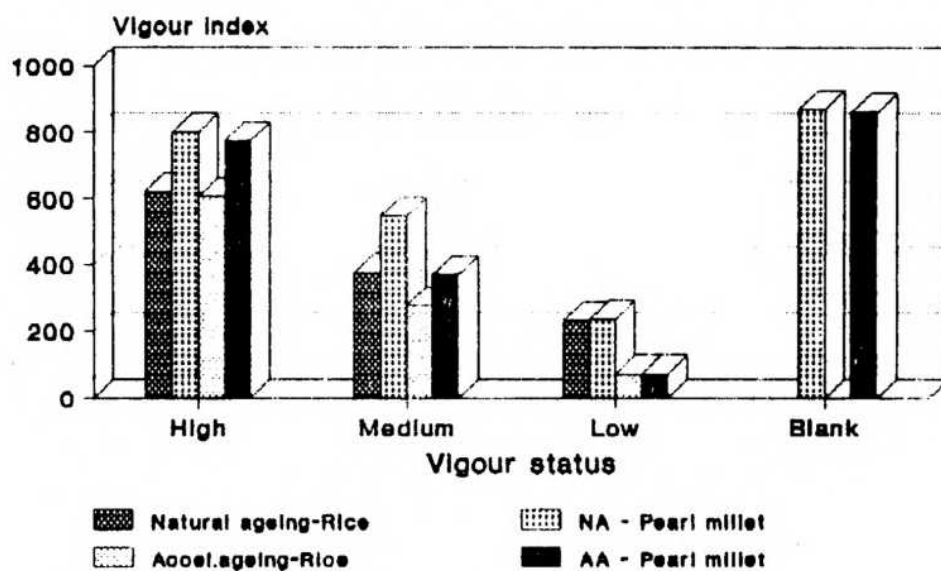


Fig.22 Vigour Index of stock and bioassay materials in bioassay study



significant (Table 118, Fig. 22).

Between the varieties V_2 recorded maximum vigour of 438 compared to V_1 (382).

Among the vigour levels, high vigour seeds recorded highest mean vigour index value of 626 followed by medium vigour (373) irrespective of varieties, while the lowest was by the low vigour seeds (230).

Germination, seedling growth and vigour of pearl millet seeds (Bioassay material)

Germination

The germination per cent of pearl millet seeds after exposure to gaseous emanations of germinating rice seeds differed significantly due to vigour levels. The varieties and their interactions were not significant (Table 119, Fig. 21).

The germination per cent of pearl millet seeds was higher (98) in the blank (desiccator without rice seeds) in which pearl millet seeds were not exposed to the gaseous emanations of rice seeds. A significant reduction in germination potential of pearl millet seeds (Bioassay material) from 97 per cent (HV) to 69 per cent (LV) was

observed when it was exposed to the volatile emanations of germinating rice seeds of different vigour levels.

Root length

The root length of pearl millet seeds differed significantly due to vigour levels. The varieties and their interactions were not significant (Table 119).

The gaseous atmosphere of low vigour seeds reduced the root length (25.7 mm) of pearl millet seeds compared to the root length (68.7) recorded under blank.

Shoot length

The shoot length of pearl millet seeds differed significantly due to vigour levels. The varieties and their interactions were not significant (Table 119). The growth of shoot due to gaseous emanations of rice seeds of different vigour levels exerted similar trend as that of root length.

Root / Shoot ratio

The root / shoot ratio did not differ significantly due to varieties, vigour levels and their interactions (Table 119).

Table 119. Germination, seedling growth and vigour index of pearl millet seeds (Bioassay material) exposed to gaseous emanations of germinating rice seeds (stock materials) of different vigour levels obtained by natural ageing.

Vigour levels of rice after natural ageing	Germination (%)			Mean Root length (mm)			Mean shoot length (mm)			Root/shoot ratio			Vigour index		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
High vigour (HV)	97	98	97	63.0	66.0	64.5	17	18	18	4.2	4.6	4.5	77	78	80
Medium vigour (MV)	82	84	83	54.3	53.3	54.3	13	11	12	3.7	3.7	3.7	55	53	54
Low vigour (LV)	68	70	69	24.3	27.0	25.7	8	9	7	3.0	3.0	3.0	21	25	23
Blank (B)	98	98	98	68.3	69.0	68.7	20	21	21	3.4	3.3	3.4	86	88	87
Mean	86	87		53.0	54.0		15	15		3.6	3.7		60	62	
C	V	CxV		C	V	CxV	C	V	CxV	C	V	CxV	C	V	CxV
NS	1.83	NS		NS	NS	2.66	NS	NS	NS	8.3	11.7	16.6	12.6	18.4	NS
CD(P=0.05)															

Vigour index

The vigour index differed significantly due to varieties, vigour levels and their interactions (Table 119, Fig. 22).

Between the varieties, the variety V_2 caused less damage to the vigour of pearl millet seeds (626) than V_1 (604).

Among the vigour levels, high vigour potential of pearl millet seeds was found in the blank. While a significant reduction in vigour index of pearl millet from 800 (HV) to 235 (LV) was observed in the seeds exposed to the volatile emanations of germinating rice seeds of different vigour levels.

In the interaction between varieties and vigour levels, highest vigour index value was recorded in V_2 at Blank and HV and V_1 at HV and the lowest vigour was in V_1 at LV.

Artificial ageing on seed quality of rice (stock material)

Germination

The germination potential of the rice seeds differed significantly due to vigour levels. The varieties and their interactions were not significant (Table 120, Fig. 21).

Among the vigour levels, high vigour seeds (Fresh seeds) recorded highest germination of 94 per cent followed by 75 per cent in medium vigour (aged for 6 days) while the least was in low vigour seeds (aged for 12 days) (39%).

Root length

The mean root length differed significantly due to varieties, vigour levels and their interactions (Table 120).

Between the varieties, V₂ recorded lengthier root of 32.3 mm compared to V₁ (26.2 mm). Among the vigour levels, the root length ranged between 44.3 mm (HV) and 16.0 mm (LV).

Shoot length

The mean shoot length of rice seedlings differed significantly due to vigour levels, however, the varieties and their interactions were not significant (Table 120).

Highest shoot length of 18.0 mm was recorded in high vigour fresh seeds and it decreased to 9.0 mm and 5.5 mm in medium and low vigour seeds due to accelerated ageing.

Root / Shoot ratio

The root / shoot ratio did not differ significantly due to varieties, vigour levels and their interactions (Table 120).

Vigour index

The vigour index varied significantly due to varieties, vigour levels and their interactions (Table 120, Fig. 22).

Between the varieties V_2 registered highest vigour of 334 compared to V_1 (300).

Among the vigour levels highest vigour value of 606 was recorded in high vigour fresh seeds and it was drastically reduced to 276 and 70 in medium and low vigour seeds due to accelerated ageing treatment.

Germination, seedling growth and vigour of pearl millet seeds (Bioassay material)

Germination

The germination per cent of pearl millet seeds differed significantly due to varieties and vigour levels of

rice and their interactions (Table 121, Fig. 21).

Maximum germination of 98 per cent seeds was recorded in the blank (desiccator without rice seeds) in which the pearl millet seeds were not exposed to the gaseous emanations of germinating rice seeds, followed by 97 per cent under exposure to high vigour fresh seeds of rice. While the lowest germination (36%) was recorded in the seeds exposed to the gaseous atmosphere of low vigour rice seeds.

Between the varieties the gaseous emanations of the variety V₂ had less inhibiting effect on germination of pearl millet seeds (77%) than V₁ (75%).

Root length

The root length of pearl millet seeds after exposure to gaseous emanations of germinating rice seeds were significant due to vigour levels. The varieties and their interactions were not significant (Table 121).

The pearl millet seeds germinated in blank recorded lengthier root of 62.5 mm, while the seeds exposed to gaseous emanations of germinating rice seeds recorded decreased root length. The decrease ranged from 57.1 mm (HV) to 11.5 mm (LV) irrespective of varieties.

Shoot length

The shoot length of pearl millet seeds after exposure to gaseous emanations of germinating rice seeds varied significantly due to vigour levels. The varieties and their interactions were not significant (Table 121).

The decrease in the shoot length followed the same trend as in the case of root length.

Root / Shoot ratio

The root / shoot ratio did not vary significantly due to varieties, vigour levels and their interactions (Table 121).

Vigour index

The mean vigour index values of pearl millet seeds differed significantly due to varieties and vigour levels of rice seeds (Table 121, Fig. 22).

Between the varieties, the pearl millet seeds exposed to variety V₂ recorded highest vigour value of 534 compared to V₁ (504).

Table 121. Germination, seedling growth and vigour index of pearl millet seeds (Bioassay material) exposed to the gaseous emanations of germinating rice seeds (stock materials) of different vigour levels obtained by accelerated ageing.

Vigour levels of rice after accelerated ageing	Germination (%)			Mean Root length (mm)			Mean shoot length (mm)			Root/shoot ratio			Vigour index		
	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean	V1	V2	Mean
High vigour (HV)	96	98	97	56.3	58.0	57.1	21.6	24.0	22.8	2.5	2.4	2.4	749	804	776
Medium vigour (MV)	72	75	73	36.0	35.0	35.5	13.0	16.0	14.5	2.8	2.2	2.5	353	383	368
Low vigour (LV)	35	38	36	11.0	12.0	11.5	7.0	8.0	7.5	1.6	1.5	1.5	53	77	71
Blank (B)	98	99	98	61.0	64.0	62.5	26.0	24.0	25.0	2.3	2.7	2.5	852	871	862
Mean	75	77		41.1	42.2		16.9	18.0		2.3	2.2		504	534	
	C	V	CxV	C	V	CxV	C	V	CxV	C	V	CxV	C	V	CxV
CD (P=0.05)	1.1	1.6	NS	NS	2.2	NS	NS	2.5	NS	NS	NS	NS	13.5	19.2	NS

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DISCUSSION

CHAPTER V

DISCUSSION

Influence of season and plant density on seed yield and quality

Selection of the right type of genotype, season, adequate population density, optimum fertilization and other crop management practices play an important role in maximizing production (Kanungo and Roul, 1994). In recent times production of quality seed as influenced by potential seed filling was considered as one of the major approaches for furthering yield potential among modern varieties (Padmajarao, 1990). The yield, yield attributes and quality of seed are influenced by multitudes of factors, such as date of sowing (Sahoo et al., 1983), season (Singh et al., 1993) age of planting (Joon and Singh, 1989), manuring (Vanangamudi, 1982), methods of seeding (Sharma et al., 1995), seed hardening treatments (Akram et al., 1993), climatic conditions during seed development and maturation (Selvaraj, 1990), edaphic factors (Munns, 1986), availability of nutrients to mother crop (Bennett et al., 1980) and place of production (Selvaraj, 1983). The pre and post harvest care, besides the storage environment, containers and seed dressers exert a positive effect on viability and vigour (Agarwal, 1980; Karivaratharaju et al., 1987). The supply of adequate nutrients and other seed crop

agronomic management practices also decide the storage potential of the resultant seeds (Vanangamudi et al., 1989).

The season of planting / sowing and varying levels of population greatly influence the days to flowering, productive tillers plant⁻¹, panicle length and weight, 1000 seed weight and seed recovery percentage (Mohammed et al., 1987, Liou, 1987, Parida and Mitra, 1989 and Jerlin, 1990).

In the present study the season of planting and density levels greatly influenced the flowering behaviour of the genotypes IR 50 and ADT 38. Among the plant densities wider plant densities viz., 50 and 44 hills/m² delayed the initiation of flowering as compared to 100 hills/m² irrespective of season and varieties. The findings are in agreement with the results of Jerlin (1990) in rice. The early initiation of flowering in the closer spacing was due to utilization of high amount of photosynthates for plant growth as reported by Murata et al. (1976).

Genetical and environmental factors apart from plant density also influence days to maturity in rice. The optimum plant density and equidistribution of plants can change the micro-environment, days to maturity and yield potential of any variety. In line with the above findings in the present study both the varieties attained physiological maturity earlier in Kharif 1992 compared to

other seasons, while the density of planting did not alter days to maturity. Similar results were reported by Shahu et al. (1989) in rice.

Among the three seasons viz., Kharif 1992 and Rabi 1993, and Kharif 1994, the yield attributes and seed yield was higher in crop raised in Kharif 1992 irrespective of varieties and plant densities. However, the resultant seeds from the crop of Kharif 1994 had maximum seed quality attributes compared to Kharif 1992 and Rabi 1993.

Number of tillers plant⁻¹, productive tillers, length and weight of panicle, number of good seeds panicle⁻¹ increased with decrease in plant population irrespective of varieties and seasons. Among the seasons the crop raised in Kharif 1992 recorded higher tillers and productive tillers plant⁻¹ under wider densities of 50 and 44 hills/m². With in the densities, 50 and 44 hills/m² induced lengthier panicle, higher panicle weight and number of seeds panicle⁻¹. The results are in conformity with the findings of Srinivasalureddy (1979), Carberry et al. (1985), and Manonmani (1990) in rice. The increased number of tillers under wider densities noticed in Kharif 1992 increased the uptake of nutrients with minimum competition and conduciveness of the climate prevailed in Kharif; while the lengthier panicle, increased panicle weight and higher number of good seeds panicle⁻¹ under wider densities

contributing to production of higher number of productive tillers facilitated by wider spacing combined with higher uptake of nutrients.

Rice is a temperature loving crop and the bright sunshine during the entire flowering phase favours dehiscence of pollen and seed set, seed development and maturation. This was met during Kharif season when the respective short and medium duration IR 50 and ADT 38 seed crops have registered maximum augmentation of yield and quality of seed.

In the present study, among the seasons the crop raised in Kharif 1992 recorded higher seed yield as compared to other seasons irrespective of varieties. Similar results were reported by Jerlin (1990) and Manonmani (1990) in rice. Among the spacings, wider spacings of 20 x 10 and 15 x 15 cm recorded 5 per cent higher seed yield, than to the spacing of 10 x 10 cm irrespective of seasons and varieties. The findings are in agreement with the results of Sahu and Lanka (1955), Flower and Ray (1977) and Manonmani (1990). The increased yield under wider spacings was due to the increment in photosynthetic efficiency and utilization of photosynthates for better crop growth and tillering. Between the varieties ADT 38 recorded higher seed yield as compared to IR 50 irrespective of spacings and season of sowing. This might be due to genetic make up and inherent vigour potential of the variety.

The crop raised during Kharif 1992 recorded higher seed yield under the spacings of 20 x 10 and 15 x 15 cm irrespective of varieties. Such an increased yield in rice due to seasons and spacings has been reported by Manonmani (1990). Better uptake of nutrients, utilization of photosynthates and conducive climate prevailed in Kharif could produce better yield under wider spacings.

The resultant seeds from the crop raised in Kharif adopting the spacings of 20 x 10 and 15 x 15 cm recorded higher seed recovery and 1000 seed weight. The results are in conformity with the findings of Jerlin (1990) and Manonmani (1990) in rice. This was due to better absorption and conduction of minerals and nutrients by the extensive root system facilitated by wider spacings and conducive climate.

Flower and Ray (1977) found that the flowering-to-vegetative ratio was significantly lower at high population levels, indicating that a greater proportion of assimilates were directed towards the vegetative growth than lower plant densities. The seed quality estimations viz., speed of germination, germination per cent, root and shoot length, dry matter and vigour index are the visible indicators of seed vigour and quality. The present study revealed the better quality of the seeds produced in Kharif 1994 season under wider spacings. This was demonstrated earlier in the

seed crop of rice by Manonmani (1990) and in pearl millet by Vanangamudi and Ramaswamy (1984). The increased quality of the seeds observed in the present study might be due to the soundness of the seed aided by proper growth and development of plants under wider spacing (20 x 10 cm and 15 x 15 cm) during Kharif season.

Seed vigour is a physiological quality which is defined as the sum total of all the properties of seed, which upon planting, results in rapid and uniform production of healthy seedlings under a wide range of environment of both favourable and stress conditions (Woodstock, 1973). In the present study, 20 x 10 and 15 x 15 cm spacings showed supremacy over 10 x 10 cm in exhibiting good vigour and beyond doubt it has been found to confer maximum vigour of seeds besides enhancing yield. In general, climatic conditions during Kharif were found to be more favourable for enhancing seed vigour than during rabi in both short and medium duration rice varieties.

Biochemical measurements that have been tested for correlations with germinability and / or vigour are changes in seed constituents, the nature and level of enzymatic activity and metabolic processes during the early hours of germination. Each has been used with various success in many crops (Ramegowda, 1992).

In the present study the biochemical estimations viz., EC, sugars, aminoacids, protein and alpha amylase activity of the resultant seeds from various seasons and spacings revealed the superior quality of the seeds produced in Kharif 1994 under wider spacings of 20 x 10 and 15 x 15 cm. This was confirmed through the estimation of fungal infection percentage. The seeds produced in Kharif season under 20 x 10 and 15 x 15 cm spacings recorded less infection percentage as compared to other seasons and spacings.

Storage life of seed starts even before harvest in the standing crop. Quality of seed in terms of storage potential is influenced by preharvest factors viz., cultural and edaphic factors (Roberts, 1972), storage conditions (Harrington and Douglas, 1970) and incidence of storage insects and fungi (Sinha et al., 1979). Seed lots of the same kind, cultivar, chronological age and even germinability do not store equally well under identical conditions (Justice and Bass, 1978).

In the present study the resultant seeds of the varieties IR 50 and ADT 38 produced in Kharif 1992 and Rabi 1993 seasons under different spacings were stored under ambient conditions.

Irrespective of seasons and spacings the speed of germination, germination potential of the seeds declined with increase in the period of storage. Between the varieties the decline in speed of germination and germination was slower in IR 50 over periods of storage as compared to the seeds of ADT 38 irrespective of seasons and plant densities. In the seasons the seeds produced in Kharif 1992 retained higher germination potential over periods of storage irrespective of varieties and plant density. Between the plant densities, the resultant seeds from lower densities of 50 hills/m² and 44 hills/m² showed slower rate of decline in germination potential irrespective of seasons and varieties. The seeds produced in Kharif 1992 with lesser plant densities retained higher germination potential over a period of 15 months of storage irrespective of varieties. The findings are in agreement with the findings of Jerlin (1990) and Manonmani (1990) in rice and Vanangamudi et al. (1990) in finger millet and Bharathi (1991) in maize. The general decline in germination potential of the stored seeds over periods of storage might be due to natural ageing and increase in membrane leakage as reported by Abdul-Baki and Andersonⁿ (1970). The varietal difference noticed in the decline of germination was due to soundness of the seed and the genetical make up of the variety. The differential retention of germination potential of the seeds produced in different seasons might be due to the effect of climatic conditions on the seed

development and maturation period. The retention of higher germination potential of the seeds produced under lower population densities over periods of storage was due to initial vigour potential of the seed produced under the lesser mother plant competition.

In general in the present study, the maximum accumulation of nutrients in the seeds produced under conducive climate combined with lesser competition for nutrients might be the reason for retention of higher speed of germination, germination potential of the seeds produced under Kharif in lower population densities.

Seed vigour is also an important parameter in assessing seed quality (Woodstock, 1973). The assessment of seed vigour by measuring root length, vigour index and dry matter production showed over all loss in the stored seeds of rice. Deterioration in seed quality associated with decrease in root length, vigour index and dry matter production became evident with the passage of time in storage and it had been confirmed by earlier workers (Jerlin 1990 and Manonmani 1990 in rice and Bharathi 1991 in maize).

In the present research vigour parameters viz., root length, vigour index and dry matter decreased with increase in the storage period irrespective of the treatments and their interactions. The vigour was maximum in the initial

period of storage, while it was minimum at the 15th month of storage.

Increased reduction of root length, vigour index and dry matter associated with heavy fungal load were noticed in the seeds harvested from the plants from Rabi 1993 as compared to crop grown in Kharif 1992 at higher plant densities. The seeds from higher plant densities were low in viability and vigour because of the competitions, the seeds are developed and matured under stress for food, water, light etc. and hence easily infected by pathogen. In the present investigation, it was noticed that the pathogen infection increased gradually with advancement in the storage period. This is in agreement with the findings of Neergaard (1977) and Jerlin (1990) in rice.

The electrical conductivity, sugar content and aminoacids increased with increase in the storage period. This is in conformity with the results of Krishnaveni (1984) and Bharathi (1991) in maize. Electrical conductivity of seed leachate is a good index of seed deterioration (Hibbard and Miller, 1928). The relatively high electrical conductivity of the leachate of the seed in the present study could also be ascribed to the leaching of sugars and aminoacids in greater amount owing to their internal concentrations than entirely due to loss of membrane integrity (Paul and Ramaswamy, 1979 and Mullat, 1979).

Increased leaching of sugar due to deterioration irrespective of treatments is in conformity with the results of Ramegowda (1992) in rice, and Bharathi (1991) in maize. Increased amount of sugars in the leachate might be due to loss of membrane integrity. The loss of membrane integrity is due to oxidation of polar lipids produced pores in the membrane and the increasing permeability (Koostra and Harrington, 1969; Villiers, 1973).

The present investigation in rice seeds revealed the decreased protein content and alpha amylase activity due to seed deterioration irrespective of varieties, seasons, plant densities and their interactions over a periods of storage.

Investigations on the protein levels in deteriorated seeds clearly demonstrated a decrease with increase in storage period (Anderson, 1973; Roberts, 1979).

In the present study the reduction in protein was less in the seeds obtained from lower plant density levels in the crop raised in Kharif 1992 season in both the varieties. Higher reduction of protein content could be related to the increased activity of proteolytic enzymes leading to degradation of protein into aminoacids (Beevers, 1968).

Decreasing activity of alpha amylase activity with decline in seed vigour in rice seeds reported by Ghose et

al. (1981) and Ramegowda (1992) are in conformity with the present findings. They suggested that the complete loss of enzyme activity prevented the germination. The same trend was reported by Thornberry and Smith (1955) in soyabean and barley.

The reduction in alpha amylase activity was higher in the seeds obtained from Rabi 1993 compared to Kharif 1992 in both the varieties under higher population densities. This could be possibly related to the decline in seed vigour.

The seeds of cv. IR 50 harvested from Kharif 1992 under lower population densities (44 and 50 hills per m²) and the seeds of cv. ADT 38 under the same population densities stored in cloth bags recorded higher germination, vigour and lower infection of storage fungi.

Accelerated ageing on seed quality

Accelerated ageing is caused by exposing seeds to an unfavourable hot and moist atmosphere and it is the activation of ageing process in a shorter period (Heydecker, 1972). It is recommended as a potential tool for predicting the storability of seeds (Delouche and Baskin, 1973) and seed lots with low survival after ageing are considered to be poor storer. Moreover, this test helps to study the ageing process in a shorter period (Heydecker, 1973).

Ray and Gupta (1979) in rice, Filipenko (1983) in barley and wheat, Purkar et al. (1981) and Chauhan, (1985) in wheat, minor millets and soyabean had employed this test for predicting the storability of seed lots.

In the present investigation, storage potential of seeds of cv. IR 50 and ADT 38 obtained from Kharif 1994 season raised with different plant densities was measured through the yardstick of accelerated ageing. The results revealed that the aged seeds from lower population densities irrespective of varieties and seasons maintained higher level of speed of germination and germination potential, whereas the seeds from higher plant densities showed drastic reduction after ageing. Such reduction in speed of germination potential of the seeds was reported by Ramegowda (1992) in rice. The decline in germination consequent to accelerated ageing might be due to proportional to initial physiological potential of the seeds (Delouche and Baskin, 1973).

The present study with accelerated aged seeds evidently implicate a drastic decline in seed vigour irrespective of varieties and plant density levels. This has been exemplified by the decline in root length, vigour index, and dry matter production after accelerated ageing.

The aged seeds from lower plant densities irrespective of varieties maintained higher values for the vigour parameters studied than the seeds from higher plant densities. Similar results were reported by several workers in rice (Sekar, 1980, Mazzini et al., 1981, Haque and Haroon, 1983, Sikder, 1988, Murugesan et al., 1989, Juliano et al., 1990, Ramegowda, 1992).

Several ageing experiments on rice seeds with different cultivars from different production conditions revealed that the reduction in seed quality and seedling vigour was certain. However, the rate and the extent of reduction varied with the cultivar and other factors like seed moisture and status of the seed at the time of ageing (Agrawal, 1980, Ghosh et al., 1981; Tomar and Singh, 1986; Krishnasamy and Seshu, 1990).

The loss of membrane integrity with ageing showed greater leakage of metabolites and this leakage closely associated with the loss of viability and vigour. The higher values of EC, sugars and aminoacids in the present study confirms the results of Simon (1974). The increased values recorded for EC, sugars and aminoacids might be due to loss of membrane permeability and movement of ions from the seed to the imbibing medium.

The present study also evidently implicate, a tremendous increase in electrical conductivity, sugar content and aminoacids with accelerated ageing. The variety ADT 38, which had lower initial speed of germination, germination potential and vigour than IR 50, recorded higher EC and aminoacids irrespective of plant densities indicating the susceptibility to membrane damage upon ageing. Similar findings were reported by Ghosh et al. (1981), Younis et al. (1990) and Ramegowda (1992) in rice, Perl et al (1978) in sorghum, Mukhtar and Laidman (1982) in wheat, Powell and Mathews (1977) in Peas and Saxena et al. (1985) in sesamum.

Several investigations revealed the association of seed vigour with that of protein synthesis (Ching, 1972; Roberts et al., 1973); Abdul-Baki and Chandra, 1977; Blowers et al., 1980; Ghosh and Chandhuri, 1984).

Protein content of the aged seeds decreased irrespective of varieties. The decrease in protein content was rapid in the resultant seeds of higher plant densities compared to lower plant densities. This is in agreement with the findings of Ray and Gupta (1980) and Ramegowda (1992) in rice and Nagarajan and Karivaratharaju (1983) in sorghum and Basavarajappa et al. (1991) in corn.

The enzymes are important for energy production and protein synthesis during germination. Alpha amylase

activity recorded in the present study in the aged seeds were found to decrease with ageing irrespective of varieties and plant densities. The results are in agreement with the findings of Ramegowda (1992) in rice.

The studies in the relationship between the germination and vigour clearly demonstrated the possibility of employing both physiological and biochemical tests as a reliable methods for studying the seed deterioration and seed vigour in rice.

Effect of seedling age and nitrogen levels on yield and seed quality

As rice is highly sensitive to diverse seedling age at transplanting plays a crucial role in realising the potential yield and behaves differently on the basis of the duration of the variety and applied nutrients. The ideal age of seedling for transplanting is governed by the duration of variety and field condition (Murthy and Sahu, 1979). Time of planting and age of seedling are two cultural practices which exercise considerable influence on the growth, yield and seed quality of transplanted rice (Joon and Singh, 1989).

In the present study, the crop raised with aged seedlings delayed the initiation of flowering compared to

the planting of the normal aged seedlings. The results are in agreement with the findings of Reddy and Reddy (1992) in rice. The delayed flower initiation due to planting of aged seedlings might be due to late recovery of the seedlings after planting.

The total number of tillers panicle⁻¹ did not differ significantly due to planting of seedlings of different age groups, however the production of productive tillers varied due to seedling age groups. Similar observations were made by Ghosh (1982), Ashraf and Mahmood, (1989) and Mannan and Siddique (1990) in rice. The production of less number of productive tillers by the aged seedlings resulted in restricted growth caused by the manifestation of anatomical changes like reduced cell division and elongation and reduced absorption of nutrients as reported by Wolswinkel (1992).

In the present investigation, the tiller number increased significantly with increased levels of nitrogen irrespective of age of the seedling. The application of 50 kg N ha⁻¹ over and above the recommended dose induced higher tillers irrespective of age groups.

Similar results were reported by Singh and Sharma (1993) in rice; Vanangamudi and Ramaswamy (1984); Bhaskaran et al. (1990) in pearl millet. The production of higher

number of tiller plant⁻¹ in the increased level of nitrogen might be due to promotion of synthetic activity of enzymes and hormones as reported by Osada and Murata (1962) and Osada (1964 and 1966).

The yield attributing characters viz., length and weight of panicle and number of good seeds panicle⁻¹ increased with increased levels of nitrogen irrespective of age groups while, 30 and 40 days old seedlings responded well for the increased dose of nitrogen. Varieties also differed in their response to doses of nitrogen irrespective of age groups. The variety ADT 38 responded better than IR 50. Similar findings were reported by Singh and Sharma (1984 and 1993), Singh (1987), Ganesh and Soundrapandian (1988), Mohapatra et al. (1990) and Kulkarni and Eswari (1994) in rice. The positive response of the age groups of the seedlings to increased dose of nitrogen might be due to the high source sink accumulation of synthates (Mohapatra, et al. 1990). The poor response of the aged seedling might be due to poor photosynthetic efficiency, high spikelet sterility and less accumulation of assimilates (Mandal et al. 1984) in rice. The differential response of the varieties for the increased dose of nitrogen might be due to differential genetical make up (Kulkarni and Eswari, 1994).

Planting of aged seedlings prolongs the days to attainment of physiological maturity (Reddy and Reddy,

1992). The present investigation confirms the above findings. Here also the planting of aged seedlings delayed the attainment of physiological maturity of the seed irrespective of varieties. The late attainment of physiological maturity of the seed of the crop raised through aged seedlings might be due to late planting recovery and poor utilization of available nutrients from the soil (Bassi et al. 1994).

Among the nitrogen levels, the increased levels induced early physiological maturity irrespective of varieties and age groups. Reddy and Narayana (1984) and Reddy and Reddy (1992) reported similar findings in rice. The early release of planting shock, establishment and better growth due to increased availability of nitrogen favouring early panicle emergence and maturity of the seeds might be reason for the early attainment of physiological maturity of the crop under increased dose of nitrogen (Singh and Sharma, 1993).

In the present study the higher level of nitrogen (50 kg ha^{-1}) combined with the planting of 30 and 40 days old seedlings enhanced the seed yield compared to other nitrogen levels and age of the seedlings irrespective of varieties. The results are in conformity with the findings of Bassi et al. (1994) and Kulkarni and Eswari (1994) in rice and Vanangamudi et al. (1989) in pearl millet. The

increased seed yield was due to the early recovery of seedlings in the main field under the influence of higher dose of nitrogen and higher photosynthetic efficiency of the plants during the grand growth period of due to higher absorption of nutrients, less spikelet sterility, increased number of productive tillers and 1000 seed weight.

The resultant seeds from the crop raised with 30 and 40 days old seedlings and higher dose of nitrogen recorded higher seed recovery and seed weight. The results are in agreement with the findings of Joon and Singh (1989) in rice. Proper establishment of seedlings and timely absorption and utilization of the available nutrients and utilizations towards proper growth of the plants and proper development of seeds increased quality and weight of the seeds observed in the present study.

The resultant seeds from the crop raised through 20, 30 and 40 days old seedlings with higher dose of nitrogen recorded higher germination, root length, dry matter, vigour index, protein and alpha amylase activity compared to other age groups and nitrogen levels irrespective of varieties. The results are in conformity with the findings of Mohapatra et al. (1990) in rice, Aswathiah (1977) in pearl millet and Bharathi (1991) in maize. The increased protein accumulation in the seeds produced under higher nitrogen levels contributed for the increment in the quality of the seed

observed in this present study under higher levels of nitrogen as reported by Ries and Everson (1973).

The decreased value of EC, sugars and aminoacids and fungal infection per cent of the resultant seeds from the above age groups of seedlings and nitrogen levels confirms the above findings.

Accelerated ageing on resultant seed quality

The resultant seeds of the crop raised from different age groups of seedlings and nitrogen levels were subjected to accelerated ageing to predict the storability. The speed of germination and germination potential declined steadily due to increase in the period of ageing of seeds. The reduction in speed of germination and germination potential after 12 days of ageing was lesser in the resultant seeds of crops raised with younger seedlings than aged ones. Similar reduced performance of the aged seeds was observed by Ram and Weisner (1988); Singh et al. (1988) and Younis et al. (1990). The rapid loss of speed of germination and germination potential might be a reflection of their low initial seed vigour.

Seedling growth is often used as an index of seed vigour (Gelmond et al., 1978). Consequent to accelerated ageing seedling growth declined in both the varieties as

indicated by reduction in root length, vigour index and dry matter production, irrespective of nitrogen levels and age groups. However, the more pronounced effect due to ageing was observed with the seeds of the variety ADT 38 than IR 50. Younis et al. (1990) have reported similar findings in rice. The resultant seeds of the crop raised with younger seedlings combined with higher dose of nitrogen recorded higher seedling growth after ageing. The reduction in physiological manifestation of vigour during ageing could be attributed to irreversible deteriorative changes occurring in seeds.

The leachates of the aged seeds of the resultant seeds from the crop raised through 30 and 40 days old seedlings with higher dose of nitrogen recorded lesser EC, sugar and aminoacids and higher values of protein and alpha amylase activity irrespective of varieties. The results are in agreement with the findings of Younis et al. (1990) in rice, Gelmond et al. (1978) in sorghum and Basavarajappa et al. (1991), Bruggink et al. (1991) and Lugo and Leopold (1992) in maize. The probable reason for the decreased EC, sugars and aminoacids might be due to the differential weakening of the membrane due to concomitant increase in the age of the seeds as reported by Anderson (1973) and Roberts (1979).

Effect of pre-sowing hardening on seed yield and quality of direct seeded rice

Transplanting is one of the more productive and surest method adopted for obtaining good yield in rice (*Oryza sativa* L.). However, direct seeding is more economical than transplanting if managed properly. In direct seeded rice a poor stand usually results due to low seed rate, poor germination or early flooding (Sharma et al., 1995). Direct seeding shortens the cropping cycle due to the absence of transplanting shock (Dingkuhn et al., 1990 and Schnier et al., 1990). Seed hardening and high seed rate help to maintain uniform stand under direct seeding (Akram et al., 1993).

In the present study, rice seeds of the varieties IR 50 and ADT 38 hardened with water, potassium chloride and potassium dihydrogen phosphate, induced early and increased germination over untreated control. Both the varieties responded well for potassium chloride and potassium dihydrogen phosphate and recorded higher values for early emergence and field emergence under direct seeding. Similar findings were reported by Kundu and Basu (1981), Saraswathi (1987) Singh and Chatterjee (1990) and Geetha (1992) in rice, Dollypan and Basu (1985) in soybean and Doijode and Raturi (1987) in vegetables. The probable reason for the improvement of germination and field emergence might be due

to activation of metabolic processes (Mitra and Basu, 1979), enzyme reactions, increased cell division, metabolization of food reserves and repair and replacement of cell membrane (Anderson, 1946, Zubenko, 1959, Sen and Osborne, 1974 and Savino et al., 1979).

The hardened seeds under direct sowing induced early flowering irrespective of varieties. The results are in conformity with the finding of Akram et al. (1993) in rice and Rosell et al. (1988) in tomato. The possible reasons for the early flowering could be due to induction of early emergence and physiological activation of growth by the hardening treatments.

The combination of direct seeding and seed hardening registered higher number of tillers, productive tillers, length and weight of panicle, higher number of good seeds panicle⁻¹, 1000 seed weight and seed yield. The results are in conformity with the findings of Dingkuhn et al. (1991), Narayanasamy et al. (1991) and Prasad et al. (1994) in rice. The probable reason for the improvement of yield attributing characters in the direct seeded rice might be due to elimination of transplanting shock (Schnier et al., 1990) combined with activation of seed and seedling vigour by the hardening treatments and chemicals used for hardening.

In the present investigation, varieties differed in their response to direct seeding and hardening treatments in inducing the production of higher tillers and yield. The genetic make up and response of the varieties for the hardening treatments might have induced variability in the yield of varieties tried as observed by Yoshida (1981) and Schnier et al. (1990 a) in their studies on rice.

The reduction of days to maturity of the crop raised with the hardened seed under direct sowing in the present study conforms the findings of Dingkuhn et al. (1991) in rice. This was due to early emergence of the seeds facilitated by seed hardening treatments, rapid growth and absence of transplanting shock.

The occurrence of awns is the physiological extension of growth in the seed and is genetically controlled and modified by the environment and cultural practices. In the present study the occurrence of awns was more in treated seeds than control irrespective of varieties. The active and vigorous growth of the plants and uptake of more nutrients of the plants raised through hardened seeds might have induced more awns while, the stress induced restricted growth might be the reason for the production of less awns in control.

The beneficial effect of the hardened direct seeded rice through potassium chloride and potassium dihydrogen phosphate could be distinctly seen from the increase in seed yield. Similar results were reported by Shad and DeDatta (1986), Rajendran (1991) and Chau et al. (1994) in rice. The manifestation of seed yield and recovery of resultant seeds in both the varieties through the usage of hardened seeds under direct sowing could be attributed to better germination, higher tiller production, uniform stand and plant growth and seed weight.

Storage studies

Loss of vigour either quickly or slowly during storage depends on the initial physical or physiological quality of the seed. It is possible to minimise the initial degenerative process by enforcing suitable treatments to mother crop by which resultant seed quality can be improved.

The resultant seeds of the direct sown rice crop of the varieties IR 50 and ADT 38 raised through hardened seeds in the present study showed increased initial vigour over the seeds of the crop raised through untreated seeds. This trend was maintained over periods of storage. Similar results were reported by Yoshida, 1972, Narayanasamy et al. (1991) and Ramamoorthy et al. (1993) in rice.

Irrespective of varieties the resultant seeds from the hardening treatments exhibited superiority over untreated seeds in maintaining higher level of speed of germination and germination throughout the storage period of 15 months. Among the hardening treatments the resultant seeds from potassium chloride and potassium dihydrogen phosphate maintained higher values compared to water hardening and control over periods of storage. However, the seeds from all the hardening treatments maintained germination above certification standard (80%) over a period of 15 months, while the germination of the seeds from control declined below the standard after six months of storage irrespective of varieties. Similar maintenance of germination due to physio-chemical treatments was reported by Sekar (1980) and Geetha (1992) in rice. The increased physical stamina of the seeds from the treated plots by way of accumulation of higher nutrients during the development period, facilitated the initial vigour and growth of the plants raised through hardened seeds.

The differential germination potential of the seeds of the varieties over periods of storage irrespective of treatments was due to genetical make up of the seeds. The findings are in conformity with the finding of Sekar (1980) in rice. The effect of chemical treatments in maintaining vigour of the seeds under storage has been reported by many authors in rice (Sekar, 1980, Sur and Basu, 1986 and Pal and

Basu, 1988). In the present study also the resultant seeds of the crop raised with the seeds hardened with potassium dihydrogen phosphate and potassium chloride recorded lengthier root, higher dry matter and increased vigour as compared to the seeds from control over periods of storage irrespective of varieties. The maintenance of physical stamina of the seeds from treatments was the reason for the maintenance of higher vigour of the seeds under storage.

The membrane function of the seed as determined by the electrical conductivity of the seed, steep water and leaching of sugar content and aminoacids of the resultant seed were increased progressively with increase in the storage period irrespective of varieties and treatments. These parameters were negatively correlated with vigour and viability of the seed. The loss in membrane integrity was reported to be a clear indication of seed deterioration as observed in the present investigations with more concentration of electrolytes in seed leachate and it was in conformity with the findings of Mathews and Bradnock (1968), Koostra and Harrington (1969) and Abdul-Baki and Baker (1973).

The relatively low electrical conductivity, sugar content and aminoacids recorded by the seed leachate of resultant seeds from hardening treatments viz., potassium dihydrogen phosphate and potassium chloride and higher

values recorded with respect to protein content and alpha amylase activity over periods of storage, irrespective of varieties compared to the seeds from control were possibly due to physical stamina of the seed and its membrane integrity.

In the present study, the estimation of protein content and alpha amylase activity of the stored seeds revealed positive correlation with the viability of the seeds, while fungal infection percentage showed negative correlation.

The study clearly indicated the effectiveness of hardening treatments with potassium dihydrogen phosphate and potassium chloride in the maintenance of higher germination and vigour over periods of storage compared to the resultant seeds from control, irrespective of varieties. However, the observations indicated the differential behaviour of the varieties to the biochemical tests. This is in accordance with the findings of DeDatta (1979) in rice and this could be accounted for the differential seed compositions and genetical make up.

Influence of levels of gypsum in sodic soil on seed yield and quality.

Sodic soils are characterised by high exchangeable sodium in the soil profile, adverse soil physical properties and reduced availability of plant nutrients. Crops grown in these soils suffer from nutritional disorders and result in low crop yield. Application of gypsum was reported to reclaim the sodic soil (Swarup, 1985 a). Sodic soils are of low productivity as crop growth is adversely affected by the presence of high amounts of sodium salts. Intensive efforts were made to bring such salt affected soils under rice cultivation and to maximise production by using various amendments, preferably gypsum (Oster, 1992).

Rice is considered to be a salt sensitive crop (Flowers and Yeo, 1981). However, considerable variability for salinity resistance among rice varieties is also apparent (Yeo and Flowers, 1982).

Plant population has been the basic factor in determining the yield unit area^{-1} and its influence on crop yield has been stressed by Rudha and Younis (1978) and Kanade and Kalra (1986). Thus, among the management practices, maintenance of optimum population unit area^{-1} assumes paramount importance in increasing seed yield.

The application of different levels of gypsum significantly influenced the plant population per m² in the present investigation. Among the gypsum levels, application of 3600 kg ha⁻¹ maintained the maximum plant population compared to other levels and control. Similar, results were reported by Chhabra and Abrol (1977) in rice. The maintenance of plant population by the increased application of gypsum might be due to the removal of ill effects of sodicity and the improvement of soil fertility (Swarup, 1987). Between the varieties, ADT 38 responded well for the gypsum application and maintained higher plant population per m². It might be due to the inherent capacity / or resistance added to the response of the variety to the applied gypsum as compared to IR 50.

Application of gypsum reclaims the soil and improves the availability of essential plant nutrients (Aruna, 1994). In conformity to the above findings, in the present investigation the days to flowering was reduced. In general, as the dose of gypsum increased the days to flowering decreased. Among the different levels of gypsum, application of 3600 kg ha⁻¹ induced earlier flowering when compared to other levels and plants under control took more number of days for flower initiation. The early flowering noted in the plots applied with gypsum was due to the creation of conducive environment for the plant to absorb essential nutrients for its growth, while delayed flowering

in the plants was observed under control due to ill effects of sodicity.

Soil amendments significantly increased the seed yield of rice and gypsum treatment resulted in more yield and seed quality than other amendments like pyrite and pressmud (Rajkumar et al., 1991). The yield parameters viz., number of tillers, length and weight of panicle, number of good seeds panicle⁻¹, seed recovery and 1000 seed weight were progressively improved and increased with the increase in the dose of gypsum irrespective of varieties.

Both the varieties expressed maximum response for 3600 kg of gypsum ha⁻¹. However, ADT 38 responded well as compared to IR 50. The increased yield attributes was due to the removal of illeffects of sodicity, improvement of soil fertility and reduced pH, SAR and ESP due to application of gypsum. This situation created conducive atmosphere for the uptake of N, P, K and build up of organic carbon. Such an altered soil condition was favourable for rice to absorb more of essential nutrients and to grow better (Srinivasalu reddy, 1988). This availability of nutrients from the crop establishment stage itself, favoured the vigorous crop growth without any stress during the peak stages resulted in improved yield attributes as compared to control. Same trend of result was reported by Anandswarup (1992) and Aruna (1994) and Swarup and Singh (1994) in rice.

In the present investigation seed yield differed significantly due to the increased levels of gypsum application. Application of 3600 kg of gypsum ha⁻¹ registered maximum seed yield ha⁻¹ when compared to other levels and control. The results are in conformity with the findings of Swarup (1987), Rajkumar et al. (1991), Gupta and Soi (1992) and Aruna (1994) in rice. The increased yield under gypsum application was due to improvement of yield parameters like productive tillers, length and weight of panicle, number of good seeds panicle⁻¹, higher seed recovery and 1000 seed weight induced by salt free condition created by the application of gypsum.

Storage studies

Proper storage conditions would slow down the ageing process and enhance the longevity of seeds. The ageing process is greatly affected by the genotypes, initial seed quality, pretreatments and storage conditions like relative humidity and temperature, which in turn are dependent on the storage container (Crocker and Barton, 1957; Harrington, 1972). The approach of storing quality seed in the best storage environment has been widely used to preserve seed viability for longer periods.

With the increase in the storage period the speed of germination and germination percentage decreased in both the

varieties irrespective of gypsum treatments. Vanangamudi (1982) and Apparao et al. (1991) in Pearl millet and Mehta and Patel (1990) in sorghum reported similar observations. The decline in germinability of the seeds over periods of storage could be attributed to the irreversible deterioration in physical, physiological and biochemical changes occurring in the seeds (Gove, 1965), pre and post harvest conditions (Zode and Patil, 1990) and storage temperature and storage conditions.

Among the levels of gypsum the seeds obtained from the plots applied with 3600 kg ha⁻¹ maintained maximum speed of germination and germination potential over a period 15 months of storage irrespective of varieties. This was due to the initial physical stamina and vigour of seeds.

A general decline in the seed quality such as root length, vigour index and dry matter production was observed with the increase in the period of storage. Vanangamudi (1982) and Ravi (1985) in Pearl millet, Singh (1988) and Shelar and Bapat (1991) in sorghum observed similar decrease of the above characters. The decrease in the growth of the seedling could be ascribed to the deteriorative process occurring in the seeds due to ageing (Wood stock and Feeley, 1965), accumulation of toxic metabolites and damage of the mitotic apparatus of the embryonic axis (Dey and Sircar,

1968; Floris, 1978) and increased frequency of the root aberrations (Tomar and Singh, 1986).

Between the varieties, ADT 38 recorded lengthier root and higher dry matter production than IR 50 irrespective of levels of gypsum application over a period of 15 months of storage. The higher vigour could possibly be due to superior genetic make up (Odiemah, 1987) or duration of the crop (Apparao, et al., 1991).

The resultant seeds from increased levels of gypsum irrespective of varieties recorded increased vigour in terms of root length, vigour index and dry matter production. Same trend of results were reported by Aruna (1994) in rice. The possible reason might be due to the soundness of the seed compared to the seeds from other treatments and control.

The electrical conductivity, sugar content and aminoacids increased with the increase in storage period irrespective of varieties and treatments in this study. Similar results have been reported by Geetha (1992) in rice, Vanangamudi and Ramaswamy (1989) in Pearl Millet and Mehta and Patel (1990) in sorghum. The increase in the EC, sugars and aminoacids might be due to the auto oxidation of the polar lipids of the membrane (Koostra and Harrington, 1969; Bewley, 1986) or due to the degradation of proteins of protease enzyme (Zeleny, 1954) or membrane aberrations

(Berjak and Villiers, 1972) or increased leaching of free sugars and free aminoacids and electrolytes with other water soluble contents (Heydecker, 1972).

Between the varieties ADT 38 recorded lower EC and sugar content values than IR 50 over periods of storage irrespective of levels of gypsum. This is due to the genetical make up of the seed.

Among the levels of gypsum, the seeds obtained from the plots applied with 3600 kg ha⁻¹ irrespective of varieties, maintained the cell membrane integrity by slowing down the rate of deterioration over periods of storage than the other levels and control.

Higher level of protein content and alpha amylase activity are good signs of seed viability and vigour. However, this should be carried over to longer period to maintain shelflife of seed (Ramegowda, 1992).

In the present study the protein content and alpha amylase activity decreased with increase in the period of storage. This is in conformity with the findings of Anderson (1973) and Roberts (1979). The decrease in protein levels and alpha amylase activity of stored seeds can be explained on the basis of increased activity of proteolytic enzymes leading to the degradation of protein into

aminoacids (Beevers, 1968) or it may be due to increased level of fungal infection during the period of storage (Mallick and Nandi, 1979).

Throughout the storage period the seeds from the plots applied with 3600 kg of gypsum ha⁻¹ recorded the highest protein content and alpha amylase activity and lowest fungal infection per cent irrespective of varieties as compared to other treatments and control. This was due to the proper filling and sound health of the seeds produced under salt free conditions created by the application of higher levels of gypsum.

Influence of green manuring and gypsum in sodic soil on seed yield and quality and storability of rice cv. Co 43.

Swarup (1987) reported greater reclamation efficiency of farmyard manure and green manure and better crop growth and increased yield in sodic soils. Green leaf manures like *Acacia* leaves are more effective in reclaiming the sodic soils by lowering the ESP and increasing the exchangeable Ca⁺⁺ mg than *casuarina* leaves (Anandswarup, 1988). The green manure crop after incorporation in the saline soil, due to release of organic acids, brings about favourable changes in physio-chemical properties of alkali soils, which ultimately leads to increased yield and seed quality of rice (Yavinder Singh et al., 1992).

In the present study the plant population differed significantly due to soil amendments. Highest plant population was observed in the plots that received the conjoint application of *Sesbania aculeata* @ 10 t ha⁻¹ + gypsum @ 3.4 t ha⁻¹ as compared to other treatments and control. This is in conformity with the findings of Aruna (1994) in rice. This might be due to the effect of conjoint application of green manure + gypsum in the removal of the ill-effects of sodicity and subsequent improvement of soil fertility (Yadav and Agarwal, 1961 and Srinivasalureddy, 1988).

The application of soil amendments was reported to reduce the soil sodicity effect and enhance the crop growth and early flowering (Anandswarup, 1991 and Aruna, 1994). In conformity, in the present investigation early flowering initiation was noticed in the conjoint application of green manure (*Sesbania aculeata*) + gypsum when compared to other amendments and control. This might be due to the better early growth of the crop due to the nullifying effect of the amendments with that of the sodicity.

Green manure (*Sesbania aculeata*) + gypsum treatment followed by *Pongamia glabra* + gypsum and gypsum alone at 3.4 t ha⁻¹ recorded higher values for the yield components viz., number of productive tillers plant⁻¹, length and weight of panicle, number of good seeds panicle⁻¹, seed recovery and

1000 seed weight in the present investigation. Similar findings were reported by Krishnamoorthy (1978), Swarup (1987), Srinivasalureddy (1988), Palaniappan et al., (1992), and Aruna (1994) in rice.

The improvement of yield components in the conjoint application of green manure + gypsum was due to decreased pH, exchangeable sodium, and improvement of microbial activity, improvement in the organic carbon and available N, P, K status facilitated by the reaction of green manure and gypsum with that of the injurious salts present in the soil.

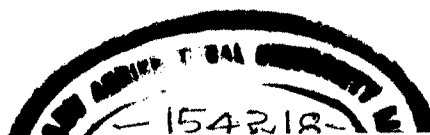
In the present study application of green manure + gypsum to sodic soil significantly reduced the days required to attain physiological maturity. This is in conformity with the findings of Aruna (1994) in rice. The creation of conducive soil conditions by the addition of organic matter and gypsum and subsequent uptake of available nutrients by the plant for proper growth and maturity contributed for the early attainment of physiological maturity.

The conjoint application of green manure (*Sesbania aculeata*) + gypsum recorded higher seed yield (3820 kg ha^{-1}) as compared to control (1480 kg ha^{-1}). The enhanced yield due to combined application of green manure + gypsum in sodic soil was reported by Bhardwaj (1982), Ghai et al. (1984), Singh (1984), and Aruna (1994).

Besides substituting the partial N requirement for the crop growth, the GM + gypsum application in sodic soil might have caused reduction in pH, ESP and redox potential and improvement in the physio-chemical condition of soil within two weeks of flooding (Ponnamperuma, 1972 and 1978; Swarup, 1981) thereby creating the most favourable environment for rice growth. This would have been instrumental for the significant increase in yield attributes and hence the yield.

Proper storage of seed is as important as production of good quality seed with improved production technologies. Seed undergoes considerable quantitative as well as qualitative changes (Singh and Choudhury, 1966 and Christensen and Kaufmann, 1969) during storage, which leads to loss of viability. The loss incurred by the stored seed is mainly attributed to period of storage (Arulnandhy and Senanayake, 1988), containers used (Bhattacharya et al., 1983), seed treatment (Basu, 1976 and Pal and Basu, 1988), chemical composition (Marnaville and clegg, 1977), season of production (Sakoo et al., 1983), weather conditions during maturation (Chopra, 1983), destructive role of fungi (Emayavaramban and Ramabadran, 1986) and genotypes (Shusilkumar and Singhal, 1991).

The germination potential of the resultant seeds from various amendments showed a progressive decline over periods



of storage irrespective of treatments. The influence of storage period on seed viability was reported by Gill (1977) and Naphade and Sagare (1983).

Among the treatments the resultant seeds from green manure + gypsum showed slow decline in viability over periods of storage when compared to other treatments and control.

Both, storability and good germinability depend on 'vigour factors' latent in seed and the seedling vigour is the ultimate and most relevant expression of seed quality (Heydecker, 1972). The root length, vigour index and dry matter production values were relatively higher in seedlings of the resultant seeds from the crop applied with green manure (*Sesbania aculeata*) + gypsum. This result is due to the initial potential vigour of seed as observed by Pollock and Roos (1972).

Deterioration in viability of seeds alters the membrane integrity (Berjak and Villiers, 1972 and Saxena, 1976). The conductivity of the seed leachate has been reported to be a good index of seed viability (Mathews and Bradnock, 1968) and vigour (Grabe, 1964).

In the present study the resultant seeds from soil amendments especially green manure + gypsum treatment

recorded relatively lower electrical conductivity, sugar content and aminoacids in the seed leachate at all the periods of storage than the seeds from control. The results are in conformity with the results of Aruna (1994). Irrespective of the treatments the electrical conductivity, sugar content and aminoacids of the leachate increased with increase in the storage period, due to ageing stress as reported by Abdul-Baki and Anderson (1970), Ching (1972), Dadlani and Agarwal (1983), Agarwal and Kharlukhi (1985).

Seed quality depends on several factors including cultural conditions of the mother plant (Merrien et al., 1988), harvest and post-harvest treatment and storage (Petruzzelli and Toranto, 1990). Seed germination capacity may be affected at the macromolecular level, involving qualitative and quantitative changes in proteins, nucleic acids, lipids, hormones and enzymes (Hailstones and Smith, 1989 and Wilson and McDonald, 1989).

Irrespective of treatments the protein content and alpha amylase activity decreased with increase in the period of storage.

The seeds obtained from the crop subjected to the soil amendment with green manure + gypsum recorded higher protein and alpha amylase activity over periods of storage compared to control in the present study. Similar positive

association of protein content and alpha amylase activity was reported by Halder and Gupta (1982), Kharlukhi (1983) and Ravinder et al. (1986). The reason for the increased protein and alpha amylase activity was due to membrane integrity and maintenance of physical stamina of the resultant seeds from the conjoint application treatment.

The fungal infection in the present study increased progressively with increase in the period of storage irrespective of treatments. However, the rate of increase was higher in the seeds from control as compared to the seeds obtained from the plots subjected to soil amendments. The results are in agreement with the findings of Emayavaramban and Ramabadran (1986).

Influence of stages of harvest and foliar spray of nutrients on shattering and seed quality of rice cv. ADT 38.

In crop production, use of quality seed results in healthy and vigorous seedlings that stand well under field conditions and will exploit the yield potential of the cultivar fully under proper mother plant care.

The quality of seed is basically dependent on seed filling and on the metabolic and synthetic efficiency during seed development and maturation, which in turn is reflected in terms of normal germination and vigorous growth of the

resultant seedling. Seed maturation refers to the morphological, physiological and functional changes that occur from the time of fertilization until the matured ovules are ready to harvest (Delouche, et al., 1973).

In quality seed production, not only harvesting the seed crop at the optimum stage of maturity is of considerable significance, but also proper care should be taken to avoid pre and post harvest losses. In the pre harvest losses shattering of seeds in rice before harvesting until threshing will cause considerable reduction in yield. Though it is controlled by genetical make up of the variety, it often changes due to agro-ecological situation of crop growth and nutritional disorders of the mother crop (Gill and Singh, 1978, Rao et al., 1980 and Sardana and Borthakur, 1987). Hence, proper management techniques will go a long way in minimising the shattering loss.

In the present study shattering loss increased with increase in the period of harvest from 2.7 per cent (physiological maturity) to 6.7 per cent (12th day after physiological maturity). The results are in agreement with the findings of Varma (1981), Ali and Ojha (1982), Singh et al. (1983) and Bhole et al., (1985) in rice. The decline in moisture content of the earheads and seed after physiological maturity contributed for higher shattering loss as reported by Deuff and Rachidian (1980).

Several means are available for increasing seed yield and decreasing pre and post harvest losses. The growth and productivity of a plant are controlled by genetical (hereditary), environmental (climatic) and chemical (growth stimulants and nutrient) factors.

The chemicals and fertilizers are applied through soil and foliage. The absorption of nutrients through foliage is quicker as compared to soil application and it is more effective in realising the desirable quality. Research efforts have not been made to study the feasibility of foliar application of chemical nutrients on arresting seed shattering and its impact on the resultant seed quality of rice. The present study was oriented towards this direction for determining the effect of foliar nutrients on seed shattering. Among the foliar nutrients tried for arresting the seed shattering, DAP 2 per cent and cytozyme 0.5 per cent at 50 per cent flowering reduced the shattering loss from 5.1 to 3.1 per cent when compared to water spray. Similar reduction in shattering loss due to foliar application of nutrients was reported by Chakravarthy et al. (1979) in cereals and Venkataswamy and Iruthayaraj (1980) and Thiagarajan and Ramasamy (1984) in cotton. The reduction in shattering due to foliar nutrients resulted in strengthening of panicle by the availability of additional nutrients in adequate quantity during seed development and maturation (Manonmani, 1990).

The resultant seeds from cytozyme treatment recorded higher seed recovery besides recording less seed shattering. The findings are in agreement with the findings of Manonmani (1990) in rice. The increased seed recovery was obtained due to translocation of organic materials in the treated plant due to higher emergence activity and better source-sink relationship (Halwankar et al., 1984).

Among the stages of harvest the seeds harvested at physiological maturity recorded higher speed of germination, germination, root and shoot length, dry matter production, vigour index, protein content and alpha amylase activity as compared to the seeds harvested at 9 and 12 days after physiological maturity. The electrical conductivity, sugar content, aminoacids and fungal infection increased with increase in the stage of harvest. Similar, findings were reported by Glueck et al. (1977), Anonymous (1980), Pandita et al. (1983), Hooda et al. (1985) and Tonapi (1988).

The seeds obtained from the crop sprayed with cytozyme recorded higher vigour and seed quality compared to other treatments and control irrespective of stages of harvest. This was achieved due to the maximum augmentation in seed quality and initial potential vigour. This is in conformity with the results of Manonmani (1990) in rice, Selvaraju (1986) in marigold and Sabirahamed (1989) in soyabean.

BIOASSAY OF SEED VIGOUR

Natural ageing on seed vigour

Seed quality depends on several factors including cultural conditions of the mother plant (Merrin et al., 1988). Seed germination capacity may be affected at the macromolecular level, involving qualitative and quantitative changes in proteins, nucleic acids, lipids and hormones (Wilson and McDonald, 1989) and lipid breakdown during storage (Dinola and Mayer, 1986). Seeds with maximum germination and vigour are the basic requirements in achieving maximum crop yield. Seed quality and seed vigour are used synonymously. Vigour is defined as the condition of seeds that permits germination to proceed rapidly, uniformly and allow production of uniform seedling stands under normal conditions. There is yet no universally accepted method for the quantitative determination of seed vigour except in wheat defined by Basu et al. (1990), although a large number of physiologically and agronomically important approaches have been made (Heydecker, 1972 and Perry, 1978).

In view of the great importance of seed vigour an attempt for quantification of vigour is an immensely inevitable one in the quality seed production programme. For this an inexpensive seed vigour bioassay method has been developed to determine the vigour status of rice seed (*Oryza sativa* L.).

The basic principle of this method is the exposure of a sensitive test material to the gaseous emanations of germinating stock seeds of different vigour levels. In the present study harvest fresh seeds of pearl millet has been used as the bioassay material for testing vigour of rice seeds of varying levels of germinability obtained through natural and artificial ageing.

Storage of rice seeds of cvs. IR 50 and ADT 38 under controlled conditions for 9 and 15 months caused a considerable reduction in germination irrespective of varieties. The germination per cent, root length and shoot length and corresponding root / shoot ratio were maximum in the harvest fresh seeds as compared to the seeds aged 9 and 15 months. The vigour index values also decreased with increase in the ageing period. This is in conformity with the results of Basu et al. (1990) in wheat seeds.

The loss of viability of seed either under natural storage or under artificial ageing is due to the accumulation of various toxic substances. This suggests the involvement of volatile compounds evolved by seeds in the deterioration process of the seed (Zhang et al., 1993).

Fielding and Goldsworthy (1982) suggested the possible relationship between the content of volatiles and the vigour of the seeds. In the present study the pearl millet seeds

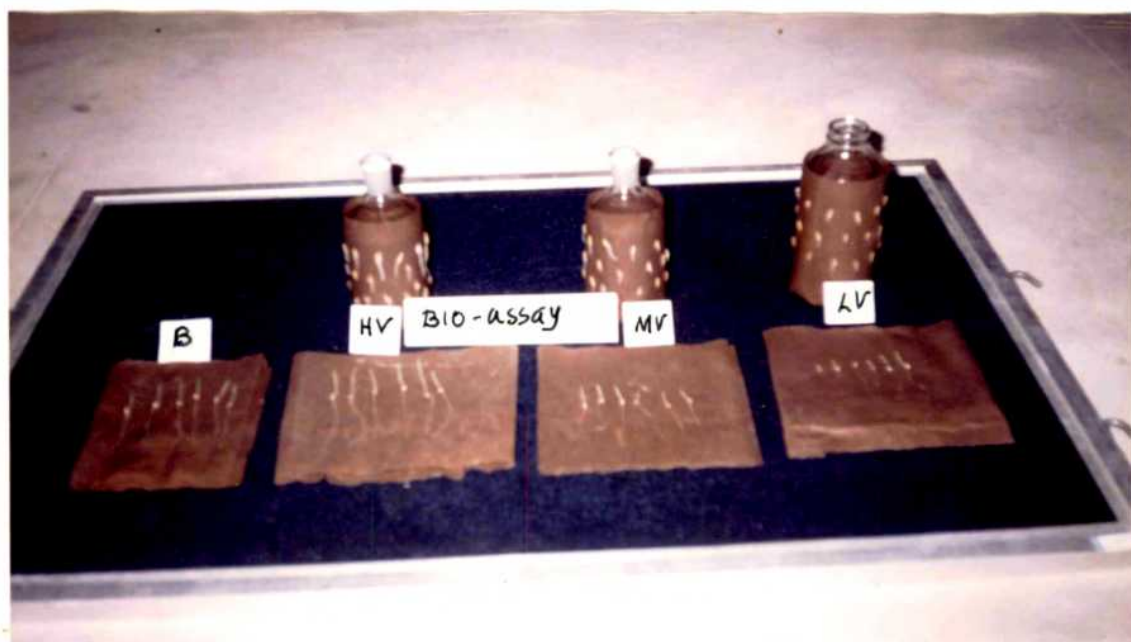
under blank (desiccator without rice seeds) recorded maximum germination, growth and vigour. While, a significant reduction in germination and seedling growth in terms of root and shoot length and vigour index of pearl millet (Bioassay material) was recorded in the pearl millet seeds exposed to the gaseous emanations of the germinating rice seeds of medium and low vigour (Plate 4). The findings are in conformity with the results of Basu et al. (1990) in wheat seeds. The possible reason for the low vigour of pearl millet seeds might be due to the injurious effect of emanating gases from the medium and low vigour rice seeds as reported by Harman et al. (1982) Wilson and McDonald (1986).

Artificial ageing on seed vigour

Accelerated/artificial ageing has attained greater importance than many other vigour tests because of its simplicity and accuracy. With accelerated ageing it is possible to bring down the vigour to medium and low levels within a shorter period.

Seed germination and seedling growth are the index for assessing seed vigour (Gelmond et al., 1978). The present study indicated maximum and minimum reduction in seed vigour of the rice seeds aged 6 and 12 days as compared to fresh seeds as measured through root and shoot length and vigour index. Similar results were reported by Younis et al.

PLATE 4. BIOASSAY OF SEED VIGOUR



(1990) in rice and Basu et al. (1990) in wheat.

The germination, seedling growth and vigour of pearl millet seeds (Bioassay material) exposed to the gaseous emanation of germinating rice seeds of medium and low vigour obtained by accelerated ageing though followed similar pattern in affecting vigour potential of the bioassay material similar to that of natural ageing, the vigour reduction was drastic under accelerated ageing.

The present study clearly indicated the adverse effect of the volatile gases emanating from the deteriorating seeds on germination, growth and vigour of the bioassay material. The plausible reason might be due to the inhibitory effect of the products of lipid peroxidation (Wilson and McDonald, 1986) significant accumulation of ethanol and acetaldehyde (Woodstock, 1981). The results of this study also indicated that besides volatile aldehydes (product of lipid peroxidation), other growth inhibiting substances in the gaseous emanations of germinating high and medium vigour rice seeds were also responsible for the reduction in germination and growth of pearl millet seedlings compared to blank where pearl millet seeds were not exposed to gaseous emanations.

The methods of quantification of the basic causes of seed deterioration should form the most sensitive vigour tests according to Delouche and Baskin (1973). As such, the present bioassay method may be looked upon as an important and effective step towards this direction.

SUMMARY

CHAPTER VI

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SUMMARY

Field and laboratory investigations were carried out to elucidate information on the influence of season and population densities, effect of age of seedling and nitrogen levels, influence of seed hardening and direct seeding and influence of levels of gypsum application in sodic soil on growth, yield, quality and storability of seeds of rice cvs. IR 50 and ADT 38. Influence of green manuring and gypsum application on seed yield, quality and storability of rice cv. CO 43, influence of stages of harvest and foliar spraying of chemical nutrients on seed shattering and seed quality of rice cv. ADT 38 and bioassay of seed vigour were also studied. The results are summarised here under.

In the season and population density studies with rice cvs. IR 50 and ADT 38, the crop raised in Kharif 1992 attained early flowering. In the plant densities 100 and 80 hills per m² induced early flowering.

In the studies on influence of varieties and the planting densities 50 and 44 hills/m² recorded higher values for the yield components viz., number of tillers, productive tillers, weight of panicle, good seeds panicle⁻¹ seed recovery and 1000 seed weight compared to 100 hills/m².

The variety ADT 38 with plant densities of 44 and 50 hills/m² in Kharif seasons and IR 50 with the plant density of 100 hills/m² in Rabi '93 recorded higher and lower yield, respectively.

Variations in season and population densities irrespective of varieties significantly altered the resultant seed quality viz., speed of germination, germination percentage, root length, vigour index, dry matter production and protein content. This was reflected in the biochemical studies namely increased alpha amylase activity and decreased electrical conductivity, sugar content, aminoacids and fungal infection. The resultant seeds of the crop raised in Kharif season with plant densities of 44 and 50 hills/m² proved to be sound when compared to the seeds of the crop raised in Rabi with 100 hills/m².

Storage studies were conducted with the seeds harvested in Kharif 1992 and Rabi 1993 seasons after seed treatment and stored in gunny bag for 15 months. The speed of germination, germination percentage, root length, vigour index, dry matter production, protein content and alpha amylase activity decreased with increase in the period of storage. While electrical conductivity, sugar content, aminoacids and fungal infection increased with increase in the storage period irrespective of varieties, seasons and

plant densities. The seeds produced in Kharif season with the plant densities of 44 and 50 hills/m² recorded higher speed of germination, germination percentage, root length, vigour index, dry matter production, protein content and alpha amylase activity and lower electrical conductivity, sugars, aminoacids and fungal infection throughout the storage period. Between varieties, IR 50 proved to be the better storer and recorded higher values for the seed quality attributes as compared to ADT 38 irrespective of seasons and plant densities. Among the population densities, 50 and 66 hill/m² for IR 50 and 44 and 50 hill for ADT 38 proved to be the best.

The resultant seeds from Kharif 1994 were subjected to artificial ageing to predict the storability. The seed quality of the aged seeds assessed through physiological and biochemical parameters showed drastic reduction at the end of the ageing period irrespective of varieties and plant densities. Among the plant densities 44 and 50 hills/m² proved to be the best by recording higher speed of germination and total germination at 14 days of ageing.

The reduction of speed of germination, germination, root length, vigour index, dry matter production, protein content and alpha amylase activity and the increase of electrical conductivity, sugars, aminoacids in seed leachates and fungal infection was lesser in the plant

densities of 50 and 44 hills/m², exhibiting their superior vigour and viability irrespective of varieties.

Between the varieties IR 50 showed its superior storability in the ageing as compared to ADT 38. The effect of age of seedling and nitrogen levels on seed yield and quality was evaluated using the rice varieties, IR 50 and ADT 38. Planting 30 day old seedlings is advantageous as it induces early flowering, more number of productive tillers, higher length and weight of panicle, more number of good seeds panicle⁻¹, seed yield and recovery.

The resultant seeds from the crop raised with 30 day old seedlings registered higher speed of germination, total germination, root length, vigour, dry matter production and protein content and lower electrical conductivity, sugar, aminoacids and fungal infection.

The days to maturity in both the varieties got reduced by 6.6 days in the crop raised with 30 day old seedlings as compared to 60 days old seedlings. However, the variety ADT 38 was better than IR 50 in most of the seed yield and quality parameters by recording higher values except in speed of germination, aminoacid and alpha amylase activity.

Among the nitrogen levels, application of 25 kg of N ha⁻¹ over and above the recommended dose irrespective of

varieties and age of seedlings induced lengthier panicle, reduced percentage of awns and fungal infection, whereas 50 kg N ha⁻¹ induced more number of tillers and vigour, reduced the days to maturity, and electrical conductivity and aminoacids in the seed leachate.

In the interaction studies application of 50 and 75 kg of N ha⁻¹ for the 40 and 50 day old seedlings could improve the growth of plants and yield attributes considerably as compared 60 day old seedlings.

The resultant seeds of the varieties, different age groups and nitrogen levels were subjected to accelerated ageing to predict the storability for 12 days. The studies clearly indicated the importance of planting optimum aged seedlings and its management. The quality in terms of physiological and biochemical parameters of the aged seeds drastically reduced. In the age groups the seeds from 30 day old seedlings registered highest speed of germination, total germination, dry matter production, protein and alpha amylase activity and lowest electrical conductivity, sugar content and fungal infection. The seeds of 40 day old seedlings recorded higher values for root length and vigour index and lower aminoacids.

Studies were made to elucidate information on the effect of seed hardening on the direct seeded rice crop of

the varieties IR 50 and ADT 38. The seeds hardened with potassium dihydrogen phosphate at 0.5 per cent and potassium chloride 1.0 per cent induced higher vigour in terms of recording higher percentage of initial and final field emergence.

Potassium dihydrogen phosphate (0.5%) and potassium chloride (1%) seed treatments induced early flowering, more number of tillers and productive tillers, length and weight of panicle, more number of good seeds panicle⁻¹, awned seeded ear, seed yield, recovery per cent, and 1000 seed weight and reduction in days to maturity, irrespective varieties in the direct seeded rice. Between the varieties ADT 38 responded better than IR 50 the hardening treatments.

The resultant seeds from seed hardening treatments were subjected to storage studies. All the seed quality attributes progressively reduced irrespective of varieties and treatments with increase in the period of storage. However, the rate of reduction was less in the resultant seeds from hardening treatments as compared to water and control.

The resultant seeds from all the treatments maintained more than 80 per cent of germination at the end of 15 months of storage period. The germination potential of the seeds from control declined after 6 months of storage,

irrespective of varieties. Among the treatments the resultant seeds from potassium chloride and potassium dihydrogen phosphate recorded increased speed of germination, germination, root length, vigour index, dry matter production, protein and alpha amylase activity and lowest values of electrical conductivity, sugar content and aminoacids and fungal infection per cent when compared to other treatments and control over periods of storage.

Between the varieties the seeds from ADT 38 maintained higher speed of germination, root length, dry matter production, protein content and alpha amylase activity and less electrical conductivity, sugar content and fungal infection over periods of storage.

To find out the effect of different levels of gypsum on yield and quality of seeds of rice cvs. IR 50 and ADT 38 field studies were conducted in sodic soil. Increased levels of gypsum in sodic soil maintained higher level of plant population per m².

Between the varieties ADT 38 responded well for gypsum applications. Application of 3600 kg of gypsum ha⁻¹ showed its supremacy over the other treatments and control by maintaining higher plant population, recording early flowering, higher tiller and productive tillers, length and weight of panicle, reduction in days to maturity, increase

in good seed number panicle⁻¹, awned ear, seed yield, recovery and 1000 seed weight.

Under storage studies resultant seeds from different levels of gypsum revealed the superiority of the seeds from the plots applied with 3600 kg ha⁻¹. The seeds from the above treatment maintained higher germination potential throughout the storage period of 15 months irrespective of varieties whereas in control drastic reduction in germination was observed after 6 months of storage.

The field studies in sodic soil with application of green manure and gypsum in rice cv. CO 43 revealed the superiority of conjoint application of green manure and gypsum in all the growth, yield and quality attributes.

The conjoint application of green manure *Sesbania aculeata* @ 10 t ha⁻¹ + gypsum 3.4 t ha⁻¹ was the best as compared to other treatments and control in reducing the sodicity effect and maintaining optimum plant population/m², inducing early flowering, reduction in days to maturity, increase in tillers and productive tillers panicle length and weight, seed yield, seed recovery and 1000 seed weight.

The storage studies on the resultant seeds of the above experiment revealed the superiority of the seeds from the conjoint application of green manure *Sesbania aculeata* +

gypsum, in maintaining all the seed quality attributes studied irrespective of storage period when compared to other treatments and control.

A field experiment was conducted with rice cv. ADT 38 to find out the seed shattering losses and the effect of foliar spraying with nutrient chemicals on arresting the losses and in improving the seed quality in different stages of harvest after the attainment of physiological maturity. The number of seeds earhead⁻¹, seed recovery, speed of germination, germination, root length, dry matter production, protein content and alpha amylase activity of the seeds harvested at physiological and 3 days after physiological maturity was maximum and there after it declined drastically.

The seeds harvested at physiological and 3 days after physiological maturity recorded lower seed shattering, electrical conductivity, sugar, aminoacids and fungal infection, while the delayed harvests recorded higher values for the above parameters.

Among the foliar nutrients, spraying of 0.5 per cent cytozyme at 50 per cent flowering recorded increased seed recovery, speed of germination, germination, root length, vigour index, dry matter production, protein, alphaamylase activity and decreased electrical conductivity and

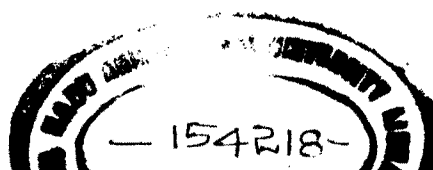
aminoacids while 1 per cent DAP at 50 flowering recorded higher seed number earhead⁻¹, reduced sugar content and fungal infection. Irrespective of the stages of harvest both cytozyme and DAP spraying increased all the seed quality attributes and reduced shattering loss as compared to water spraying and control. Hence, by spraying of DAP and cytozyme even in the delayed stages of harvests the loss in yield and seed quality of rice could be minimised to a certain extent as compared to control.

A new, simple and inexpensive seed vigour bioassay method has been developed in the laboratory studies to determine the vigour status of rice seeds (cvs. IR 50 and ADT 38) by employing high vigour fresh seeds of pearl millet of the bioassay material. In this method in an air tight desiccator, germinating pearl millet seeds (bioassay material) were exposed to the gaseous emanations of germinating rice seeds (stock material) of different vigour levels. Highly significant and positive relationships between germination, growth and vigour of rice and pearl millet seedlings were obtained irrespective of varieties whether the rice seed was aged naturally or artificially for obtaining stock materials of rice of different vigour levels.

REFERENCES

REFERENCES

- Abdul-Baki, A.A., 1969. Metabolism of barley seed during early hours of germination. *Pl. Physiol.*, 44: 733.
- Abdul-Baki, A.A. and J.D. Anderson. 1970. Viability and Leaching of sugars from germination of barley. *Crop Sci.*, 10(1): 31-34.
- Abdul-Baki, A.A. and J.D. Anderson, 1973. Vigour determination in soybean seed by multiple criteria. *Crop Sci.*, 13: 630-633.
- Abdul-Bari, A.A. and J.E. Baker, 1973. The changes in cellular organelles or membranes related to vigour loss in seed. *Seed Sci. and Technol.*, 1: 89-125.
- Abdul-Baki, A.A. and G.R. Chandra, 1977. Effect of rapid ageing on nucleic acid and protein synthesis by embryonic axes during germination. *Seed Sci. and Technol.*, 5: 689-698.
- Agrawal, R.L. 1965. *Seed Technology*. Oxford and IBH Publishing Co., New Delhi.
- Agrawal, P.K., 1980. Relative storability of seeds of ten species under ambient conditions. *Seed Res.*, 8(2): 94-99.
- Agrawal, R.L. 1980. *Seed Technology*, Oxford and IBH Publishing Co., New Delhi.
- Agrawal, P.K. and L. Kharlukhi, 1987. Enzyme activities in seeds during storage. *Indn. J. Expt. Biol.*, 25: 719-722.
- Agrawal, A.P., R.K. Sahu and D.K. Sharma, 1990. Studies on grain shattering in rice. *Oryza*, 27: 483-484.
- Akram, M., D.V. Seshu, and M. Amin khan, 1993. Inheritance of seedling vigour in rice. *Oryza*, 30: 179-185.
- Ali, N. and T.P. Ojha, 1982. Harvesting, threshing and transportation of food grains. Workshop on post harvest losses with special emphasis on farm level storage, organised by commonwealth secretariate in collaboration with Dept. of Food. Govt. of India, New Delhi.
- Ali-Khan, S.T. and C.G. Youngs, 1973. Variation in protein content of field peas. *Can. J. Pl. Sci.*, 53: 37-41.



Amarlal, A.S. 1978. Effect of vigour and seed density on the yield of irrigated rice. IRGA. 34-42. Seed Abstr., 1982 5(9): 68-568.

Anandswarup, 1988. Influence of organic matter and flooding on the chemical and electro chemical properties of sodic soil and rice growth. Pl. and Soil., 106: 135-141.

Anandswarup, 1991. Long term effect of green manuring (*sesbania rostrata*) on soil properties and sustainability of rice and wheat yield on a sodic soil. J. Ind. Soc. Soil Sci., 39: 777-780.

Anandswarup, 1992. Effect of organic amendments on the nutrition and yield of wet land rice and sodic soil reclamation. J. Ind. Soc. Soil. Sci., 40: 816-822.

*Anderson, J.D. 1946. Enzymes and their role in wheat technology. Interscience Publishers, Inc., New York, p. 371.

Anderson, J.D. 1973. Metabolic changes associated with seed senescence. Seed Sci. and Technol., 1: 401-416.

Anonymous, 1980. Cytozyme news letter published by cytozyme. Andra Pradesh Ltd., Hyderabad. (A.P.).

Anonymous, 1985. International rules for seed testing. Seed Sci. and Technol., 13: 299-495.

Anonymous, 1992. Progress report. All India Coordinated Rice improvement project, 3: 120-124.

Anonymous, 1993. Rice in crucial environments. Int. Rice Res. Inst. Newsl., 18(2): 10-17.

Anonymous, 1994. Field crops research soils and Agroclimatology division, ICRISAT, 39: 163-170.

Anonymous, 1995. Development of drought resistant cultivars using physio morphological traits in rice. A review. Field Crops Res., 40: 67-86.

Ansari, R., S.M. Naqui and S.A. Ala, 1980. Response of wheat cultivars to the presence of sodium salt at germination and in early development. Biologic plantarum, 22(6): 470-472.

Apparao, S., N. Kameswararao and M.H. Mangesha, 1991. Germination of pearl millet (*Pennisetum glaucum*) seeds stored under different conditions for six years. Seed Sci. and Technol., 19: 605-610.

Apparao, S., N. Kameswararao and M.H. Mangesha, 1993. Germinability and seedling vigour pearl millet seeds harvested at different stages of maturity. *Crop Res.*, 32: 141-145.

Arulnandhy, V. and Y.D.A. Senanayake, 1988. Deterioration of soybean seed stored in different containers under ambient conditions. *Seed Res.*, 16(2): 183-192.

Aruna, 1994. Studies on decomposition and Mineralisation of green manures under salt affected rice soils. M.Sc (Ag.), Thesis, Tamil Nadu Agricultural University, Coimbatore.

Arunin, S., C. Dissataporn, Y. Aruluxtipan and D. Nana, 1988. In "Green manure in rice farming". pp. 83-85. *Int. Rice Res. Inst.*, Los Banos, Laguna, Philippines.

Ashraf, M. and S. Mahmood, 1989. Effect of seedling age on basmati growth and yield. *Int. Rice Res. Newsl.*, 14(1): 8.

Aslam, M., R.C. Huffaker and D.W. Rains, 1984. Early effects of salinity on nitrate in barley seedlings. *Pl. Physiol.*, 76: 321-325.

Aswathaiah, B. 1977. Influence of season plant density and fertilizer doses on the yield and quality of hybrid bajra (*P.typhoides* S. and H.) M.Sc. (Ag.) Thesis, Tamil Nadu Agrl. Univ. Coimbatore.

Austin, R.B. 1972. Effects of environment before harvesting on viability. In: '*Viability of seeds*' (Ed. E.H. Roberts,) Syracuse University Press, London, pp. 114-149.

Austin, R.B. and P.C. Longman, 1980. Effect of nutritional treatment of seed bearing plants on the performance of their progeny. *Nature*, 205: 819-820.

Ayyasamy, M., C. Udayasooriyan and P. Balamurugan, 1991. Influence of nursery sowing methods, irrigation frequencies and seedling age on transplanted rice. *Madras agric. J.*, 78(9-12): 531-533.

Babu, A. ^{M.}~~Munendra~~, 1987. Effect of planting and variety on growth and yield of rice. *Oryza*, 25(3): 319-322.

Bailey, S.D., D.G. Mitchell, M.L. Bazinet and C.J. Weurman, 1962. Studies on the volatile components of different varieties of Cocoa beans. *J. of Food Sci.*, 27: 165-170.

Balakrishnan, K., A. Arjunan, and S. Ganapathy, 1994. Effect of seed and nursery treatments on short duration rice. *Madras Agric. J.*, 81(1): 48-49.

Balasubramanian, R. 1976. Note on the effect of pre-sowing seed treatment on total and reducing sugars of two sorghum hybrids. *Indian J. Agric. Sci.*, 46(7): 346-347.

Balasubramaniam, P. and R. Vaithialingam, 1983. Nitrogen requirement and spacing for the long duration rice in cauvery delta. *Madras agric. J.*, 72(9): 537:538.

Basavarajappa, B.S., H.S. Shetty and H.S. Prakash, 1991. Membrane deterioration and other biochemical changes associated with accelerated ageing of maize seeds. *Seed Sci. and Technol.*, 19: 229-288.

Bassi, G., A. Rang, and D.P. Joshi, 1994. Effect of seedling age on flowering of cytoplasmic male sterile and restorer lines of rice. *Int. Rice Res. Newsl.*, 19(1): 4.

Basu, R.N. 1976. Physio-chemical control of seed deterioration. *Seed Res.*, 4(1): 15-23.

Basu, R.N., K. Chattopadhyaya and P. Pal., 1974. Maintenance of seed viability in rice and Jute. *Indian Agric.*, 18: 75-79.

Basu, R.N., Pampa Kuchlem and Kalpane Sur., 1990. Bioassay of seed vigour *Ind. J. of exptal. Biology*, 28: 166-170.

Bathkal, B.G. and D.H. Patil, 1970. Effect of inter-row spacing and nitrogen levels on yield of drilled paddy. *Indian J. Agron.*, XV(3): 288.

Beevers, L. 1968. Protein degradation and proteolytic activity in the cotyledons of germinating pea seeds (*pisum sativum*). *Phytochem.*, 6: 1837-1844.

Bengtsson, B. and I. Bolund, 1964. Gas chromatographic evaluation of the formation of volatile substances in stored peas. *Food Technol.*, 18: 179-182.

Bennett, J.M., L.S.M. Mutti, P.S.C. Rao and J.W. Jones, 1980. Interactive effects of nitrogen and water stresses on biomass accumulation, nitrogen uptake and seed yield of maize. *Field crop. Res.*, 19: 297-311. ✓

Berjak, P. and T.A. Villiers, 1972. Ageing in plant embryos. II. Age-induced damage and its repair during early germination. *New phytol.*, 71: 135-144.

Bewley, J.D. 1986. Membrane changes in seeds as related to germination and the ruptures resulting from deterioration in storage. *Special Publication, CSSA*, 11: 27-45.

Bharathi, A., 1991. Irrigation management and nitrogen fertilization on yield, quality and storability of maize (*Zea mays*). M.Sc. (Ag.) Thesis, Tamil Nadu Agril. University, Coimbatore.

Bhardwaj, K.K.R. 1982. Effect of the age and decomposition period of dhaincha on the yield of rice. *Ind. J. Agron.*, 27: 284-285.

Bhaskaran, M., K.R. Ramasamy and K.S. Subramanian, 1990. Influence of levels of spacings and nitrogen on yield and quality of baja. *New Botanist*, 12(1): 48-50.

Bhattacharya, P., R.C. Samui and S. Sen. 1983. Studies on the germination and viability of stored sunflower seed. *Seed Res.*, 11(2): 162-171.

Bhole, N.G., T.P. Ojha and A.C. Pandya, 1985. Harvesting and drying machinery and storage structure. pp. 658-691, In *Rice Res.*, in India. Indian Council of Agricultural Research, New Delhi.

Blowers, L.E., Smith, D.A. and C.M. Bray, 1980. Nucleic acid and protein synthesis and loss of vigour in germinating wheat embryos. *Plant*, 150: 19-25.

Bruggink, H., H.L. Kraak, M.H. G.E. Dijkema and J. Bekendam. 1991. Some factors influencing electrolyte leakage from maize (*Zea mays* L.) kernels. *Seed Sci. Res.*, 1: 15-20.

Budhar, M.N., Sp. Palaniappan and A. Rangasamy, 1990. Performance of CR 666-18 rice under transplanted and direct seeded conditions. *Oryza*, 27: 208-209.

Buragohain, A.S. and M.M. Kalita, 1985. Effect of varieties, spacings and fertility levels on maize. *J. Res. Assam. Agric. Univ.* 6(1): 8-11.

Cada, E. and S. Taleon, 1963. The effect of age of seedlings at transplanting upon the growth and yield of early, medium and late maturing rice varieties. Philippines. *J. Pl. Introd.*, 28: 115-130.

Carberry, P.S., L.C. Campbell and F.R. Bidinger, 1985. the growth and development of rice as affected by plant population. *Field Crops Res.*, 11: 193-205.

- Chakravorthy, S.K., H. Sinha and K.P. Singh, 1979. Note on boron nutrition of cereals and legumes in a sand-culture study. *Indian J. Agric. Sci.*, 49(5): 382-383.
- Chau, N.M. 1994. Performance of anaerobically direct seeded rice plants in the Mekong Delta, Vietnam, *Int. Rice Res. Newsl.*, 19(2): 6-7.
- Chauhan, K.P.S. 1985. The incidence of deterioration and its localisation in aged seeds of soybean and barley. *Seed Sci and Technol.*, 13: 769-773.
- Chhabra, R. and J.P. Abrol, 1977. Reclaiming effect of rice grown in sodic soil. *Soil Sci.*, 124: 4955.
- Ching, T.M. and K.K. Ching, 1964. Freeze drying Pine Pollen. *Pl. Physiol.*, 39: 705-709.
- Ching, T.M., 1972. Ageing stresses on physiological and biochemical activities of crimson clover seeds. *Crop Sci.*, 12: 415-418.
- Chopra, K.R., 1983. Effect of pre-harvest growing conditions and production practices on the storability of sorghum seeds. Paper presented in the National Seminar on Seed Technology held at college of Agril. and Res. Inst., Coimbatore on 7th and 8th April, 1983.
- Choudhary, D., M.J.B.K. Rao, A.B. Prasad and A.V.S. Rao, 1980. Heritability and correlation in rice. *Oryza*, 17: 194-199.
- *Christensen, C.M. and H.H. Kaufmann, 1969. In: "Grain storage". Univ. of Minnesota, Press Minneapolis.
- Cramer, G.R., A. Lauchli and V.S. Polito, 1985. Displacement of Ca^{2+} by Na^{+} from the plasmalemma of root cells. A primary response to salt stress. *Pl. Physiol.*, 81: 792-797.
- *Crocker, W. and L.V. Barton, 1957. *Physiology of Seeds*. Chronica Botanica Co., pp. 87-101. Waltham Mass., USA.
- D'Amato, F. and O. Hoffman-Ostenhof, 1956. Metabolism and spontaneous mutations in plants. *Adv. Genet.*, 8: 1-28.
- Dadlani, M. and P.K. Agrawal. 1983. Factors influencing leaching of sugars and electrolytes from carrot and okra seeds. *Hort. Sci.*, 10: 39-44.
- Data, S.K. and S.S. Pradhan, 1981. A screening method for salt tolerance of rice varieties at seedling stage. *Sci. and Cult.*, 47: 444-446.

DeDatta, G.C. 1979. Seed quality studies in some important cultivars of rice (*Oryza sativa* L.). M Sc. (Ag) Thesis. Tamil Nadu Agricultural University, Coimbatore-3.

DeDatta, S.K., and P.M. Zarate, 1970. Environmental conditions affecting growth characteristics, nitrogen response and grain yield of tropical rice. *Biometeorology*, 4: 71-89.

Delouche, J.C. and C.C. Baskin, 1973. Accelerated ageing technique for predicting the relative storability of seed lots. *Seed Sci. and Technol.*, 1: 427-452.

Delouche, J.C., R.K. Mathews, G.M. Dougherty and A.H. Boijd. 1973. Storage of seed in subtropical and tropical regions. *Seed Sci. and Technol.*, 1: 663-692.

Deuff, Y.Z. and Z. Rachidian, 1988. Interruption of water delivery at physiological maturity is essential for seed development, germination and seedling growth in pea. *J. Exptl. Bot.*, 39(206): 1221-1230.

Dey, B. and S.M. Sircar. 1968. The presence of an abscisic acid like factor in non viable rice seeds. *Physiol. Plant.*, 24: 1054-1059.

Dharmalingam, C., 1978. Long term storage of rice germ plasms. *TNAU Newsl.*, 8(5): 3.

Dimov, J., L. Ivanav, and K. Millier, 1978. Preplanting seed treatment for direct sown tomatoes and capsicums. *Gradinavsto*, 59(5): 11-14.

Dingkuhn, M., H.F. Schnier, S.K. DeDatta, E. Wijangeo, and K. Dorffling, 1990. Diurnal and developmental change in canopy gas exchange in relation to growth in transplanted and direct seeded flooded rice. *Aust. J. Pl. Physiol.*, 17: 119-134.

Dingkuhn, M., H.F. Schnier, S.K. DeDatta, K. Dorffling and C. Javellana, 1991. Relationships between ripening phase productivity and crop duration, canopy photosynthesis and senescence in transplanted and direct seeded lowland rice. *Field Crops Res.*, 26: 327-345.

Dingkuhn, M., S.K. DeDatta, C. Javellana, R. Pamplona and H.F. Schnier, 1992. Effect of late season N fertilization on photosynthesis and yield of transplanted and direct seeded tropical flooded rice growth dynamics. *Field Crops Res.*, 28: 223-234.

- Dinola, L. and A.M. Mayer, 1986. Effect of temperature on glycerol metabolism in membranes and on phospholipase C and D of germinating pea embryo. *Phytochem.*, 25: 2255-2259.
- Doijode, S.D. and Raturi, G.B., 1987. Effect of hydration - dehydration on germination and vigour of certain vegetable seeds. *Seed Res.*, 15(2): 156-159.
- Dolly Pan and R.N. Basu, 1985. Mid-storage and pre-sowing treatments for lettuce and carrot. *Sci. Hort.*, 25: 11-19.
- Dong, C.T., Z.G. Liu, B.J. Zoo, C.Zhu, C.L. Zheng and W. Liang, 1982. Study on the nutrition of rice. *Lianoning Agric. Sci.*, 1981(4): 13-18. *Seed Abstr.*, 1982; 5(10): 334-2228.
- Dwvedi, K.N., C.N. Chaubey and N.R. Gupta, 1991. Study of saline-alkali soil resistance in rice. *Oryza*, 28: 265-267.
- Eagles, C.F. 1984. Crop efficiency of solar energy conversions. In. U.S. Gupta ed. *Crop physiology advanceing frontiers*. Oxford and IBH, New Delhi, 41-95.
- El-Damaty, A.H., H. Kahn and H. Linser, 1965. Water relations to wheat plants under the influence of CCC. *Physiol. Pl.*, 18: 650-657.
- Ells, J.E. 1963. The influence of treating seed with nutrient solution on emergence rate and seedling growth. *Proc. Amer. Soc. Hort. Sci.*, 83: 684-687.
- Emayavaramban, N. and R. Ramabadrnan, 1986. Incidence of seed borne fungi of finger millet as influence by moisture content, storage temperature, Relative humidity and storage period. *Seed Res.*, 14(2): 189-196.
- Eswarareddy, S. and S. Ramaireddy, 1983. Salinity and germination. *Seeds and Farms.*, p. 9-10.
- Evans, L.T. and S.K. DeDatta, 1979. The relationship between irradiance and grain yield of irrigated rice in the crops as influenced by cultivar, fertilizer application and month of planting. *Field Crops Res.*, 2: 1-17.
- *Ewart, A.J. 1908. On the longevity of seeds. *Proc. Roy. Soc. Victoria*, 21: 2-210.

Fielding, J.L. and A. Goldsworthy, 1982. The evolution of volatiles in relation to ageing in dry wheat seed. *Seed Sci. and Technol.*, 10: 277-282.

Filipenko, G.I. 1983. Peculiarities of physiological and biochemical changes in barley and wheat seeds during accelerated ageing. *Fld. Crop. Abstr.*, 38(9): 4757.

Floris, C. 1978. Ageing in *Triticum durum* seeds, behaviour of embryos and endosperm from aged seeds as revealed by the embryo transplantation technique. *J. Exptl. Bot.*, 21: 462-468.

Flower, J.L. and Ray, L.L., 1977. Response of cotton genotypes to five equidistant spacing patterns. *Agron. J.*, 69: 733-738.

Flowers, T.J. and A.R. Yeo, 1981. Variability in the resistance of sodium chloride salinity within rice (*Oryza sativa* L.) varieties. *New Phytol.*, 88: 363-373.

Forno, D.A., C.J. Asher and S. Voshida, 1975. Studies on two varieties susceptibility to zinc deficiency. *Pl. soil.*, 42: 551-563.

Ganesh, S.K. and G. Soundarapandian, 1988. Stability analysis in short duration varieties of rice. *Madras Agric. J.*, 75: 189-195.

Gangadhariah, H.B. 1983. Productivity of contrasting rice plant types at varied levels of fertility and spacing. M.Sc. (Ag.) Thesis, Univ. of Agrl. Sci., Bangalore, India.

Gargo, M. 1978. Effect of increased nitrogen rates and plant density on the grain protein content of maize hybrids. BCS K JA, BCSK 21-22 and Pace 280 and their lines polyopriv redna znanstven smota, 1977. *Seed Abstr.*, 40(50): 223-232, 12(1): 2580.

Gelmond, H., I. Luria, L.W. Woodstock and M. Perl, 1978. The effect of accelerated ageing of sorghum seeds on seedling vigour. *J. Exptl. Bot.*, 29(109): 489-495.

Gelmond, D.P. 1976. Viability of rice seeds in storage. *Oryza*, 13(1): 33-36.

*Genkel, P.A. and S.S. Kolotova, 1934. *IZV. Per. ms. kogo. biolnaucno-issled in-ta* 9: 1-3.

Geetha, R. 1992. Seed invigoration treatments on production potential and storability of rice (*Oryza sativa* L.) cultivars. M.Sc. (Ag.) Thesis, Tamil Nadu Agri. University, Coimbatore.

Ghai, S.K., D.L.N. Rao and L. Batra, 1984. More rice through daincha. *Intensive Agrl.*, 22(5): 21-22.

Ghai, S.K., D.L.N. Rao and L. Batra, 1988. Nitrogen contribution to wetland rice by green manuring with *sesbania* spp. in an alkaline soil. *Biol. Fertil. soils.*, 6: 22-25.

Ghorai, D.P. and K. Pande, 1982. Inheritance of yield and yield components and their association in rice cross Ac 1063 x Ac 27. *Oryza*, 19: 185-187.

Ghosh, D.C. 1982. Effect of age of seedlings and planting density on growth and yield of rice under late planting. *Madras Agrl. J.*, 69: 367-380.

Ghosh, B., Adikary, J. and N.C. Banerjee, 1981. Changes of some metabolite in rice seed during ageing with special reference to seedling vigour. *Seed Sci and Technol.*, 9: 469-473.

Ghosh, B and M.M. Chaudhuri, 1984. Ribonucleic acid breakdown and loss of protein synthetic capacity with loss of viability of rice embryos. *Seed Sci. and Technol.*, 12: 669-667.

Ghosh, B., J. Adhikary and N.C. Banerjee, 1981. Changes of some metabolites in rice seed during storage. *Seed Sci. and Technol.*, 9: 469-473.

Gill, M.K. 1977. Studies on physiology of seed viability and deterioration in soybean (*Glycine max* (L.) Merrill). Thesis Abstract. 3(4): 308-310.

Gill, P.S. and H.N. Shahi, 1985. Effect of transplanting schedule and post-harvest time intervals for threshing on rice grain yield and head rice recovery. *Int. Rice. Res. Newsl.*, 10(6): 28-29.

Gill, R.S. and K.H. Singh, 1978. Effect of zinc sulphate on the growth and yield performance of tall and dwarf varieties of rice. *Indian J. Agron.*, 23(4): 375-376.

*Glueck, J.A., Rooney, D.T. Rosemow and F.R. Miller, 1977. Physical and structural properties of field deteriorated (weathered) sorghum grain. pp. 102-112. In: Third Progress report of Texas At M University on Development of Improved high yielding sorghum cultivars

with disease and insect resistance. 1976-77.

*Gove, P.B. 1965. Webster's Seventh New Collegiate Dictionary. G. and C. Meriam Co., Springfield, Illinois.

Grabe, D.F., 1964. Glutamic acid decarboxylase activity as a measure of seedling vigour. Proc. Ass. Off. Seed Anal., 54: 100-109.

Greenway, H. and R. Munns, 1980. Mechanisms of salt tolerance in non halophytes. Annu. Rev. Pl. Physiol., 31: 149-190.

Gukova, M.M., V.T. Rymar, M. Isakh and S. Poul, 1986. Requirement of rice for zinc during early developmental stage. Referativnyi Zhurnal. Rice Abstr., 1987; 11: 2564.

Gupta, J.P. and A.T.R. Soi, 1992. Effect of gypsum application on physico-chemical characteristics of sodic soil and crop yield of rice and wheat. Indian J. Agron., 37(4): 812-814.

Hailstones, M.D. and M.T. Smith, 1989. Thermally - derived volatile aldehydes in relation to seed viability in soybean seeds. Seed Sci. and Technol. 10: 277-282.

Halder, S. and K. Gupta, 1982. On the mechanism of sunflower seed deterioration under low and high RH. Seed Sci., and Technol., 10: 267-270.

Halwankar, G.B., V.M. Raut and V.P. Patil, 1984. Effect of cytozyme and N on growth and yield of soybean Biovigyanam, 10(1): 21-24.

Haque, M.Z. and M. Haroon, 1983. Rice seed viability under two storage conditions. Intl. Rice Res. Newsl., 8(5): 3-4.

Harman, G.E., B.L. Nedrow, B.E. Clark and L.R. Mattick, 1982. Association of volatile aldehyde production during germination with poor soybean and pea seed quality. Crop Sci., 22: 712-716.

Harrington, J.A. 1972. Seed storage and longevity. In: Seed Biology, Volume III (Ed.) T.T. Kozlowski. pp. 145-245. Academic Press, New York.

Harrington, J.F. and J.E. Douglas, 1970. Seed storage and packing application for India. Published by National Seeds Corporation Ltd., New Delhi.

Hart, R.H. and W. Burton, 1985. Effect of row spacing, seedling rate and nitrogen fertilization of forage yield and quality of Gahi-I pearl millet - *Agron. J.*, 57: 376-378.

Hayashi, H. 1969. Efficiency of solar energy conversion and relating characterisation in rice varieties. *Proc. Crop Sci. Soc., Japan.*, 38: 495-500.

Heydecker, W. 1962. Report on the activities of seedling vigour test committee. *Proc. Int. Seed Test. Assoc.*, 27: 211-219.

Heydecker, W. 1972. Vigour. IN: *Viability of Seeds* (E.H. Roberts ed.), Chapman - Hall Lond. p. 246.

Heydecker, W. 1973. In: *Vigour and viability of seeds* (ed. Robert, E.H.) syracuse University, Press, New York, pp. 209-252.

Hibbard, R.P. and I.V. Miller. 1928. Biochemical studies on seed viability. Measurements of conductance and reduction. *Plant physiol.*, 3: 335-52.

Honda, T. 1977. Studies on tillering in rice. *Bulletin of the institute for Agril. Res. Tohoru Univ., Rice Abstr.*, 1978 28(2): 171-312.

Honing, D.H. and J.I. Rackis, 1975. Volatile components of maturing soybeans. *Cereal chem.*, 52: 400-503.

Hooda, R.S., A.S. Sidhu and M.L. Pandita, 1985. Effect of seedling treatment and foliar application of cytozyme on growth and yield of tomato, brinjal and chilli. *Haryana Agric. Univ. J. Res.*, 15(3): 329-335.

*Hou, E.F. 1978. Grain yield and growth behaviour affected by seedling age and plant spacing. *Bull. Taichung Dist. Agril. Improv. Stn.*, 2: 32-39.

Ibrahim, A.A., E.M. Zeidan, A.A. Assey and A.E. Badawy, 1980. Growth and hill yield of rice crop as influenced by nitrogen fertilizers hill spacing and time of harvest *Ann. Agric. Sci.*, 12: 63-78.

Iwaki, S., 1956. Studies on the salt injury in rice plant. *Mem. thine univ. seet. VI-Arl.*, 2: 1: 156.

Jerlin, R., 1990. Studies on seed yield and quality of rice and *Echinochloa crus-galli* as influenced by crop-weed interference. M.Sc (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Jones, M.P., 1980. A methods for rapid evaluation of salt tolerance of rice varieties and breeding lines. **WARDA Tech. Newsl.**, 2: 19-20.

Jones, E., J. Divine and C. Gersdorff, 1942. The effect of storage of corn on the chemical properties of its proteins and on its growth promoting value. **Cereal chem.**, 19: 819.

Joon R.K. and O.P. Singh, 1989. Effect of time of transplanting and age of seedling on growth and yield of dwarf rice. **Indian J. Agron.**, 34(3): 325-327.

*Juliano, B.O., Perez, C.M. and T.T. Chang, 1990. Varietal differences in longevity of tropical rough rice stored under ambient conditions. **Seed Sci. and Technol.**, 18: 361-69.

*Justice, O.L., and L.N. Bass. 1978. Principles and practices of seed storage. **Agricultural Hand book no. 506.** U.S. Government Printing Office, Washington.

Kameswararao, N., Apparao, M.H. Mengesha and R.H. Ellis, 1991. Longevity of pearl millet (*Pennisetum glaucum*) seeds harvested at different stages of maturity. **Ann. Appl. Biol.**, 119: 97-103.

Kanade, N.M. and G.S. Kalra, 1986. Response of Mashuri variety of rice to different levels of plant spacings and nitrogen fertilization. **Seeds and Farms.**, 12(7): 25-26.

Kanungo, A.P. and P.K. Roul, 1994. Response of transplanted summer rice genotypes to varying levels of fertility and plant density. **Indian J. Agron.**, 39(2): 216-219. ✓

Karivaratharaju, T.V. and V. Ramakrishnan, 1985. Seed hardening studies in two varieties of Ragi (*Eleusine coracana* Gaerth). **Indian J. Pl. Physiol.**, 28(3): 243-248.

Karivaratharaju, T.V., R. Vaithialingam, and J. Saktharam Rao, 1973. Effect of water stress and Hardening of seeds on certain physiological aspects in bajra. **Madras Agric. J.**, 60(9-12): 1266-1272.

Karivaratharaju, T.V., V. Palanisamy, and K. Kumaresan. 1987. Effect of seed treatment and containers on the storability of brinjal seed. **Seed Res.**, 52(2): 169-171. ✓

- Kaul, J.N., S.S. Cheema and D.S. Bains, 1972. Effects of missing irrigation at silking and grain development stages on composite maize (Vijay) grown under varying nitrogen levels. *Indian J. Agron.*, 17: 133-135.
- Kaushik, S.K. and R.C., Gautam, 1984. Effect of varying dates of planting and row spacing on yield of peral millet varieties under rainfed conditions. *Indian J. Agron.*, 29(4): 480-484.
- Kearns, V. and E.H. Toole, 1939. Relation of temperature and moisture content to longevity of chewing sescue seed. *U.S. Dept. Agric. Tech. Bull.*, 670.
- *Kharlukhi, L. 1983. Physiological and Biochemical changes in seeds during storage under controlled condition. Ph.D. Thesis, IARI, New Delhi.
- Khisbuchi, K. 1981. Variety x environment interactions in rice under direct sowing conditions and their implications in breeding. *J. of the central Agrl. Expt. Stn.*, 35: 1-50.
- Koostra, P.J. and J.F. Harrington. 1969. Biochemical effects of age on membranal lipids of *Cucumiss satilvus* L. *Seed Proc. Int. Seed Test. Ass.*, 34: 329-340.
- Krishnamurthy, K. 1978. A manual on compost and their organic manures, To-day and Tomorrow printers and publisher, New Delhi. p. 157.
- Krishnamoorthy, R, M. Anbazhagan and K.A. Bhagwat. 1987. Effect of NaCl on the inorganic ions, growth and yield of rice. *Oryza*, 24: 66-69.
- Krishnaswamy, V. and K.R. Ramaswamy, 1984. Seed quality in CSH 5 hybrid sorghum as influenced by the spacing of mother plant. *Madras agric. J.*, 71(9): 595-598.
- Krishnasamy, V. and D.V. Seshu, 1989. Seed germination rate and associated characters in rice. *Crop Sci.*, 29(4): 904-908.
- Krishnasamy, V. and D.V. Seshu, 1990. Germination after accelerated ageing and associated characteristics in rice varieties. *Seed Sci. and Technol.*, 18: 147-156.
- Krishnaveni, 1984. Studies on certain aspects of production, processing and storage of sorghum seed. M.Sc. (Ag.) Thesis, Tamil Nadu Agrl. University, Coimbatore.

- Krishnaveni, K. and K.R. Ramaswamy, 1985. Influence of spacing on yield and quality of COH 1 hybrid maize seed. *Madras agric. J.*, 72(8): 432-435.
- Kudo, K. 1975. The effect of climatic factors on grain yield of rice. In. Murata, Y. Ed. crop productivity and solar energy utilization in various climates in Japan. Univ. of Tokyo Press. Tokyo.
- Kulkarni, N. and K.B. Eswari, 1994. Genotypes x environment interaction of varieties to age of seedling in rice. *Oryza*, 31: 88-92.
- Kundu, C. and R.N. Basu, 1981. Hydration-dehydration treatment of stored carrot seed for the maintenance of vigour, viability and productivity. *Sci. Hort.*, 15: 117-125.
- Kundu, D.K., K.V. Rao and K.G. Pillai, 1993. Comparative yields and N uptake in six transplanted and direct seeded lowland rices. *Int. Rice Res. Newsl.*, 18(3): 29-30.
- Kurmi, K., R.K.S.M. Baruah, and G.R. Das, 1993. Effect of seedling age on grain yield and yield components of ahu rice. *Oryza*, 30: 136-138.
- Liou, T.M. 1987. Effect of spacing and fertilizer levels on changes of ear type in rice. *J. Agrl. Assoc., China.*, 140: 1-10. ✓
- Lugo, B.I. and Carl A. Leopold. 1992. Changes in soluble carbohydrates during seed storage. *PI. Physiol.*, 98: 1207-1210.
- Macalinga, V.M. and R.A. Obordo, 1970. *Rice Prodn. Manual*, University of Philippines coll. Agric. Los Banos, Laguna, Philippines. 357 pp.
- Malabuyoc, J.A., J.G. Real and S.K. DeDatta, 1993. Grain yield as a function of rainfall, soil moisture and solar radiation in upland rice. *Field Crops Res.*, 34: 37-45.
- Mallick, A.K. and B. Nandi. 1979. Role of moisture content in deterioration of rough rice in storage. *Seed Sci and Technol.*, 7(3): 423-429.
- Mandal, B.K., T.R. Sainik and P.K. Ray, 1984. Effect of age of seedling and level of nitrogen on productivity of rice. *Oryza*, 21: 225-232.

Mannan, M.A. and S.B. Siddique, 1990. Effect of seedling age on growth and yield of T. aman rice. Int. Rice Res. Newsl., 15(5): 18.

Manonmani, V., 1990. Certain aspects of seed production and storage in rice seeds. M.Sc. (Ag.) Thesis, Tamil Nadu Agri. University, Coimbatore. ✓

Marnaville, J.H. and Max D. Clegg. 1977. Influence of seed size and density on germination, seedling emergence and yield of grain sorghum. Agron. J., 69: 329-330.

Massodali, 1976. Response of spring planted maize to irrigation and nitrogen rates. Indian J. Agron., 21: 298-300.

Mathews, S. and W.T. Bradnock. 1968. Relationship between seed exudation and field emergence in peas and french beans. Hort. Res., 8: 89-93.

*Mazzini, F. DE., E. Bonandin, G.C. Fantone and G. Fossati, 1981. Rice Storage. 2. Relationship between some physical and biochemical variables. Riso., 29(1): 69-78.

Mehta, P.M. and B.V. Patel. 1990. Effect of storage periods and temperatures on micronutrient content and germination in jowar (*Sorghum vulgare* L. J-35) seeds. Adv. Pl. Sci., 3(2): 228-235.

Mengel, D.B., F.E. Wilson, J.E. Sedberry, and F.J. Peterson, 1979. Seed treatment to overcome zinc deficiency in direct seeded rice, Int. Rice. Res. Newsl., 4(1): 18-19.

*Merrin, A., A. Quinsac and C. Maisonneuve, 1988. Variability de la teneur en proteines des graines de tournesol en relation avec l'et al proteique foliaire pp. 158-169. In: Proc. of the 12th Interl. sunflower conf. Novi-sad, Yugoslavia, 25-29, July 1988.

Mishusting, E.N. and V.K. Shilnikova, 1973. In: Biological fixation of Atmospheric nitrogen. Macmillan, pp. 196.

Misra, P.N. 1976. Effect of some organic and inorganic soil amendment with and without NPK fertilisation on paddy yield on saline-sodic soils. Ind. J. Agric. Res., 10: 253-257.

Mitra, R. and R.N. Basu, 1979. Seed treatment for viability, vigour and productivity of tomato. Sci. Hort., 11: 365-369.

Mirta, S., B. Ghose and S.m. Sircar, 1974. Physiological changes in rice seeds during loss of viability. *Indn. J. Agric. Sci.*, 44(11): 744-751.

Mitra, A.K., A. Roy and S.K.B. Roy, 1992. Rice varieties direct seeded in puddled soil during boro season in West Bengal. *Int. Rice Res. Newsl.*, 17(1): 8.

Mohammad, Ay-ub. M.S. Sharar and M.S. Nazir, 1987. The yield and yield components of fine rice as influenced by different spacings. *Pakistan. J. Scientific and Ind. Res.*, 30(7): 523-525.

Mohapatra, A.K., P.C. Kar, and A.K. Sarkar, 1990. Effect of age of seedlings and fertilisation on late transplanted rice. *Oryza*, 27: 491-492.

Mukhtar, N.O. and D.L. Laidman, 1982. Mineral ion contents, solute release and aspects of ion transport in embryos from germinating low and high vigour wheat (*Triticum aestivum*). *J. Expt. Bot.*, 33(135): 619-630.

Mullat, H.J. 1979. The relationship between seed size total seed electrolytes leakage and embryo growth of *phaseolus vulgaris*. *Aust Seed Sci News letter.*, 5: 60-64.

Munda, G.C., M. Pal and S.L. Pandey, 1983. Effect of N and P on the yield, quality and yield attributing characters of pearl millet. *Indian J. Agron.*, 28(4): 332-338.

Munns, R. and A. Termaat, 1986. Whole - plant responses to salinity. *Aust. J. Plant Physiol.*, 13: 143-160. ✓

Murata, Y. 1976. Productivity of rice in different climatic regions of Japan. In climatic and Rice Int. *Rice Res.*, Inst., Los Banos, Laguna, Phillippines.

Murthy, K.S. and G. Sahu, 1979. Effect of age of seedlings at normal transplanting on growth and yield of rice varieties. *Indian J. Agric. Sci.*, 49: 797-801.

Murugesan, N.V., C.P. Thiagaranan and K.K. Lakshmanan, 1989. Viability in rice seed vigour after storage. *Intl. Rice Res. Newsl.*, 14(1): 18.

Nagarajan, K. and T.V. Karivaratharaju, 1983. Protein content as an index of seed viability in sorghum. Proc. National Seminar on research perspectives on seed storage. Tamil Nadu Agril. Univ., Coimbatore, India. pp. 97-99.

- Nandhisa, B.S. and Mahadevappa, 1984. Influence of mother plant nutrition and spacing on planting value of rice seeds. (*Oryza sativa* L.) *Seed Res.*, 12(2): 25-32.
- Naphade, K.T. and B.N. and Sagare, 1983. Influence of seed treatment, storage material and duration of storage on germinability, oil content of sunflower. *Seed PKV Res.*, J. 7(2): 6-11.
- Narasimhareddy, C., S.R.V. Reddy, V. Raja and V. Munaswamy, 1988. Response of some new maize germplasm to nitrogen levels. *Haryana. J. Agron.*, 4(2): 69-73.
- Narayanasamy, R., Sp. Palaniappan and V. Veerabadran, 1991. Effect of irrigation regimes and seed treatment on dry seeded irrigated short duration Kharif rice (Kuruvai) in Thanjavur delta. *Madras Agric. J.* 78(9-12): 398-402.
- Nayak, R.L., A. Sarkar, and R. Naskar, 1994. Response of late planted wet season rice to age of seedlings. *Indian J. Agron.*, 39(2): 294-296.
- Neergaard, P. 1977. In: *Seed pathology* - McMillan Pvt. Ltd. England.
- Odiemah, M. 1987. Germinability and vigour of wheat seed compartment at different periods of storage. *Acta Agrono. Hungarica*, 36(4): 303-308.
- Osada, A., 1964. Studies on the photosynthesis of indica rice. *Proc. Crop Sci. Soc., Japan*, 33: 69-76.
- Osada, A. 1966. Relationship between photosynthetic activity and dry matter production in rice varieties, especially as influenced by nitrogen supply. *Bull. Nat. Inst. Agrl. Sci., Japan Ser. D.*, 14: 117-118.
- Osada, A. and Y. Murata, 1962. Studies on the relationship between photosynthesis and varietal adaptability for heavy manuring in rice Plant. *Proc. Crop. Sci. Soc. HJap.* 30: 220-225.
- Osada, A., S. Dhammanuvong, M. Rahong, and W. Chawanayotin, 1975. Premature heading of non-photosensitive indica rice varieties by long nursery duration. *Jap. J. Trop. Agric.*, 19: 15-20.
- Oster, J.D. 1992. Gypsum use in irrigated agriculture a review. *Fert. Res.*, 3: 73-89.
- Padmajarao, S. 1987. Relationship of agro-climatic parameters to high grain production. *Int. Rice Res. Newsl.*, 12(12): 13-141.

Padmajarao, S. 1988. Production trends of high density grain as influenced by nitrogen, season, crop canopy and duration of low land irrigated paddy. *Oryza*, 25: 47-51.

Padmajarao, S. 1989. Influence of population pressures and nitrogen on the production of high density grain in rice. *Indian J. Plant Physiol.*, 32: 4-8.

/ Padmajarao, S. 1990. Influence of date of planting on high density grain in rice. *Oryza*, 27: 101-103. | ✓

Pal, P. and R.N. Basu, 1988. Treatment of rice seed with iodine and chlorine for the maintenance of vigour, viability and productivity. *Indian Agric.*, 32(1): 71-75.

Palaniappan, Sp., K. Siddeswaran and K. Natarajan, 1992. Management of sodic soils-Tamil Nadu experience. Paper presented in the National conference and workshop on sodic soils, Nov. 9-12, held at the University of Adelaide, Waite campus, Adelaide, Australia.

Panda, S.C., Deuwrack and I.C. Mahapatra, 1974. Performance of hybrid and composite varieties of maize under sambalpur condition. *Indian J. Agron.*, 19(1): 14-17.

Pandita, M.L., R.S. Hooda and A.S. Sidhu, 1983. Effect of seed treatment and foliar application of cytozyme on growth and green pod yield of Okra. *Haryana Agric. Univ. J. Res.*, 13(2): 245-248.

/ Panse, V.G. and P.V. Sukhatme. 1985. Statistical methods for Agricultural Workers, ICAR Publications, New Delhi.

Paramasivam, P., Rani Perumal, A. Gopalswamy and S. Subramaniam, 1990. Effect of ameliorants on yield, uptake of nutrients and quality of rice under sodic soils. *Andra Agric. J.*, 37(40): 357-362.

Parida, R.C. and G.N. Mitra, 1989. Effect of genotypes and environment on grain quality in rice. *Orissa J. Agric. Res.*, 2(1): 74-77.

/ Parkinson, A.H., 1948. Seed age and storage affect cucumber growth. *Food Res.*, 14: 7.

Pattee, H.E., J.A. Singleton and W.Y. Cobb, 1969. Volatile components of raw peanuts. Analysis by gas liquid chromatography and mass spectrometry. *Journal of Food Sci.*, 34: 625-627.

- Paul, S.R. and K.R. Ramasamy. 1979. Relationship between seed size and seed quality attributes in cowpea. *Seed Res.*, 7: 63-70.
- Pearson, G.A., 1961. The salt tolerance of rice. *IRC. Newsl.*, 10: 1-4.
- Peeran, S.N. and S. Natanasabathy (1980). Potassium chloride pre treatment on rice seeds. *Int. Rice. Res. Newsl.*, 5(4): 19.
- Peltonen-sainio, P. and P. Jarvinen, 1995. Seedling rate effects on tillering, grain yield and yield components of oat at high latitude. *Field Crops Res.*, 40: 49-56.
- Perl, M., I. Luria and H. Gelmond, 1978. Biochemical changes insorghum seeds affected by accelerated ageing. *J. Expt. Bot.*, 29(109): 497-509.
- Perry, D.a., 1978. Seed vigour and establishment. *Seed Sci. and Technol.*, 6: 159.
- Petibskaya, V.S., 1984. *Vestn. S-kh. Nauki (Moscow)*, 10: 54-58.
- Petruzzelli, L. and G. Toranto, 1990. Amylase activity and loss of viability in wheat. *Ann. Bot.*, 66: 375-378.
- Pogosov, O.K. 1962. Pre sowing treatment of tomato seeds. In: *Physiological Basis of Seed Germination* (Ed. Ovacharov) Amerind. Pub. Co. Pvt. Ltd., India.
- Pollock, B.M. and E.E. Roos. 1972. Seed and seedling vigour. pp. 313-387. In: *Seed Biology -I.* (Ed. T.T. Kozlowski), Academic press, New York. pp. 313-387.
- Ponnamperuma, F.N. 1972. The chemistry of submerged soils. *Adv. Agron.*, 24: 29-96.
- Ponnamperuma., F.N. 1978. Electrochemical changes in submerged soils and the growth of rice. *International Rice Research Inst., Soils and Rice.* Los Banos, Philippines, pp. 421-441.
- Poongothai, S. 1989. Seed treatment for sowing and storing of paddy seeds. M.Sc. (Ag.) Thesis, Tamil Nadu Agrl. Univ., Coimbatore.
- Pothiraj, P., Y. B. Morachan and K.K. Subbiah, 1977. Effect of planting pattern on yield of rice. *Madras agric. J.*, 64(7): 427-429.

Powell, A.A. and S. Matthews, 1977. The deterioration of pea seeds in humid or dry storage. *J. Expt. Bot.*, 29: 1215-1229.

Prasad, P., Ashok Kumar and U.K. Prasad, 1994. Effect of irrigation and nitrogen on yield of medium duration direct seeded rice. *Indian J. Agron.*, 39(2): 294-296.

Presley, J.T. 1958. Relation of protoplast permeability to cotton seed viability and predisposition to seedling disease, *Pl. Dis. Repter.*, 42: 842.

Priestley, D.A., 1986. Chapter 3, loss of seed viability in storage. In: seed ageing cornell university press. Bhaca, London. pp. 39: 75.

Purkar, J.K., R.B. Mehra and S.K. Banerjee, 1981. Quantitative genetical changes in wheat induced through seed ageing. *Seed Res.*, 9: 172-187.

Puthaswamygowda, B.S., Wallihan, and P.F. Pratt, 1973. Effect of drainage and organic amendments on the reclamation of a sodic soil cropped with rice. *Soil Sci. Soc. Ann. Proc.*, 37: 621.

Qadar, A. 1990. Effect of seedling age of two rice varieties on their sodicity tolerance. *Indian J. Pl. Physiol.*, 33: 162-164.

Rajendran, P. 1991. Management of semi dry rice in Thanjavur delta. *Madras agric. J.*, 78 (9-12) 529-531.

Rajkumar, R., A. Room Singh, Shivarant, S.K. Pandey and S. Kumar, 1991. Effect of different soil amendments on chemical changes and yield of rice in salt affected soils. *Ind. J. Agrl. Sci.*, 61(2): 139-142.

Ram, C. and L.E. Wiesner. 1988. Effect of artificial ageing on physiological and biochemical parameters of seed quality in wheat. *Seed Sci. and Technol.*, 16: 579-587.

Ramachandran, K., A.B. Raybhowmik and T.K. Janabandhu, 1980. Cotton farming in India, cotton Dev., 9(4): 19-36. Improved techniques.

Ramamoorthy, K. and T.V. Karivaratharaju, 1989. Effect of accelerated ageing on viability and vigour of seeds of tomato (PKM-1). *Ann. Pl. Physiol.*, 3(2): 116-121.

Ramamoorthy, K., P. Srimathi and Syed Nazir Prem, 1990. Effect of growth regulators on seed quality and storability of rice. *Oryza*, 27: 248-250.

- Ramamoorthy, K., M. Thanakodi, P. Srimathi and D. Kalavathi, 1993. Yield and seed quality studies of dry seeded rice ADT 36 in relation to irrigation regimes. *Madras agric. J.*, 80(1): 621-625.
- Ramanathan, P. 1980. Effect of seed treatment, nursery manuring and method of phosphorus application on yield components of rice. *Indian J. Pl. Physiol.*, 26: 126-132.
- Ramegowda, 1992. Studies on seed senescence and seed vigour in some genotypes of rice. Ph.D. Thesis, Tamil Nadu Agril. University, Coimbatore.
- Rani, S.K. 1988. Studies on seed treatment for sowing and storing of seed in tomato (*Lycopersicon esculentum* Mill). cv. Co 1. M.Sc. (Ag.) Thesis, Tamil Nadu Agril. Univ., Coimbatore.
- Rao, C.P. and M.S. Raju, 1987. Effect of age of seedling, nitrogen and spacing on rice. *Indian J. Agron.*, 32: 100-102.
- Rao, B.K., A.B. Prasad and A.V.S. Rao, 1980. Heritability and correlation in rice. *Oryza*, 17: 194-199.
- Rao, V.P.P., P.N. Rao and S.C. Verma, 1985. Response of rice variety sacket 4 to seed treatment and seed bed and main field manuring. *Oryza*, 22(2): 113-119.
- Rao, A.V., N.K. Mahana, K.M. Sahoo and M.N. Sahay, 1993. Post harvest losses of some paddy varieties during farmers operations. *Oryza*, 30: 150-153.
- Rao, A.V., N.K. Mahana, K.M. Sahoo and M.N. Sahay, 1993. Post harvest losses of some paddy varieties during farmers operations. *Oryza*, 30: 150-153.
- Ravi, N. 1985. Genotypes regulation of storage and viability potential in bajra (*pennisetum americanum* L. Leeke). M.Sc. Thesis. Tamil Nadu Agric. University, Coimbatore.
- Ravinder, S., M. Yadav, M. Dadlani and P.K. Agrawal, 1986. Loss of seed vigour in two pearl millet hybrids and their parents under controlled conditions of storage. *Seeds of Farms*, 10(9): 23-25.
- Ray, M.B. and K. Gupta, 1979. Effect of accelerated ageing on germination, vigour and membrane permeability of different varieties of rice seeds. *Indn. agric.*, 23: 225-233.

Ray, M.B. and K. Gupta, 1979 a. Effect of storage of rice seeds on solute leaching and nucleic acid synthesis. *Indn. J. Agric. Sci.*, 49(9): 715-719.

Ray, M.B. and K. Gupta. 1980. Effect of storage of early and late varieties of rice seeds in different RH on viability, leaching and dehydrogenase activity. *Seed Tech News*, 10: 10.

Ray, M.B., S. Halder and K. Gupta, 1990. Differential responses of early and late cultivars of rice seeds under accelerated ageing. *Seed Sci. and Technol.*, 18: 823-831.

Reddy, K. and B. Reddy, 1992. Effect of time of planting, spacing and age of seedlings on flowering and duration of Surekha rice. *Oryza*, 29: 157-159.

Reddy, P.S., G.V. Reddy, and M. Gopinath, 1987. Effect of seedling age and nitrogen on growth and yield of Kothamolagolukulu rice. *Oryza*, 24: 174-176.

Reddy, S. Narayana Reddy and P. Narayana, 1984. Pattern of dry matter accumulation and N-uptake by rice as influenced by age of seedlings and data of planting. *Andhra Agri. J.*, 31(2): 155-156.

Rengasamy, M. 1995. Hybrid rice: present status in Tamil Nadu and India. *Madras agric. J.*, 82(3): 209-211.

Ries, S.K. and E.H. Everson, 1973. Protein content and seed size relationship with seedling vigour of wheat cultivars. *Agron. J.*, 65: 884-886.

Roberts, E.H., 1972. Loss of viability and crop yields. In: "Viability of seeds" (ed. E.H. Roberts). p. 313, Chapman and Hall Ltd., London.

Roberts, E.H., 1973. Loss of seed viability: Ultrastructural and physiological aspects. *Seed Sci. and Technol.*, 1: 529-545.

Roberts, E.H., 1979. Seed deterioration and loss of viability. In: *Advances in research and Technology of seeds*. part 4, 25-42.

Roberts, B.E., P.I. Payne and D.J. Osborne, 1973. Loss of activity of protein synthesising systems in vitro associated with a loss of viability. *Biochem. J.*, 131: 275-286.

- Rosell, E. Martiny and M. Lopetegir, 1988. Study of preparation of tomato seeds for direct sowing centro Agrícola, 1987; 14(1): 68-76. Seed Abstr., 1988; 11(2): 435.
- Rudha, A.L. and A.H. Younis. 1978. The effect of row spacings and nitrogen levels on yield and yield components and quality of maize (*Zea mays* L.). Seed Abstr., 4: 2.
- Sabirahamed, A., 1989. Studies on the production of quality seed and storage in soybean (*Glycinema L. Merrill*) M.Sc. (Ag.) Thesis, Tamil Nadu Agrl. Univ., Coimbatore.
- Sahoo, P., A.K. Pradhan and D.K. Sahoo. 1983. Effect of sowing dates of wheat seed crops on seed weight and maintenance of viability and vigour of seeds in storage. paper presented in the National Seminar on Seed Technology held at college of agriculture Univ.
- Sahu, B.N. and D. Lanka, 1955. Cultural cum materials trials on paddy. Indian J. Agron., 11(2): 127-137.
- Sahu, R.K. and V.N. Sahu, 1981. Mode of grain shattering in rice. Int. Rice Res. Newsl., 6(1): 6.
- Sakoo, P., A. K. Pradhan and D.k. Sakoo, 1983. Effects of sowing dates of wheat seed crops on seed weight and maintenance of viability and vigour of seeds in storage. Paper presented in the National Seminar on seed technology held at college of Agrl. and Res. Inst., Coimbatore on 7th and 8th April, 1983. ✓
- Sankarreddy, G.H., T. Bapi Reddy and R. Sudhakararao, 1983. Effect of cytozyme on rice, groundnut and/groundgram. Seeds and Farms, 6: 19-20.
- Saraswathy, A. 1987. Seed storage studies in paddy. M.Sc. (Ag.) Thesis, Tamil Nadu Agricultural University, Coimbatore.
- Sardana, S. and D.N. Borthakur, 1987. Combining ability for yield in rice. Oryza, 24: 14-18.
- Sastry, K.S.K., S. Rama Rao and K.M. Appaiah, 1969. Effect of pretreatment of seeds of *Eleusine coracana* on tolerance to high concentrations of sodium chloride and mannitol solutions. Mysore J. Agric. Sci., 3: 47-54.
- Savant, N.K., G. Carmona and E.R. Austin, 1994. Effect of plant density on methane emission from transplanted rice. Int. Rice. Res. Newsl., Philippines 19(4): 24.

- Savino, G., P.M. Haigh and P. De Leo, 1979. Effects of pre soaking upon seed vigour and viability during storage. *Seed Sci. and Technol.*, 7: 57-64.
- Saxena, O.P., 1976. Peroxidase as the basis of rapid viability determination in sorghum. *Sorghum News letter*, 19: 29.
- Saxena, O.P., T. Pakeeraiah and P. Lakshmi, 1985. Studies on accelerated ageing in sesamum. *Indn. J. Pl. Physiol.*, 28: 35-42.
- Schnier, H.F., M. Dingkuhn, S.K. DeDatta, K. Mengel and J.E. Faronilo, 1990. Response of direct seeded and transplanted flooded rice to nitrogen fertilizer application. I. plant nitrogen uptake, canopy photosynthesis, growth and yield. *Crop Sci.*, 30: 1276-1284.
- Schnier, H.F., M. Dingkuhn, S.K. DeDatta, K. Mengel, E. Wijangco, and C. Javellana, 1990 a. Nitrogen economy and canopy CO_2 assimilation in tropical lowland rice. *Agron. J.*, 82: 451-459.
- Sedberry, J.E. J.R. Stevens and J.C. Mengel, 1979. The effect of seed treated with zinc on the yield of vista rice grown on crowley silt loam. *Seed Abstr.*, 1979 2(1): 30-31, 268.
- Sekar, N., 1980. Seed storage studies in paddy cultivars (*Oryza sativa* L.). M.Sc. (Agri) Thesis, Tamil Nadu Agril. Univ., Coimbatore, India.
- Selvaraj, R. 1990. Influence of irrigation scheduling, irrigation methods and nitrogen levels on maize (*Zea mays* L.). M.Sc. (Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore, (unpublished).
- Selvaraj, S. 1983. Seed viability and storage studies on sorghum *Sorghum bicolor* (L.) Moench). M.Sc. (Ag.) Thesis. Tamil Nadu Agri. Univ., Coimbatore. ✓
- Selvaraju, P. 1986. Studies on certain aspects of production, grading, treating and storage of seed in Marigold (*Tagetes erecta* L.) M.Sc. (Ag.) Thesis, Tamil Nadu Agri. Univ. Coimbatore.
- Sen, S. and Osborne, D.J. 1974. Germination of rye embryos following hydration-dehydration treatments-Enhancement of protein and RNA synthesis and earlier induction of DNA replication. *J. Exp. Bot.* 25: 1010-1019.

Seshu, D.V. and M. Dadlani, 1990. Seed vigour in rice. Its assessment and impact on crop performance. Abstr. Intl. Conf. Seed Sci. and Technol., ISST, New Delhi, India. p. 87.

Seshu, D.V., V. Krishnasamy and S.B. Siddique, 1990. Seed vigour in rice. In: "Rice seed health". IRRI publication. pp. 315-329.

Shad, R.A. and S.K. DeDatta, 1986. Evaluation of methods of crop establishment in wetland rice. *Pakistan J. Agric. Res.*, 7: 186-192.

Shahi, H.N., P.S. Gill and G.S. Khind, 1976. Effect of number of seedlings per hill and spacing on growth and yield of rice. *Indian J. Agron.*, 21(4): 392-395.

Shahu, G., CH.N. Rao and K.S. Murthy, 1989. Solar energy utilisation by modern rice varieties. *Oryza*, 26: 381-385.

Shands, H.L., D.C. Janisch and A.O. Dickson, 1967. Germination response of barley following different harvesting conditions and storage treatments. *Crop Sci.*, 7: 444-446.

Sharma, S.R., 1986. Effect of plant growth stimulants on productivity of soybean. In: Crop productivity, oxford and IBH Publn. Co. Pvt. Ltd., pp. 179-185.

Sharma, J.K., H.B. Singh and G.S. Sethi, 1990. Analysis of seed and seedlings characteristics of rice in the hills. *Seed Res.*, 18(2): 135-138.

Sharma, S.K., S.V. Subbaiah, and K. Krishnamurthy, 1995. Nitrogen sources and application methods for direct sown rice under rainfed lowland conditions. *Oryza*, 32: 71-72.

Shelar, V.R. and D.R. Bapat, 1991. Effect of storage conditions on viability and vigour in sorghum. *Ann. PI. Physiol.*, 5(2): 176-182.

Shenoy, V.V., M. Dadlani and D.V. Seshu, 1990. Association of laboratory assessed parameters with field emergence in rice. The nonanoic acid stress as a seed vigour test. *Seed Res.*, 18(1): 60-64.

Shetty, K.S. 1975. Reclamation of saline-alkaline soils with gypsum, pressmud and zinc sulphate. *Ind. J. Agric. chem.*, 8: 253-256.

- Sheudzhen, A.K.H. and V.T. Rymar, 1987. Efficiency of different copper compounds applied to rice, soybeans and wheat. *Seed Sci. and Technol.*, 9: 697-705.
- Shirwal, S. and Despande, 1977 : p. 164: In *adv. In Agron.*, 45.
- Shukla, S.C. and M. Wassay, 1970. Influence of time and methods of nitrogen application on protein content in grain of hybrid maize. *Madras Agric. J.*, 57: 387-389.
- Shusilkumar and N.C. Singhal, 1991. Effect of accelerated ageing on parents and their crossed seeds in pea (*pinus Sativum L.*) *Seed Res.*, 19(1): 51-53.
- Siddique, E.A. 1993. Rice production strategy for the 21st century. *Oryza*, 30: 186-196.
- Sikder, H.P., 1988. Varietal differences in seed longevity. *Intl. Rice Res. Newsl.*, 13(4): 21.
- Simon, E.W., 1974. Phospholipids and plant membrane permeability. *New Phytol.*, 73: 377-420.
- Simpson, G.M. and J.M. Naylor, 1962. Dormancy studies in seeds of *Avena fatua*. 3. A relationship between maltase, amylases and gibberellins. *Canadian J. Bot.*, 40: 1659-1673.
- Singh, K.N. and D.K. Sharma, 1984. Effect of nitrogen on rice. *Int. Rice Res. Newsl.*, 12: 6.
- Singh, G.B. 1987. Nitrogen management for rice-wheat sequence. *Indian J. Agron.*, 32: 387-391.
- Singh, A.R. 1988. Storability of sorghum seed as influenced by genotype and weight on germination and seedling growth in bold seeded genotypes of sorghum. *Res. Bull. Marathwada Agric. Univ.*, 6: 23-25.
- Singh, A.R. and S.T. Borikar, 1990. Studies on seed development and physiological maturity in parents of sorghum hybrids. *J. Maharashtra Agric. Univ.*, 15(1): 15-17.
- Singh, A.I. and B.N. Chatterjee, 1990. Effect of seed treatment and fertilization on upland rice production. *Indian J. Agron.*, 25: 479-486.
- Singh, S.N. and B. Choudhury, 1966. Effect of various maize stored at different kernel moisture and in different containers. *Indian Agril.*, 12(1): 71-73.

Singh, K.N. and D.K. Sharma, 1993. Effect of seedling age and nitrogen levels on yield of rice on a sodic soil. *Field Crops Res.*, 31: 309-319.

Singh, J., O.P. Govila and P.K. Agrawal, 1988. Preliminary results from a study of seed germinability of pearl millet (*Pennisetum typhoides* L.) F1 hybrids and their parents during accelerated ageing test. *Seed Sci. and Technol.*, 16: 685-692.

Singh, G., N. Sekhon and M. Kaur, 1978. Effect of cytozyme on the yield and some quality characters of groundnut. *Punjab Agril. Univ. J. Res.*, 15: 412-415.

Singh, N.T. 1984. Green manures as sources of nutrients in rice production. *International Rice Research Inst., Organic matter and Rice*. Los Banos, Philippines, pp. 217-28.

Singh, R.P., R.R. Singh, S.P. Singh and R.V. Singh, 1980. Estimation of genetic component of variation in rice. *Oryza*, 17: 24-27.

Singh, S.P., K.G. Pillai, D. Pati and N. Shobha Rani, 1993. Influence of time of planting on grain yield and quality of dwarf scented rice varieties. *Oryza*, 30: 285-288.

Singh, T., R.P.S. Tyagi and G.K. Garish, 1983. Post harvest system of rice in India. A review. *Bull. Grain Tech.*, 21: 149-159.

Sinha, V.K., M.L. Nagar and S.K. Chauhan, 1979. Storage rotting micro organisms and physico chemical studies of gram (*Cicer arictinum* L.) seeds. *J. Indian Bot. Soc.*, 58(1): 94-97.

*Sircar, S.M., 1970. The physiology of ageing in rice seeds. *J. Indn. Bot. Soc.*, 49: 1-7.

Sircar, S.M. and B. Dey, 1967. Germination In: *Proc. Int. Synp. Physiol Ecol. Biochem.* (Ed. H. Bonis), pp. 969-973. Emtz - Moritz - Arndt - Universitat, Greifswald.

Sircar, S.M. and M. Biswas, 1960. Viability and germination inhibitor in rice seed. *Nature, Lond.* 187: 620-621.

Somogyi, M. 1952. Note on sugar determination *J. Biol. Chem.*, 195: 19-23.

Srinivasalureddy, 1983. Integrated nitrogen management in rice based cropping system. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

- Srinivasan, P.S. and K.M. Naidu, 1986. Effect of zinc on electrical conductivity, endosperm weight, germination and vigour of three rices. *Int. Rice. Res. Newsl.*, 11(2): 16-17.
- Srinivasalureddy, D. 1979. Effect of nitrogen and plant population on yield and yield components of Jaya rice under recommended irrigation practice. *Madras Agric. J.*, 73(6): 321-324.
- Sung, J.M., 1981. Effects of sodium chloride salinity on germination of barley cultivars. *J. Agric. Assn. China.*, No. 113: 41-47.
- Sur, K. and R.N. Basu, 1986. Control of age and irradiation induced seed deterioration in rice (*Oryza sativa* L.) by hydration-dehydration treatments. *Seed Res.*, 14(2): 205-211.
- Suzuki, S. 1981. Cold tolerance in rice plants with special reference to the floral characters. 1. varietal differences in anther and stigma length and the effects of platinum densities on these characters. *Jpn. J. Breeding*, 31(1): 57-67.
- Swamy, N.R. and P.S.S. Murthy, 1993. Performance rice cultivars under direct sown rainfed conditions. *Oryza*, 30: 323-326.
- Swan, Z.M., M.S. Maddaheldin and B.R. Gregg, 1993. Cotton seed yield, viability and seedling vigour as affected by plant density, growth retardants, copper and manganese. *Seed Sci. and Technol.*, 21: 417-431.
- Swarup, A. 1981. Effect of flooding in physico-chemical changes in sodic soils. *Z. Pflanzenernahr Bodenkd*, 144: 136-142.
- Swarup, A. 1985a. Effect of exchangeable sodium percentage and pre-submergence on yield and nutrition of rice under field conditions. *Pl. and soil.*, 85: 279-288.
- Swarup, A. 1985b. Yield and nutrition of rice as influenced by pre submergence and amendments in a highly sodic soil. *J. Ind. Soc. Soil Sci.*, 33: 352-357.
- Swarup, A. 1987. Effect of pre-submergence and green manuring (*sesbania aculeata*) on nutrition and yield of wetland rice (*Oryza sativa* L.) on a sodic soil. *Biol. Fertil. Soils.*, 5: 203-208.

Swarup, A. and K.N. Singh, 1989. Effect of 12 years rice wheat cropping sequences and fertilize use on soil properties and crop yields in a sodic soil. *Field Crops Res.*, 21: 277-287.

Swarup, A. and K.N. Singh, 1994. Effects of gypsum, farmyard manure and N on ameliorating highly sodic soil and on yields of rice and wheat. *Int. Rice Res. Newsl.*, 19(3): 22-23.

Takkar, P.N. and N.S. Randhawa, 1978. Micro nutrients in Indian Agriculture. *Fert. News.*, 23(8): 3-26.

Taylorson, R.B., 1979. Release of volatiles during accelerated after-ripening of seeds. *Seed Sci. of Technol.*, 7: 369-378.

Tekrony, D.M., D.B. Egli and A.D. Phillips, 1980. Effect of field weathering on the viability and vigour of soybean seed. *Agron. J.*, 72: 749-753.

Thakur, R.B. 1993. Effect of sowing method and seed rate on the performance of high yielding varieties of rice. *Indian J. Agron.*, 38(4): 547-550.

Thangamuthu, G.S. and S. Subramaniyan, 1983. Effect of plant population and urea super granule deep placement on rice yield, *Int. Rice Res. Newsl.* 8(5): 23-24.

Thiyagarajan, C.P. and K.R. Ramaswamy, 1984. Influence of foliar application of nutrients and growth regulators on yield and quality of seeds in cotton Cv. MCU 9. *Madras Agric. J.*, 71(6): 508-511.

Thornberry, G.O. and F. Smith, 1955. Relation of respiratory and enzymatic activity to corn seed viability. *Plant Physiol.*, 30: 337-343.

Tomar, J.B. and M.P. Singh, 1986. Effects of temperature and moisture content during storage on the seed viability in rice. *Indn. J. Agric. Sci.*, 56(11): 782-787.

Tomar, R.P.S., C. Ram, and R. Promila, 1987. Breaking seed dormancy in paddy varieties. *Seeds and Farms*, 13(6): 23-24.

Tonapi, V.A. 1988. Studies on the effect of harvesting conditions on vigour potential, viability and storability of seeds in sorghum genotypes (*Sorghum bicolor* (L.) Moench.) Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

- Toole, E.H., V.K. Toole and E.A. Gorman, 1948. Vegetable seed storage conditions to germination and to abnormal seedlings of bean Proc. Intl. Seed Test. Ass., 18: 123.
- Tregubengo, M.V.A., G.L. Filippov and M.V. Vishneskii, 1974. Grain yield and quality of maize in relation to application of fertilizers and irrigation. Fld. Crop. Abstr., 27(8): 3840.
- Trivedi K.K. and Kwart, 1985. Effect of dates of transplanting and hill spacing on growth and yield of rice. JNKVV Res. J., 17(1): 227-231.
- Vanangamudi, K. 1982. Studies on certain aspects of production processing and storage of bajra seed. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.
- Vanangamudi, K. and K.R. Ramasamy. 1984. Relationship between seed weight and germination and seedling vigour. Madras agric. J., 71(4): 252-254.
- Vanangamudi, K. and K.R. Ramasamy. 1989. Biochemical studies in bajra seed during storage. Madras agric. J., 76(8): 470-473.
- Vanangamudi, K., R. Kulandaivelu and K.V. Selvaraj. 1990. Effect of irrigation on seed yield and quality of sorghum. Seed Sci and Technol., 18: 255-258.
- Vanangamudi, K., Subramanian, K.S. and M. Bhaskaran. 1989. Irrigation and nitrogen management for quality seed production. Seeds and farms, XV (9-10): 28-31.
- Vankeulen, H. and N.G. Seligman, 1987. Stimulation of water use, Nitrogen nutrition and growth of a spring wheat Crop. Pudoc., Wageningen, The Netherlands.
- Varma, B.K., 1981. Post harvest operation in India with special reference to paddy and wheat. A review. Bull. Grain Tech., 19: 112-136.
- Venkataraman, S., W. Wilfred Manuel, P. Parthasarathy, and R. Vaithialingam, 1978. Germination of seeds in chemical medium. Aduthurai Rep., 2(8): 87-88.
- Venkataswamy, R. and M.R. Iruthayaraj, 1980. Effect of agronomic methods and plant density on yield attributes and yield of cotton Mcu 9. seminar on cotton Dept. of Agron. Ac and RI, Madurai, TNAU, Coimbatore, 60-66.
- Verma, O.P., R.K. Singh and H.R. Verma, 1990. Effect of storage period on yield and yield contributing characters in rice (*Oryza sativa* L.) Abstr. Intl. Conf. Seed Sci. and Technol., Isst, New Delhi, India, p. 48.

- Vijayalakshmi, P., 1987. Studies on seed viability and vigour in rice (*Oryza sativa* L.) M.Sc. (Ag.) Thesis, Tamil Nadu Agril. Univ., Coimbatore.
- Villiers, T.A. 1973. Ageing and the longevity of seeds in field condition. In: *Seed Ecology* (Ed.). W. Heydecker. pp., and London. pp 265-288.
- West, S.H. and H.C. Harris, 1963. Seed coat colour associated with physiological changes in alfalfa and crimson and white clovers. *Crop Sci.*, 3: 190.
- Wester, R.E., 1970. Chlorophyll, a genetic marker for quality seed in lima bean. *Seed World*, 101: 24.
- Wilson, D.O. and M.E. McDonald, 1986. The lipid peroxidation model of seed ageing. *Seed Sci. and Technol.*, 14: 269-300.
- Wilson, D.O. and J.R. McDonald, 1989. The lipid peroxidation model of seed ageing. *Seed Sci. and Technol.*, 14: 269-360.
- Wolswinkel, P., 1992. Transport of nutrients into developing seeds: a review of physiological mechanisms. *Seed Sci. Res.*, 2: 59-73.
- Woodstock, L.W. 1973. Physiological and biochemical tests for seed vigour. *Seed Sci. and Tech.*, 1: 127-157.
- Woodstock, L.W. and J. Feeley, 1965. Early seedling growth and initial respiration rates as potential indicator of seed vigour in corn. *Proc. Ass. Off. Seed Analyst*, 55: 131-139.
- Woodstock, L.W. and R.B. Taylorson, 1981. Soaking injury and its reversed with polyethylene glycol in relation to respiratory metabolism in high and low vigour soybean seeds. *Pl. Physiol.*, 67: 424.
- Xiong, C.C., 1987. Effect of different concentrations of boron and nitrogen on the economic characters of rice. *Pl. Physiol. Commun.*, 6: 38-40.
- Yadav, J.S.P. and R.R. Agarwal, 1961. A comparative study on the effectiveness of gypsum and daincha (*Sesbania aculeata*) in the reclamation of a saline-alkali soil. *J. Ind. Soc. Soil Sci.*, 9: 151-156.
- Yadvindersingh, C.S. Khind and Bijay Singh, 1992. Efficient management of leguminous green manures in wet land rice. *Adv. Agron.*, 45: 135-189.

- Yambao, E.B. and K.T. Ingram, 1988. Drought stress index for rice. *Philipp. J. Crop Sci.*, 13: 105-111.
- *Yang, Chiu-Chung, K.O., 1975. Hsueh Nung Yeh (Taipei), 23: 241-245. (ch.)
- Yasin, M. and IT. Carpuz, 1989. Response of rice to fertilizers and cytozyme applications. *Int. Rice. Res. Newsl.*, 14(1): 22-23.
- Yeo, A.R. and T.J. Flowers, 1982. Accumulation and localisation of sodium ions within the shoots of rice (*Oryza sativa* L.) varieties differing in salinity resistance. *Physiol. Pl.*, 56: 343-348.
- Yogeeswararao, A. 1989. Effect of temperature and solar radiation on dry matter accumulation and grain yield in certain lowland rice varieties. *Oryza*, 26: 64-70.
- Yoshida, S. 1972. Physiological aspects of grain yield. *Annu. Rev. Plant Physiol.*, 23: 437-464.
- Yoshida, S. 1981. Fundamentals of rice crop science. *Int. Rice Res. Instt.*, Manila, The Philippines.
- *Yoshida, S., G.W. Mclean, M. Shafi and K.F. Muelte, 1970. Effects of different methods of zinc application on growth and yield of rice in a calcareous soil. *Pakistan Soil Sci. Pl. Nutr.*, 16: 147-149.
- Younis, S.A., F.I. Al-Pawi and E.G. Hagop, 1990. Physiological and biochemical parameters of seed quantity in some rice varieties. *Seed Res.*, 18(2): 148-153.
- *Zeleny, L. 1954. Chemical, physical and nutritive changes during storage. In: "storage of cereal Grains and their products" (Ed: J.A. Anderson and A.W. Alcock), pp. 46-76. Amer. Ass. cereal chem., st. paul, Minnesota.
- Zhangxian-guang and Huang yong-kai, 1990. Effect of seedlings per hill on individual rice plant yield and yield components. *Int. Rice Res. Newsl.*, 15(4): 21.
- Zhang, M., Y. Liu, L. Terii, H. Sasaki and Y. Esashi, 1993. Evaluation of volatile compounds by seeds during storage periods. *Seed Sci. and Technol.*, 21: 359-373.
- Zia, M.S. and M. Yousuf, 1986. Management of zinc deficiency in lowland rice. *Int. Rice. Res. Newsl.*, 11(6): 32.

Zode, N.G. and V.N. Patil. 1990. Storability of crop seeds as influenced by genotypes and season. *Ann. Pl. Physiol.*, 4(1): 127-129.

Zoysa, A.K.N., G. Koerthisinghe and S.H. Upasana, 1990. Effect of *Leucaena leucocephala* (lam) de wit. as a green manure on nitrogen uptake and yield of rice. *Biol.Fertil. Soils*, 9: 68-70.

Zubenko, V.K.H., 1959. The effect of preplanting hardening of corn in late plantings. *Transl. Pl. Physiol.*, 6: 341-343.

* ORIGINALS NOT SEEN

Annexure I

Monthly Mean Weather 1992 - 1993

Year and month	Temp °C		Mean RH (%)	RF (mm)	No. of rainy days	Pan evaporation (mm/day)	Sun shine (hrs/day)
	Max.	Min.					
1992							
May	36.2	25.3	63.1	70.0	6	7.7	-
June	33.3	21.6	65.8	54.0	5	6.6	-
July	34.4	20.8	74.7	15.6	2	6.2	-
August	33.9	20.1	56.2	13.4	2	6.9	-
September	30.3	19.4	63.9	305.6	11	5.4	-
October	30.8	19.8	67.7	79.7	4	5.3	-
November	28.7	19.0	67.2	221.5	9	4.2	-
December	34.4	21.0	70.9	-	-	5.9	7.4
1993							
January	29.0	18.9	68.3	-	-	5.7	8.2
February	31.0	20.0	67.7	10.0	1	7.9	8.6
March	33.2	21.9	79.0	16.0	3	6.7	7.0
April	35.6	23.8	79.9	-	-	8.1	8.9
May	35.5	22.4	83.8	54.1	6	6.9	7.3
June	35.5	20.6	84.5	60.4	4	10.0	9.9

Annexure I (Contd....)
Monthly Mean Weather 1994 - 1995

Year and month	Temp °c		RH (%)	RF (mm)	No. of rainy days	Pan evaporation (mm/day)	Sun shine (hrs/day)
	Max.	Min.					
1994							
June	37.2	24.9	70.8	-	-	11.5	-
July	36.1	25.7	76.0	44.1	1	8.2	-
August	36.3	24.0	77.4	79.2	3	8.0	-
September	36.5	23.3	93.7	84.0	4	5.7	-
October	37.6	22.7	96.7	191.3	10	2.8	-
November	32.1	20.9	93.9	108.9	8	1.9	-
December	30.5	19.5	94.0	26.5	4	3.4	-
1995							
January	31.6	19.9	89.9	1.5	1	4.2	-
February	34.1	20.2	83.7	-	-	7.2	-
March	35.4	20.8	80.9	100.4	1	8.1	-
April	38.5	24.3	76.9	-	-	-	-

ANNEXURE - II

MORPHOLOGICAL DESCRIPTION OF VARIETIES

S.No.	CHARACTERS	IR 50	ADT 38	CO 43
1.	Parentage	IR 2153 - 14 x IR 28 x IR 36	IR 1529 - 680 - 3 - 2/ IR 4432 - 52 - 6 - 4/ IR 7963 - 30 - 2 130 - 135	Dasal x IR 20
2.	Duration (Days)	105 (Summer) 130 (Winter)		135 - 140
3.	1000 graint wt (g)	20.35	21.00	20.00
4.	Grain L/E ratio	3.90	3.20	3.50
5.	Size (mm) LxBxT	7.90x2.20x1.60	6.90x2.40x2.00	8.10x2.30x1.80
6.	Grain type	Long slender	Long slender	medium slender
Morphological				
7.	Habit	Erect	Semi dwarf erect	Erect
8.	Leaf sheath	Green	Green	Green
9.	Septum	Green	White	Green
10.	Ligule	Colourless	White, non- prominent	White, longer
11.	Auricle	Colourless	White	Colourless
12.	Panicle	Long and drooping	Long moderately	Long drooping
13.	Husk colour	Straw	Straw	Straw
14.	Rice colour	White	White	White
15.	Abdominal White	Absent	Absent	Absent

Annexure - III

Initial soil properties of the experimental field

S. No.	Properties	Results
1.	Physical parameters	
	Mechanical fractions (per cent)	
	Clay	20.4
	Silt	16.8
	Coarse sand	31.1
	Fine sand	33.0
2.	Chemical properties	
	cation exchange capacity	
	(centinol (P+) kg ⁻¹)	20.8
	Organic carbon (per cent)	0.65
3.	Nitrogen Available N (kg ha ⁻¹)	146.5
	Phosphorus - Available P (kg ha ⁻¹)	12.0
	Potassium - Available K (kg ha ⁻¹)	218.0
4.	Parameters to characterise sodicity	
	Soil reaction	9.3
	Electrical conductivity (ECe - dSm ⁻¹)	0.76
	Exchangeable sodium (centinol (P+) kg ⁻¹)	13.1
	Exchangeable sodium percentage (ESP)	60.2
	Sodium Absorption ratio (SAR)	16.8
	Gypsum requirement (t ha ⁻¹)	3.6

Annexure IV

Initial soil properties of the experimental field

S. No.	Properties	Results
1.	Physical parameters	
	Mechanical fractions (per cent)	
	Clay	21.5
	Silt	16.0
	Coarse sand	30.9
	Fine sand	33.5
2.	Chemical properties	
	Cation exchange capacity	
	(centinol (P+) kg ⁻¹)	22.0
	Organic carbon (per cent)	0.41
3.	Nitrogen Available N (kg ha ⁻¹)	106.0
	Phosphorus - Available P (kg ha ⁻¹)	5.4
	Potassium - Available K (kg ha ⁻¹)	135.0
4.	Parameters to characterise sodicity	
	Soil reaction	9.25
	Electrical conductivity (ECe - dSm ⁻¹)	1.05
	Exchangeable sodium (centinol (P+) kg ⁻¹)	12.5
	Exchangeable sodium percentage (ESP)	56.8
	Sodium Absorption ratio (SAR)	16.0
	Gypsum requirement (t ha ⁻¹)	3.4