

**STANDARDIZATION OF HYBRID RICE SEED
PRODUCTION UNDER SRI METHOD IN UPLAND
ECOSYSTEM**

**Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfilment of the requirements for the
Degree of**

DOCTOR OF PHILOSOPHY

IN

SEED SCIENCE AND TECHNOLOGY

BY

HALESHKUMAR H. B.

**DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES
DHARWAD-580 005**

JULY, 2012

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4.

(N.G. HANUMARATTI)

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1. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the oldest domesticated irrigated crops known to mankind, since 4,000 years. It is the world's most important food crop and a primary food source for over one third of the world's population. In India it is the most important staple food for over two third of the population. It is the means of livelihood for millions of rural households and plays a vital role in our national food security, hence the slogan 'Rice is Life' is most appropriate. In India, rice occupies an area of 43.77 million ha with an annual production of 94.2 million tonnes and yield of 2148kg/hectare (Anon., 2011). Rice is being grown extensively in the state of Karnataka over 1.49 million ha with a production of 3.69 million tonnes and yield of 2716, respectively (Anon., 2011).

Achieving self sufficiency in rice production and maintaining price stability are important objectives in low income countries. Although India achieved food self sufficiency during the past decade, the country must increase food production every year to meet the demand of growing population and to maintain self sufficiency. Demand for rice is increasing every year and it is estimated that in 2015 and 2025 AD the requirement would be 110 and 140 million tonnes respectively. To sustain present food self-sufficiency and to meet future food requirements, India has to increase its rice productivity by 5 per cent per annum (Thiyagarajan and Selvaraju, 2002). The task is quite challenging but the options available are very limited. Among the various possible approaches, hybrid rice cultivation is the most feasible and the practical one.

In the late seventies, the scientists from China have developed hybrids using male sterility system and amply demonstrated that the cultivation of hybrid rice could increase rice yields by 15-20 percent. In China, hybrid rice covers about 55 per cent (17 mha) of total rice area, contributing more than 66 per cent of the total rice production from 1976 to 1995, resulting in to increased rice production from 129 m tonnes to 200 m tonnes. Presently, farmers growing hybrid rice in China are obtaining more than 30 per cent yield advantage over the high yielding conventional pure line varieties (Yuan, 1988).

China's initial success led International Rice Research Institute (IRRI), Philippines to intensify research on hybrid rice, particularly for developing the technology for the tropics. Further, success in China and encouraging results at IRRI created interest for initiating the research on hybrid rice by countries like India, Vietnam and Philippines.

Efforts to develop hybrid rice technology in India, though initiated in 1970, have gained momentum with the launching of a mission mode oriented project sponsored by Indian Council of Agricultural Research. After few years of research more than twelve public sector hybrids have been released for cultivation apart from some hybrids from Private sector. During 1995-96 dry seasons, 1300 tonnes of hybrid seeds were produced which is enough to plant more than 60, 000 hectares. Within a decade, some commercially usable Cytoplasmic Male Sterile and restorer lines and some elite hybrids were identified for evaluation and utilization. Some of these hybrids were released for commercial cultivation in the Philippines (IR64616H, IR68284H), India (IR64611H, IR64618H, IR69690H), Vietnam (IR64615H, IR64616H, IR69690H) in the years 1993-1998. Some IRRI CMS lines, IR58025A and IR62829A, were also used by national programs to develop local hybrids in India (APHR-1, APHR-2, CORH 2, KRH 2, ADTRH 1 etc). Concurrently, several private seed companies in Asia were also provided with IRRI-bred parental lines.

Currently, about 6,10,000 ha are covered under hybrid rice in Vietnam (3,40,000 ha), India (2,00,000 ha), Bangladesh (50,000 ha), USA (10,000 ha), Philippines (5,000 ha) and Myanmar (5,000 ha). These have given on average yield about 20-25% (1 - 1.5 t/ha) higher yields than the inbred high yielding varieties, thereby contributing towards higher on-farm productivity. Currently, hybrid rice technology is considered a viable option to increase rice yields globally (Yuan 1988, Virmani 1994, Janaiah and Hossain 2000).

In Karnataka, the work on hybrid rice was initiated as early as 1970's and a cytoplasmic male sterile line (Cytoplasmic Male Sterile) was obtained in a cross between IR-8 and Jeerigesanna in 1971 (Mahadevappa, 1973). So far two hybrids, KRH-1 and KRH-2 have been released for cultivation.

The efficient and economic seed production technology is one of the basic prerequisites for the success of hybrid seed production. With the seeds of one to two tonnes per hectare is viable, but to popularize it is essential to increase hybrid seed yields consistently beyond two tonnes per hectare. This can be achieved by developing male sterile lines with higher out crossing potential and improving seed production practices. The success of hybrid rice seed production depends on various factors, such as selection of suitable agro climatic region, sowing season, synchronization of parental flowering, GA₃ application, supplementary pollination techniques *etc.* Rice being a self pollinated crop, out crossing rate even on CMS lines is very low and is from 0 to 44% (Stansel and Craigmiles, 1996). The morphological and floral characters are not well adapted for cross pollination and hence, that results in poor seed set.

Rice cultivation requires large quantity of water, for producing one kg rice, about 3000 - 5000 litres of water is required depending on the different rice cultivation methods such as transplanted rice, direct sown rice (wet seeded), alternate wetting and drying method (AWD), system of rice intensification (SRI) and aerobic rice Geethalakshmi *et al.*, (2008). Owing to increasing water scarcity, a shifting trend towards less water demanding crops against rice is noticed in most part of the India and this warrants alternate methods of rice cultivation that aims at lower water and higher crop productivity.

There are evidences that cultivation of rice through System of Rice Intensification (SRI) can increase rice yields by two to three fold compared to current yield levels. Aerobic rice cultivation where fields remain unsaturated throughout the season like an upland crop offers an opportunity to produce rice with less water (Barah., 2009). Under this scenario SRI may be an appropriate practice to produce more food with less input. In search of a solution to the food crisis, Fr. Henry de Laulanie rediscovered this novel method for small land holdings-oriented practice of SRI (Latif *et al.*, 2005).

SRI is actually an amalgamation of refined and intensive management practices for rice production in farmers' fields. SRI is the method developed in Madagascar in the early 1980's, where, it has been shown that yields can be enhanced by suitably modifying certain management practices such as controlled supply of water, planting of younger seedlings and providing wider spacing (Latif *et al.*, 2005). This methodology is gaining momentum all over the world, although it is in a budding stage in India. SRI method of cultivation is said to promote greater root growth and higher soil biological activity in the rhizosphere.

By adopting SRI system of cultivation we could save water, protect soil productivity, save environment by checking methane gas from water submerged paddy cultivation practices, bring down the input cost, besides increasing the production for providing food to the growing population.

Plants are exposed to several abiotic stresses during its growth and development. Among the abiotic stresses, water stress drastically affects crop growth and poses a major threat to agricultural productivity. In most crop species, stress usually inhibits seed germination, seedling growth and vigour. Seed treatment is the most important basic activity in crop production especially under rainfed farming condition. Drought resistance of plants by hardening before sowing under rainfed condition was first suggested by Henckel and Kolotova (1934). Pre-sowing hardening of seeds involves a number of physio-chemical changes which influence the emergence of specific, protective adaptive reaction against moisture stress due to stimulatory effects on root growth. These changes in the properties of protoplasm leading to an overall increase in the grain yield (Henckel, 1965). Subbian *et al.* (2000) observed several physiological and biochemical changes during seed hardening process,. These include changes in the properties of colloids from hydrophobic to hydrophilic. There will be increase in the viscosity of protoplasm and plasticity of plasma lemma and osmotic potential which will help in drought withstanding capacity. These events include in activation of enzymes and increase in the rate of respiration, synthetic activity and the increased levels of nucleo-proteins and organic phosphorus. There is increase in the activity of RNA and rate of protein synthesis, smaller epidermal and stomatal cells and total absorbing surface of the root system.

Storage of seeds till the next sowing season is an essential segment of seed industry. The seed deterioration begins immediately after physiological maturity and it is reflected in terms of loss in viability and vigour. The seed viability and vigour largely depends on the genotype, production location, mechanical injury to the seed, initial seed quality, seed treatment, packaging material and storage conditions. The knowledge of seed storability is very essential to avoid huge financial losses due to non selling of the seeds and to carry over the seed stock for use in next season. The female parents of rice hybrids are known to be poor storers because of the problem connected with male sterility system besides methods of storage and seed treatment.

Morphological characters are usually used to identify the crop varieties because they can easily be observed at phenotypic level and provide the unique identification of crop varieties. However, these traits are under the control of many genes and show instability due to interaction with environments, which restrict reliable identification. On the other hand, increased number of genetically released varieties through the efforts of plant breeders have created phenotypic uniformity which has further imposed restrictions on utilizing the morphological traits as markers especially for crops where genetic base is narrow. Thus reliable identification of genotypes is difficult to achieve on this basis. The advancement in genetics, biochemistry and molecular biology have made available new tools based on protein and DNA complements of individuals and are common in use. Biochemical markers especially the electrophoretic profiles of Isozymes and proteins, have been widely used for identification and characterization of hybrids with their parental lines (Rehana *et al.* 2004).

Considering the above points, to exploit the feasibility of better performance of hybrid rice and their seed production through SRI method and parental seed storage under ambient conditions and characterization of better performed hybrid and their parents, the present investigation is proposed with the following observations:

1. To screen selected rice hybrids for suitability under modified SRI method in upland eco-system
2. To evaluate suitable seed treatment to improve early seedling vigour under SRI method
3. To standardize hybrid seed production techniques for promising rice hybrid under modified SRI method in upland eco system
4. To ascertain storability of KRH-2 hybrid and its Parents under ambient conditions of Dharwad
5. Characterization of hybrid and its parents of rice using isozymes

2. REVIEW OF LITERATURE

The literature pertaining to the screening of selected rice hybrids for suitability under modified SRI method in upland eco-system, evaluation of suitable seed treatment to improve early seedling vigour under SRI method, standardization of hybrid seed production techniques for promising rice hybrid under modified SRI method in upland eco system, storability studies on KRH-2 hybrid and its parents at ambient conditions of Dharwad, characterization of parents and hybrid of rice suitable under SRI method by isozymes are reviewed in this chapter.

2.1 SRI method-features

Systematic research on 'System of Rice Intensification' (SRI) has started recently, and till date now hybrid rice seed production under SRI method has not been undertaken, hence the literature available is scanty and not available.

Working with a non-governmental organization called "Association Tefy Saina" in Madagascar, Laulanie (1993) developed the system of rice intensification. This NGO is instrumental in further improving this system of rice cultivation. Based on the observations on the farmers' fields and collaborative research with Association Tefy Saina, Laulanie has reported the following features of SRI. Though rice can survive under flooded conditions, it cannot be highly productive under continuous submergence where the most of the plants' roots remain in top six cm of soil and the most of them degenerate by the time the plant is at reproductive phase. Rice seedlings lose much of their growth potential when they are transplanted after fourth phyllochron begins (*i.e.* about 15 days after emergence in nursery). Hence, early transplanting well before fourth phyllochron initiation is advisable. However, transplanting should be done with lot of care to reduce the damage to roots and transplanting trauma. Wider spacings will provide space for greater root growth and better tillering. More organic matter in the soil with good aeration provides better plant growth conditions, especially through profuse tiller growth. System of rice intensification (SRI) farming method is on practice in several countries as an alternative, sustainable, low-cost system to the conventional farming systems (Uphoff, 1999, Krupakar reddy., 2004, Uphoff., 2005 and Krishna *et al.*, 2008)

2.1.1 Effect of methods of cultivation on growth, flowering behaviour and seed yield

2.1.1.1 Effect on growth parameters

Under SRI cultivation biomass-portioning efficiency increases distinctively, resulting in higher grain yield (11750 kg ha^{-1}) than conventional cultivation (11497 kg ha^{-1}). Higher translocation of assimilates *viz.*, dry matter, carbohydrates, nitrogen, and their conversion rates enhanced the grain filling and spike weight in SRI method of cultivation of rice. The advantages of SRI cultivation were increase in the tillers per plant and effective leaf area (Wang Shao Hua *et al.*, 2002).

Tao Longxing *et al.* (2002) reported that root growth was markedly greater in the plants raised under SRI method than in traditional system of cultivation. Root dry matter and root depth were also more in SRI method compared to the traditional rice cultivation.

Rice plants in SRI farming system grow vigorously, produce more tillers and leaves ensuring better resource utilization, resulting in higher grain production compared to the conventional transplanting and broadcasting system. Dry weight of stems, leaves, roots, and total root length per hill during the growth period as well as the tiller numbers per plant at heading were significantly higher in SRI method than the conventional rice cultivation system in the dry regions of Sri Lanka (Sarath and Thilak, 2004).

Uphoff (2004) reported that SRI method of cultivation recorded higher plant height, more number of tillers than farmer practiced method. The increase in the yield with SRI cultivation was to the tune of 30 to 40 per cent over the traditional method.

SRI method of cultivation promotes more vigorous growth *viz.*, plant height, leaf area index and dry matter production than the normal planting (Zheng *et al.*, 2004).

Udayakumar (2005) observed profuse tillering under SRI method. The number of tillers per plant and per unit area were more under SRI method compared to the normal method.

2.1.1.2 Effect on flowering

The plants raised under SRI method of cultivation of rice flowered a week earlier under Cambodian conditions and eight to ten days earlier under Indian conditions compared to the plants raised in the traditional method of cultivation (Anon., 2004).

Krupakar Reddy (2004) noticed that SRI plots took significantly lesser days (4-5) to flowering and maturity as compared to the traditional method of planting in BPT-5204 variety.

According to Udayakumar (2005) the days to 50 per cent flowering and maturity was 4-5 days early (71 and 116 days) in SRI as compared to the normal method (75 and 120 days) in MTU-1010 rice variety.

2.1.1.3 Effect on yield and yield parameters

Abu Yameb (2002) reported that yield components like number of panicles per square meter and grains per panicle were more with SRI method (448 and 122, respectively) than in farmer's technique (338 and 295, respectively).

Andrianaivo (2002) obtained significantly higher net returns of \$250 under SRI cultivation when compared to traditional method (\$210). The higher net returns was due to efficient use of resources, better yield levels with SRI method than traditional method of cultivation.

Barison (2002) reported a significant difference in grain yield among the three systems of cultivation. The highest grain yield was obtained with SRI method of cultivation (6.26 t ha^{-1}) compared to other conventional methods of cultivation (2.63 t ha^{-1}).

Kumar *et al.* (2002) conducted a preliminary trial on SRI at Directorate of Rice Research with ten genotypes which were evaluated under 4 methods of crop establishment *viz.*, SRI method with young seedlings, SRI method with older seedlings, integrated crop management and conventional method. The varieties responded differentially to SRI method. Hybrids performed exceedingly well under SRI method (46-47% yield advantage) and also indicated that SRI with young seedlings gave 15 - 20% higher yield than the traditional method.

According to McHugh *et al.* (2002) SRI method of cultivation increases the yield levels by 147 per cent over traditional method. Further, it was observed that, method of irrigation influenced the yield levels under SRI. Alternate wetting and drying method of irrigation gave higher yield (6.7 t ha^{-1}) compared to flooding (5.6 t ha^{-1}).

Rafaralahy (2002) reported grain yields above 15.0 t ha^{-1} under SRI method as compared to the traditional method (7.0 t ha^{-1}). The increase in the yield with SRI were attributed to the increase in number of ear bearing tillers per hill, total number of spikelets per panicle and panicle length.

Thiyagarajan and Selvaraju (2002) concluded that CO-43, maximum seed yield (7612 kg/ha) from the modified SRI method by planting young seedlings of 14 days old, restricted irrigation, adaption of green manure, and incorporation of weed with soil aeration.

Wang Sha Hua *et al.* (2002) observed increased leaf area percentage, leaf area index, total spikelet number and percentage of productive tillers under SRI method of cultivation. The grain yield was also significantly higher in SRI than under conventional cultivation (11497 kg ha^{-1}).

Ceesay and Uphoff (2003) reported that under SRI method, 1000 grain weight and biomass accumulation were higher by 6.7 and 20.1 per cent, respectively compared to conventional method of cultivation.

Peng Jiming (2003) showed that high yields from Chinese hybrid rice (9232 kg/ha) with modified SRI can be obtained. He also observed that Chinese hybrid rice with modified SRI method has vast yield potential compared with present Guinea's varieties.

Krupakar Reddy (2004) reported that significantly higher panicle length, grains per panicle, test weight and seed yield per ha under SRI method compared to the traditional method in BPT-5204 rice variety. SRI farming method produced greater grain yield compared to the conventional transplanting and broadcasting rice farming systems (Sarath and Thilak, 2004).

Zheng *et al.* (2004) reported that SRI method of cultivation is a promising way to increase the yields of hybrid rice in China. The yield increase was to the extent of 20 per cent over farmers practices.

Udayakumar (2005) reported that SRI method of cultivation recorded significantly higher seed yield of 6136 kg ha⁻¹ compared to the traditional method of cultivation (4282 kg ha⁻¹) in MTU-1010 rice variety. The yield attributing parameters *viz.*, number of productive tillers, number of filled spikelet's and panicle length were also high with this method.

Subbaiah *et al.* (2004) conducted multi location and on stations trials during 2004 and 2005 to evaluate System of Rice Intensification (SRI) method of rice cultivation in comparison with normal transplanting (NT) and Integrated Crop Management (ICM) methods. Grain yield recorded under SRI was significantly higher as compared to that under NT at 53% of the locations, while it was similar to that under ICM at 33% of locations involved. Higher grain yield under SRI method was recorded in diverse soil types, with wide range of soil pH (6-8) and different regions which could be associated with increased number of panicles per unit area, biomass and panicle weight.

Hussain *et al.* (2009) reported that SRI method along with the recommended dose of fertilizers N, P and K applied @ 80:45:20 kg ha⁻¹ gave better results under temperate zones of Kashmir valley regions.

2.2 Evaluation of suitable seed treatment to improve seedling vigour under SRI method

Seed priming or osmopriming is a water based process that is carried out on seeds to increase uniformity in germination and emergence, to enhance plant establishment. It entails the partial germination of seeds by soaking them in water (or in a solution of salts) for specified period of time, and then re-dry them just before radicle emerges (Copeland and McDonald, 1995; Desai *et al.*, 1997). Priming stimulates many of the metabolic processes involved with the early phases of germination. As a part of the germination process have been initiated due to priming, seedlings from primed seed grow faster, grow more vigorously, and perform better in adverse conditions (Baskar and Hatton, 1987; Desai *et al.*, 1997), the duration of the emergence period decreases with priming, leading to more uniform plant stand (Mikkelsen, 1981; Baskar and Hatton, 1987).

2.2.1 Proline

Lale Yildiz Aktaş *et al.* (2007) showed that exogenous ABA (100 Mm) and proline (1 mM) treatment to dormant seeds of *Laurus nobilis* L. significantly affected physiological and biochemical traits, by inducing the responses against drought, in a well watered condition.

Bukhari (2007) reported that, proline application proved helpful in enhancing the growth of plants under drought stress. proline 20 mmol L⁻¹ and 30 mmol L⁻¹ treatments proved to be the most effective levels for increasing germination percentage and growth of wheat plants.

Chedlia *et al.* (2010) reported that, the proline supplements seem to improve olive salt tolerance by amelioration of some antioxidative enzyme activities, photosynthetic activity, and so, plant growth and the preservation of a suitable plant water status under salinity conditions.

Anamul Hoque *et al.* (2007) concluded that exogenous proline mitigates the detrimental effects of salt stress more than exogenous betaine because of its superior ability to increase the activities of antioxidant enzymes.

Exogenous application of proline as a pre-sowing seed treatment (control, 20 mM and 40 mM) on 5 wheat cultivars *viz.*, SARC-I, Inqlab-91, MH-97, Bhakar and S-24, improved shoot and root fresh and dry weights, shoot length and grain yield under both non-stress and stress conditions and total leaf area per plant only under stress conditions. (Kamran *et al.*, 2009)

Qasim Ali (2007) concluded that foliar applied proline ameliorated the adverse effects of water stress on growth and photosynthetic capacity of two maize cultivars. *viz.*, EV-1098 and AGAITI- 2002.

Naseem (2007) reported that various levels of proline as pre-sowing seed treatment showed remarkably increasing effect on shoot and root fresh weights, shoot and root Na^+ , Cl^- and K^+ concentrations while, non-significant effect on shoot and root dry weights and chlorophyll content.

Rizwan Rasheed *et al.* (2011) observed soaking of sugarcane buds in 20 mM proline and glycine betaine (Glycine betaine) solutions substantially reduced the H_2O_2 production, improved the accumulation of soluble sugars and protected the developing tissues from heat stress effects, although proline was more effective than Glycine Betaine.

Posmyk and Janas (2007) reported that hydropriming of mung bean seeds with proline at 5 mM grew better at chilling injury.

Deivanai *et al.* (2011) demonstrated that rice seeds pretreated with proline (1 mM, 5 mM and 10 mM) and grown at different NaCl concentrations counteracted the adverse effect of salt. Pretreatment of proline at a concentration of 1 mM was found to be effective and stimulated cellular activities, whereas 10 mM proline was ineffective in improving plant growth under high level of salt (300 and 400 mM NaCl).

2.2.2 Glycine betaine

Paleg *et al.* (1981) reported that proline, glycine betaine and other organic samples protect several different enzymes like α -amylase, glucose-6-phosphate dehydrogenase, hexokinase, pyruvate carboxylase against heat stress.

Gorham *et al.* (1998a) reported that, seed cotton yields were the highest with 3 and 6 kg/ha glycine betaine applied at squaring. Glycine betaine dose and time of application also significantly increased the total dry matter production. The number of bolls per plant, and nodes at maturity were more than the control. But some of the characters that were not affected included mean boll weight and per cent flower and boll shedding. Similarly, Gorham *et al.* (1998b) reported that all glycine betaine treatments produced higher yields. The higher yields were associated with higher boll number in the glycine betaine treated plants.

Alia *et al.* (1998) noticed that transformation of the *codA* gene to *Arabidopsis thaliana* significantly enhanced the tolerance against low temperature and high salt stress and also exogenously applied glycine betaine found effective in alleviating the harmful effects of salts stress during germination of seeds and growth of young seedlings.

Makela *et al.* (1998) observed that glycine betaine application significantly increased stomatal conductance of tomato plants grown in well watered, water deficient or saline conditions; however glycine betaine did not affect the leaf abscisic acid concentration, relative water content, sap osmotic potential or shoot water potential.

Makela *et al.* (1999) reported that foliar application of glycine betaine (50 and 100 mM) increased net photosynthesis of stressed plants but glycine betaine application resulted in a significant decrease of photorespiration both in drought and salt stressed plants.

Xing-Weiblu and Rajashekar (1999) observed that little or no effect of glycine betaine on shoot biomass and pod yield was observed in water stressed beans.

Lutts (2000) stated that the application of nutrient solution containing glycine betaine, had no deleterious effect on unstressed plants, but improved plant survival and growth under salt stress. The positive effect of exogenous application of glycine betaine is associated with reduced sodium accumulation and maintenance of K concentration in salinised plants

Makela *et al.* (2000) reported that application of glycine betaine (100 mM concentration) increased the chlorophyll content and total protein content of leaves, but chloroplast area and the number of plastoglobuli were not significantly affected by the glycine betaine application.

Cassandra and Oosterhuis (1999) showed that foliar spray of glycine betaine did not increase seed cotton yield significantly. Although the plants treated biweekly with 2 kg/ha glycine betaine had the highest lint yield.

Sakamoto and Alia (2000) transformed the *codA* gene from *Arthrobacter globiformis* to *Arabidopsis* which encodes choline oxidase, responsible for synthesizing glycine betaine from choline. The transformation enabled the plants to accumulate glycine betaine in chloroplasts and significantly enhanced the freezing tolerance of plants and also photosynthetic machinery of transformed plant was more tolerant to freezing stress. They also reported that exogenous application of glycine betaine increased tolerance against freezing stress.

Diaz *et al.* (2001) reported that application of foliar fertilizer containing osmoprotectants like glycine betaine, at vegetative stages of crop development enhanced grain yield by increasing the number of grains per spike. Hallikeri *et al.* (2002) reported that foliar application of 2 per cent urea, 2 per cent DAP and 1 per cent KCl had improved the cotton yield by 19, 5 and 6 per cent, respectively over control.

Rahman *et al.* (2002) reported that under salt stress, glycine betaine treated plant had significantly lower Na and higher K concentration in the shoots of rice, than the plant grown without glycine betaine treatment.

Abou El-Yazied (2011) concluded that productivity and dry seed yield characteristics of common bean were responded positively to irrigation at depletion of 30 % available soil water in clay loam soil, foliar application of 2 or 4 mM/L glycinebetaine and 500 ppm chelated calcium.

Korkmaz and Şirikçi (2011) reported that in case of pepper seeds treated with 10 mM glycine betaine recorded the highest final germination and emergence percentage.

Exogenous application of glycine betaine as seed treatment in wheat variety MH-97 showed greater value of germination percentage under both saline or control conditions. (Nosheen *et al.* 2007)

Tahir Mahmood *et al.* (2009) showed pre-sowing seed treatment with Glycine betaine improved the plant biomass of the wheat cultivars and glycine betaine level 50 mM was found to be more effective than 100 mM in promoting wheat growth.

Mohammad Ali Rezaei *et al.* (2012) conducted pot experiments and indicated that the crop stability and yield were often increased due to foliar applications of glycine betaine, when sprayed during the stress compared to the control plants; the number of branches, number of seeds per plant and grain weight increased with the use of exo-glycine betaine in different levels of drought stress, significantly. Application of exo-glycine betaine on soybean seed grains weight of 1000 in stress is time-, cultivar- and dose dependent

2.2.3 Polyethylene glycol (PEG-6000)

Chatterjee *et al.* (1985) reported that groundnut seed treated with PEG recorded higher number of pods per plant in the variety MH₂ and AK12-24 but recorded less pod yield per ha and weight compared to other seed treatments.

Ali *et al.* (1990) reported that the seeds of tomato and onion have shown that the minimum period for osmo conditioning treatment is seven days and enhanced germination of osmo conditioned seed is dependent on temperature. The priming of seed in PEG-8000 (-8.6 bars) at 15°C for two days was the best, this enhanced seedling emergence, plant development and fruit yield.

Fu and Fu (1990) reported improved germination rate and uniform emergence both in laboratory and field conditions of two groundnut seed lots when treated with 20 to 25 per cent PEG at 15°C for two days. Emergence of high and low vigour seeds increased from 67.7 per cent and 52.5 per cent to 70 per cent and 85.6 per cent, respectively.

Seeds took 10 to 12 per cent less time for 50 per cent germination both in field and laboratory when onion seeds primed with PEG-6000 (300 g/kg H₂O) for seven days (Murray *et al.*, 1992).

Jagadesh *et al.* (1994) reported hydration-dehydration treatment improved germination capacity of slightly deteriorated seeds in tomato, chilli and onion. They reported significant enhancement in germination and seedling growth when these seeds were treated with PEG 1.20 MPa

The study with osmotic priming of soybean seeds with polyethylene glycol (PEG-6000) at -5 bars water potential increased the seed germination to the magnitude of 10, 8, 11 and 12 per cent with concomitant increase in the seed yield in all the four types of soils (Narasimha Prasad, 1994).

Bailly *et al.* (2000) experimented osmopriming of sunflower seeds and found that osmopriming markedly shortened the subsequent lag time of germination irrespective of redrying the seeds. Mean time of germination of primed seeds was 1.5 days without redrying and after redrying *i.e.*, about 60 per cent of that of unprimed seeds for which it was 2.6 days.

Cotton seed lots primed with PEG 6000 at -15 bars for 72 hours recorded maximum germination percentage, field emergence, seedling vigour index and low electrical conductivity compared to control (Ramegowda *et al.*, 2006).

Pallavi *et al.* (2006) reported that seeds primed with PEG 6000 at -1.0 MPa, significantly increased the germination percentage in low vigour (74 – 87%) and medium vigour seed lot (85 – 90 %) of cauliflower compared to control.

Fatemeh *et al.* (2011) reported that the seeds primed with PEG 6000 (-3 bar), significantly improved germination percentage, radicle and shoot length, seedlings weight and germination rate, compared to control in marigold.

2.2.4 Potassium nitrate

Pfahler and Barnett (1990) showed that in Rye cv. Florida 401 and Wrens Abruzzi seeds when treated with combinations of 0, 0.1 or 1.0 mM gibberellic acid (GA) and 0 or 0.3 M potassium nitrate for 1 h using 0.01% between 80 as a surfactant, increased coleoptiles and primary leaf length and percentage primary leaf emergence, but decreased root length.

Motoyukia and Mitsuo (1991) showed that in KNO₃ coated paddy seeds, emergence and establishment of seedling began earlier, and the percentage of seedling emergence and of foliage leaf emergence were higher than in non coated seeds

Pfahler *et al.* (1991) proved that in wheat cv. Florida 301 and Florida 302 seeds when treated with combinations of 0, 0.1 or 1.0 mM of gibberellic acid (GA₃) and 0 or 0.3 M potassium nitrate for soaking them in 2 h increased coleoptile and primary leaf length and percentage primary leaf emergence, but decreased root length.

Roy (1991) stated that by treating seeds of *A. lebeck* with 0.3% potassium nitrate increased germination percentage from 58.4 (control) to 69.3% (trated)

In pigeonpea (*Cajanus cajan*), seed treated with KNO₃ or CaCl₂ generally exhibited improvement in proteins, free aminoacids and soluble sugars during germinating under salt stress (Jyotsna and Srivastava, 1998).

In bajra and sorghum, plants raised from seeds treated with 100 mg per litre solution of CaCl₂ or KNO₃ had increased plant height, chlorophyll content and yield compared to the plants raised from the untreated seeds (Kadirri and Hussaini, 1999).

Basra *et al.* (2004) reported that soaking of seeds of coarse (cv. KS282) and fine rice (cv. Super Basmati) in solutions containing KNO₃ (30 g/litre) at 27 degrees C for 24 h, followed by redrying to initial moisture under shade with forced air, maintaining the osmotic potential of a solutions at -1.25 MPa. recorded the highest emergence percentage, root/shoot ratio, seedling fresh weight and seedling dry weight than all other treatments in both coarse and fine rice.

Reddy *et al.* (2004) showed the effects of seed soaking (for 8 h) with 1% KNO₃ in black gram cultivars LBG 645 and LBG 709 in a rice fallow ecosystem which gave the maximum mean plant height 44.67 cm.

Purbey and Meghwal. (2005) reported maximum seed germination (93.33%), root length (31.33 cm) and root diameter (0.39 cm) were observed in Aonla seeds treated with 1% KNO₃ for 18 h, while the least seed germination (53.33%), main root length (12.67 cm) and root diameter (0.22 cm) were recorded in the control.

Nighat Sarwar *et al.* (2006) showed that the biomass of roots and shoots of seedlings grown from treated with water, mannitol and lower concentration of K_2HPO_4 and KNO_3 were higher as compared to the biomass of seedlings grown from non-treated seeds sown in saline soil.

Seed invigoration studies in cotton revealed that KNO_3 was the most effective in improving the quality of marginal seed lots in terms of viability and vigour followed by NaCl and hydration-dehydration and dry dressing with thiram (Dahiya *et al.* 2007)

Kenanoglu *et al.* (2007) concluded, priming specifically KNO_3 , appears to be promising in enhancing germination percentages of *L. siceraria* particularly at 15 °C that is the prevailing temperature in rootstock production for grafted watermelon seedling in unheated glasshouse conditions in early spring.

2.2.5 Calcium chloride ($CaCl_2$)

Sashidhar *et al.* (1977) observed increased yield in groundnut when seeds were treated with one per cent calcium chloride for eight hours with high free proline accumulation which is an adaptive mechanism of drought tolerance.

On sandy soil at Kalyani (West Bengal) soaking of barley seeds with $CaCl_2$ caused increased yield to an extent of 31 per cent over control. This was attributed to enhanced plant height, number of tillers per m^2 , dry weight per meter row length, LAI at flowering, number of ear per m^2 and 1000-grain weight (Singh and Chatterjee, 1980).

Avijit Sen (1983) reported that pre-sowing treatment with $CaCl_2$ brought about significant difference in all growth characters viz., plant height, tiller number, leaf number, leaf area, dry weight of shoot and eventually the grain yield of rainfed wheat as compared to that of water soaked treatment and no soaking.

Nagappa (1983) observed that soaking sunflower seeds for 24 hours in one per cent calcium chloride increased germination percentage and seedling vigour with an increased proline accumulation under moisture stress conditions revealing that calcium chloride imparted drought resistance character to plant and resulted higher seed yield compared to other treatments.

Kulkarni and Eshanna (1988) reported that one per cent calcium chloride seed treatment of maize seeds increased germination, speed of germination, vigour index and seedling vigour significantly over control.

Arjunan and Srinivasan (1989) reported that seed treatment with 0.5 per cent $CaCl_2$ did not significantly influence the germination, leaf number per plant, matured pods per plant and pod yield compared to control in TMV-2 groundnut.

Subbaraman and Selvaraj (1989) reported that groundnut kernel cv. JL-24 presoaked in calcium chloride (0.5%) for 30 hours and air drying for 10 hours resulted in higher field emergence over control. Seed treatment with $CaCl_2$ (0.5%) registered an increase in pod and graded seed yield over control by 47.5 and 52.7 per cent, respectively.

Gopal Singh and Ramarao (1993) reported that sunflower seed treated with calcium chloride (100 ppm) recorded significantly increase in germination, seedling length, seedling vigour compared to control.

Rangaswamy *et al.* (1993) found that seed hardening with $CaCl_2$ at 0.4 per cent and CCC at 0.2 per cent increased the germination per cent, vigour index and root: shoot ratio in sorghum, pigeonpea, groundnut and cowpea.

Narayanaswamy and Channarayappa (1996) stated that pre-sowing treatment of groundnut seeds with 0.5 per cent calcium chloride for six hours followed by shade drying for 16 hours resulted in significantly higher germination, field emergence, number of graded pods per plant, test weight and also registered an increase in graded pod yield of 1614 and 1667 kg per ha over control of 1260 and 1292 kg per ha during summer and *kharif* seasons, respectively.

Narayanaswamy and Shambulingappa (1998) reported that pre-sowing seed treatments in groundnut significantly differed in field emergence among treatments, during both *kharif* and summer seasons. It was the highest with CaCl_2 and the lowest with boron seed treatment.

On medium black soil at Rahuri (Maharashtra) under rainfed condition, the wheat seed soaked in 2.5 per cent CaCl_2 produced significantly higher number of effective tillers per plant or per meter row length, ear head length, number of spikelets per ear, number of grains per ear and eventually the yield (4014 kg/ha) over that of un soaked seeds (3177 kg/ha) (Ugale and Mungse, 2001).

Verma *et al.* (2006) studied the effect of pre-sowing seed treatments in mung bean with Glycine betaine and revealed that seeds invigorated with CaCl_2 (2%) recorded maximum germination percentage and field emergence, and took minimum days to 50 per cent flowering and days to maturity compared to control.

Cotton seeds invigorated with CaCl_2 (2%) recorded significantly higher germination, seedling dry weight, speed of germination and yield in both fresh and revalidated lots at Coimbatore (Anon., 2007).

Hafeez *et al.* (2010) concluded that Osmohardening with CaCl_2 was the best way to reduce sterile spikelets, abortive and chalky kernels, and improve kernel length in direct seeded rice.

Ramezani and Rezaei Sokht-Abandani (2011) showed that the maximum length of stem in sorghum was achieved with the priming treatment of calcium chloride with density of 4 per cent.

Liela Yari *et al.* (2012) evaluated the effect of temperature, seed priming techniques and duration on germination and early growth of three rice cultivars (Fajer, Sherodi and Taram), seeds were primed by soaking in calcium chloride (CaCl_2) solutions at concentrations of 0.5% and 1% and distilled water for 12, 24 and 36 hours, at three temperature levels (20, 25 and 30°C) Maximum seed germination percentage was related to cv. Sherodi when the seeds primed by CaCl_2 (1%). All seed priming treatments resulted in lower Mean germination time than that of control. The seed priming duration of 24h was found suitable for all cultivars.

2.3 Techniques of hybrid rice seed production, to improve seed set and seed yield

2.3.1 Planting Ratio

Sahai *et al.* (1987) reported that in hybrid seed production, the best combination was one row of restorer line at 10x10 spacing and six rows of A line at 20 × 15 cm spacing. In the CMS seed production, the best combination was 4 rows of A line at 10 × 10 cm spacing and two rows of B line at 15 × 10 cm spacing

Pradhan and Rathod (1987) indicated that in rice row ratios of 1:1 and 2:1 of V20A to V20B gave higher seed set of 30 to 35 percent in contrast to the row ratio of 4:1 which gave seed set of only 10 to 15 per cent.

Out of the five planting ratios studied by Ramachandra (1989), 6:2 ratio recorded the highest seed yield (416.6 kg) with 9.39 percent seed set is seen in rice hybrid seed production.

Akhter *et al.* (2007) obtained the highest seed yield of 1.24 t ha⁻¹ in row ratio of 10:2. However, the seed yield from 0.80-1.10 t ha⁻¹ was produced by row ratios 12:2, 10:3 and 12:3. The lowest hybrid seed yield was produced in row ratio 3:8.

Ramos *et al.* (2004) conducted an experiment in rice to determine the optimum row ratio between the male (IR34686R) and female (IR58025A) parents for maximum pollination for maximum seed yield. Out of the Seven treatments, *i.e.* male:female row ratios T₁ (2:6), T₂ (2:8), T₃ (2:10), T₄ (2:12), T₅ (2:14), T₆ (2:16) and T₇ (3:10), used. 2:6 and 2:8 ratio, gave the highest seed yields of more than 1.3 tonnes/ha, the differences between the yields of the two treatments were not statistically significant.

In order to find out a location specific technology recommendations for hybrid rice seed production in Region 2, [Cagayan Valley] Philippines came out with a conclusion, A row ratio of 2:6 appeared practical during the wet season while 2:8 is optimum during dry season. (Guzman 2001)

Gangadharaiah *et al.* (2008) reported that in rice row ratio of 12A:2B and 8A:2B produced higher seed yields of IR 58025A than the other row ratios. The seed set and seed yield of IR 58025A were higher during summer than during *kharif*.

Pandya *et al.* (1996) stated that for CMS multiplication, in rice a row ratio of 2B to 8A is optimum.

An experimental study on rice revealed that a row ratio of female:male of 6:1 recorded the highest hybrid seed yield (1921 kg/ha) (Ponnuswamy *et al.*, 1998).

Singh *et al.* (1998) conducted an experiment on rice hybrid seed production during the 1993-95 wet and dry seasons to determine the optimum row ratio of the pollen parent to the seed parent. The optimum row ratio in hybrid seed production varied from 2:8 (1993 and 1994) to 2:12 (1995) in the wet season. Seed yields obtained at these optimum row ratios were the highest in the 1995 wet season (1636 kg/ha) and the lowest in the 1993 wet season (720 kg/ha).

Prabakaran and Ponnuswamy (1997) reported that in hybrid seed production of rice cv. MGR (CORH 1) was examined using the parents IR 62829 A and IR 10198-66-2R. Seedlings transplanted in female:male row ratios of 4:1, 5:1, 6:1, 8:2, 10:2 or 12:2. The 6:1 ratio produced the highest seed yield of 1.92 t per ha.

Mandal *et al.* (2000) reported that intercropping rice cultivars Jaya + IR 36 at 4:2 planting ratio recorded the minimum percentage of unfilled spikelets panicle⁻¹ and the highest amount of dry matter, number of tillers /m², matured panicles /m², filled grains panicle⁻¹ and grain yield (6.24 t/ha) per unit area and time which was 28.4 and 30.82% higher than sole Jaya and IR 36.

Yadav *et al.* (2003) suggested, that the planting ratios of 2:10 and/or 2:12 should be exploited to maximize CMS multiplication and hybrid seed production in rice on a large scale.

Sohu and Phul (1993) reported that row proportions of 2B : 2A gave the highest mean seed setting percentage (18.7) and the most economical row proportions for the multiplication of A lines were 2B : 4A and 2B : 6A.

2.3.2 Effect of GA₃, flag leaf clipping and rope pulling on seed set and seed yield.

2.3.2.1 Gibberellic Acid

Gibberellic Acid plays very important role in rice hybrid seed production as evident by the experience of Chinese over the last two decades in solving the problems of poor panicle exertion and seed set on the Indica CMS lines that have been developed based on WA cytoplasm

In the 1980's in China foliar application of Gibberellic acid at the start of panicle emergence was widely adopted as an essential technique for promoting panicle exertion and obtaining higher seed yield.

Tiwari *et al.* (2011) concluded that a treatment combination of (GA₃ 45 g + Urea 10 g + boric acid 2 g + ZNSO₄ + KH₂PO₄ 2 g) significantly increased seed yield with a range of 14.85 g to 23.54 g and could be used to enhance hybrid rice seed production and a substitute of GA₃ in India and almost all rice growing countries.

Thu-Bui Viet *et al.* (2008) indicated that in hybrid seed production of PRH-10, application of GA₃ @ 90g/ha and two time supplementary pollinations at 10:30 h and 11:30 h in a favorable condition during flowering period would give the highest hybrid seed yield upto 4.2 tons/ha. Orapiore watenesk *et al.* (1998) indicated that no need to apply neither GA₃ nor 1.5 percent urea for producing F1 hybrid seeds, only leaf clipping and supplementary pollination during peak anthesis period for one week were enough. Suralta and Robles (2003) showed that GA₃ application at 150 g/ha applied in two splits beginning at 5-10% panicle heading of the female parent population, increased the percentage of panicle exertion from the flag leaf sheath by a maximum of 80 per cent.

Gibberellic acid at 50 g/ha was found significantly effective to increase the effective tillers and grain yield (Katiyar *et al.*, 2001).

Gavino *et al.* (2005) found GA₃ application was very effective in increasing the seed set and seed yield through elongation of plant height, promoting panicle and spikelet exertion, enhancing stigma exertion and longevity and receptivity. During the 2005 wet season in the Philippines, 225, 150, 150 g ha⁻¹ of GA₃ dosage were found to be the most effective and economical thus recommended for Mestizo 1, 2, 3 seed production.

Ponnuswamy *et al.* (1998) revealed that application of GA₃ (125 g/ha) at the 15-20% panicle exertion stage increased plant height, panicle exertion, flag leaf angle, seed setting percentage and seed yield.

Application of GA₃ + 2, 4-D + nutrients gave seed yields of 2151 kg/ha of CMS line IR 58025A and 2542 kg/ha of hybrid seed. (Liang-Man Zhong and Zaman., 2005)

Nihal-ud-Din-Mari *et al.* (2005) indicated that GA₃ at 80 g/ha is optimum for hybrid rice seed production.

Sudipta Basu and Ilyas Ahmed (2005) indicated that application of GA₃ @ 120 and 150 g/ha with Knapsack sprayer, and @ 60 and 75 g/ha with ultra low volume sprayer were superior and spraying at five per cent particle exertion and flowering gave better results than application at late boot leaf stage.

Application of gibberellic acid (GA₃) at 75 or 25 g/ha in combination with urea (2%), boric acid (1.5%), NAA (100 ppm) or arappu [*Albizia amara*] leaf extract (4%) significantly enhanced the flag leaf angle, angle of glume opening, panicle exertion, seed set, and seed yield (Biradarpatil and Shekhargouda 2006).

2.3.2.2 GA₃ + Rope pulling

Rice is basically a self-pollinated crop and hence there is a need to go for supplementary pollination in order to enhance the extent of out crossing supplementary pollination is a technique of shaking the pollen parent so that the pollen grains are shed and effectively dispersed over the A-line plant. This can be done either by rope pulling or shaking the pollen parent with the help of two bamboo sticks. Timing and frequency of pollination are very important. The first supplementary pollination should be given at peak anthesis time *i.e.* at 30-40% are opened, repeated two to four times a day at An interval of 30 mins. Rope pulling has to be done for 7 days during the flowering period.

Gibberlic acid spray alone was not effective in enhancing the seed yield at maruteru, but it was effective in combination with leaf cutting and rope pulling. Similar effects were observed in Coimbatore and faizabad (Anon., 1991).

Djecoumer (1988) recorded higher seed set in IR 54752A with spraying of 60 ppm GA₃ along with supplementary pollination, but the similar effect was not noticed in Intan mutant A.

According to Gangadharaiah *et al.* (2008) leaf cutting, rope pulling and gibberellic acid application increased seed yield and seed set of IR 58025A during the 2006 *kharif* season.

Bong *et al.* (1992) showed a combination of flag leaf clipping, rope pulling and spraying with 60 ppm gibberellic acid resulted in the largest average increase in out crossing rate (105.8 and 100.9%, respectively).

Monila *et al.* (2003) showed supplementary pollination using rod driving and rope pulling during peak anthesis has proven very important for increasing the hybrid rice seed yield, this activity was carried out at 30-minute interval 3-5 times daily until no pollen remained in the hybrid restorer line (R).

Rope pulling or rod driving for 10 days from 20 percent flowering done at 10-12 noon and 3-4 p.m. for one week facilitated the pollen dispersal and effective pollination. Anonymous (2009)

According to anonymous (2005), supplementary pollination twice a day at peak anthesis during flowering phase enhances rice yield.

2.3.2.3 Boron

Boron stimulates the enzymatic activity and nitrogen metabolism which may be linked with improvement in pollen fertility and growth. The application of boron at 2.5 ppm increased the number of grains/panicle, grain yield/plant and thousand grain weights. Further increase in the concentration of boron (5.0 ppm) adversely affected all these parameters (Garg *et al.*, 1980)

Application of 0.05, 0.10, 0.50 per cent boron tillering increased the number of spikelet/panicle, decreased the spikelet's sterility and increased the grain yield in rice. The optimum concentration was found to be 0.10 per cent (Sheudzhen, 1992).

Deshpande (1993) noticed increased panicle length, panicle exertion, and filled spikelet's/plant, seed set percentage and seed yield of hybrid rice with application of boric acid either at 0.5 or 1 per cent

Boron (1 ppm) increased the plant height recorded significantly higher yield in IR-36 rice variety when grown in acid lateritic soils of kharagpur (Subbaiah and Mitra, 1987).

Singh and Sahu (1998) in a study observed the beneficial effect with boric acid (1.5 %) in combination with GA₃ for better exertion of panicle and seed yield of hybrid rice. GA₃ + boric acid (1.5%) helped in increasing the plant height duration of floret opening and the percentage of stigma exertion.

Foliar application of zinc and boron resulted in maximum grains spike⁻¹ (52.2), thousand grains weight (52.2 as mean over years), biological yield (10069.4 kg ha⁻¹) and grain yield (2555 kg ha⁻¹) of wheat. (Sajid Ali *et al.* 2009)

Muhammad Arif *et al.* (2006) concluded that three foliar sprays of nutrient solution (Boron) at tillering, jointing and boot stages along with half of the recommended doses of N and P helped in enhancing yield and yield components of wheat.

David Dunn *et al.* (2005) in their Field research in Missouri showed that rice yields were the greatest when boron fertilized with soil and foliar application.

A relevant local salient experience is an appreciable improvement in cooking quality of rice with fertilizer B use. In 3-year extensive rice field experiments (*cvs. Super Basmati, Basmati-385, KS-282 and IR-6*) carried out by the National Agricultural Research Centre in the rice belt of Punjab province (in collaboration with Punjab's Agricultural Extension & Adaptive Research Department) as well as in Sindh province (in collaboration with Engro Chemical Pakistan Ltd.), B use not only enhanced paddy yields appreciably but also increased kernel milling recovery and head rice recovery as well as improved cooking quality traits, *i.e.*, increased elongation upon cooking, reduced bursting upon cooking and reduced stickiness upon cooking. Improvement in cooking quality of rice, with better B nutrition of plants, is attributed to better grain filling and uniform crop maturity (Rashid *et al.*, 2004).

2.3.2.4 Flag Leaf Clipping

The flag leaf is the last formed leaf and emerges with the panicle and functions only during the last part of the life cycle. It contributes to not less than ten percent to the yield. Enhancing out crossing rate is one of the key factors to increase the seed yield. Normally the flag leaves are erect and longer than the panicles and they come in the way of easy pollen dispersal. Clipping of flag leaf at ear emergence reduced the grain yield of primary tiller by 10.4 percent and secondary tiller by 20.6 percent as compared to intact flag leaf.

Ghosh *et al.* (1990) while studying the role of flag leaf in rice observed that intact flag leaf recorded the highest grain yield in all the varieties.

Dharmarajan (1990) reported that clipping of flag leaf of both female and male parent increased seed set of hybrid seeds. Flag leaf clipping with supplementary pollination recorded the higher seed yield.

Bong *et al.* (1994) in their two years study reported that flag leaf clipping increased the out crossing rate in IR62829A CMS line during 1990 and 1991 but the increase in the seed yield was during 1990 only on the contrary it reduced the seed yield during compared to control. However flag leaf clipping did not affect plant height and panicle length.

Mishra and Pandey (1994) observed that clipping of flag leaf increased the seed yield significantly over control. Flag leaf clipping at boot leaf stage has been recommended for hybrid rice seed production.

Ali Abdalla *et al.* (2008) reported that cutting of both flag leaf and the second leaf contributed maximum to the yield of rice grains.

Prakash *et al.* (2011) concluded that enhanced dry matter production could have been contributed from increased flag leaf area. Increased dry matter could be responsible for enhanced yield.

Application of GA₃ along with flag leaf clipping in female parent of IR 58025A recorded the highest out crossing rate and produced the highest seed yield (Islam *et al.*, 2005).

According to Salgotra *et al.* (2005) out crossing percentage was higher under GA₃ spray compared to flag leaf clipping.

2.4 Assessment of storability of KRH-2 hybrid and its parents under ambient conditions

2.4.1 Seed storability

In stored seeds, ageing is an universal physiological phenomenon followed by deterioration resulting in loss of viability. Usually it progresses at a faster rate under unfavorable environment. The mechanism of deterioration which is the final stage of ageing is still an enigma. Seeds go through a serious of changes before they finally lose viability. Roberts (1973) postulated the loss of viability due to intrinsic and extrinsic factors based on internal and external agents causing loss of viability. The role of various external factors that affect viability during storage are briefly reviewed.

2.4.2 Genotypic variability on storability

Inheritance of seed longevity is not limited to species, several studies show that principles prevailing at the species are also effective at the cultivar levels. Cultivars of same species differ significantly with respect to their seed longevity. Some kinds of seeds are inherently long lived, others are short lived, while some others have intermediate life span.

Under open storage conditions, seeds of different species differed in viability. Seeds of maize, paddy, sorghum, soybean and wheat maintained viability at 85, 88, 78, 90 per cent respectively, at the end of 30 months storage (Delouche, 1973). Among the cereal seeds, bajra seeds deteriorated faster followed by maize, sorghum, paddy and ragi under all storage conditions like warehouse, flat ventilated and air conditioned storage.

Gomez *et al.* (1986) reported that in rice, under prolonged storage conditions, the genotypes differed in maintaining the seed viability.

Sikader (1988) reported the varietal differences in germinability of paddy seeds stored under ambient conditions. The seeds of dwarf ponalis recorded less than 40 percent germination after one year of storage when compared to other dwarf varieties.

Juliano *et al.* (1990) studied the varietal variation of seeds with respect to seed longevity in 31 tropical rice varieties under ambient conditions. The waxy rice varieties lost viability faster than non-waxy rice varieties.

The genotypes differed significantly for storability. Genotypes V20B, Pushpa, Mangala and Madhu were good storers, maintaining more than 80% viability until the end of 19 months of storage (Deshpande, 1993)

Kalavati *et al.* (1994) observed variation in the storage potential among the parental lines of rice hybrids after accelerated ageing for nine days. The restorer lines (R) were better storers followed by maintainer lines (b) and hybrids (h). The female lines (a) were poor storers.

Yogalakshmi *et al.* (1996) while comparing the storage potential of rice hybrids and their parental lines, found that hybrids retained higher germination and followed by restorer and female lines, after 12 months of storage. The maintainer lines were poor storers. Similar observations were made with KRH-2 hybrid and its parents under Bangalore conditions by Thungeswara (1996).

2.4.3 Effect of storage containers

Generally seeds stored in moisture impervious sealed containers store better compared to moisture pervious containers under ambient conditions. The prevailing relative humidity and temperature of the storage atmosphere influence greatly the longevity of seeds since moisture content of the seeds fluctuates more in the moisture pervious containers than in moisture proof containers.

Jalote and Vaish (1976) stored IR-8 paddy seeds under ambient conditions with 10, 12, 14 and 16 percent seed moisture in gunny and polythene bags and observed that storage in gunny bags was better for the seeds of higher moisture content. Where as, the seeds with ten percent moisture stored in polythene bags was found to store better.

Asokan *et al.* (1980) tested the storability of rice seeds under different containers. Polythene bags and glass bottles were found to be superior than cloth bags and gunny bags.

Angamuthu (1996) observed that moisture pervious containers, *viz.*, cloth bag, gunny bag, mud-pot maintained the seed germinability of 80 per cent in all the lines and hybrid seed of rice for nine months, Where as, the moisture resistant containers, *viz.*, polythene bags (300 and 700 gauge) and polylined gunny bags maintained the standard germ inability for a period of 12 months with out seed treatment. Similarly, Yogalakshmi *et al.* (1996) also observed the superiority of polythene bags over cloth bags in storage of rice hybrids and their parental lines.

Biradar patil and Shekargouda (2007) reported that the seeds in polythene bag (700gauge) were superior over cloth bag throughout the storage period for all the seed quality parameters.

According to Raiker *et al.* (2011) seeds treated with insecticide (malathion 10 g/kg of seed) and fungicide (thiram 2 g/kg of seed), calcium oxy chloride (5 g/kg of seed), and arappu leaf powder (25 g/kg of seed) stored in polythene bag retained seed germination and seedling vigour more than 20 months of storage period under ambient conditions of Dharwad (Mugad).

2.4.4 Effect of fungicidal treatment

Seed treatment with fungicides help in reducing the seed deterioration in storage by fungal invasion, controls diseases by seed borne infection and protects seedlings from the attack of soil born e pathogens.

Asokan *et al.* (1980) reported that treating the rice seeds with fungicides preserved the viability better than the untreated control in the storage. In most of the cases, higher concentration of 0.3 per cent of fungicides registered higher germination than 0.2 pert cent concentration. Seeds treated with cereson and agrason GN showed higher germination after 24 hours of treatment where as vitavax proved to be the best for long term storage.

Vidhyasekaran *et al.* (1980) reported that, the fungicides treated seeds of sorghum with initial moisture content of 8.5 per cent maintained viability even after 15 months of storage while the untreated seeds lost their viability significantly. The treatment with vitavax + captan had shown 92 and 85 percent germination after 4 and 15 months of storage, when compared to control 94 and 38 percent respectively. The seedling dry weight was also more 22 and 19 mg in treated as compared to control 22 and 14 mg after 4 and 15 months of storage, respectively.

Ashokan *et al.* (1981) reported that seed treatment with vitavax @ 2 g and 3 g kg⁻¹ seeds of finger millet were found effective in preserving viability as compared to control in the storage.

Hooda and Singh (1993) reported that seed treatment with vitavax @ 2 g kg⁻¹ seed did not affect seed viability even after fifteen months of storage of wheat seeds. The germination per cent was above the minimum seed certification standard (85%) at 10.50, 12.50 and 15.0 per cent of moisture content. The seedling emergence was also found above the required standard even after fifteen months of storage.

Pieta and Patucha (1993) reported that, soybean seed treated with the thiram + carboxin (vitavax) and thiram + carbendazim increased the germination per cent of seeds and controlled *Phoma exina* and *Alternaria* seed borne fungi.

Li-Jian Qiang *et al.* (2001) reported that the seed coating of carbofuron + thiram controlled seed borne fungi *viz.*, *Penicillium*, *Rhizopus*, *Paecilomyces* and *Trichoderma* and increased seed germination and seedling emergence in maize varieties. Maize varieties Jingsan, Huidan 4 and Yundan 13 from Yunnan province which were treated with 40% vitavax 400 (carboxin), 2.5% celest (of unstated composition), 30% apron (metalaxyl) and 20% maize seed treating chemical (carbofuron + thiram).

Biradar patil and Shekargouda (2007) reported that the untreated seeds lost their viability and vigour at a faster rate during storage compared to thiram (2.0g/kg) treated seeds.

Bapurayagouda Patil and Ashok sajjan., (2011).concluded that seed treatment with vitavax power (carboxin + thiram) and captan @ 3 g kg⁻¹ of seeds was effective in maintaining the viability of sorghum seeds during storage.

2.5 Molecular Characterization of parents and hybrids of rice suitable under SRI

Seed proteins are very helpful in genetic diversity evaluation in cereal crops because the seeds of these crops have nutritional value. Glutelin, globulin and prolamin are important seed proteins in rice. Variation in these proteins at subunit level changes the quality of rice. Various tools were used to assess variability at peptide level. Biochemical markers have some disadvantages being tissue specific and affected by environmental and developmental changes. These disadvantages could be eliminated by the use of seed storage protein as they are conservative in nature and least effected by environmental changes. Sodium Dodecyl Sulphate-Polyacrylamide Gel Electrophoresis (SDS-PAGE) is useful method not only for revealing variations but also for identification of a variety in seed storage proteins.

Gelani *et al.* (2011) revealed negligible polymorphism, with reference to the total seed protein profiles, among the rice genotypes of Sindh, Pakistan.

Seed storage proteins polymorphism can be used as a potential molecular marker for varietal identification and economic characterization of rice germplasm (Netra and Prasad, 2007).

Kanchan singh (2006) reported that the Lentil varieties were analyzed for varietal identification through electrophoresis of seed protein. In all 15 bands were recorded with relative mobility of 0.90 presence or absence of any particular band helps in demarcation and identification of variety. Similarity index was calculated to have an idea about evolutionary relationship among the varieties which varied from 53.3 to 93.3 per cent.

Varma *et al.* (2005) studied the differences in banding patterns obtained from electrophoresis of seed proteins for 10 genotypes of maize for their identification at laboratory level. The differences were either in the total number of bands present, location of bands or intensity of band or it can even be the presence or absence of four categories of bands namely very light, light, medium and dark intense bands. This technique was found more suitable for distinguishing even among the closely related genotypes and can be used by the breeders to characterize differences and by seed certification agencies to make available good quality seed to the growers.

Rehana *et al.* (2004) investigated twenty accessions of Pakistani rice germplasm for total seed protein by using SDS-PAGE, to determine the magnitude of genetic variation with respect to geographical distribution. Variation in protein banding pattern with respect to various geographical regions was evaluated and it was suggested that the inter-specific variations were more pronounced as compared to intra-specific variations.

Thanh and Hirata (2002) used seed storage protein profiles of different rice species from Mekong delta in China for evaluation of genetic purity and variability. Two lines were observed in evaluations which were high in waxy protein contents.

Bhowmik *et al.* (1990) suggested the application of SDS-PAGE as useful technique for grouping rice genotypes into several classes.

Electrophoresis of total protein was found to be extremely useful technique for distinguishing rice genotypes by several workers (Iwasaki *et al.*, 1989).

Ivanova (1983) was able to differentiate subspecies, varietal groups and individual genotypes on the basis of specificity of protein banding pattern in 5 Indica and no Japonica genotypes through electrophoresis.

3. MATERIAL AND METHODS

The study on “Standardization of hybrid rice seed production techniques through SRI method in upland eco-system” was carried out during *kharif* seasons of 2010-11 at Agricultural Research Station, Mugad, the only centre working exclusively on rain fed drill sown rice in south India,. The information on the materials used and techniques adopted during the course of investigation are described in this chapter.

3.1 Experimental site

The agricultural Research Station is located at an altitude of 697 meters above mean sea level (MSL), 15°15' North latitude and 70°40' East longitude, which falls in Agro-Climatic Zone No. 8 of Karnataka.

3.1.1 Soils

The soils of this tract are found to have been originated from different rocks and they vary widely in their productivity or fertility. Most of these soils are late rites, characterized by low water and nutrient holding capacities and thus are low in productivity. The information on the materials used and techniques adopted during the course of investigations are described in this chapter.

3.1.2 Experimental material used

Promising rice hybrids grown under different agro ecological regions were selected and tested for their adoptability under SRI method. The hybrids used were; PRH-10, Sahyadri-2, PA 6122, PSD-3, Indam 200-017, DRRH-2, GK-5003 CORH-3, Sahyadri-3, Sahyadri-4, KRH-2 and Local check variety (MGD-101). The following hybrid were obtained from Directorate of Rice Research, Hyderabad, VC Farm Mandya, Regional Research Station, Tamil Nadu Agricultural University, Coimbatore.

3.2 Experiment - I: Screening of selected rice hybrids for suitability under modified SRI method in upland eco-system

The experiment was conducted during *kharif 2010*. The details of experiment are given below.

3.2.1 Treatment details

Main factor: Methods of cultivation (M) -2

M₁ : Modified System of rice intensification.

M₂ : Normal method (Traditional method)

Sub factor: Hybrids (H) -12

H₁ : PRH-10

H₂ : Sahyadri-2

H₃ : PA 6122

H₄ : PSD-3

H₅ : Indam 200-017

H₆ : DRRH-2

H₇ : GK-5003

H₇ : CORH-3

H₉ : Sahyadri-3

H₁₀ : Sahyadri-4

H₁₁ : KRH-2 (Karnataka Rice Hybrid-2)

Local check : MGD-101.

Treatment combination : 2 × 12 = 24

Replication : 3

3.2.2 Experimental design

Experiment was laid out in split plot design with three replications.

3.2.3 Plot size

Gross plot size : 3.8 m × 4.8 m

Net plot size : 3.1 m × 3.1 m

3.2.4 Main field preparation

3.2.4.1 Sowing

The seeds of different hybrids were directly sown by hand dibbling in both the method of planting.

3.2.4.2 Modified SRI method

The main field was prepared by ploughing twice, puddling was not done in this method. The perfect leveling was done by using wet land leveler. The field was laid out into plots and arrangements were made to provide irrigation and draining channels for each treatment. The seeds were hand dibbled with a spacing of 20x20cm with single seed per hill.

3.2.4.3 Traditional method

The main field was ploughed with bullock drawn mould board plough followed by thorough puddling. Five centimeter water was maintained after puddling and leveling was done by providing irrigation and draining channels according to layout plan. Seeds were directly hand dibbled with a spacing of 20cm x 10 cm with two to three seedlings per hill.

3.2.5 Water management

3.2.5.1 Modified SRI Method

Eighty per cent field capacity was maintained throughout the vegetative phase in modified SRI method. This was achieved by irrigating the field at fine crack stage. At this stage irrigation was scheduled to the extent of about two centimeter at each irrigation. From flowering to 10-12 days before harvesting, a thin film of water was maintained continuously by frequent irrigation.

3.2.5.2 Traditional Method

A thin film of two to three centimeter water was maintained after transplanting by irrigating the plots daily. From flowering to maturity three to four centimeters of water was allowed to stagnate in the field upto two weeks before harvest.

3.2.6 Fertilizer application

The fertilizers of N, P₂O₅ and K₂O at each location as per the zonal recommendations @150: 75: 75 NPK kg/ha were applied in accordance with the treatments. Fifty per cent N, K₂O and entire quantities of P₂O₅ were applied at the time of planting, 25 per cent of N and 50 per cent of K₂O were applied at tillering stage and remaining 25 per cent N was applied at the time of panicle initiation stage.

3.2.7 Plant protection

The severe incidence of blast during crop growth was observed in both the method of cultivation. One spray of tricyclozole @0.5% was given as prophylactic measures in *kharif* season.

3.2.8 Observations recorded

1. Plant height (cm) : Plant height was measured from ground level to tip of the longest leaf in case of juvenile plants and also for mature plants, it was measured from ground level to the tip of the tallest panicle and expressed in centimeters.
2. Days to 50 per cent flowering: The number of days taken from sowing to 50 per cent of the plants in the plot to flower was recorded as days to 50 per cent flowering.

3. Root depth(cm) and dry root weight(g):Root samples were collected by removing a cylinder of soil along with the hill using an auger 10 cm in diameter and 45 cm depth .Roots were carefully washed, and their length and dry weight were measured
4. Total number of tillers per plant: In each plot, tillers of labelled plants were counted and their mean was recorded as total number of tillers per plant.
5. Number of productive tillers per plant: The entire ear bearing tillers were counted from the labelled plant to calculate the mean number of productive tillers per plant.
6. Panicle length (cm): The length of panicle was measured in centimeters from the tip of the panicle to the ciliate ring at the base.
7. Total number of spikelets per panicle: The total number of filled and unfilled spikelet's per panicle were counted and expressed in number of spikelet per panicle.
8. Number of filled spikelets per panicle: The number of filled spikelet per panicle counted and expressed in number.
9. Number of unfilled spikelets per panicle: the number of unfilled spikelet per panicle counted and expressed in number.
10. Panicle weight (g): The seeds with panicle from the five tagged plants were separated manually weighed after cleaning. The average was worked out and expressed in grams.
11. Seed yield per plant (g): Total weight of the sun dried seeds was recorded from the labelled plants to estimate the mean seed yield per plant in grams.
12. Seed yield per ha: Seeds from the corresponding net plot area were sun dried and weighed. Seed yield per hectare was computed and expressed in tonnes per hectare.
13. Thousand seed weight: Thousand seeds were counted manually from a sample drawn randomly from each treatment in four replications and weight was recorded in grams.
14. Straw weight/plot (kg): Total weight of the sun dried straw was recorded from the respective plot to estimate the mean straw weight.

3.3 Experiment-II: Evaluation of suitable seed treatment to improve early seedling vigour under SRI method

Factor – I: Genotypes (G)

- | | |
|----------------|----------------------------|
| P ₁ | : Female parent-(IR58025A) |
| P ₂ | : Male parent-(KMR-3) |
| P ₃ | : Hybrid-(KRH-2) |

Factor-II : Seed Treatment as Hydro priming (T)

- | | |
|----------------|--------------------------|
| T ₁ | : Proline (0.1%) |
| T ₂ | : Glycine betaine (0.3%) |
| T ₃ | : PEG-6000 (2%) |
| T ₄ | : Potassium nitrate (1%) |
| T ₅ | : Calcium chloride (1%) |
| T ₆ | : Control |

Design : Factorial CRD

Treatments : 3 × 6 = 18.

3.3.1 Seed quality parameters

1. Germination (%)

Germination test was carried out by adopting between-paper-method as per the procedures of (ISTA, 2010). The blotter paper was not fully saturated with water in order to create stress condition. The number of normal seedlings was counted on the 14th day (final count) of germination from all the replications. The average of four replications was expressed as germination percentage.

2. Shoot length (cm)

Shoot length was measured from collar region of the apex in ten randomly selected 14 days old normal seedlings and the mean was recorded as shoot length in centimeters.

3. Root length (cm)

The root length between collar region and the tip of root in ten randomly selected 14 days old normal seedlings was measured. The mean was calculated and expressed in centimeters.

4. Dry weight of seedlings (mg/ 10 seedling)

Ten seedlings selected for measuring shoot and root length were dried in an oven at 70° + 1°C for 24 hours and after cooling in a dessicator. The weight of the ten seedlings measured and expressed in milligrams.

5. Vigour index

Vigour index was computed by using the following formula suggested by Abdul Baki and Anderson (1973) and expressed in number.

$$\text{Vigour index} = \text{Germination (\%)} \times \text{Shoot length} + \text{Root length in (cm)}$$

6. Speed of germination/ Germination rate index (GRI)

Daily germination count was taken and seeds which have produced minimum 3 cm root taken as germinated. The speed of germination was calculated by using the following formula suggested by Maguire (1962).

$$\text{GRI} = \frac{G_1}{D_1} + \frac{G_2}{D_2} + \dots + \frac{G_n}{D_n}$$

Where,

G_1, G_2, \dots, G_n are the number of seeds germinated on D_1, D_2, \dots, D_n day respectively.

3.4 Experiment-III: Standardization of hybrid seed production techniques for promising rice hybrid under SRI method in upland eco system

Factor – I: Planting ratio (Female parent : Male parent)

P_1	- 3:1
P_2	- 4:1
P_3	- 6:2

Factor – II: Techniques to enhance the seed set percentage

T_1	: GA_3 spray (@ 90 g/ha) at boot leaf initiation
T_2	: GA_3 spray + rope pulling
T_3	: Boron spray (1%) at boot leaf stage
T_4	: Flag leaf clipping

Experimental design : Split plot design.

Treatments	: 3 × 4 = 12
Plot size	
Gross plot size	: 4.7m × 3.8 m
Net plot size	: 4m × 3 m
Spacing	: 20 cm × 20 cm
Replication	: 3
Season	: <i>Kharif</i> 2011.

3.4.1 Seed source

The seeds of KRH-2 hybrid and their parental line seeds were obtained from the Agricultural Research Station, VC Farm, Mandya.

3.4.2 Nursery bed preparation

The raised dry nursery beds of 1.0 m length and 1.2 m width and 0.1 m height was prepared by adding required quantity of farmyard manure. The recommended dose of fertilizers (1.0, 0.5 and 0.5 kg urea, single super phosphate and muriate of potash, respectively per 100 m² area) were incorporated in to beds as per the nursery area. Drainage channels were provided all along the bed to drain out the excess water. Sowing or transplanting of female line early by seven days, so staggered sowing was taken for R-line.

3.4.3 Method of staggering

Sowing of the male line was taken as follows:

1. 1st day of 200 g male +(total female).
2. 3rd day of 200 g male.
3. 5th day of 250 g remaining male.

3.4.4 Main field preparation

The main field was prepared by ploughing twice followed by thorough puddling. The perfect levelling was done by using wet land leveller. The field was laid out into plots and arrangements were made to provide irrigation and draining channels for each treatment.

3.4.4.1 Transplanting

Seedlings of 20 days old were transplanted with a spacing of 20 x 20 cm, in square pattern according to the treatments. Marked ropes were used to achieve square planting in spacing

3.4.4.2 Gap filling

Gap filling was undertaken using seedlings of respective parental nursery beds during 10 days after transplanting. Gap filling was undertaken using seedlings along with soil and intact roots in treatments under SRI method.

3.4.5 Water management

Eighty per cent field capacity was achieved by irrigating the field once in four to five days throughout the vegetative phase. Drying of the field till fine cracks appearance was allowed. At this stage irrigation was scheduled to the extent of about two centimeters at each irrigation. From flowering to 10-12 days before harvesting by thin film of water was allowed by light irrigation frequently.

3.4.6 Weeding

Manual weeding was employed in SRI method plots on 18 days after transplanting (DAT). The weeds around the clumps were removed manually.

3.4.7 Observations recorded

1. Plant height (cm)

Plant height was measured from ground level to tip of the longest leaf in case of juvenile plants and for mature plants, it was measured from the ground level to the tip of the tallest panicle and expressed in centimeters.

2. Days to 50 per cent flowering

The number of days taken from sowing to 50 per cent of the plants in the plot to flower was recorded as days to 50 per cent flowering.

3. Total number of tillers per plant

In each plot, tillers of labeled plants were counted and their mean was recorded as total number of tillers per plant.

4. Number of productive tillers per plant

All the ear bearing tillers were counted from the labeled plant to calculate the mean number of productive tillers per plant.

5. Panicle length (cm)

The length of panicle was measured in centimeters from the tip of the panicle to the ciliate ring at the base.

6. Total number of spikelets per panicle

The total number of filled and unfilled spikelets per panicle were counted and expressed in number.

7. Number of filled spikelets per panicle

The number of filled spikelets per panicle was counted and expressed in number

8. Panicle weight (g)

The seeds from the five tagged plants were separated manually weighed after cleaning. The average was worked out and expressed in grams.

9. Seed yield per plant (g)

Total weight of the sun dried seeds was recorded from the labelled plants to estimate the mean seed yield per plant in grams.

10. Seed set (%)

The seed set per cent was calculated by using the following formula and expressed as seed set in percentage.

$$\text{Seed set (\%)} = \frac{\text{No of filled spikelets}}{\text{Total number of spikelets}} \times 100.$$

11. Spikelet sterility (%)

Spikelet sterility was calculated by using the following formula and expressed as percentage.

$$\text{Spikelet sterility (\%)} = \frac{\text{Total spikelets} - \text{Number of filled spikelets}}{\text{Total spikelets}} \times 100$$

12. Seed yield per ha

Seeds from the corresponding net plot were sun dried and weighed. Seed yield per hectare was computed and expressed in tonnes.

13. Thousand Seed weight

Thousand seeds were counted manually from a sample drawn randomly from each treatment in four replications and weight was recorded in grams.

3.5 Experiment–IV: Studies on seed storability of Karnataka Rice Hybrid-2 and its parental lines

The storage studies were carried out under ambient condition of the Department of Seed Science and Technology, Agricultural College, Dharwad for 12 months during July 2010 to June 2011.

3.5.1 Treatment details

A. Genotypes (g)

G1 - Female parent-(IR58025A)

G2 - Male parent-(KMR-3)

G3 - Hybrid-(KRH-2)

B. Containers (C)

C1 - Cloth bag

C2 - Polythene bag (700 gauge)

C. Seed Treatment

T₁ - Untreated

T₂ - Treated with vitavax (carboxin + thiram @ 3g per kg)

3.5.2 Observations

Samples from each container were drawn bimonthly. Care was taken to avoid the entry of atmospheric moisture into the container during drawing of samples. Observations on seed germination, shoot length, root length, dry weight of seedling vigor index and field emergence were recorded by adopting the procedure mentioned in earlier experiment.

1. Electrical conductivity of seed leachate

The observations on electrical conductivity of seed leachate (EC) were recorded bimonthly on four replications of five grams seeds of each treatment weighed up to two decimal places. The seeds were treated with mercuric chloride (0.1%) for half minute and were thoroughly washed in distilled water for two to three times. The seeds were soaked in 25 ml distilled water. Flasks were placed in an incubator at constant temperature at 25°C ± 1°C for 24 hours. The EC of seed leachate was measured in the digital conductivity meter and recorded as ds⁻¹m at 25°C ± 1°C.

2. Field emergence (%)

Four replications of 100 seeds each per treatment were sown at a depth of three to four centimeter with a spacing of 10 cm x 2 cm. The emergence was recorded on 14 day after sowing. The seedlings with more than three centimeters in height from the soil surface were counted as emerged and expressed in percentage.

3. Seed moisture content (%)

The seed samples were drawn from different treatments to determine the moisture content by adopting the ISTA procedures on oven dry basis following the below formula and expressed in percentage.

$$\text{Moisture content (W.B) per cent} = \frac{W2 - W3}{W2 - W1} \times 100$$

W1 - Weight of the empty aluminium box

W2 - Weight of aluminium box + crushed seed material (before drying)

W3 - Weight of box + crushed seedmaterial (after drying)

3.6 Experiment–V: Characterization of hybrid and its parents of rice using isozymes

Quantification of enzymes like catalase, polyphenol oxidase and peroxidase.

3.6.1 Sample preparation

Leafs were ground to fine powder. The ground 5g leaf sample was put into eppendorf tubes and 15 ml of 0.1M phosphate buffer was added. These suspensions were agitated thoroughly and kept at 8°C overnight for protein extraction. Then the suspensions were centrifuged at 10, 000 rpm for 30 minutes. The clear supernatant was collected. These samples were used for loading.

3.6.2 Electrophoresis

Resolving gel (12%) solution was prepared by mixing 11.6 ml distilled water, 10 ml Acryl amide solution, 7.5 ml resolving gel buffer, 0.3 ml 10% APS and 30 µL TEMED and quickly pipetted under a layer of saturated 2-butanol for 45 minutes. Stacking gel (4%) solution was prepared by mixing 8.9 ml distilled water, 2 ml acrylamide solution 3.75 ml stacking gel buffer, 0.15 ml 10% APS and 15 µL TEMED. Just before pouring the stacking gel, the top of the resolving gel was thoroughly rinsed with distilled water and then the stacking gel solution was poured on top of the resolving gel. Immediately a comb was inserted to form wells of depth 2.5 cm taking care not to trap air bubbles under the teeth. The gel was allowed to polymerise for about half an hour. Then the acrylic comb was removed and the wells were rinsed with distilled water. The upper and lower reservoir was filled with electrode buffer. Then 25 µL of the prepared sample was loaded into the wells in the stacking gel by layering them under electrode buffer using a micropipette. With cathode at the top, a current of 1.5 mA per well with voltage 80 volts was applied until the tracking dye (Bromophenol Blue) crossed the stacking gel. Later the current was increased to 2 mA per well and voltage to 120 volts. The electrophoresis was stopped when the tracking dye reached the bottom of the resolving gel.

3.6.3 Staining of peroxidase

The gels were incubated in 0.25 per cent guaicol for 30 minutes followed by incubation in 0.3 per cent hydrogen peroxide for 15 minutes. Reddish brown bands of peroxidase appeared gradually.

The migration distance of each band and tracking dye was recorded. The migration distance was expressed as the ratio of the migration distance of isozyme to the tracking dye. This factor is known as Relative mobility (Rm) and calculated as follows.

$$R_m = \frac{\text{Distance moved by the isozyme (cm)}}{\text{Distance moved by the tracking dye (cm)}}$$

3.6.4 Polyphenol oxidase

The isozymes of polyphenol oxidase were localised on poly acrylamide gels as per the procedure suggested by Park *et al.* (1980). The enzyme source preparation and electrophoretic technique was essentially the same as in case of peroxidase isozyme studies, except the staining procedure. The isozymes of polyphenol oxidase were localized by incubating the gels for 30 min.in 0.1 per cent poly phenol diamine in 0.1 M potassium phosphate buffer pH (7.00) followed by 10 mM catechol in the same buffer. Observations and calculations of Rm values were similar to that of peroxidase isozymes.

3.6.5 Catalase

Catalase isozyme extraction and the electrophoretic technique was essentially the same as in case of peroxidase isozyme studies except the staining procedure. The isozymes of catalase were localized by incubating the gels in H_2O_2 (0.01%) solution for 5-10 minutes depending upon activity level. Staining solution consisting of Ferric chloride 500 mg, potassium ferricyanide 500 mg and water 50 ml were added to the gels and shaken gently until achromatic bands were developed. The catalase activity was revealed as achromatic zones at green background. These gels were stored in distilled water. Observations and calculations of R_m values were similar to that of peroxidase isozyme.

3.7 Statistical Analysis

The data of individual seasons were statistically analyzed using MSTAT-C programme. The level of significance in F test was 5 per cent. The germination percentage and field emergence were converted into arc-sine transformation values and then subjected to statistical analysis (Gomez and Gomez, 1984).

4. EXPERIMENTAL RESULTS

The results obtained in the field and laboratory experiments conducted at Agricultural Research Station (Paddy), Mugad and Department of Seed Science and Technology, College of Agriculture Dharwad, during *kharif* 2010-12 are presented in this chapter.

4.1 Experiment–I: Screening of Selected Promising Rice Hybrids for Modified SRI method of cultivation under upland eco system

4.1.1 Plant height (cm)

Effect of methods of cultivation, on plant height (cm) at harvest and days to 50% flowering of different promising hybrids evaluated during *kharif* season 2011 are presented in Table 1.

Methods of cultivation influenced the plant height significantly. Higher plant height was obtained under SRI method of cultivation (64.20 cm) as compared to normal method of cultivation (57.31cm).

Check variety MGD-101 recorded the mean highest plant height (80.13 cm), followed by GK-5003 (69.65 cm), INDAM200-0017 (67.33 cm), KRH-2 (63.57 cm), PRH-10 (62.50 cm). SAHYADRI-3 (58.80 cm), PSD-3 (58.35 cm) and SAHYADRI-2 (57.58 cm) which were on par with each other. PA-6129 and SAHYADRI-4 differed significantly for plant height (54.87 cm, 53.97 cm). The lowest plant height was recorded by CORH-3 (51.74 cm) and DRRH-2 (50.55 cm) which were on par with each other.

Interaction effect between methods of cultivations on plant height of 11 different promising hybrids showed the significant differences. M_1H_{12} recorded the highest plant height (81.27 cm), followed by M_2H_{12} (79.00 cm), M_1H_7 (70.87 cm) and M_1H_5 (70.07 cm). The lowest plant height was recorded by M_2H_4 (52.37 cm), M_2H_2 (51.50 cm) and M_2H_{10} (50.60 cm). Rest all of the interaction effects were on par with each other.

4.1.2 Days to 50 per cent flowering

The data on days to 50 per cent flowering varied significantly due to methods of cultivation. The flowering was early under SRI method of cultivation compared to traditional method. Hybrids under SRI method recorded lesser days (89.11) for 50 per cent flowering compared to traditional method (92.58).

Hybrids showed significant difference with respect to 50 per cent flowering. Among the 11 different hybrids H_6 took less number of days for 50 per cent flowering (83.33). H_2 , H_7 showed no significant difference in 50 per cent flowering (86.00, 86.00) and were on par with each other, followed by H_4 (88.00), H_{10} (88.50), H_{11} (89.50), H_{12} (89.67), H_3 (90.33), H_5 (91.17), H_1 (91.83) and H_7 (98.17). More number of days to 50 per cent flowering was noticed in H_9 (107.67).

The interaction effects between the methods of cultivation on days to 50 per cent flowering of 11 different promising hybrids were found significant. M_1H_6 significantly took less number of days to 50 per cent flowering (80.67) compared to all other interaction effects, followed by M_1H_8 (82.67), M_1H_4 (86.00) and M_2H_6 (86.00) which found on par with each other. Among the interactions M_2H_9 took more days to 50 per cent flowering (108.67) followed by M_1H_9 (106.67), M_2H_7 (100.33) and M_1H_7 (96.00).

4.1.3 Root Depth (cm)

Effect of method of cultivation on root depth (cm) and dry weight of different promising hybrids are presented in Table 2.

Root depth differed significantly due to method of cultivation. SRI method of cultivation recorded significantly higher root depth (31.64 cm) as compared to traditional method (19.50 cm).

Table 1. Effect of methods of cultivation on plant height and days to 50 per cent flowering of different promising hybrids

Hybrids (H)	Plant height (cm)			Days to 50 per cent flowering		
	Methods of cultivation (M)					
	M ₁	M ₂	Mean	M ₁	M ₂	Mean
H ₁	66.20	58.80	62.50	90.00	93.67	91.83
H ₂	63.67	51.50	57.58	84.00	88.00	86.00
H ₃	57.90	51.83	54.87	89.33	91.33	90.33
H ₄	64.33	52.37	58.35	86.00	90.00	88.00
H ₅	70.07	64.60	67.33	89.67	92.67	91.17
H ₆	52.17	48.93	50.55	80.67	86.00	83.33
H ₇	70.87	68.43	69.65	96.00	100.33	98.17
H ₈	54.45	49.03	51.74	82.67	89.33	86.00
H ₉	65.00	52.60	58.80	106.67	108.67	107.67
H ₁₀	57.33	50.60	53.97	87.67	89.33	88.50
H ₁₁	67.13	60.00	63.57	87.67	91.33	89.50
H ₁₂	81.27	79.00	80.13	89.00	90.33	89.67
Mean	64.20	57.31		89.11	92.58	
	SEm_±		CD at 5%	SEm_±		CD at 5%
M	0.38		2.33	0.53		3.22
H	0.56		1.60	0.30		0.86
M x H	0.85		2.98	0.67		3.26

M₁ - Modified SRI method

M₂ - Traditional method

M x H - Main plot means at same or different levels of sub plot

H₁ - PRH-10

H₂ - Sahyadri-2

H₃ - PA-6129

H₄ - PSD-3

H₅ - Indam 200-0017

H₆ - DRRH-2

H₇ - GK-5003

H₈ - CORH-3

H₉ - Sahyadri-3

H₁₀ - Sahyadri-4

H₁₁ - KRH-2

H₁₂ - MGD-101

Table 2. Effect of methods of cultivation on root depth (cm) and dry root weight (g) different promising hybrids

Hybrids (H)	Root depth (cm)			Dry root weight (g)		
	Methods of cultivation (M)					
	M ₁	M ₂	Mean	M ₁	M ₂	Mean
H ₁	31.20	19.20	25.20	11.41	5.10	8.25
H ₂	31.20	19.20	25.20	11.44	5.12	8.28
H ₃	31.30	19.20	25.25	11.34	5.11	8.22
H ₄	31.40	19.40	25.40	11.52	5.12	8.32
H ₅	31.60	19.50	25.55	11.60	5.20	8.40
H ₆	32.00	19.70	25.85	11.63	5.23	8.43
H ₇	32.70	20.40	26.55	12.17	5.37	8.77
H ₈	32.20	19.90	26.05	11.72	5.26	8.49
H ₉	31.40	19.40	25.40	11.53	5.14	8.33
H ₁₀	31.40	19.40	25.40	11.57	5.16	8.36
H ₁₁	32.40	20.01	26.21	11.82	5.24	8.53
H ₁₂	30.90	18.70	24.80	10.89	4.90	7.90
Mean	31.64	19.50		11.55	5.16	
	SEm_±		CD at 5%	SEm_±		CD at 5%
M	1.63		9.91	0.14		0.85
H	0.03		0.09	0.03		0.10
M x H	1.63		9.91	0.15		0.85

M₁ - Modified SRI method

M₂ - Traditional method

M x H - Main plot means at same or different levels of sub plot

H₁ - PRH-10

H₂ - Sahyadri-2

H₃ - PA-6129

H₄ - PSD-3

H₅ - Indam 200-0017

H₆ - DRRH-2

H₇ - GK-5003

H₈ - CORH-3

H₉ - Sahyadri-3

H₁₀ - Sahyadri-4

H₁₁ - KRH-2

H₁₂ - MGD-101

Among the 11 different hybrids H₇ differed significantly by recording higher root depth (26.55 cm), followed by H₁₁ (26.21 cm), H₈ (26.05 cm), H₆ (25.85 cm) and H₅ (25.55 cm). While H₁₀ (25.40), H₉ (25.40) and H₄ (25.40) were found on par with each other. H₃ recorded (25.25 cm), H₂ (25.20 cm), H₁ (25.20 cm). Shallow root depth was recorded by MGD-101 (24.80 cm).

The interaction effects between the method of cultivation and hybrids were found significant. M₁H₇ (32.70 cm), M₁H₁₁ (32.40 cm) and M₁H₈ (32.20 cm) recorded the higher root depths and were found on par with each other. While the M₂H₁₂ recorded lower root depth (18.70 cm).

4.1.4 Root weight (g)

Root weight (g) differed significantly due to method of cultivation. SRI method of cultivation recorded significantly higher dry root weight (11.55g) as compared to traditional method (5.16 g).

Among the different hybrids H₇ differed significantly by recording higher dry root weight (8.77g), followed by H₁₁ (8.53g), H₈ (8.49 g), H₆ (8.43 g), H₅ (8.40 g). While, H₁₀ (8.36 g), H₉ (8.33g), H₄ (8.32), were found on par with each other. Whereas, H₂ recorded (8.28g), H₁ (8.25g), H₃ (8.22g). Lower root depth was recorded by MGD-101 (7.90g).

The interaction effect between the method of cultivation and hybrids were found significant for root weight. M₁H₇ recorded higher root weight (12.71g). followed by M₁H₁₁ (11.82 g) and M₁H₇ (11.72 g) which were found on par with each other. While the M₂H₁₂ recorded lower root weight (4.90 g).

4.1.5 Total number of tillers

The data on effect of methods of cultivation on total number of tillers and productive tillers of different promising hybrids is presented in the Table 3.

The data on number of tillers per plant revealed significant differences between the methods of cultivation. SRI method of cultivation recorded significantly higher number of tillers per plant (25.49) as compared to the traditional method of cultivation (13.04). All the 11 hybrids showed significant differences with respect to total number of tillers. Among them, H₁₁ and H₁₀ produced higher number of tillers (23.15, 22.15 respectively) and were found on par with each other. Subsequently followed by H₃, H₈, H₇, H₆, H₁, H₄, H₂, H₅ and H₉ (21.20, 20.95, 20.08, 19.57, 18.80, 18.38, 17.73, 17.37 and 16.57, respectively). Least number of tillers were observed with H₁₂ (15.12).

The interaction effects between the methods of cultivation on hybrids for total number of tillers were found significant. Interaction M₁H₁₁ registered the highest number of tillers per plant (31.43) followed by M₁H₁₀, M₁H₈, M₁H₇ (29.87, 27.93, 26.87) respectively. Whereas, M₂H₁₂ recorded lower number of tillers per plant (10.37) followed by M₂H₅, M₂H₉, M₂H₂ and M₂H₆ (11.53, 12.00, 12.33 and 12.87 respectively).

4.1.6 Productive tillers

The data on the number of productive tillers per plant revealed significant differences among the various treatments.

The two methods of cultivation differed significantly for number of productive tillers. SRI method revealed more number of productive tillers per plant (23.13) compared to traditional method (10.07).

Significant difference was observed in hybrids for number of productive tillers per plant. Among the different hybrids, H₇ and H₁₁ recorded higher number of productive tillers per plant (19.37, 19.07) which were found on par with each other, followed by H₈, H₆, H₃, H₁, H₁₀, H₅, H₂, H₄ and H₉ (18.57, 17.97, 17.03, 16.73, 16.47, 15.90, 15.63, 14.62 and 14.20 respectively). Significantly lower number of productive tillers was recorded in check, variety MGD-101 (13.63).

Table 3. Effect of methods of cultivation, total number of tillers and productive tillers of different promising hybrids

Hybrids (H)	Total number of tillers			Productive tillers		
	Methods of cultivation (M)					
	M ₁	M ₂	Mean	M ₁	M ₂	Mean
H ₁	24.40	13.20	18.80	23.20	10.27	16.73
H ₂	23.13	12.33	17.73	22.20	9.07	15.63
H ₃	28.13	14.27	21.20	24.80	9.27	17.03
H ₄	23.63	13.13	18.38	20.17	9.07	14.62
H ₅	23.20	11.53	17.37	22.13	9.67	15.90
H ₆	26.27	12.87	19.57	25.07	10.87	17.97
H ₇	26.87	13.30	20.08	26.00	12.73	19.37
H ₈	27.93	13.97	20.95	26.27	10.87	18.57
H ₉	21.13	12.00	16.57	18.53	9.87	14.20
H ₁₀	29.87	14.63	22.25	22.27	10.67	16.47
H ₁₁	31.43	14.87	23.15	27.27	10.87	19.05
H ₁₂	19.87	10.37	15.12	19.60	7.67	13.63
Mean	25.49	13.04		23.13	10.07	
	SEm_±		CD at 5%	SEm_±		CD at 5%
M	0.11		0.68	0.88		5.36
H	0.35		1.00	0.31		0.89
M x H	0.49		1.47	0.98		5.35

M₁ - Modified SRI method

M₂ - Traditional method

M x H - Main plot means at same or different levels of sub plot

H₁ - PRH-10

H₂ - Sahyadri-2

H₃ - PA-6129

H₄ - PSD-3

H₅ - Indam 200-0017

H₆ - DRRH-2

H₇ - GK-5003

H₈ - CORH-3

H₉ - Sahyadri-2

H₁₀ - Sahyadri-3

H₁₁ - KRH-2

H₁₂ - MGD-101

The interaction effects between the methods of cultivation on 11 hybrids, for productive tillers per plant showed significant differences. Among the interaction effects M_1H_{11} , M_1H_8 and M_1H_7 , recorded higher number of productive tillers per plant (27.27, 26.27 and 26.00 respectively) which were found on par with each other. Lowest numbers of productive tillers were noticed by a treatment combination of M_2H_{12} , M_2H_1 and M_2H_3 (7.67, 9.07, and 9.27 respectively).

4.1.7 Panicle length (cm).

The results obtained on panicle length (cm) and panicle weight (g) are presented in Table 4.

The method of cultivation differed significantly for panicle length (cm). SRI method recorded significantly higher panicle length (21.51 cm) as compared to traditional method (19.59 cm).

Significant variation in panicle length (cm) was observed in 11 different hybrids. Among different hybrids, H_7 recorded the highest panicle length (23.45 cm), followed by H_{11} , H_5 , H_1 , H_{10} , H_9 , H_2 , H_4 , H_3 , H_{12} and H_6 (22.38, 21.07, 20.82, 20.73, 20.67, 20.53, 20.13, 19.88, 19.68 and 19.17 respectively). Lowest panicle length was recorded by H_8 (18.05).

Interaction effect between the methods of cultivation and hybrids showed significant difference with respect to panicle length (cm). Treatment combination of M_1H_7 , M_1H_{11} recorded the highest panicle length (24.00, 23.93 cm) and were found on par with each other, followed by M_2H_7 , M_1H_5 , M_1H_9 , M_1H_{10} and M_1H_2 (22.90, 22.00, 21.93, 21.87 and 21.53 cm) respectively. M_2H_8 recorded the lowest panicle length (16.33) of all the treatment combinations, followed by M_2H_6 , M_2H_4 , M_2H_{12} and M_2H_9 (18.47, 19.10, 19.10 and 19.40 respectively).

4.1.8 Panicle weight (g)

Panicle weight differed significantly due to methods of cultivation. Higher panicle weight was noticed in SRI method of cultivation (3.61g), as compared to the normal method of cultivation (3.23g).

Among the eleven different hybrids H_7 recorded the highest panicle weight per panicle (4.00g), followed by H_7 , H_{11} , H_6 , H_3 , H_{10} , H_9 , H_5 , H_{12} and H_4 (3.72 g, 3.72 g, 3.67 g, 3.42 g, 3.42 g, 3.40 g, 3.25 g, 3.24 g, 3.16g) respectively. The lowest panicle weight per panicle was recorded by both H_2 and H_1 (3.03g and 3.02g) which were found on par with each other.

Interaction effect between the methods of cultivation on panicle weight of different hybrids were found significant. Among the interaction effects M_1H_7 recorded highest panicle weight (4.24g), followed by M_1H_{11} , M_1H_7 , M_1H_6 and M_2H_7 (3.94, 3.93, 3.88 and 3.75 respectively). M_2H_4 recorded the lowest panicle weight (2.93g) which was found on par with treatment M_2H_2 and M_2H_1 (2.95g and 2.94g, respectively).

4.1.9 Seed weight per plant (g)

Effect of methods of cultivation on seed weight per plant and 1000 seed weight (g) of different promising hybrids are presented in Table 5.

Seed weight per plant differed significantly due to methods of cultivation. SRI method of cultivation recorded significant higher seed weight per plant (34.27g) as compared to the normal method of cultivation (20.93g).

Hybrids showed significant difference with respect to seed weight per plant. Of all the hybrids H_7 produced higher seed weight per plant (33.96g), followed by H_{11} , H_8 (32.36g, 31.91g) which were on par with each other. H_6 , H_5 , H_{10} , H_9 , H_4 , H_3 , H_2 and H_1 recorded (31.08g, 28.54g, 27.35g, 26.55g, 25.09g, 24.65g, 24.46g and 24.42g respectively). MGD-101 recorded the lowest seed weight per plant (20.84g).

The interaction effects between the methods of cultivation and hybrids were found significant. M_1H_7 interaction recorded significantly higher seed weight per plant (42.34g) followed by M_1H_{11} , M_1H_8 and M_1H_6 (40.29g, 39.41g and 38.86g) and were on par with each other. Where as M_2H_{12} recorded lowest seed weight per plant (13.75g). M_2H_{12} was followed by M_2H_3 , M_2H_2 and M_2H_1 (19.26, 19.19 g and 19.12g respectively).

Table 4. Effect of methods of cultivation on panicle length (cm) and panicle weight (g) of different promising hybrids

Hybrids (H)	Panicle length (cm)			Panicle weight (g)		
	Methods of cultivation (M)					
	M ₁	M ₂	Mean	M ₁	M ₂	Mean
H ₁	21.40	20.23	20.82	3.11	2.94	3.02
H ₂	21.53	19.53	20.53	3.10	2.95	3.03
H ₃	20.67	19.10	19.88	3.56	3.29	3.42
H ₄	20.83	19.43	20.13	3.39	2.93	3.16
H ₅	22.00	20.13	21.07	3.49	3.01	3.25
H ₆	19.87	18.47	19.17	3.88	3.46	3.67
H ₇	24.00	22.90	23.45	4.24	3.75	4.00
H ₈	19.77	16.33	18.05	3.93	3.51	3.72
H ₉	21.93	19.40	20.67	3.61	3.19	3.40
H ₁₀	21.87	19.60	20.73	3.63	3.20	3.42
H ₁₁	23.93	20.82	22.38	3.94	3.51	3.72
H ₁₂	20.27	19.10	19.68	3.45	3.02	3.24
Mean	21.51	19.59		3.61	3.23	
	SEm_±		CD at 5%	SEm_±		CD at 5%
M	0.11		0.68	0.05		0.29
H	0.27		0.76	0.04		0.11
M x H	0.38		1.19	0.07		0.30

M₁ - Modified SRI method

M₂ - Traditional method

M x H - Main plot means at same or different levels of sub plot

H₁ - PRH-10

H₂ - Sahyadri-2

H₃ - PA-6129

H₄ - PSD-3

H₅ - Indam 200-0017

H₆ - DRRH-2

H₇ - GK-5003

H₈ - CORH-3

H₉ - Sahyadri-3

H₁₀ - Sahyadri-4

H₁₁ - KRH-2

H₁₂ - MGD-101

Table 5. Effect of methods of cultivation on seed weight/plant (g) and 1000-seed weight (g) of different promising hybrids

Hybrids (H)	Seed weight/plant (g)			1000-seed weight (g)		
	Method of cultivation (M)					
	M ₁	M ₂	Mean	M ₁	M ₂	Mean
H ₁	29.72	19.12	24.42	24.63	23.73	24.18
H ₂	29.73	19.19	24.46	21.47	20.57	21.02
H ₃	30.05	19.26	24.65	21.73	20.83	21.28
H ₄	30.72	19.47	25.09	19.94	19.03	19.49
H ₅	35.40	21.68	28.54	24.83	23.92	24.38
H ₆	38.86	23.29	31.08	24.81	23.91	24.36
H ₇	42.34	25.58	33.96	25.13	24.23	24.68
H ₈	39.41	24.42	31.91	22.75	21.85	22.30
H ₉	32.60	20.51	26.55	22.47	21.57	22.02
H ₁₀	34.24	20.47	27.35	22.70	21.79	22.25
H ₁₁	40.29	24.42	32.36	22.58	21.68	22.13
H ₁₂	27.92	13.75	20.84	22.81	21.91	22.36
Mean	34.27	20.93		22.99	22.09	
	SEm_±		CD at 5%	SEm_±		CD at 5%
M	0.69		4.19	0.54		NS
H	0.50		1.44	0.08		0.24
M x H	0.97		4.35	0.55		NS

M₁ - Modified SRI method M₂ - Traditional method NS – Non-significant
M x H - Main plot means at same or different levels of sub plot

H₁ - PRH-10 H₂ - Sahyadri-2 H₃ - PA-6129 H₄ - PSD-3
H₅ - Indam 200-0017 H₆ - DRRH-2 H₇ - GK-5003 H₈ - CORH-3
H₉ - Sahyadri-3 H₁₀ - Sahyadri-4 H₁₁ - KRH-2 H₁₂ - MGD-101

4.1.10 Thousand seed weight (g)

Methods of cultivation did not influence significant difference on thousand seed weight. However SRI method of cultivation recorded higher seed weight (22.99g) as compared to the normal method of cultivation (22.09g). Thousand seed weight significantly differed for 11 different hybrids.

Among the 11 different hybrids H₇ differ significantly from all others and recorded higher thousand seed weight (24.68g). H₇ was followed H₅ (24.38g), H₆ (24.36), H₁ (24.18), H₁₂ (22.36), H₇ (22.30), H₁₀ (22.25), H₉ (22.02), H₃ (21.28) and H₂ (21.02). H₄ differed significantly by recording lowest thousand seed weight (19.49g).

Interaction effects were found non significant.

4.1.11 Total number of spikelets

Effect of methods of cultivation on total number of spikelets, number of filled spikelets and unfilled spikelets per panicle of different promising hybrids are presented in Table 6.

The methods of cultivation differed significantly for total spikelets per panicle. SRI method recorded significantly higher number of spikelets per panicle (183.29) compared to the traditional method (139.85).

Among the hybrids, H₇ differed significantly for total number of spikelets and recorded highest number of spikelets per panicle (189.17) followed by H₁₁ (175.56), H₈ (175.32), H₆ (168.74), H₁₀ (160.93), H₉ (160.79), H₅ (159.76), H₂ (152.91), H₄ (152.74), H₃ (152.91) and H₁ (151.36). Check variety MGD-101 differed significantly from all other hybrids and recorded the lowest number of spikelets per panicle (139.56).

The interaction effects between the methods of cultivation and hybrids were found significant. M₁H₇ registered the highest number of spikelets per panicle (212.67) followed by M₁H₁₁ (195.00), M₁H₈ (192.34) and M₁H₉ (185.67). While M₂H₁₂ recorded the lowest spikelets per panicle (119.99).

4.1.12 Number of filled spikelets

The number of filled spikelets per panicle differed significantly due to method of cultivation. SRI method of cultivation recorded significantly higher number of filled spikelets (144.44) compared to traditional method.

Among the 11 different hybrids, H₇ differed significantly by recording highest number of filled spikelets per panicle (166.14), followed by H₁₁ (146.17), H₈ (144.91), H₆ (135.23), H₅ (128.31), H₁ (119.98), H₁₀ (119.15), H₄ (117.80), H₂ (116.68) and H₉ (116.48). Lower number of filled spikelets was recorded by H₃ (114.14).

The interaction effect between the method of cultivation and hybrids were found significant. M₁H₇ interaction differed significantly by recording the higher number of spikelets (180.00), followed by M₁H₁₁ (164.00) and M₁H₈ (161.67) which were found on par with each other. Whereas lowest number of filled spikelets was recorded by interaction treatment of M₂H₉ (96.97) which was found on par with M₂H₃ (96.62) and M₂H₁₀ (99.30).

4.1.13 Unfilled spikelets

The data obtained on unfilled spikelets revealed significant difference among the methods of cultivation. SRI method of cultivation significantly recorded lower number of unfilled spikelets per panicle (37.21) compared to traditional method (46.33). Hybrids differed significantly for the number of unfilled spikelets.

Among the hybrids H₇ differ significantly by obtaining the less number of unfilled spikelets (34.57), this was followed by H₁₁ (35.73), H₈ (35.82), H₁₂ (38.15), H₅ (39.38), H₆ (40.40), H₁₀ (42.62), H₄ (42.78), H₂ (43.74), H₃ (44.28) and H₁ (48.20). Out of 11 different hybrids H₉ differed significantly by recording higher number of unfilled spikelets (55.59).

The interaction effect between the method of cultivation and hybrids were found significant. M₁H₇ recorded lower number of unfilled spikelets (27.00), followed by M₁H₁₂ and M₁H₁₁ (28.56, 29.33) which were found on par with each other. While interaction effect M₂H₉ differed significantly by recording more number of unfilled spikelets per panicle (69.63).

Table 6. Effect of methods of cultivation on total number of spikelets, number of filled spikelets and unfilled spikelets/ panicle of different promising hybrids

Hybrids (H)	Total number of spikelets			Number of filled spikelets			Unfilled spikelets		
	Methods of cultivation								
	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean
H ₁	176.33	126.39	151.36	134.00	105.95	119.98	41.00	55.40	48.20
H ₂	178.14	127.68	152.91	134.67	98.70	116.68	43.00	44.49	43.74
H ₃	176.00	128.02	152.01	131.67	96.62	114.14	44.33	44.23	44.28
H ₄	174.70	130.78	152.74	135.00	100.60	117.80	43.22	42.34	42.78
H ₅	179.07	140.44	159.76	142.67	113.96	128.31	36.78	41.99	39.38
H ₆	185.74	151.74	168.74	144.67	125.78	135.23	39.33	41.46	40.40
H ₇	212.67	165.67	189.17	180.00	152.28	166.14	27.00	42.13	34.57
H ₈	192.34	158.31	175.32	161.67	128.16	144.91	32.67	38.98	35.82
H ₉	185.67	135.91	160.79	136.00	96.97	116.48	41.56	69.63	55.59
H ₁₀	184.67	137.20	160.93	139.00	99.30	119.15	39.78	45.47	42.62
H ₁₁	195.00	156.13	175.56	164.00	128.33	146.17	29.33	42.13	35.73
H ₁₂	159.14	119.99	139.56	130.00	103.74	116.87	28.56	47.74	38.15
Mean	183.29	139.85		144.44	112.53		37.21	46.33	
	SEm_±		CD at 5%	SEm_±		CD at 5%	SEm_±		CD at 5%
M	1.06		6.47	0.92		5.58	0.39		2.35
H	1.97		5.62	1.49		4.25	1.00		2.86
M x H	2.87		9.46	2.22		7.55	1.41		4.37

M₁ - Modified SRI method M₂ - Traditional method
M x H - Main plot means at same or different levels of sub plot

H₁ - PRH-10 H₂ - Sahyadri-2 H₃ - PA-6129 H₄ - PSD-3
H₅ - Indam 200-0017 H₆ - DRRH-2 H₇ - GK-5003 H₈ - CORH-3
H₉ - Sahyadri-3 H₁₀ - Sahyadri-4 H₁₁ - KRH-2 H₁₂ - MGD-101

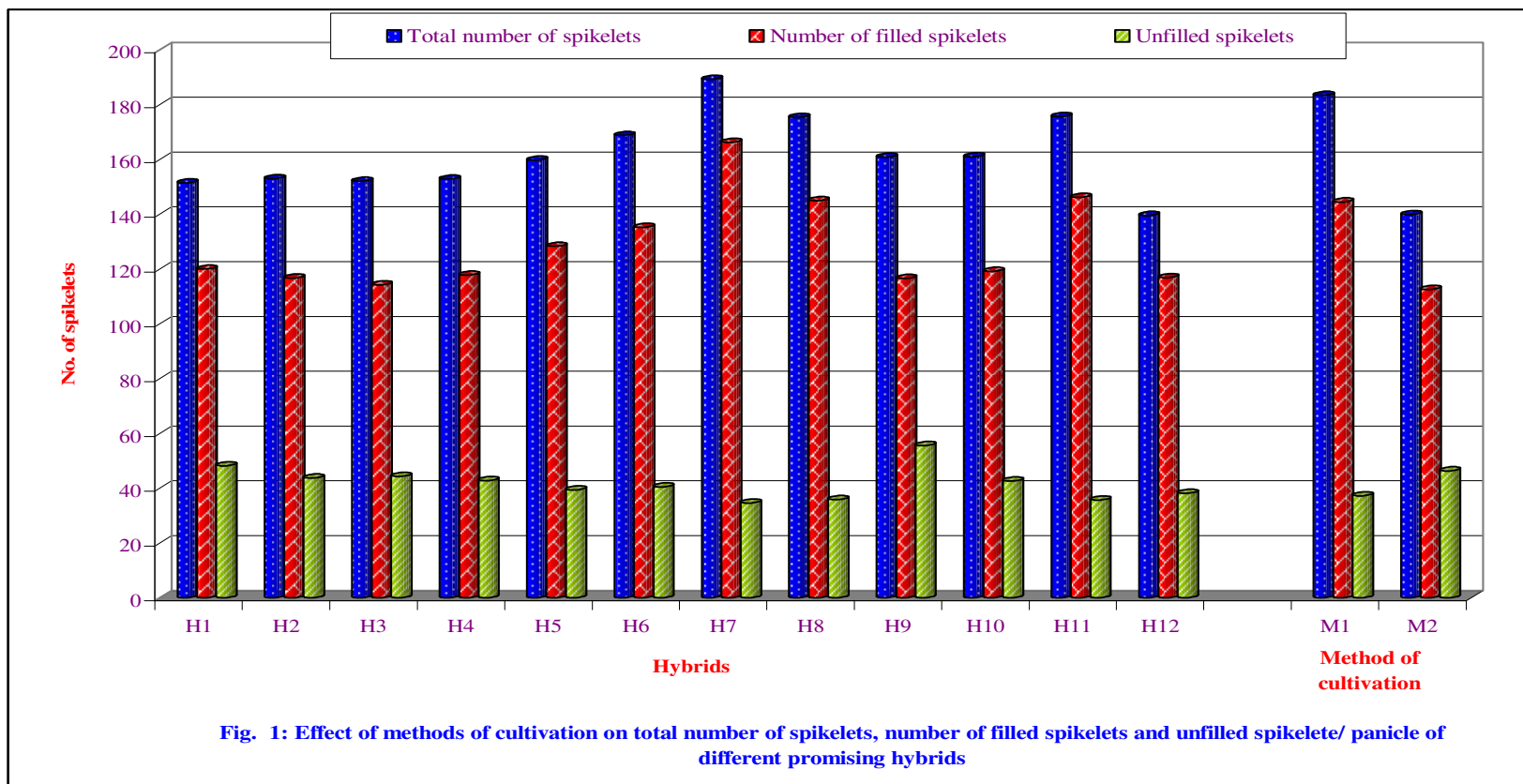


Fig. 1: Effect of methods of cultivation on total number of spikelets, number of filled spikelets and unfilled spikelets/ panicle of different promising hybrids

4.1.14 Grain yield (g)

Effect of method of cultivation on grain yield per plot (g) and grain yield (t/ha) and straw weight (kg/plot) of different promising hybrids is presented in Table 7:

Grain yield per plot revealed significant difference among the methods of cultivation. SRI method recorded significantly higher grain yield per plot (2973g) compared to traditional method (1879g).

Among the Hybrids H₇ differed significantly for grain yield and recorded higher grain yield (2923g) followed by H₁₁ (2778g), H₈ (2738g), H₆ (2668g), H₅ (2501g), H₁₀ (2461g), H₉ (2376g), H₄ (2257g), H₃ (2218g), H₁ (2197g), H₂ (2117g) respectively. Lower grain yield as recorded by MGD-101 (1875g).

Interaction effects between the methods of cultivation and hybrids were found significant. M₁H₇ recorded significantly higher grain yield per plot (3544g) which was found on par with M₁H₁₁ (3359g), followed by M₁H₆ (3289g), M₁H₈ (3279g). Whereas, lower grain yield per plot was recorded by M₁H₁₂ (1237g).

4.1.15 Grain yield (t/ha)

Effect of method of cultivation on grain yield (t/ha) of different promising hybrids are presented in Table 7.

Grain yield (t/ha) revealed significant difference among the methods of cultivation. SRI method recorded significantly higher grain yield (9.91t/ha) compared to traditional method (6.27t/ha).

Among the Hybrids H₇ differ significantly for grain yield, recorded higher grain yield (9.74t/ha) followed by H₁₁ (9.26 t/ha), H₈ (9.13 t/ha), H₆ (8.89 t/ha), H₅ (8.34 t/ha), H₁₀ (8.21 t/ha), H₉ (7.92 t/ha), H₄ (7.53 t/ha), H₃ (7.40 t/ha), H₁ (7.33 t/ha) and H₂ (7.06 t/ha) respectively. Lower grain yield was recorded by MGD-101 (6.25 t/ha).

Interaction effects between the methods of cultivation and hybrids were found significant. M₁H₇ recorded significantly higher grain yield (11.81 t/ha) which was found on par with M₁H₁₁ (11.20 t/ha), followed by M₁H₆ (10.97 t/ha) and M₁H₈ (10.93 t/ha). Where as lower grain yield per plot was recorded by M₂H₁₂ (4.13 t/ha).

4.1.16 Straw weight (kg/plot)

The data on straw weight as influenced by methods of cultivation on hybrids is presented in Table 7. SRI method of cultivation recorded significantly higher straw weight (4.08 kg) compared to the traditional method of cultivation (3.50)

Straw weight differed significantly with respect to different hybrids Out of the 11 hybrids H₁₁ recorded significantly higher straw weight (4.51 kg) followed by H₇ (4.26 kg), H₈ (4.25 kg), H₆ (4.09 kg), H₃ (3.96 kg), H₁₀ (3.78 kg), H₉ (3.72 kg), H₁ (3.54 kg), H₂ (3.48 kg), H₄ (3.44 kg) and H₅ (3.36 kg). Lowest straw weight was recorded by H₁₂ (3.14 kg).

Interaction effects between the methods of cultivation and hybrids for straw weight differed significantly. M₁H₁₁ recorded higher straw weight (5.01Kg) subsequently followed by M₁H₇, M₁H₈ and M₁H₆ (4.62 kg, 4.62 kg and 4.49 kg respectively) which were found on par with each other. M₂H₁₂ totally differed from all other interaction effect by recording lower straw weight (2.87 kg).

4.2 Experiment-II: Evaluation of suitable seed treatment chemicals to improve seedling vigour under SRI method of cultivation

4.2.1 Germination (%)

Significant difference in germination due to various seed treatment on KRH-2 hybrid and its parental lines were observed (Table 8).

Germination was significantly higher in KRH-2 hybrid (96.77%) followed by KMR-3 (94.68%). The lowest germination percentage was recorded by IR-58025A (91.69%).

Table 7. Effect of methods of cultivation on grain yield/plot (g), grain yield (t/ha) and straw weight (kg/plot) of different promising hybrids

Hybrids (H)	Grain yield/plot (g)			Grain yield (t/ha)			Straw weight (kg/plot)		
	Methods of cultivation								
	M ₁	M ₂	Mean	M ₁	M ₂	Mean	M ₁	M ₂	Mean
H ₁	2675	1720	2197	8.92	5.74	7.33	3.71	3.37	3.54
H ₂	2508	1727	2117	8.36	5.76	7.06	3.61	3.36	3.48
H ₃	2704	1733	2218	9.01	5.78	7.40	4.31	3.61	3.96
H ₄	2763	1752	2257	9.21	5.84	7.53	3.61	3.28	3.44
H ₅	3052	1951	2501	10.17	6.50	8.34	3.51	3.21	3.36
H ₆	3289	2046	2668	10.97	6.82	8.89	4.49	3.68	4.09
H ₇	3544	2302	2923	11.81	7.67	9.74	4.62	3.91	4.26
H ₈	3279	2197	2738	10.93	7.33	9.13	4.62	3.88	4.25
H ₉	2907	1845	2376	9.69	6.15	7.92	4.01	3.44	3.72
H ₁₀	3081	1842	2461	10.27	6.14	8.21	4.11	3.45	3.78
H ₁₁	3359	2198	2778	11.20	7.33	9.26	5.01	4.01	4.51
H ₁₂	2512	1237	1875	8.38	4.13	6.25	3.41	2.87	3.14
Mean	2973	1879		9.91	6.27		4.08	3.50	
	SEm_±		CD at 5%	SEm_±		CD at 5%	SEm_±		CD at 5%
M	29.72		180.85	0.10		0.60	0.03		0.17
H	46.21		131.69	0.15		0.44	0.07		0.19
M x H	69.26		238.67	0.23		0.80	0.09		0.29

M₁ - Modified SRI method M₂ - Traditional method
M at H - Main plot means at same or different levels of sub plot

H₁ - PRH-10 H₂ - Sahyadri-2 H₃ - PA-6129 H₄ - PSD-3
H₅ - Indam 200-0017 H₆ - DRRH-2 H₇ - GK-5003 H₈ - CORH-3
H₉ - Sahyadri-3 H₁₀ - Sahyadri-4 H₁₁ - KRH-2 H₁₂ - MGD-101

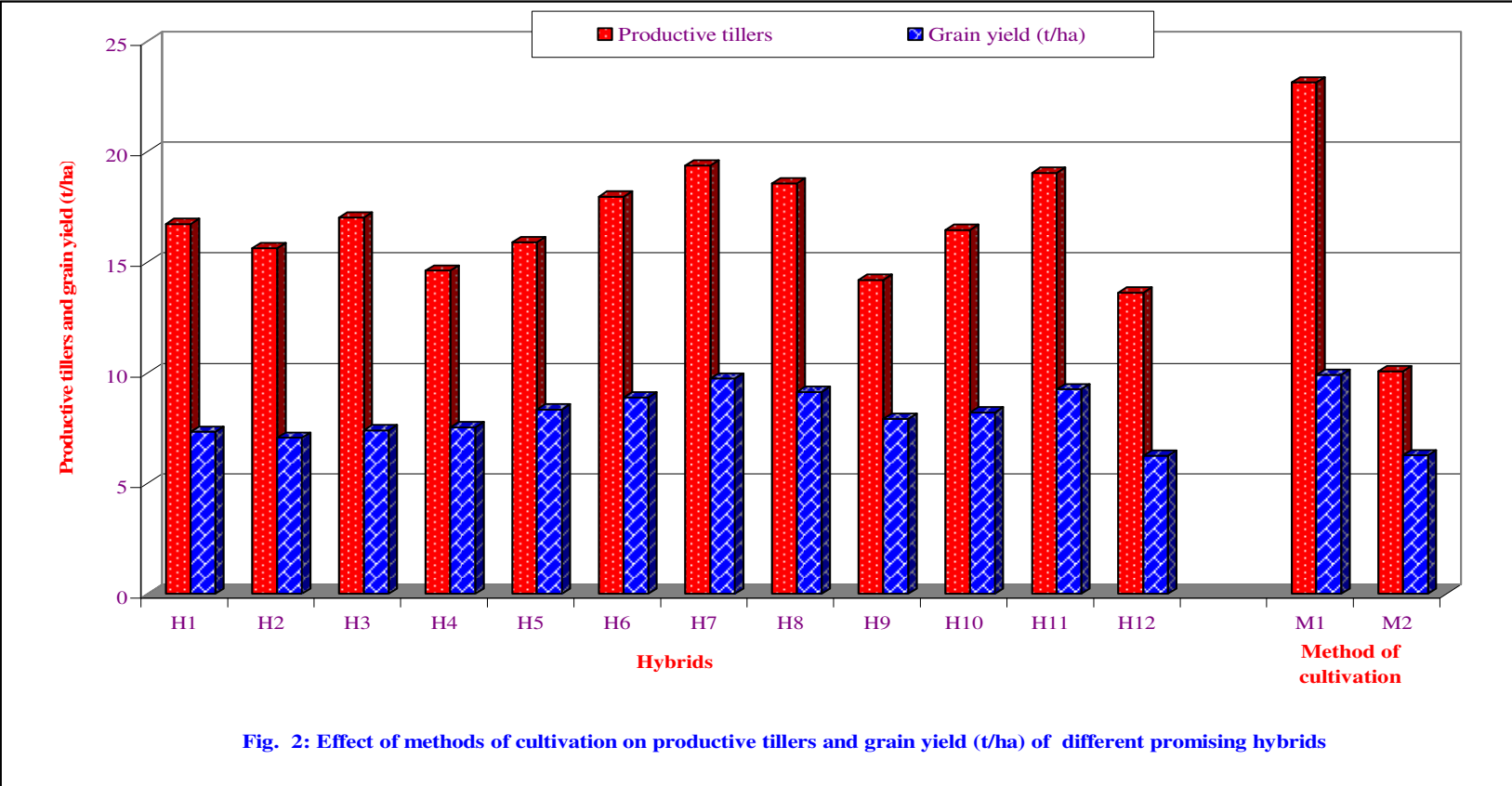


Fig. 2: Effect of methods of cultivation on productive tillers and grain yield (t/ha) of different promising hybrids

Among the seed treatments proline @ 0.1% recorded higher germination percentage (94.96%) followed by glycine betaine @ (0.3%) (94.70), PEG-6000 (2%) (94.40%), potassium nitrate @ 1% (94.18), calcium chloride @ 1% (94.05%). The lowest germination was recorded by control (93.61%).

Interaction effect between genotypes and seed treatments were non significant.

4.2.2 Speed of germination

The results on speed of germination indicated significant influence of different seed treatments on genotypes (Table 8).

The genotypes differed significantly with respect to speed of germination. KRH-2 hybrid recorded higher speed of germination (26.48) followed by KMR-3 (22.45). IR-58025A recorded the lowest speed of germination (21.51).

Among the seed treatments, proline @ 0.1% differed significantly from all other seeds treatments and recorded higher speed of germination (24.05), followed by glycine betaine @ 0.3% (23.86), PEG-6000 (23.43), potassium nitrate (23.32), calcium chloride (23.22). Control recorded lower speed of germination (22.99).

Interaction effect between the genotypes and seed treatments was found significant.

P_3T_1 recorded higher speed of germination (26.95), followed by P_3T_2 (26.95), P_3T_3 (26.45), P_3T_4 (26.40), P_3T_5 (26.27) and P_3T_6 (26.13). The similar trend was followed by KMR-3 and IR-58025A.

4.2.3 Shoot length (cm)

Shoot length was significantly influenced by genotypes and seed treatments as presented in Table 9.

Genotypes differed significantly for shoot length. Higher shoot length was recorded by KRH-2 (12.67 cm) and KMR-3 (11.97 cm). The lowest shoot length was recorded by IR-58025A (11.08 cm).

Among the seed treatments, proline differed significantly and recorded higher shoot length (12.28 cm) which was found on par with glycine betaine (12.16). PEG-6000 (12.01cm), KNO_3 (11.83cm), and $CaCl_2$ (11.74cm). The lowest shoot length was recorded by control (11.41cm).

Interaction effect between genotypes and chemical treatment were found significant. P_3T_1 recorded higher shoot length (12.95cm), followed by P_3T_2 (12.79cm), P_3T_3 (12.73cm), P_3T_4 (12.63cm) and P_3T_5 (12.62cm). The lowest was recorded by p_3t_6 (12.30cm). similar trend was followed by KMR-3 (P_2T_1) and IR-58025A (P_1T_1).

4.2.4 Root length (cm)

The results on root length was significantly influenced by genotypes and seed treatment as presented in Table 9.

Genotypes differed significantly for root length. Higher root length was recorded by KRH-2 (13.34 cm) and KMR-3 (12.66 cm). Lower root length was recorded by IR-58025A (11.82 cm).

Seed treatment showed significant difference with respect to root length. Among the seed treatments, proline differed significantly over control and recorded higher root length (13.00 cm) which was found on par with glycine betaine (12.87 cm). PEG-6000 (12.68 cm), KNO_3 (12.52 cm), and $CaCl_2$ (12.50 cm). The lowest shoot length was recorded by control (12.06 cm).

Interaction effects between the genotypes and seed treatments were found significant. Interaction P_3T_1 recorded higher root length (13.62 cm) followed by P_3T_2 (13.55 cm) P_3T_3 (13.42 cm), P_3T_4 (13.27 cm) and P_3T_5 (13.26 cm). The lowest shoot length was recorded by P_3T_6 (12.90 cm). Similar trend was noticed in interactions of P_2T_1 and P_1T_1 respectively.

Table 8. Effect of seed treatment on germination (%) and speed of germination of KRH-2 hybrid and its parents

Treatments	Germination (%)				Speed of germination			
	Genotypes							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	92.33 (73.90)*	95.25 (77.39)	97.28 (80.48)	94.96 (77.26)	22.33	22.87	26.95	24.05
T ₂	92.15 (73.70)	94.83 (76.82)	97.12 (80.19)	94.70 (76.91)	22.14	22.75	26.69	23.86
T ₃	91.84 (73.37)	94.37 (76.25)	96.99 (79.98)	94.40 (76.54)	21.37	22.47	26.45	23.43
T ₄	91.61 (73.13)	94.25 (76.10)	96.68 (79.46)	94.18 (76.23)	21.27	22.30	26.40	23.32
T ₅	91.56 (73.08)	94.20 (76.03)	96.41 (79.04)	94.05 (76.05)	21.18	22.20	26.27	23.22
T ₆	90.67 (72.19)	94.00 (75.79)	96.15 (78.65)	93.61 (75.54)	20.76	22.09	26.13	22.99
Mean	91.69 (73.23)	94.48 (76.40)	96.77 (79.64)		21.51	22.45	26.48	
	SEm_±		CD at 1%		SEm_±		CD at 1%	
p	0.06		0.22		0.03		0.10	
T	0.08		0.32		0.04		0.14	
P × T	0.14		NS		0.06		0.24	

P₁- Female parent P₂- Male parent P₃ - Hybrid NS – Non-significant
P × T Interaction effect of genotypes and chemicals

T₁ - Proline (0.1%) T₂ - Glycine betaine (0.3%) T₃ - PEG-6000 (2%)
T₄ - Potassium nitrate (1%) T₅ - Calcium chloride (1%) T₆ - Control

* - Figures in the parentheses indicate arc sine root transformed values

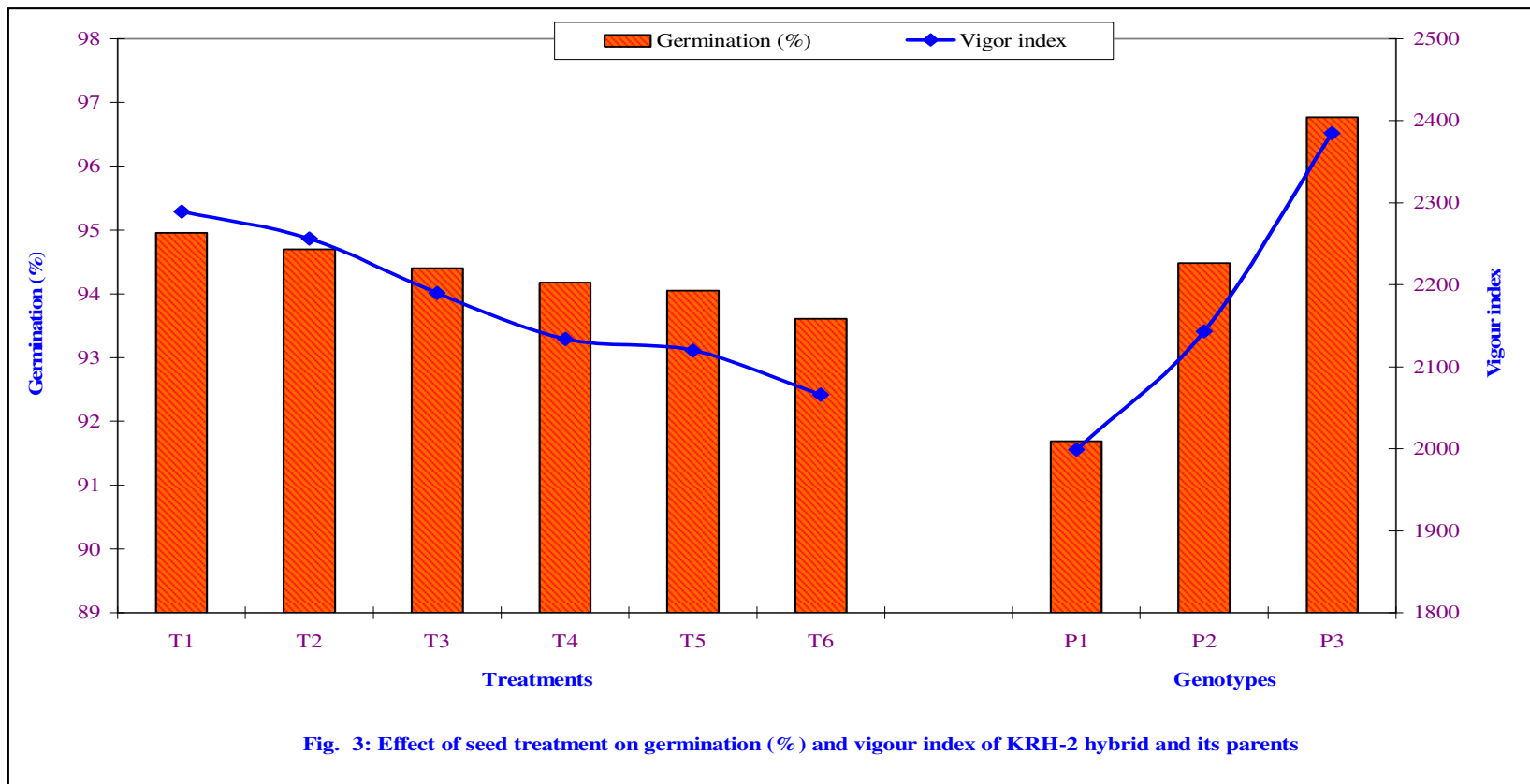


Fig. 3: Effect of seed treatment on germination (%) and vigour index of KRH-2 hybrid and its parents

Table 9. Effect of seed treatment on shoot length and root length of KRH-2 hybrid and its parents

Treatments	Shoot length (cm)				Root length (cm)			
	Genotypes							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	11.48	12.40	12.95	12.28	12.30	13.07	13.62	13.00
T ₂	11.40	12.29	12.79	12.16	12.24	12.83	13.55	12.87
T ₃	11.20	12.11	12.73	12.01	11.93	12.70	13.42	12.68
T ₄	10.99	11.87	12.63	11.83	11.65	12.65	13.27	12.52
T ₅	10.87	11.73	12.62	11.74	11.63	12.60	13.26	12.50
T ₆	10.53	11.43	12.30	11.42	11.17	12.10	12.90	12.06
Mean	11.08	11.97	12.67		11.82	12.66	13.34	
	SEm_±		CD at 1%		SEm_±		CD at 1%	
p	0.02		0.08		0.02		0.08	
T	0.03		0.12		0.03		0.11	
P × T	0.05		0.20		0.05		0.20	

P₁- Female parent P₂- Male parent P₃ - Hybrid
P × T Interaction effect of genotypes and chemicals

T₁ - Proline (0.1%) T₂ - Glycine betaine (0.3%) T₃ - PEG-6000 (2%)
T₄ - Potassium nitrate (1%) T₅ - Calcium chloride (1%) T₆ - Control

4.2.5 Vigour index

The results on vigour index indicated significant influence of genotypes and seed treatments are presented in Table 10.

Genotypes differed significantly for vigour index. KRH-2 differed significantly and recorded higher vigour index (2385) followed by KMR-3 (2143). The lowest vigour index was recorded by IR58025A (1999).

Among the seed treatments proline recorded significantly higher vigour index (2289) over the control, This was subsequently followed by glycine betaine (2256), PEG-6000 (2190), KNO_3 (2134) and CaCl_2 (2120). The lowest was recorded by control (2066).

Interaction effect between genotype and seed treatment was found significant. P_3T_1 interaction recorded higher vigour index (2484) followed by P_3T_2 (2453), P_3T_3 (2403), P_3T_4 (2347), P_3T_5 (2343) and P_3T_6 (2277). The same trend was noticed in P_2T_1 and P_1T_1 interaction respectively.

4.2.6 Seedling dry weight (mg/10 seedlings):

The data are presented in the Table 10 revealed that the significant difference in seedling dry weight with respect to genotype and seed treatment was found.

KRH-2 recorded higher seedling dry weight (152.64 mg) followed by KMR-3 (146.03 mg). The lowest was recorded by IR58025A (141.15 mg).

Among the seed treatments proline recorded significantly higher vigour index (156.37mg) over the control followed by glycine betaine (153.90 mg), PEG-6000 (145.94mg), KNO_3 (144.61 mg), CaCl_2 (143.39 mg). The lowest was recorded by Control (135.44 mg).

Interaction effect between the genotypes and seed treatments were found significant. P_3T_1 interaction recorded higher seedling dry weight (160.33 mg), P_3T_2 (159.17mg) P_3T_3 (154.40mg), P_3T_4 (151.93 mg) P_3T_5 (151.67 mg) and P_3T_6 (138.33 mg).

Similar trend was noticed in interaction effects of P_2T_1 and P_1T_1 respectively.

4.3 Experiment–III: Standardization of seed production Techniques in KRH-2 hybrid

4.3.1 Plant height (cm)

The results on Influence of different levels of planting ratio and seed production techniques on plant height, days to 50 per cent flowering (female and male) in hybrid rice seed production under SRI method are presented in Table 1.

Plant height did not differ significantly with planting ratio. Although higher plant height was noticed in the planting ratio of P_1 -3:1 (67.88 cm) followed by P_2 -4:1 (67.75 cm), P_3 -6:2 (67.42 cm). Significant difference among the various techniques for plant height was observed. The treatment GA_3 spray alone recorded significantly higher plant height (71.21 cm) this was followed by GA_3 coupled with rope pulling (70.83 cm), flag leaf clipping (64.46 cm). The lowest plant height (64.23cm) was noticed in boron spray.

Interaction effects were found to be non significant.

4.3.2 Days to 50 per cent flowering (female)

No significant difference was observed for days to 50 per cent flowering on female parent with respect to planting ratio, techniques and their interaction effect. However GA_3 spray took less number of days to 50 per cent flowering (97.17 days).

4.3.3 Days to 50 per cent flowering (male)

Days to 50 per cent flowering in male parent was not influenced by planting ratio and techniques. While GA_3 spray took less number of days to 50 per cent flowering (93.50 days).

Table 10. Effect of seed treatment on vigor index and seedling dry weight of KRH-2 hybrid and its parents

Treatments	Vigor index				Seedling dry weight (mg/10 seedlings)			
	Genotypes							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	2103	2279	2484	2289	149.77	159.00	160.33	156.37
T ₂	2081	2235	2453	2256	147.13	155.40	159.17	153.90
T ₃	2003	2163	2403	2190	140.12	143.30	154.40	145.94
T ₄	1945	2110	2347	2134	139.73	142.17	151.93	144.61
T ₅	1934	2082	2343	2120	137.17	141.33	151.67	143.39
T ₆	1929	1993	2277	2066	133.00	135.00	138.33	135.44
Mean	1999	2143	2385		141.15	146.03	152.64	
	SEm_±		CD at 1%		SEm_±		CD at 1%	
p	4.51		17.34		0.64		2.45	
T	6.38		24.52		0.90		3.46	
P x T	11.04		42.47		1.56		NS	

P₁- Female parent P₂- Male parent P₃ - Hybrid NS – Non-significant
P x T Interaction effect of genotypes and chemicals

T₁ - Proline (0.1%) T₂ - Glycine betaine (0.3%) T₃ - PEG-6000 (2%)
T₄ - Potassium nitrate (1%) T₅ - Calcium chloride (1%) T₆ - Control

Table 11. Influence of different levels of planting ratio and techniques on plant height (female parent), days to 50 per cent flowering (female), days to 50 per cent flowering (male) in hybrid rice seed production under SRI Method

Techniques (T)	Plant height (cm) (female)				Days to 50 per cent flowering (female)				Days to 50 per cent flowering (male)			
	Planting ratio (P)											
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	71.90	71.07	70.67	71.21	97.00	97.17	97.33	97.17	93.33	93.50	93.67	93.50
T ₂	71.00	71.17	70.33	70.83	97.33	97.27	97.50	97.37	93.67	93.60	93.83	93.70
T ₃	64.13	64.35	64.20	64.23	99.00	99.90	99.37	99.42	94.10	94.57	94.17	94.28
T ₄	64.47	64.43	64.47	64.46	98.67	98.67	98.33	98.56	94.00	94.00	94.00	94.00
Mean	67.88	67.75	67.42		98.00	98.25	98.13		93.78	93.92	93.92	
	SEm_±		CD at 5%		SEm_±		CD at 5%		SEm_±		CD at 5%	
p	3.20		NS		4.73		NS		0.10		NS	
T	3.59		10.67		5.51		NS		0.19		NS	
P x T	6.27		NS		9.53		NS		0.31		NS	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

4.3.4 Total number of tillers

Influence of different levels of planting ratio and techniques on total number of tillers and productive tillers in seed parent of KRH-2 hybrid under SRI method are presented in Table 2.

No significant difference was observed in total number of tillers per plant due to planting ratio. However, the planting ratio of 6:2 recorded more number of tillers (40.00) followed by 3:1 (39.88) and 4:1 (39.77). Total number of tillers was greatly influenced by chemical spray.

Among the techniques, GA₃ + Rope pulling, GA₃ recorded higher number of tillers per plant (41.46, 41.35) and were found on par with each other. Flag leaf clipping (38.40) and boron recorded lower tillers (38.25) which were on par with each other.

Interaction effects between the planting ratios and techniques for total number of tillers was found non significant.

4.3.5 Productive tillers

Productive tillers did not show any significant difference due to planting ratio.

Significant difference was observed for number of productive tillers per plant due to techniques. GA₃ coupled with rope pulling and GA₃ alone recorded higher number of productive tillers per plant (36.18, 35.06) and were on par with each other. Boron spray and flag leaf clipping differed significantly by recording lower number of tillers (29.21 and 29.31) found on par with each other.

All the interaction effects were found to be non significant with respect to productive tillers per plant.

4.3.6 Total number of spikelets per plant

Influence of different levels of planting ratios and techniques on total number of spikelets and number of filled spikelets in seed parent of KRH-2 hybrid under SRI method are presented in Table 13.

No significant difference was observed with total number of spikelets per plant. However, numerically higher number of spikelets were observed in GA₃ coupled with rope pulling (183.57) followed by GA₃ (183.49), boron spray (181.91) and flag leaf clipping recorded spikelets (182.27).

4.3.7 Number of filled spikelets

The number of filled spikelets per panicle varied significantly due to planting ratios. Among the planting ratio 6:2 differed significantly and recorded higher number of filled spikelets per panicle (54.44) and was subsequently followed by 3:1 (47.47). Lowest number of filled spikelets per panicle was observed in planting ratio of 4:2 (43.39).

GA₃ along with the rope pulling recorded more number of filled spikelets per panicle (52.76) followed GA₃ spray alone (50.21) and boron spray (46.67). The lowest number of spikelets was observed in flag leaf clipping (44.08).

Interaction effect on total number of filled spikelets per panicle were found to be significant. P₃T₂ differed significantly from all other combinations recorded higher number of spikelets (57.99), P₃T₁ (56.49), P₃T₃ (53.09). While P₂T₄ recorded the lowest number of filled spikelets per panicle (39.03).

4.3.8 Panicle length (cm)

Influence of different levels of planting ratios and techniques on panicle length (cm), panicle weight (g) and panicle exertion in seed parent of KRH-2 hybrid under SRI method are presented in Table 14.

Panicle length was not influenced by planting ratios and was found non significant.

Table 12. Influence of different levels of planting ratios and techniques on total number of tillers and Productive tillers in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Total number of tillers				Productive tillers			
	Planting ratio							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	41.25	41.25	41.54	41.35	35.01	35.00	35.16	35.06
T ₂	41.67	41.20	41.53	41.46	36.30	36.36	35.89	36.18
T ₃	38.25	38.18	38.33	38.25	29.24	29.38	29.00	29.21
T ₄	38.33	38.29	38.58	38.40	29.38	29.22	29.33	29.31
Mean	39.88	39.73	40.00		32.48	32.49	32.35	
	SEm_±		CD at 5%		SEm_±		CD at 5%	
p	0.30		NS		0.29		NS	
T	0.22		0.66		0.77		2.30	
P x T	0.45		NS		1.20		NS	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

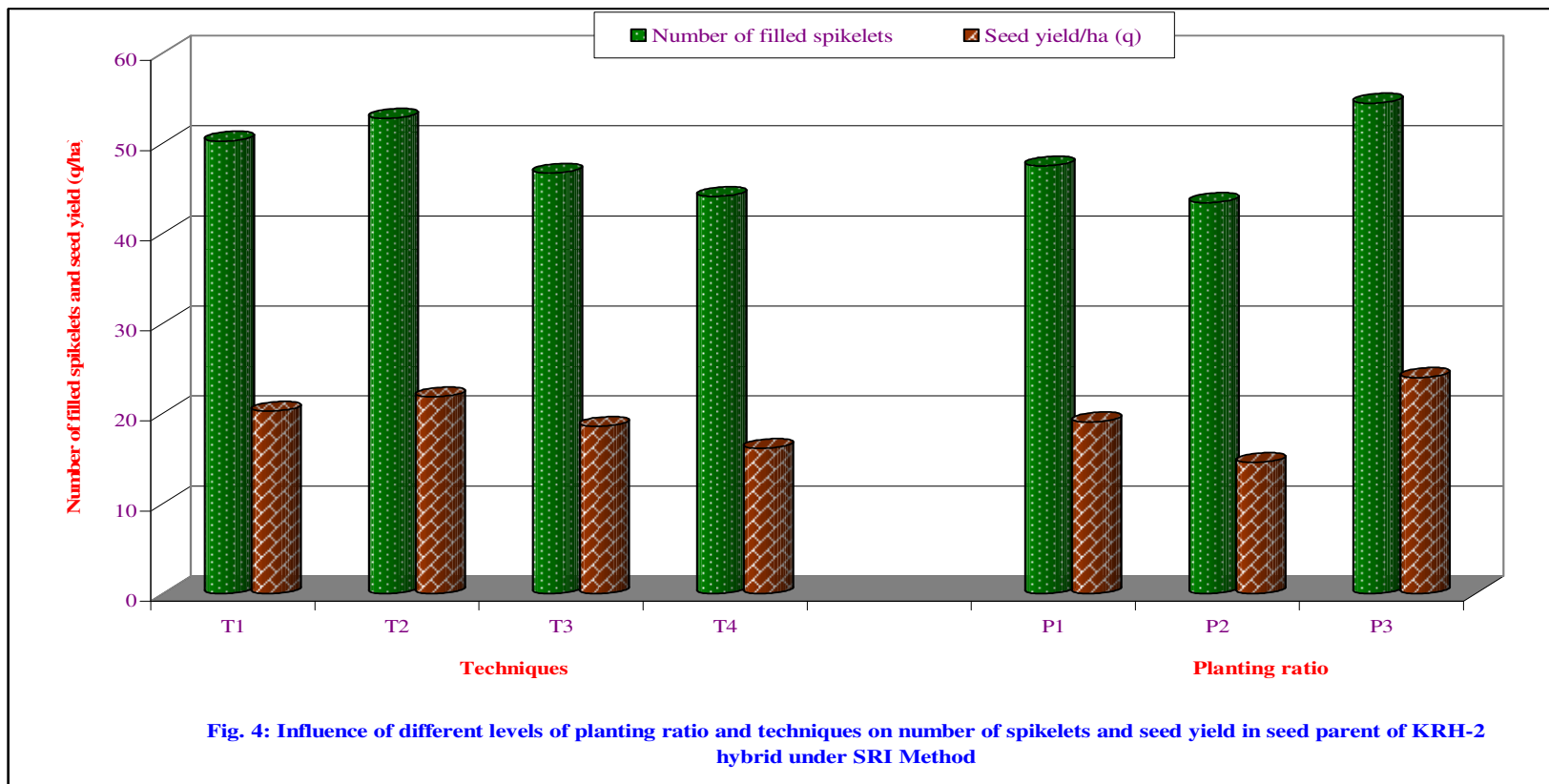


Fig. 4: Influence of different levels of planting ratio and techniques on number of spikelets and seed yield in seed parent of KRH-2 hybrid under SRI Method

Table 13. Influence of different levels of planting ratio and techniques on number of seeds and filled spikelets in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Total number of spikelets/plant				Number of filled spikelets			
	Planting ratio							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	183.67	182.91	183.88	183.49	49.23	44.90	56.49	50.21
T ₂	183.67	183.83	183.21	183.57	52.14	48.14	57.99	52.76
T ₃	181.85	181.96	181.91	181.91	45.47	41.47	53.09	46.67
T ₄	182.33	182.33	182.15	182.27	43.03	39.03	50.17	44.08
Mean	182.88	182.76	182.79		47.47	43.39	54.44	
	SEm_±		CD at 5%		SEm_±		CD at 5%	
P	0.20		NS		0.08		0.33	
T	0.49		NS		0.16		0.49	
P x T	0.76		NS		0.26		0.80	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

Table 14. Influence of different levels of planting ratio and techniques on panicle length, panicle weight, panicle exertion in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Panicle Length (cm)				Panicle weight (g)				Panicle exertion			
	Planting ratio											
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	22.87	22.90	22.87	22.88	1.23	1.25	1.48	1.32	86.33	86.35	86.30	86.33
T ₂	22.92	22.96	24.26	23.38	1.40	1.10	1.55	1.35	86.10	86.12	86.13	86.12
T ₃	15.37	15.07	15.04	15.16	1.22	0.88	1.30	1.13	73.23	72.90	73.90	73.34
T ₄	20.70	20.73	20.71	20.71	0.85	0.77	1.14	0.92	73.90	73.92	74.03	73.95
Mean	20.46	20.41	20.72		1.17	1.00	1.37		79.89	79.82	80.09	
	SEm_±		CD at 5%		SEm_±		CD at 5%		SEm_±		CD at 5%	
P	0.07		NS		0.07		NS		0.15		NS	
T	0.24		0.72		0.07		0.21		0.30		0.89	
P x T	0.37		NS		0.13		NS		0.48		NS	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

The chemical spray GA₃ increased the panicle length significantly over the boron spray. Significantly higher panicle length was recorded with GA₃ coupled with rope pulling (23.88 cm) followed by GA₃ spray alone (22.88 cm) and were found on par each other. Flag leaf clipping recorded panicle length of 20.71 cm. The lowest panicle length was recorded with boron spray (15.16 cm).

Interaction effect between the planting ratio and chemical spray was found significant. Among the interaction, P₃T₂ recorded higher panicle length (24.26 cm) where as P₃T₃ differed significantly from each other interaction effects, produced lower panicle length (15.04 cm).

4.3.9 Panicle weight (g)

Panicle weight was not influenced by planting ratio and was non significant.

Panicle weight was highest with GA₃ coupled with rope pulling (1.35 g) which was found on par with GA₃ spray alone (1.32 g). Boron spray recorded panicle weight of (1.13 g). Lowest panicle weight was recorded by flag leaf clipping (0.92 g).

Interaction effect between the planting ratio and chemical spray was found significant. Among the interactions, P₃T₂ recorded higher panicle weight (1.55 g) where as P₂T₄ differed significantly from other interaction effect, produced lower panicle weight (0.77 g).

4.3.10 Panicle exertion

Panicle exertion had no significant difference with planting ratio.

Techniques showed significant variation with respect to panicle exertion. GA₃ with rope pulling and GA₃ spray alone produced higher degree of panicle exertion (86.22, 86.33) which reported on par with each other. Lower panicle exertion was noticed in boron spray and flag leaf clipping (73.34 and 73.95, respectively) both were on par with each other.

Interaction effects between the techniques and planting ratio was found significant. P₁ T₂, P₁ T₁, P₃ T₁, P₃ T₂, P₂ T₂ and P₁ T₂ (86.35, 86.33, 86.30, 86.13, 86.13 and 86.10, respectively) all the interaction effects were found on par with each other. While P₂T₃ recorded lower panicle exertion (72.90).

4.3.11 Seed set (%)

Data presented in the Table 15 reveal significant influence of different treatments and planting ratios on seed set percentage.

Planting ratio showed higher influence on seed set percentage and differed significantly. Row ratio of 6:2 recorded the highest per cent of seed set (30.90%) followed by 3:1 (27.33%) and 4:1 (20.10%)

All the techniques enhanced the out crossing resulting in significant increase in seed setting. The mean seed setting was higher with GA₃ coupled with rope pulling (27.08%). GA₃ spray alone (26.52%), boron spray (25.84%). Lower out crossing rate was observed in the flag leaf clipping (25.00%).

The interaction effects between the planting ratio and techniques were found significant. P₃T₂ differed significantly produced higher seed set per cent (31.46%) which were found on par with P₃T₁ (31.41%) and P₃T₃ (30.69%). Where as interaction P₂T₄ recorded significantly lower seed set compared to chemical spray (19.63%).

4.3.12 Spikelet sterility

The data on the per cent spikelet sterility as represented in Table 15 indicated significant difference among the treatments. Spikelet sterility differed significantly among the planting ratio. Lower spikelet sterility per cent was recorded by 6:2 (70.22%), followed by 3:1 (73.97%) and 4:1 (75.91%).

The chemical spray lowered the spikelet sterility per cent compared to the flag leaf clipping. GA₃ along with rope pulling differed significantly and recorded the lower per cent of spikelet sterility (71.03%), followed by GA₃ spray (72.39%), boron spray (74.34%). Higher spikelet sterility per cent was observed with flag leaf clipping (75.71%).

Table 15. Influence of different levels of planting ratio and techniques on seed set (%) and spikelet sterility in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Seed set (%)				Spikelete sterility			
	Planting ratio							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	28.05	20.11	31.41	26.52	73.19	74.69	69.28	72.39
T ₂	28.97	20.81	31.46	27.08	71.61	73.14	68.35	71.03
T ₃	26.98	19.86	30.69	25.84	75.00	77.21	70.81	74.34
T ₄	25.33	19.63	30.04	25.00	76.07	78.59	72.46	75.71
Mean	27.33	20.10	30.90		73.97	75.91	70.22	
	SEm_±		CD at 5%		SEm_±		CD at 5%	
P	0.30		1.18		0.17		0.66	
T	0.18		0.53		0.13		0.39	
P x T	0.40		1.41		0.26		0.87	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

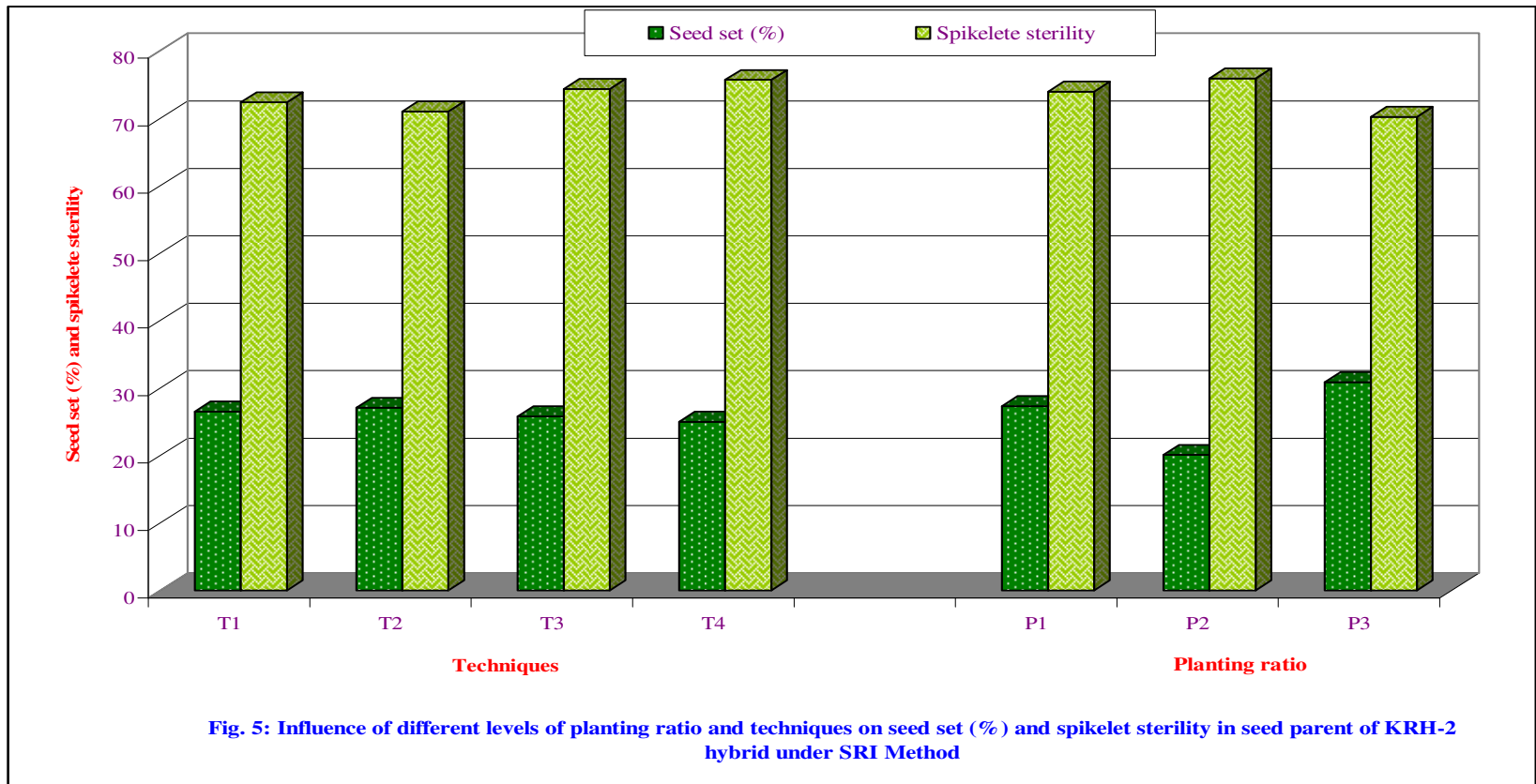


Fig. 5: Influence of different levels of planting ratio and techniques on seed set (%) and spikelet sterility in seed parent of KRH-2 hybrid under SRI Method

Interaction effects between the planting ratio and techniques were found significant. P_3T_1 showed lower spikelet sterility (69.28%) compared to other interaction effects. While P_2T_4 differed significantly by recording higher per cent of spikelet sterility (78.59%).

4.3.13 Filled seed weight per panicle

Influence of different levels of planting ratio and techniques on filled seed weight (g), seed weight per plant (g) and thousand seed weight in seed parent of KRH-2 hybrid under SRI method are presented in Table 16.

Filled seed weight per panicle was not significantly influenced by planting ratio.

Among the techniques GA_3 coupled with rope pulling recorded higher filled seed weight per panicle (0.72 g), followed by GA_3 spray alone (0.69 g), Boron spray (0.63g). Flag leaf clipping recorded the lowest filled seed weight per panicle (0.58g).

Interaction effect between the planting ratios and techniques on filled seed weight per panicle was found non significant.

4.3.14 Seed weight per plant (g)

The results on the seed yield revealed significant difference among the planting ratio and techniques as presented in Table 16.

Planting ratios have greater influence on seed weight per plant and produced significant difference. Among the planting ratios 6:2 row ratio produced higher seed weight per plant (24.50g) followed by 3:1 (23.34g) 4:1 (14.61g).

The chemical spray significantly increased the seed weight per plant over the flag leaf clipping. GA_3 coupled with rope pulling recorded higher number of seed weight per plant (22.51g) followed by GA_3 spray alone (21.47g), boron (20.19g) and Lower seed weight per plant was recorded by flag leaf clipping (19.09g).

The interaction effect on the planting ratio and techniques were found significant. P_3T_2 recorded higher seed weight per plant (26.53g) followed by P_3T_1 (25.44g) and P_1T_2 (25.37g) which were on par with each other. Whereas P_3T_4 recorded lower seed weight per plant (13.79g).

4.3.15 Thousand seed weight(g)

The data obtained from the experiment revealed that 1000 seed weight was not influenced by planting ratio and techniques imposed under hybrid seed production.

4.3.16 Seed yield per plot (g)

Influence of different levels of planting ratios and techniques on seed yield per plot (g) and seed yield per hectare (q) in seed parent of KRH-2 hybrid under SRI method are presented in Table 17.

Seed yield differed significantly with respect to planting ratios. Among the planting ratios, 6:2 produced higher seed yield per plot (2156.92g) as compared to 3:1 (1714.33g) and 4:1 (1309.67g)

All the treatments increased their seed yield over the flag leaf clipping.

The average seed yield per plot was higher with GA_3 + rope pulling (1965.67g), followed by GA_3 spray alone (1822.00g), boron (167.00g). The lowest seed yield was obtained by Flag leaf clipping (1450.22g).

Interaction effect between the plating ratio and techniques showed significant differences. Among the interactions treatment P_3T_2 recorded the highest seed yield per plot (2260.00g) which was found on par with P_3T_2 (2195.00g) and P_3T_3 (2167.33g). P_2T_4 recorded the lowest seed yield per plot (1001.67g).

Table 16. Influence of different levels of planting ratio and techniques on Filled seed weight/panicle, seed weight/plant and 1000 seed weight in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Filled seed weight/panicle (g)				Seed weight/plant (g)				1000 seed weight (g)			
	Planting ratio											
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	0.71	0.67	0.68	0.69	24.07	14.89	25.44	21.47	22.21	22.27	22.00	22.16
T ₂	0.70	0.70	0.77	0.72	25.37	15.64	26.53	22.51	22.27	22.07	22.90	22.41
T ₃	0.63	0.64	0.62	0.63	22.73	14.11	23.72	20.19	21.26	21.26	21.31	21.28
T ₄	0.56	0.62	0.56	0.58	21.19	13.79	22.29	19.09	21.44	21.44	21.44	21.44
Mean	0.65	0.66	0.66		23.34	14.61	24.50		21.80	21.76	21.91	
	SEm_±		CD at 5%		SEm_±		CD at 5%		SEm_±		CD at 5%	
P	0.01		NS		0.16		0.64		0.11		NS	
T	0.01		0.03		0.19		0.56		0.36		NS	
P x T	0.02		NS		0.33		1.05		0.55		NS	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

Table 17. Influence of different levels of planting ratio and techniques on seed yield/plot (gm) and seed yield/ha (q) in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Seed yield/plot (g)				Seed yield/ha (q)			
	Planting ratio							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	1888.67	1382.33	2195.00	1822.00	20.99	15.36	24.39	20.24
T ₂	2008.00	1629.00	2260.00	1965.67	22.31	18.10	25.11	21.84
T ₃	1617.00	1225.67	2167.33	1670.00	17.97	13.62	24.08	18.56
T ₄	1343.67	1001.67	2005.33	1450.22	14.93	11.13	22.28	16.11
Mean	1714.33	1309.67	2156.92		19.05	14.55	23.97	
	SEm_±		CD at 5%		SEm_±		CD at 5%	
P	48.04		188.64		0.53		2.10	
T	36.12		107.32		0.40		1.19	
P x T	72.41		245.60		0.80		2.73	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

4.3.17 Seed yield per hectare (q)

Seed yield differed significantly with respect to planting ratio. Among the planting ratio, 6:2 produced higher seed yield per hectare (23.97 q) as compared to 3:1 (19.05 q) and 4:1 (14.55 q)

All the treatments increased the seed yield over the flag leaf clipping.

The average seed yield per hectare noticed higher in GA₃ with rope pulling (21.84 q), followed by GA₃ spray alone (20.24 q), Boron (18.56 q). The lowest seed yield was obtained by flag leaf clipping (16.11 q). Interaction effect between the plating ratio and techniques showed significant differences.

Among the interactions treatment P₃T₂ recorded the highest seed yield per hectare (25.11 q) which was found on par with P₃T₁ (24.39 q) and P₃T₃ (24.08 q). P₂T₄ recorded the lowest seed yield per plot (22.28 q).

4.3.18 Seed quality attributes

4.3.18.1 Germination percentage(%)

Germination percentage was greatly influenced by techniques rather than planting ratio (Table 18).

Germination percentage was significantly higher with GA₃ spray alone (97.06%) which was on par with GA₃ coupled with rope pulling (97.03%) followed by flag leaf clipping (94.64%). The lowest was recorded by boron spray (91.58%). Planting ratio and interaction effects were found non significant.

4.3.18.2 Speed of germination

Techniques had greater influence on speed of germination as presented in Table 18.

Speed of germination was significantly higher with GA₃ spray alone (31.35) which was on par with GA₃ coupled with rope pulling (31.11) followed by flag leaf clipping (30.54). The lowest was recorded by boron spray (28.76).

No significant difference was found with planting ratio and interaction effects.

4.3.18.3 Shoot length (cm)

Shoot length was significantly influenced by techniques of seed production (Table 19).

Techniques differed significantly for shoot length. Higher shoot length was recorded by GA₃ alone (13.39 cm), found on par with GA₃ coupled with rope pulling (13.06 cm) followed by flag leaf clipping (10.88 cm). Boron spray recorded the lowest shoot length (10.44 cm).

No significant difference was found with planting ratio and interaction effects.

4.3.18.4 Root length (cm)

Root length was significantly influenced by techniques of seed production (Table 19).

Techniques differed significantly for root length. GA₃ alone recorded higher root length (13.79 cm), found on par with GA₃ coupled with rope pulling (13.79 cm), flag leaf clipping (12.10 cm). Boron spray recorded the lowest root length (11.79 cm).

No significant difference was found with planting ratio and interaction effects.

4.3.18.5 Vigour index

The results on vigour index indicate significant influence of techniques and planting ratio on vigour index (Table 20).

Chemical spray had greater influence on vigour index. GA₃ alone recorded higher vigour index (2616), found on par with GA₃ coupled with rope pulling (2614), followed by flag leaf clipping (2147). The lowest vigour index was recorded by boron spay (2019).

Planting ratio and interaction effects were found non significant.

Table 18. Influence of different levels of planting ratio and techniques on germination % and speed of germination in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Germination %				Speed of germination			
	Planting ratio							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	97.02 (80.03)*	97.06 (80.09)	97.11 (80.24)	97.06 (80.12)	32.22	31.97	31.72	31.97
T ₂	97.03 (80.06)	97.18 (80.31)	96.88 (79.68)	97.03 (80.07)	31.36	31.11	30.86	31.11
T ₃	91.11 (72.64)	91.30 (72.82)	92.34 (73.91)	91.58 (73.12)	29.96	29.71	29.83	29.83
T ₄	95.22 (77.35)	94.33 (76.20)	94.38 (76.25)	94.64 (76.60)	30.79	30.54	30.29	30.54
Mean	95.09 (77.52)	94.97 (77.35)	95.18 (77.56)		31.08	30.83	30.67	
	SEm_±		CD at 1%		SEm_±		CD at 1%	
P	0.15		NS		0.11		NS	
T	0.25		0.74		0.29		0.85	
P x T	0.40		NS		0.44		NS	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

* - Figures in the parentheses indicate arc sine root transformed values

Table 19. Influence of different levels of planting ratio and techniques on shoot length and root length in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Shoot length (cm)				Root length (cm)			
	Planting ratio							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	13.39	13.39	13.39	13.39	13.81	13.84	13.73	13.79
T ₂	13.06	13.06	13.06	13.06	13.81	13.84	13.73	13.79
T ₃	10.44	10.44	10.44	10.44	11.80	11.83	11.73	11.79
T ₄	10.88	10.88	10.88	10.88	12.11	12.14	12.04	12.10
Mean	11.94	11.94	11.94		12.88	12.91	12.81	
	SEm_±		CD at 1%		SEm_±		CD at 1%	
P	0.00		NS		0.09		NS	
T	0.13		0.39		0.06		0.18	
P x T	0.20		NS		0.13		NS	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

Table 20. Influence of different levels of planting ratio and techniques on vigour index and seedling weight in seed parent of KRH-2 hybrid under SRI Method

Techniques (T)	Vigour index				Seedling dry weight (mg/10seedlings)			
	Planting ratio							
	P ₁	P ₂	P ₃	Mean	P ₁	P ₂	P ₃	Mean
T ₁	2608	2629	2611	2616	162.40	162.63	159.90	161.64
T ₂	2627	2624	2588	2614	159.34	159.57	160.04	159.65
T ₃	2054	2063	2049	2055	143.07	143.30	144.14	143.50
T ₄	2115	2160	2166	2147	150.10	150.33	150.27	150.23
Mean	2356	2379	2356		153.73	153.96	153.59	
	SEm_±		CD at 1%		SEm_±		CD at 1%	
P	16.91		NS		0.36		NS	
T	13.49		40.09		0.99		2.94	
P x T	26.38		NS		1.53		NS	

P₁ - 3:1

P₂ - 4:1

P₃ - 6:2

NS – Non-significant

T₁ - GA₃ spray

T₂ - GA₃ + rope pulling

T₃ - Boron spray

T₄ - Flag leaf clipping

P x T - Main plot means at same or different levels of sub plot

4.3.18.6 Seedling dry weight (mg)

The results on seedling dry weight indicate significant influence of techniques and planting ratio on seedling dry weight (Table 20).

Chemical spray had greater influence on seedling dry weight. GA₃ alone recorded higher seedling dry weight (161.64 mg), found on par with GA₃ coupled with rope pulling (159.55 mg), followed by flag leaf clipping (150.23 mg). The lowest seedling dry weight was recorded by boron spray (143.50 mg).

Planting ratio and interaction effects were found non significant.

4.4 Experiment-IV: Storability studies on KRH-2 hybrid and its parents at ambient conditions of Dharwad

Results obtained on seed storability of KRH-2 hybrid and its parental lines are presented below

4.4.1 Germination percentage (%)

The data on seed germination percentage during ambient storage indicated significant influence of genotypes, containers and seed treatment as represented in Table 21.

Irrespective of genotypes, containers and seed treatment a steady decline in germination per cent (92.80 to 82.16%) was observed with the progress in seed storage period.

The seed germination differed significantly with the genotypes in all the months of the storage. The initial germination percentage was significantly higher with hybrid KRH-2 (94.23%) followed by KMR-3 (93.14%). Female line IR58025A recorded the lowest initial germination (91.04%). KRH-2 maintained higher germination upto eight months of storage, while the KMR-3 recorded higher germination from tenth month to 12th month of the storage. The seed germination recorded during 12th month of storage was significantly higher in KMR-3 (83.33%) followed by KRH-2 (82.35%) and IR58025A (80.80%).

The seed germination was greatly influenced by the storage containers. The seeds stored in polythene bag recorded significantly higher seed germination in all the months of storage over the cloth bag. The average seed germination recorded at the end of 12th month of storage was 83.46 and 80.86 per cent with polythene and cloth bags respectively.

Seed treatment maintained higher seed germination throughout the storage period. The seeds treated with carboxin + thiram @ 3 g/kg *i.e.* (vitavax powder) recorded significantly higher germination in all the months of storage, the average seed germination recorded was 83.36 and 80.96 per cent with treated and untreated seeds, respectively.

The interaction effects due to container and seed treatment was significant during 10th and 12th month of storage (Table 21 a). The vitavax treated seeds stored in polythene bag recorded higher germination of 86.13 and 84.10 per cent at the end of 10th and 12th month of storage, respectively. The lowest seed germination during both the months was observed with untreated seeds stored in cloth bag. All other interactions were found non-significant.

4.4.2 Shoot length (cm)

Shoot length was significantly influenced by genotype, container and seed treatment throughout the storage period (Table 22)

The shoot length declined steadily with the progress in the storage period. The genotype differed significantly with shoot length in all the months of the storage. The hybrid KRH-2 recorded significantly higher shoot length initially (12.96 cm) to till the end of 12th month (7.80 cm) of storage followed by KMR-3. The minimum shoot length was observed with IR58025A (11.72 cm to 6.35 cm) throughout the storage.

The containers influenced the shoot length significantly in all the months of storage. The seeds stored in polythene bag recorded higher shoot length throughout the storage. At the end of 12th month of storage. The seeds stored in polythene bag recorded higher shoot length (7.11 cm) than the seeds stored in cloth bag (6.66 cm).

Table 21. Influence of seed treatment and container on germination (%) of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	91.04 (72.55)	90.28 (71.8)	88.87 (70.50)	87.18 (69.00)	84.97 (67.17)	82.53 (65.28)	80.80 (64.01)
	G ₂ - KMR-3	93.14 (74.79)	92.15 (73.7)	90.59 (72.12)	89.38 (70.96)	88.02 (69.73)	86.34 (68.31)	83.33 (65.92)
	G ₃ - KRH-2	94.23 (76.07)	93.20 (74.86)	91.79 (73.36)	90.86 (72.41)	88.59 (70.27)	85.01 (67.23)	82.35 (65.16)
	S.Em±	0.10	0.09	0.11	0.16	0.20	0.22	0.30
	C.D. (0.01)	0.38	0.36	0.45	0.65	0.80	0.88	1.19
Containers (C)	C ₁ - Cloth bag	92.81 (74.47)	91.74 (73.32)	89.96 (71.54)	88.66 (70.32)	86.65 (68.58)	83.48 (66.03)	80.86 (64.07)
	C ₂ - Polythene bag	92.80 (74.47)	92.01 (73.60)	90.88 (72.44)	89.62 (71.25)	87.74 (69.54)	85.77 (67.85)	83.46 (65.99)
	S.Em±	0.08	0.07	0.09	0.13	0.17	0.18	0.25
	C.D. (0.01)	NS	NS	0.37	0.53	0.65	0.72	0.97
Seed treatment (T)	T ₁ - Untreated	92.79 (74.46)	91.68 (73.25)	89.72 (71.31)	88.7 (70.41)	86.63 (68.56)	83.89 (66.37)	80.96 (64.15)
	T ₂ - Vitavax	92.81 (74.48)	92.07 (73.67)	91.12 (72.67)	89.53 (71.16)	87.76 (69.55)	85.35 (67.51)	83.36 (65.92)
	S.E m±	0.08	0.07	0.09	0.13	0.17	0.18	0.25
	C.D. (0.01)	NS	0.29	0.37	0.53	0.65	0.72	0.97
	Mean	92.80 (74.47)	91.88 (73.44)	90.42 (71.99)	89.14 (70.79)	87.19 (69.06)	84.62 (66.94)	82.16 (65.03)

NS – Non-significant

Table 21a. Interaction of genotype, container and seed treatment on seed germination (%) of KRH-2 hybrid and its parents during storage

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	91.07 (72.58)	90.07 (71.61)	88.38 (70.05)	86.77 (68.65)	84.58 (66.85)	81.54 (64.54)	79.58 (63.13)
G ₁ C ₂	91.00 (72.52)	90.49 (72.01)	89.35 (70.94)	87.58 (69.35)	85.36 (67.48)	83.52 (66.03)	82.03 (64.90)
G ₂ C ₁	93.13 (74.78)	92.02 (73.57)	90.40 (71.93)	89.18 (70.76)	87.71 (69.46)	85.10 (67.27)	81.83 (64.78)
G ₂ C ₂	93.15 (74.79)	92.27 (73.83)	90.79 (72.32)	89.58 (71.16)	88.33 (70.00)	87.58 (69.35)	84.83 (67.06)
G ₃ C ₁	94.22 (76.06)	93.13 (74.77)	91.10 (72.64)	90.03 (71.56)	87.66 (69.42)	83.81 (66.28)	81.18 (64.30)
G ₃ C ₂	94.24 (76.09)	93.28 (74.94)	92.49 (74.07)	91.69 (73.25)	89.51 (71.13)	86.21 (68.18)	83.52 (66.02)
Mean	92.80 (74.47)	91.88 (73.44)	90.42 (71.99)	89.14 (70.79)	87.19 (69.06)	84.62 (66.94)	82.16 (65.03)
SEm _±	0.14	0.13	0.16	0.23	0.29	0.32	0.43
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	92.7 (74.45)	91.57 (73.13)	89.19 (70.80)	88.39 (70.10)	86.09 (68.11)	82.38 (65.19)	79.11 (62.80)
C ₁ T ₂	92.83 (74.49)	91.91 (73.50)	90.72 (72.28)	88.92 (70.55)	87.21 (69.04)	84.58 (66.87)	82.61 (65.34)
C ₂ T ₁	92.80 (74.46)	91.79 (73.36)	90.24 (71.82)	89.10 (70.73)	87.17 (69.02)	85.41 (67.54)	82.81 (65.50)
C ₂ T ₂	92.80 (74.47)	92.24 (73.83)	91.51 (73.06)	90.14 (71.77)	88.30 (70.05)	86.13 (68.16)	84.10 (66.49)
Mean	92.80 (74.47)	91.88 (73.46)	90.42 (71.99)	89.14 (70.79)	87.19 (69.06)	84.62 (66.94)	82.16 (65.03)
SEm _±	0.11	0.11	0.13	0.19	0.23	0.26	0.35
CD at 1%	NS	NS	NS	NS	NS	1.02	1.37
G x T							
G ₁ T ₁	91.00 (72.51)	90.09 (71.62)	88.23 (69.91)	86.67 (68.56)	84.50 (66.79)	81.77 (64.72)	79.50 (63.07)
G ₁ T ₂	91.07 (72.59)	90.47 (72.00)	89.51 (71.08)	87.69 (69.44)	85.44 (67.54)	83.29 (65.85)	82.10 (64.96)
G ₂ T ₁	93.17 (74.83)	91.88 (73.41)	89.86 (71.41)	89.28 (70.86)	87.74 (69.48)	85.72 (67.78)	82.08 (64.97)
G ₂ T ₂	93.11 (74.75)	92.42 (73.99)	91.32 (72.84)	89.48 (71.06)	88.31 (69.98)	86.96 (68.84)	84.59 (66.87)
G ₃ T ₁	94.20 (76.03)	93.07 (74.71)	91.07 (72.61)	90.30 (71.82)	87.65 (69.42)	84.20 (66.60)	81.30 (64.40)
G ₃ T ₂	94.26 (76.11)	93.34 (75.01)	92.52 (74.10)	91.42 (72.99)	89.52 (71.13)	85.82 (67.86)	83.39 (65.93)
Mean	92.80 (74.47)	91.88 (73.46)	90.42 (71.99)	89.14 (70.79)	87.19 (69.06)	84.62 (66.94)	82.16 (65.03)
SEm _±	0.14	0.13 ()	0.16	0.23	0.29	0.32	0.43
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Contd.....

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	91.00 (72.51)	90.03 (71.57)	87.80 (69.54)	86.17 (68.14)	84.00 (66.40)	80.32 (63.65)	78.00 (62.01)
G ₁ C ₁ T ₂	91.14 (72.65)	90.11 (71.64)	88.97 (70.57)	87.38 (69.16)	85.16 (67.31)	82.75 (65.43)	81.16 (64.25)
G ₁ C ₂ T ₁	91.00 (72.51)	90.14 (71.67)	88.65 (70.29)	87.16 (68.98)	85.01 (67.19)	83.21 (65.79)	81.01 (64.14)
G ₁ C ₂ T ₂	91.00 (72.53)	90.83 (72.36)	90.05 (71.59)	88.00 (69.71)	85.72 (67.77)	83.82 (66.26)	83.05 (65.67)
G ₂ C ₁ T ₁	93.19 (74.85)	91.66 (73.19)	89.79 (71.34)	89.05 (70.65)	87.31 (69.11)	84.67 (66.92)	80.00 (63.41)
G ₂ C ₁ T ₂	93.07 (74.71)	92.38 (73.96)	91.00 (72.52)	89.30 (70.88)	88.11 (69.80)	85.52 (67.61)	83.67 (66.14)
G ₂ C ₂ T ₁	93.16 (74.81)	92.09 (73.64)	89.94 (71.48)	89.51 (71.08)	88.16 (69.85)	86.77 (68.64)	84.16 (66.52)
G ₂ C ₂ T ₂	93.14 (74.78)	92.45 (74.02)	91.63 (73.16)	89.65 (71.2)	88.50 (70.15)	88.40 (70.06)	85.50 (67.59)
G ₃ C ₁ T ₁	94.17 (76.00)	93.01 (74.64)	90.00 (71.54)	89.96 (71.50)	86.97 (68.82)	82.15 (64.99)	79.33 (62.97)
G ₃ C ₁ T ₂	94.26 (76.11)	93.24 (74.90)	92.20 (73.75)	90.09 (71.62)	88.35 (70.02)	85.47 (67.57)	83.02 (65.64)
G ₃ C ₂ T ₁	94.23 (76.07)	93.13 (74.77)	92.14 (73.69)	90.63 (72.15)	88.34 (70.02)	86.25 (68.20)	83.27 (65.83)
G ₃ C ₂ T ₂	94.25 (76.10)	93.43 (75.12)	92.84 (74.45)	92.76 (74.36)	90.69 (72.23)	86.17 (68.15)	83.76 (66.21)
Mean	92.80 (73.46)	91.88 (73.46)	90.42 (71.99)	89.14 (70.79)	87.19 (69.06)	84.62 (66.94)	82.16 (65.03)
SEm _±	0.19	0.18	0.23	0.33	0.41	0.45	0.60
CD at 1%	NS	NS	NS	NS	NS	NS	NS

NS – Non-significant

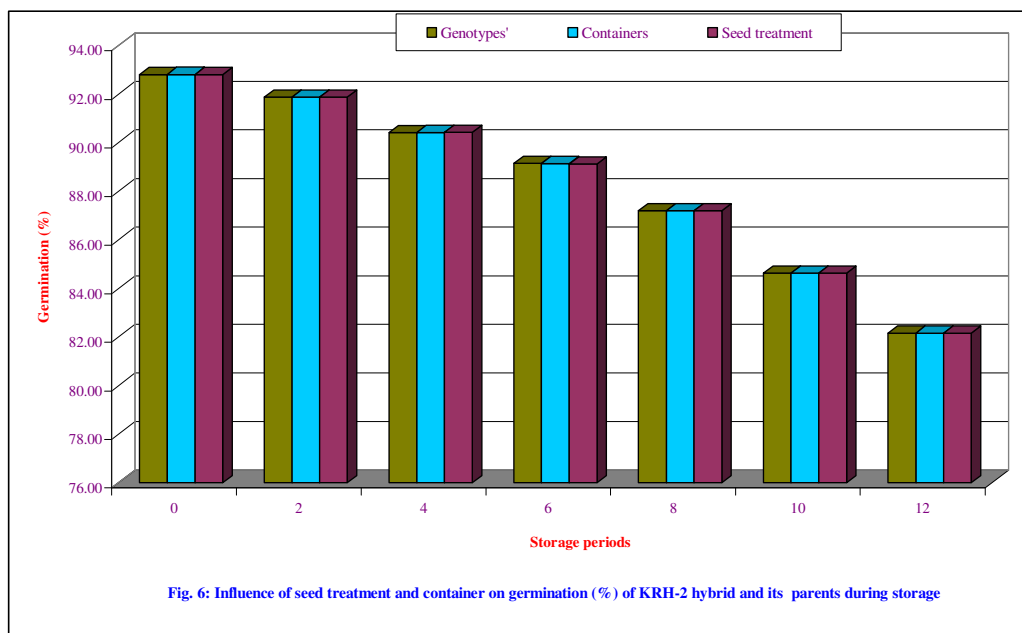


Fig. 6: Influence of seed treatment and container on germination (%) of KRH-2 hybrid and its parents during storage

Table 22. Influence of seed treatment and container on shoot length of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	11.72	10.94	9.54	8.82	7.89	6.89	6.35
	G ₂ - KMR-3	11.90	11.12	9.97	9.11	8.27	7.10	6.50
	G ₃ - KRH-2	12.96	12.71	11.55	10.42	8.96	9.00	7.80
	S.Em±	0.02	0.08	0.11	0.25	0.18	0.27	0.09
	C.D. (0.01)	0.08	0.32	0.42	0.98	0.72	1.07	0.36
Containers (C)	C ₁ - Cloth bag	12.16	11.43	9.80	8.85	7.91	7.20	6.66
	C ₂ - Polythene bag	12.22	11.74	10.90	10.05	8.84	8.12	7.11
	S.Em±	0.02	0.07	0.09	0.20	0.15	0.22	0.08
	C.D. (0.01)	NS	0.26	0.35	0.80	0.59	0.87	0.30
Seed treatment (T)	T ₁ - Untreated	12.16	11.45	10.01	8.88	7.95	7.21	6.70
	T ₂ - Vitavax	12.22	11.72	10.69	10.02	8.79	8.11	7.07
	S.E m±	0.02	0.07	0.09	0.20	0.15	0.22	0.08
	C.D. (0.01)	NS	0.26	0.35	0.80	0.59	0.87	0.30
	Mean	12.19	11.59	10.35	9.45	8.37	7.66	6.88

NS – Non-significant

Table 22a. Interaction of genotype, container and seed treatment on shoot length of KRH-2 hybrid and its parents during storage

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	11.69	10.70	9.15	8.49	7.53	6.53	6.15
G ₁ C ₂	11.74	11.19	9.92	9.15	8.26	7.26	6.56
G ₂ C ₁	11.85	10.93	9.49	8.22	8.14	6.69	6.33
G ₂ C ₂	11.95	11.30	10.45	10.01	8.39	7.51	6.67
G ₃ C ₁	12.94	12.68	10.77	9.84	8.06	8.40	7.49
G ₃ C ₂	12.98	12.74	12.32	11.00	9.86	9.60	8.11
Mean	12.19	11.59	10.35	9.45	8.37	7.66	6.88
SEm \pm	0.03	0.11	0.15	0.35	0.26	0.38	0.13
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	12.14	11.42	9.41	7.92	7.23	6.33	6.32
C ₁ T ₂	12.18	11.44	10.20	9.78	8.59	8.08	6.99
C ₂ T ₁	12.18	11.48	10.61	9.83	8.67	8.10	7.07
C ₂ T ₂	12.26	12.00	11.19	10.27	9.00	8.15	7.15
Mean	12.19	11.59	10.35	9.45	8.37	7.66	6.88
SEm \pm	0.02	0.09	0.12	0.29	0.21	0.31	0.11
CD at 1%	NS	NS	NS	NS	NS	NS	NS
G x T							
G ₁ T ₁	11.68	10.74	9.30	8.51	7.46	6.52	6.24
G ₁ T ₂	11.75	11.14	9.78	9.12	8.33	7.27	6.47
G ₂ T ₁	11.87	10.93	9.81	8.25	8.06	6.69	6.34
G ₂ T ₂	11.93	11.30	10.13	9.98	8.47	7.50	6.66
G ₃ T ₁	12.92	12.69	10.92	9.88	8.34	8.43	7.51
G ₃ T ₂	13.00	12.72	12.17	10.96	9.58	9.57	8.09
Mean	12.19	11.59	10.35	9.45	8.37	7.66	6.88
SEm \pm	0.03	0.11	0.15	0.35	0.26	0.38	0.13
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Contd.....

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	11.68	10.69	8.81	7.90	6.78	5.87	6.02
G ₁ C ₁ T ₂	11.71	10.70	9.50	9.07	8.28	7.18	6.28
G ₁ C ₂ T ₁	11.69	10.80	9.80	9.12	8.13	7.16	6.46
G ₁ C ₂ T ₂	11.78	11.59	10.05	9.17	8.38	7.35	6.65
G ₂ C ₁ T ₁	11.82	10.91	9.30	7.11	7.93	6.12	6.02
G ₂ C ₁ T ₂	11.89	10.94	9.68	9.34	8.34	7.25	6.64
G ₂ C ₂ T ₁	11.93	10.95	10.31	9.38	8.18	7.26	6.65
G ₂ C ₂ T ₂	11.97	11.66	10.59	10.63	8.61	7.76	6.69
G ₃ C ₁ T ₁	12.92	12.67	10.12	8.76	6.97	7.00	6.93
G ₃ C ₁ T ₂	12.96	12.68	11.41	10.92	9.14	9.80	8.05
G ₃ C ₂ T ₁	12.92	12.71	11.72	11.00	9.71	9.86	8.09
G ₃ C ₂ T ₂	13.04	12.76	12.92	11.00	10.01	9.34	8.13
Mean	12.19	11.59	10.35	9.45	8.37	7.66	6.88
SEm±	0.04	0.16	0.21	0.50	0.36	0.54	0.18
CD at 1%	NS	NS	NS	NS	NS	NS	NS

NS – Non-significant

Table 23. Influence of seed treatment and container on root length of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	12.19	11.36	10.06	9.57	8.38	7.94	6.91
	G ₂ - KMR-3	12.90	12.10	11.29	9.89	9.22	8.79	7.80
	G ₃ - KRH-2	13.99	12.62	11.80	10.90	9.88	9.43	8.42
	S.Em±	0.02	0.01	0.21	0.25	0.27	0.27	0.30
	C.D. (0.01)	0.07	0.03	0.85	1.00	1.08	1.06	1.18
Containers (C)	C ₁ - Cloth bag	13.00	12.00	10.59	9.64	8.57	8.15	7.03
	C ₂ - Polythene bag	13.05	12.05	11.52	10.60	9.75	9.30	8.39
	S.Em±	0.01	0.01	0.17	0.21	0.22	0.22	0.24
	C.D. (0.01)	NS	0.03	0.69	0.82	0.88	0.87	0.96
Seed treatment (T)	T ₁ - Untreated	13.01	12.01	10.67	9.66	8.60	8.15	7.08
	T ₂ - Vitavax	13.04	12.04	11.44	10.58	9.72	9.30	8.34
	S.E m±	0.01	0.01	0.17	0.21	0.22	0.22	0.24
	C.D. (0.01)	NS	0.03	0.69	0.82	0.88	0.87	0.96
	Mean	13.03	12.03	11.05	10.12	9.16	8.72	7.71

NS – Non-significant

Table 23a. Interaction of genotype, container and seed treatment on root length of KRH-2 hybrid and its parents during storage

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	12.18	11.34	9.63	8.96	7.80	7.36	6.16
G ₁ C ₂	12.19	11.37	10.50	10.17	8.96	8.53	7.66
G ₂ C ₁	12.85	12.05	10.81	9.41	8.62	8.21	7.21
G ₂ C ₂	12.95	12.15	11.78	10.37	9.82	9.37	8.39
G ₃ C ₁	13.96	12.60	11.33	10.55	9.30	8.86	7.72
G ₃ C ₂	14.02	12.64	12.27	11.25	10.46	10.00	9.11
Mean	13.03	12.03	11.05	10.12	9.16	8.72	7.71
SEm _±	0.02	0.01	0.30	0.36	0.39	0.38	0.42
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	12.99	11.98	9.89	8.78	7.58	7.14	5.93
C ₁ T ₂	13.01	12.01	11.29	10.50	9.57	9.15	8.14
C ₂ T ₁	13.03	12.04	11.45	10.53	9.62	9.15	8.24
C ₂ T ₂	13.07	12.07	11.58	10.66	9.88	9.45	8.53
Mean	13.03	12.03	11.05	10.12	9.16	8.72	7.71
SEm _±	0.02	0.01	0.25	0.29	0.32	0.31	0.34
CD at 1%	NS	NS	NS	NS	NS	NS	NS
G x T							
G ₁ T ₁	12.18	11.35	9.72	8.97	7.85	7.41	6.44
G ₁ T ₂	12.19	11.37	10.41	10.16	8.92	8.48	7.38
G ₂ T ₁	12.87	12.07	10.85	9.42	8.66	8.20	7.12
G ₂ T ₂	12.93	12.13	11.74	10.36	9.79	9.38	8.48
G ₃ T ₁	13.97	12.61	11.44	10.58	9.30	8.83	7.69
G ₃ T ₂	14.00	12.63	12.16	11.22	10.47	10.03	9.15
Mean	13.03	12.03	11.05	10.12	9.16	8.72	7.71
SEm _±	0.02	0.01	0.30	0.36	0.39	0.38	0.42
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Contd.....

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	12.18	11.33	9.00	7.82	6.89	6.46	5.32
G ₁ C ₁ T ₂	12.19	11.35	10.26	10.11	8.70	8.26	7.01
G ₁ C ₂ T ₁	12.19	11.36	10.44	10.13	8.80	8.36	7.56
G ₁ C ₂ T ₂	12.20	11.38	10.55	10.21	9.13	8.69	7.75
G ₂ C ₁ T ₁	12.82	12.02	10.00	8.53	7.59	7.16	6.04
G ₂ C ₁ T ₂	12.89	12.09	11.62	10.29	9.65	9.27	8.39
G ₂ C ₂ T ₁	12.93	12.13	11.70	10.30	9.72	9.25	8.20
G ₂ C ₂ T ₂	12.97	12.17	11.86	10.43	9.92	9.49	8.57
G ₃ C ₁ T ₁	13.96	12.59	10.67	9.99	8.26	7.82	6.42
G ₃ C ₁ T ₂	13.96	12.60	12.00	11.11	10.35	9.91	9.03
G ₃ C ₂ T ₁	13.98	12.63	12.22	11.17	10.33	9.84	8.96
G ₃ C ₂ T ₂	14.05	12.66	12.33	11.33	10.59	10.16	9.27
Mean	13.03	12.03	11.05	10.12	9.16	8.72	7.71
SEm±	0.03	0.02	0.43	0.51	0.55	0.54	0.60
CD at 1%	NS	NS	NS	NS	NS	NS	NS

NS – Non-significant

The seeds treated with vitavax powder (0.2%) recorded significantly higher shoot length throughout the storage period. The reduction in shoot length with increase in the storage period was higher with the untreated seeds. At the end of storage period, the treated and untreated seeds recorded 7.07 cm and 6.70 cm shoot length respectively.

4.4.3 Root length (cm)

Root length was significantly influenced by genotype, container and seed treatment throughout the storage period (Table 23).

The root length declined steadily with the progress in the storage period. The genotype differed significantly with root length in all the months of the storage. The hybrid KRH-2 recorded significantly higher root length in all the month of storage (13.99 to 8.42 cm) followed by KMR-3 (12.90-7.80 cm). The lowest shoot length was observed with IR58025A (12.19-6.91 cm) throughout the storage.

Containers showed greater influence over the root length during storage. The seeds stored in polythene bag recorded higher with the root length throughout the storage. At the end of 12th month of storage, the seeds stored in polythene bag recorded higher root length (8.39 cm) than the seeds stored in cloth bag (7.03 cm).

Seeds treatment significantly influenced the root length. Seeds treated with vitavax powder recorded significantly higher root length throughout the storage period. The root length at the end of 12th month of storage was higher with the treated seeds (8.34cm) as compared to untreated seeds (7.08 cm).

4.4.4 Dry weight of seedlings (mg/10 seedlings)

Genotype, container and seed treatment influenced dry weight of seedlings. In general the dry weight of seedlings decreased from 158.3 mg in the beginning to 112.9 mg after 12th month of storage (Table 24).

The genotype differed significantly with dry weight of seedlings in all the months of the storage. The hybrid KRH-2 recorded significantly higher dry weight of seedlings in all the month of storage (163.5-118.8 mg) followed by KMR-3 (159.08-113.1 mg).

Containers showed greater influence over dry weight of seedlings during storage. The dry weight of seedlings was significantly higher with the seeds stored in polythene bag than the cloth bag. At the end of 12th month of storage, the seeds stored in polythene bag recorded higher dry weight of seedlings (115.3 mg) than the seeds stored in cloth bag (110.4 mg).

The vitavax treated seeds produced the seeds with higher dry weight through the storage. The dry weight of seedlings recorded at the end of 12th month of storage, with treated and untreated seeds was 114.9 mg and 110.8 mg respectively.

4.4.5 Seed moisture content (%)

The data on seed moisture content during storage indicate significant influence of container and seed treatment.(Table 25). Genotypes did not vary with moisture content over the storage period and found non significant for moisture content.

Containers had significant influence on moisture content of seeds. The average moisture content of seeds at the end of storage period stored in polythene bag was (9.87%) as of cloth bag was (10.65%). The seeds treated with vitavax powder differed significantly for moisture content throughout the storage period. The moisture content recorded out at the end of 12th month of storage with treated and untreated seeds was 9.92% and 10.62% respectively.

4.4.6 Electrical conductivity of seed leachate(dsm^{-1})

The data presented on electrical conductivity of seed leachate indicated significance influence of genotype, container and seed treatment throughout storage.(Table 26).

The electrical conductivity of seed leachate increased with increase in the storage period. The average electrical conductivity recorded before 12 months of storage was 258.2 dsm^{-1} and 293.8 dsm^{-1} , respectively.

Table 24. Influence of seed treatment and container on seedling dry weight (mg/10 seedlings) of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	152.3	142.2	142.2	137.9	129.7	119.4	106.7
	G ₂ - KMR-3	159.0	154.1	148.9	145.0	137.1	125.6	113.1
	G ₃ - KRH-2	163.5	159.2	154.1	150.3	142.3	131.5	118.8
	S.Em±	0.39	1.74	0.70	0.70	0.96	1.05	1.12
	C.D. (0.01)	1.53	6.87	2.78	2.78	3.79	4.14	4.44
Containers (C)	C ₁ - Cloth bag	157.8	149.8	147.2	143.0	134.8	123.5	110.4
	C ₂ - Polythene bag	158.7	153.9	149.7	145.8	138.0	127.5	115.3
	S.Em±	0.32	1.42	0.57	0.57	0.78	0.85	0.92
	C.D. (0.01)	NS	NS	2.27	2.27	3.09	3.38	3.62
Seed treatment (T)	T ₁ - Untreated	157.9	149.8	147.0	142.9	134.6	123.5	110.8
	T ₂ - Vitavax	158.7	153.8	149.8	146.0	138.1	127.5	114.9
	S.E m±	0.32	1.42	0.57	0.57	0.78	0.85	0.92
	C.D. (0.01)	NS	NS	2.27	2.27	3.09	3.38	3.62
	Mean	158.3	151.8	148.4	144.4	136.4	125.5	112.9

NS – Non-significant

Table 24a. Interaction of genotype, container and seed treatment on seedling dry weight (mg/10 seedlings) of KRH-2 hybrid and its parents during storage

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	151.4	136.3	141.1	136.4	127.6	116.9	103.7
G ₁ C ₂	153.3	148.1	143.3	139.5	131.9	122.0	109.7
G ₂ C ₁	158.7	154.0	147.4	143.5	135.5	123.2	110.4
G ₂ C ₂	159.4	154.1	150.4	146.5	138.6	128.0	115.8
G ₃ C ₁	163.4	159.2	153.1	149.3	141.3	130.4	117.2
G ₃ C ₂	163.6	159.3	155.2	151.4	143.4	132.6	120.4
Mean	158.3	151.8	148.4	144.4	136.4	125.5	112.9
SEm _±	0.55	2.46	0.99	0.99	1.35	1.48	1.59
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	157.7	145.9	144.8	140.3	131.6	119.8	106.6
C ₁ T ₂	158.0	153.8	149.6	145.7	138.0	127.2	114.3
C ₂ T ₁	158.2	153.8	149.2	145.4	137.7	127.2	115.0
C ₂ T ₂	159.3	153.9	150.1	146.2	138.3	127.8	115.6
Mean	158.3	151.8	148.4	144.4	136.4	125.5	112.9
SEm _±	0.45	2.01	0.81	0.81	1.11	1.21	1.30
CD at 1%	NS	NS	NS	NS	NS	NS	NS
G x T							
G ₁ T ₁	151.6	136.3	141.1	136.4	127.6	117.6	104.3
G ₁ T ₂	153.1	148.1	143.3	139.5	131.8	121.3	109.1
G ₂ T ₁	158.7	154.0	147.5	143.5	135.6	124.2	112.0
G ₂ T ₂	159.4	154.1	150.3	146.5	138.5	127.0	114.3
G ₃ T ₁	163.5	159.2	152.4	148.7	140.7	128.8	116.1
G ₃ T ₂	163.5	159.3	155.8	152.0	144.0	134.2	121.5
Mean	158.3	151.8	148.4	144.4	136.4	125.5	112.9
SEm _±	0.55	2.46	0.99	0.99	1.35	1.48	1.59
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Contd.....

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	151.4	124.6	138.9	133.3	123.0	112.8	98.6
G ₁ C ₁ T ₂	151.4	148.0	143.3	139.4	132.2	121.0	108.7
G ₁ C ₂ T ₁	151.8	148.0	143.3	139.5	132.2	122.3	110.1
G ₁ C ₂ T ₂	154.8	148.3	143.4	139.5	131.5	121.6	109.4
G ₂ C ₁ T ₁	158.2	153.9	144.9	140.9	132.9	120.7	108.5
G ₂ C ₁ T ₂	159.2	154.1	149.9	146.1	138.1	125.6	112.4
G ₂ C ₂ T ₁	159.1	154.1	150.1	146.2	138.2	127.7	115.5
G ₂ C ₂ T ₂	159.7	154.2	150.8	146.9	138.9	128.4	116.2
G ₃ C ₁ T ₁	163.4	159.2	150.5	146.9	138.8	126.0	112.7
G ₃ C ₁ T ₂	163.5	159.2	155.6	151.7	143.7	134.9	121.7
G ₃ C ₂ T ₁	163.5	159.2	154.3	150.5	142.5	131.7	119.5
G ₃ C ₂ T ₂	163.6	159.3	156.0	152.3	144.3	133.5	121.3
Mean	158.3	151.8	148.4	144.4	136.4	125.5	112.9
SEm±	0.77	3.48	1.40	1.40	1.91	2.09	2.24
CD at 1%	NS	NS	NS	NS	NS	NS	NS

NS – Non-significant

Table 25. Influence of seed treatment and container on Moisture percentage (%) of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	9.21	9.68	10.16	10.82	10.70	10.58	10.39
	G ₂ - KMR-3	9.23	9.78	10.10	10.77	10.80	10.54	10.27
	G ₃ - KRH-2	9.22	9.65	10.14	10.77	10.76	10.52	10.12
	S.Em±	0.00	0.04	0.05	0.10	0.11	0.18	0.21
	C.D. (0.01)	NS	NS	NS	NS	NS	NS	NS
Containers (C)	C ₁ - Cloth bag	9.22	9.84	10.22	11.03	10.99	10.89	10.65
	C ₂ - Polythene bag	9.22	9.57	10.05	10.54	10.51	10.20	9.87
	S.Em±	0.00	0.03	0.04	0.08	0.09	0.15	0.17
	C.D. (0.01)	NS	0.11	0.16	0.32	0.35	0.57	0.67
Seed treatment (T)	T ₁ - Untreated	9.22	9.83	10.24	10.99	10.95	10.85	10.60
	T ₂ - Vitavax	9.22	9.58	10.03	10.58	10.56	10.24	9.92
	S.E m±	0.00	0.03	0.04	0.08	0.09	0.15	0.17
	C.D. (0.01)	NS	0.11	0.16	0.32	0.35	0.57	0.67
	Mean	9.22	9.70	10.14	10.79	10.75	10.54	10.26

NS – Non-significant

Table 25a. Interaction of genotype, container and seed treatment on seed moisture (%) of KRH-2 hybrid and its parents during storage

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	9.21	9.79	10.26	11.06	10.87	10.92	10.72
G ₁ C ₂	9.22	9.57	10.07	10.58	10.53	10.24	10.07
G ₂ C ₁	9.24	9.91	10.12	10.96	11.19	10.85	10.52
G ₂ C ₂	9.22	9.65	10.09	10.58	10.40	10.23	10.02
G ₃ C ₁	9.22	9.81	10.29	11.09	10.92	10.91	10.71
G ₃ C ₂	9.22	9.49	9.99	10.46	10.61	10.13	9.53
Mean	9.22	9.70	10.14	10.79	10.75	10.54	10.26
SEm _±	0.01	0.05	0.07	0.14	0.15	0.25	0.29
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	9.23	9.98	10.34	11.10	11.12	10.93	10.73
C ₁ T ₂	9.22	9.69	10.10	10.97	10.87	10.86	10.57
C ₂ T ₁	9.22	9.68	10.13	10.88	10.78	10.77	10.47
C ₂ T ₂	9.22	9.46	9.97	10.19	10.25	9.62	9.28
Mean	9.22	9.70	10.14	10.79	10.75	10.54	10.26
SEm _±	0.01	0.04	0.06	0.12	0.12	0.21	0.24
CD at 1%	NS	NS	NS	NS	NS	NS	NS
G x T							
G ₁ T ₁	9.22	9.75	10.22	11.02	10.83	10.88	10.69
G ₁ T ₂	9.21	9.61	10.11	10.63	10.58	10.28	10.10
G ₂ T ₁	9.23	9.97	10.25	10.92	11.15	10.81	10.61
G ₂ T ₂	9.22	9.59	9.96	10.61	10.44	10.27	9.93
G ₃ T ₁	9.22	9.76	10.24	11.05	10.88	10.87	10.50
G ₃ T ₂	9.22	9.53	10.03	10.50	10.65	10.17	9.74
Mean	9.22	9.70	10.14	10.79	10.75	10.54	10.26
SEm _±	0.01	0.05	0.07	0.14	0.15	0.25	0.29
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Contd.....

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	9.22	9.84	10.27	11.12	10.83	10.94	10.74
G ₁ C ₁ T ₂	9.21	9.75	10.24	11.00	10.90	10.89	10.69
G ₁ C ₂ T ₁	9.22	9.67	10.16	10.92	10.82	10.81	10.63
G ₁ C ₂ T ₂	9.21	9.47	9.98	10.25	10.25	9.67	9.51
G ₂ C ₁ T ₁	9.25	10.21	10.40	10.99	11.55	10.88	10.68
G ₂ C ₁ T ₂	9.23	9.61	9.84	10.92	10.82	10.81	10.36
G ₂ C ₂ T ₁	9.22	9.73	10.10	10.85	10.75	10.74	10.54
G ₂ C ₂ T ₂	9.22	9.58	10.08	10.30	10.06	9.72	9.51
G ₃ C ₁ T ₁	9.22	9.89	10.35	11.20	10.97	10.96	10.76
G ₃ C ₁ T ₂	9.21	9.72	10.22	10.97	10.87	10.86	10.66
G ₃ C ₂ T ₁	9.22	9.64	10.14	10.89	10.79	10.78	10.24
G ₃ C ₂ T ₂	9.22	9.34	9.84	10.03	10.43	9.48	8.81
Mean	9.22	9.70	10.14	10.79	10.75	10.54	10.26
SEm±	0.01	0.07	0.10	0.20	0.22	0.36	0.42
CD at 1%	NS	NS	NS	NS	NS	NS	NS

NS – Non-significant

Table 26. Influence of seed treatment and container on Electrical Conductivity (dsm^{-1}) of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	273.4	281.0	286.2	292.2	298.8	306.1	314.2
	G ₂ - KMR-3	246.4	252.1	246.2	251.6	258.6	266.4	274.3
	G ₃ - KRH-2	254.7	258.8	264.6	270.0	275.7	284.4	292.8
	S.Em±	0.2	0.3	2.7	2.79	2.7	2.79	2.7
	C.D. (0.01)	0.6	1.3	11.0	11.0	11.0	11.0	11.0
Containers (C)	C ₁ - Cloth bag	258.1	264.5	270.8	276.7	283.1	290.8	298.9
	C ₂ - Polythene bag	258.2	263.4	260.6	265.9	272.3	280.4	288.6
	S.Em±	0.13	0.27	2.2	2.2	2.2	2.2	2.2
	C.D. (0.01)	NS	NS	9.0	9.0	9.01	9.0	9.0
Seed treatment (T)	T ₁ - Untreated	258.1	264.5	272.3	278.0	284.3	292.7	300.3
	T ₂ - Vitavax	258.2	263.4	259.1	264.5	271.0	278.6	287.2
	S.E m±	0.1	0.2	2.2	2.2	2.2	2.2	2.2
	C.D. (0.01)	NS	1.0	9.0	9.0	9.0	9.0	9.0
	Mean	258.2	264.0	265.7	271.3	277.7	285.6	293.8

NS – Non-significant

Table 26a. Interaction of genotype, container and seed treatment on Electrical conductivity (dS m^{-1}) of KRH-2 hybrid and its parents during storage

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	273.4	281.3	286.5	292.9	299.6	306.9	314.6
G ₁ C ₂	273.4	280.7	285.9	291.6	298.0	305.2	313.9
G ₂ C ₁	246.1	252.5	257.4	262.7	270.2	276.7	285.6
G ₂ C ₂	246.6	251.8	235.0	240.4	247.1	256.0	263.0
G ₃ C ₁	254.7	259.7	268.5	274.4	279.5	288.8	296.6
G ₃ C ₂	254.7	257.8	260.8	265.7	271.8	280.1	288.9
Mean	258.2	264.0	265.7	271.3	277.7	285.6	293.8
SEm \pm	0.2	0.4	3.9	3.9	3.9	3.9	3.9
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	258.1	265.1	278.6	284.7	290.7	299.3	306.7
C ₁ T ₂	258.1	263.9	263.0	268.6	275.5	282.3	291.2
C ₂ T ₁	258.2	263.9	265.9	271.4	278.0	286.0	294.0
C ₂ T ₂	258.3	263.0	255.2	260.4	266.6	274.9	283.2
Mean	258.2	264.0	265.7	271.3	277.7	285.6	293.8
SEm \pm	0.1	0.3	3.2	3.2	3.2	3.2	3.2
CD at 1%	NS	NS	NS	NS	NS	NS	NS
G x T							
G ₁ T ₁	273.4	281.3	296.5	302.9	309.5	316.9	324.4
G ₁ T ₂	273.4	280.7	275.9	281.6	288.0	295.3	304.1
G ₂ T ₁	246.3	252.5	255.3	260.7	267.4	275.7	283.5
G ₂ T ₂	246.5	251.8	237.1	242.4	249.9	257.0	265.1
G ₃ T ₁	254.8	259.7	265.1	270.5	276.1	285.4	293.2
G ₃ T ₂	254.7	257.8	264.2	269.6	275.3	283.5	292.4
Mean	258.2	264.0	265.7	271.3	277.7	285.6	293.8
SEm \pm	0.2	0.4	3.9	3.9	3.9	3.9	3.9
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Contd....

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	273.4	281.4	296.6	304.0	310.6	318.1	324.6
G ₁ C ₁ T ₂	273.3	281.2	276.4	281.8	288.5	295.8	304.6
G ₁ C ₂ T ₁	273.3	281.2	296.3	301.8	308.4	315.7	324.1
G ₁ C ₂ T ₂	273.5	280.2	275.4	281.4	287.5	294.8	303.6
G ₂ C ₁ T ₁	246.1	252.9	267.0	272.4	279.0	286.3	295.3
G ₂ C ₁ T ₂	246.2	252.1	247.8	253.0	261.3	267.2	275.8
G ₂ C ₂ T ₁	246.4	252.0	243.6	249.0	255.7	265.2	271.6
G ₂ C ₂ T ₂	246.8	251.5	226.4	231.8	238.5	246.8	254.4
G ₃ C ₁ T ₁	254.7	261.1	272.2	277.7	282.3	293.6	300.2
G ₃ C ₁ T ₂	254.7	258.3	264.7	271.1	276.8	284.0	293.0
G ₃ C ₂ T ₁	254.8	258.3	257.9	263.3	269.9	277.1	286.2
G ₃ C ₂ T ₂	254.6	257.3	263.7	268.1	273.7	283.0	291.7
Mean	258.2	264.0	265.7	271.3	277.7	285.6	293.8
SEm±	0.3	0.6	5.5	5.5	5.5	5.5	5.5
CD at 1%	NS	NS	NS	NS	NS	NS	NS

NS – Non-significant

The electrical conductivity varied significantly with the genotypes. KMR-3 recorded lowest electrical conductivity before the storage (246.4 dsm^{-1}) and till the end of the storage (274.3 dsm^{-1}) followed by KRH-2 and IR58025A.

The storage container influenced the electrical conductivity significantly. The seeds stored in polythene bag recorded lower electrical conductivity values throughout the storage compared to seeds stored in cloth bag. Their electrical conductivity recorded at the end of 12th month of storage was higher with the seeds stored in cloth bags (298.9 dsm^{-1}) than in polythene bag (288.6 dsm^{-1}) respectively.

The seeds treated with vitavax powder significantly recorded lower values of electrical conductivity throughout the storage period. The electrical conductivity recorded out at the end of 12th month of storage with treated and untreated seeds was 287.2 dsm^{-1} and $300. \text{ dsm}^{-1}$, respectively.

4.4.7 Vigour index

The data presented in the Table 27 on vigour index indicates significant influence of genotype, container and seed treatment throughout storage.

In general, the vigour index decreased from 2333 in the beginning to 1159 after 12th month of storage.

The genotype differed significantly for vigour index in all the months of the storage. The hybrid KRH-2 recorded significantly higher vigour index in all the months of storage followed by KMR-3 and IR58025A. The vigour index observed before and at the end of 12th month of storage period with KRH-2 was 2532 and 1391, respectively. The female line IR58025A recorded significantly lower vigour index throughout the storage period (2173-967).

The seeds stored in polythene bag and cloth bag differed significantly for vigour index. The vigour index recorded with polythene bag was highest throughout the storage period. At the end of the storage period, the vigour index observed with polythene bag and cloth bag was 1259 and 1060, respectively.

The seeds treated with vitavax powder differed significantly for vigour index throughout the storage period. The vigour index recorded at the end of 12th month of storage with treated and untreated seeds was 1282 and 1036 respectively.

The interaction effect due to container and seed treatment were significant from eight month of storage onwards (Table 27a). The seeds treated with vitavax and stored in polythene bag recorded the higher values of vigour index (1687) and the lowest vigour index was observed with the untreated seeds when stored in cloth bag (1359).

4.4.8 Field emergence (%)

The data on field emergence during storage indicated significant influence of genotypes, container and seed treatment (Table 28).

Irrespective of genotypes, containers and seed treatment, a steady decline in field emergence (88.81% to 76.04%) was observed with the progress in seed storage period.

The field emergence differed significantly with the genotype in all the months of the storage. The initial field emergence was significantly higher with hybrid KRH-2 (90.24%) followed by KMR₃ (88.33%). Female line IR58025A recorded the lowest initial field emergence (87.86%). KRH-2 maintained higher field emergence percentage from beginning till sixth month of storage. During 8th, 10th and 12th month of storage KMR-3 recorded higher field emergence compared to other genotypes. At the end of 12th month of storage period KMR-3 recorded higher field emergence (78.01%) followed by KRH-2 hybrid (76.45%).

The field emergence varied significantly with storage containers from fourth month of storage onwards. The reduction in field emergence with progress in storage period was higher with seeds stored in cloth bag. At the end of 12th month of storage the seeds stored in polythene bag recorded significantly higher field emergence (77.23%) compared to cloth bag (74.84%).

Table 27. Influence of seed treatment and container on vigour index of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	2173	2010	1827	1643	1424	1187	967
	G ₂ - KMR-3	2292	2113	1918	1734	1531	1310	1120
	G ₃ - KRH-2	2532	2338	2160	1951	1748	1594	1391
	S.Em±	1	30	31	31	25	40	44
	C.D. (0.01)	2	118	122	122	100	157	175
Containers (C)	C ₁ - Cloth bag	2332	2101	1909	1691	1476	1274	1060
	C ₂ - Polythene bag	2333	2206	2028	1861	1659	1453	1259
	S.Em±	1	24	25	25	21	32	36
	C.D. (0.01)	NS	96	100	100	81	128	143
Seed treatment (T)	T ₁ - Untreated	2332	2103	1910	1710	1495	1250	1036
	T ₂ - Vitavax	2333	2204	2026	1842	1640	1477	1282
	S.E m±	1	24	25	25	21	32	36
	C.D. (0.01)	NS	96	100	100	81	128	143
	Mean	2333	2153	1968	1776	1568	1363	1159

NS – Non-significant

Table 27a. Interaction of genotype, container and seed treatment on vigour index of KRRH-2 hybrid and its parents during storage

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	2173	2001	1813	1529	1310	1035	799
G ₁ C ₂	2174	2019	1841	1757	1538	1338	1135
G ₂ C ₁	2292	2097	1886	1702	1495	1295	1092
G ₂ C ₂	2293	2128	1950	1766	1566	1325	1147
G ₃ C ₁	2532	2205	2027	1843	1624	1491	1288
G ₃ C ₂	2532	2471	2293	2059	1872	1697	1494
Mean	2333	2153	1968	1776	1568	1363	1159
SEm _±	1	42	44	44	36	56	63
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	2331	2009	1803	1585	1359	1087	861
C ₁ T ₂	2333	2192	2014	1797	1594	1461	1258
C ₂ T ₁	2333	2196	2018	1834	1631	1414	1211
C ₂ T ₂	2333	2216	2038	1887	1687	1492	1306
Mean	2333	2153	1968	1776	1568	1363	1159
SEm _±	1	34	36	36	29	46	51
CD at 1%	NS	NS	NS	NS	115	182	202
G x T							
G ₁ T ₁	2173	1985	1797	1613	1392	1167	931
G ₁ T ₂	2174	2034	1856	1672	1456	1206	1003
G ₂ T ₁	2292	2091	1880	1696	1485	1185	982
G ₂ T ₂	2292	2135	1957	1773	1577	1435	1258
G ₃ T ₁	2531	2232	2054	1820	1608	1400	1197
G ₃ T ₂	2533	2444	2266	2082	1888	1788	1585
Mean	2333	2153	1968	1776	1568	1363	1159
SEm _±	1	42	44	44	36	56	63
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Contd....

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	2172	1955	1757	1473	1239	939	669
G ₁ C ₁ T ₂	2174	2046	1868	1584	1381	1131	928
G ₁ C ₂ T ₁	2174	2015	1837	1753	1545	1395	1192
G ₁ C ₂ T ₂	2174	2022	1844	1760	1531	1281	1078
G ₂ C ₁ T ₁	2292	2059	1815	1631	1406	1106	903
G ₂ C ₁ T ₂	2291	2135	1957	1773	1585	1485	1282
G ₂ C ₂ T ₁	2293	2122	1944	1760	1564	1264	1061
G ₂ C ₂ T ₂	2293	2134	1956	1772	1569	1385	1233
G ₃ C ₁ T ₁	2530	2014	1836	1652	1432	1215	1012
G ₃ C ₁ T ₂	2534	2396	2218	2034	1816	1766	1563
G ₃ C ₂ T ₁	2532	2450	2272	1988	1784	1584	1381
G ₃ C ₂ T ₂	2532	2491	2313	2129	1960	1810	1607
Mean	2333	2153	1968	1776	1568	1363	1159
SEm±	1	59	62	62	50	80	89
CD at 1%	NS	NS	NS	NS	NS	NS	669

NS – Non-significant

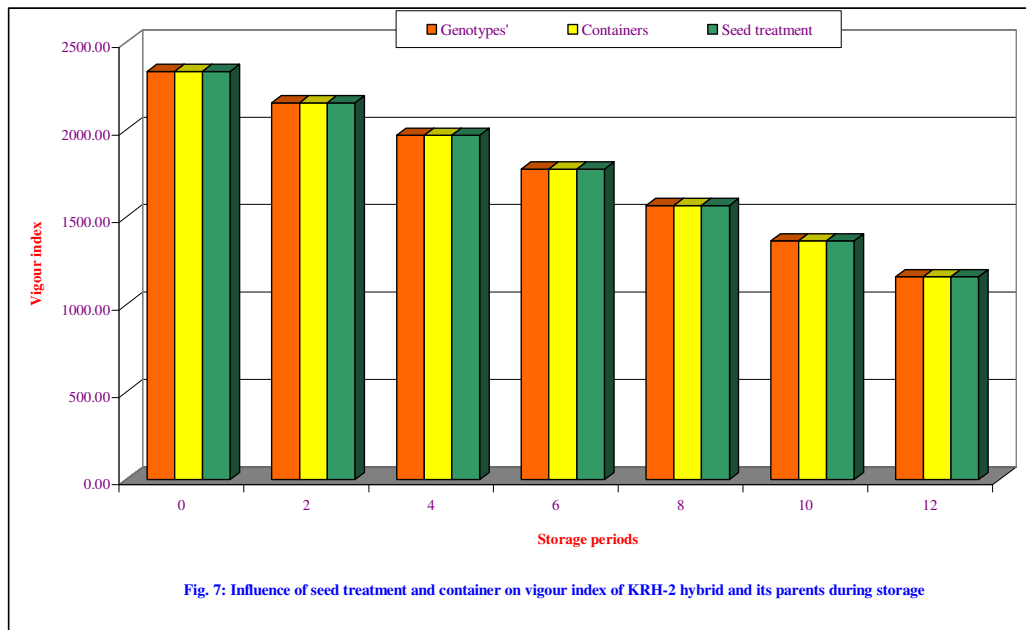


Fig. 7: Influence of seed treatment and container on vigour index of KRH-2 hybrid and its parents during storage

Table 28. Influence of seed treatment and container on field emergence (%) of KRH-2 hybrid and its parents during storage

Treatment		Storage periods (Months)						
		0	2	4	6	8	10	12
Genotypes (G)	G ₁ - IR58025A	87.86 (69.58)	85.88 (67.94)	84.36 (66.69)	80.96 (64.12)	75.84 (60.56)	75.68 (60.44)	73.65 (59.12)
	G ₂ - KMR-3	88.33 (70.00)	86.83 (68.70)	85.62 (67.71)	83.44 (66.02)	82.91 (65.62)	79.99 (63.41)	78.01 (62.01)
	G ₃ - KRH-2	90.24 (71.76)	88.11 (69.81)	86.91 (68.77)	84.01 (66.41)	82.42 (65.19)	78.84 (62.60)	76.45 (61.01)
	S.Em±	0.04	0.28	0.23	0.28	0.34	0.21	0.52
	C.D. (0.01)	0.18	1.11	0.90	1.11	1.33	0.83	2.07
Containers (C)	C ₁ - Cloth bag	88.74 (70.38)	86.60 (68.55)	85.08 (67.28)	81.85 (64.79)	79.26 (62.96)	77.44 (61.64)	74.84 (59.92)
	C ₂ - Polythene bag	88.88 (70.51)	87.27 (69.09)	86.17 (68.16)	83.76 (66.24)	81.52 (64.62)	78.90 (62.66)	77.23 (61.50)
	S.Em±	0.04	0.23	0.19	0.23	0.27	0.17	0.43
	C.D. (0.01)	NS	NS	0.73	0.90	1.08	0.68	1.69
Seed treatment (T)	T ₁ - Untreated	88.76 (70.40)	86.47 (68.43)	84.95 (67.17)	81.72 (64.69)	79.28 (62.98)	77.42 (61.63)	74.82 (59.90)
	T ₂ - Vitavax	88.86 (70.49)	87.41 (69.20)	86.31 (68.28)	83.89 (66.35)	81.50 (64.60)	78.92 (62.67)	77.25 (61.52)
	S.E m±	0.04	0.23	0.19	0.23	0.27	0.17	0.43
	C.D. (0.01)	NS	0.90	0.73	0.90	1.08	0.68	1.69
	Mean	88.81 (70.45)	86.94 (68.82)	85.63 (67.72)	(82.80) (65.78)	80.39 (63.79)	78.17 (62.15)	76.04 (60.71)

NS – Non-significant

Table 28a. Interaction of genotype, container and seed treatment on field emergence (%) of KRH-2 hybrid and its parents during storage

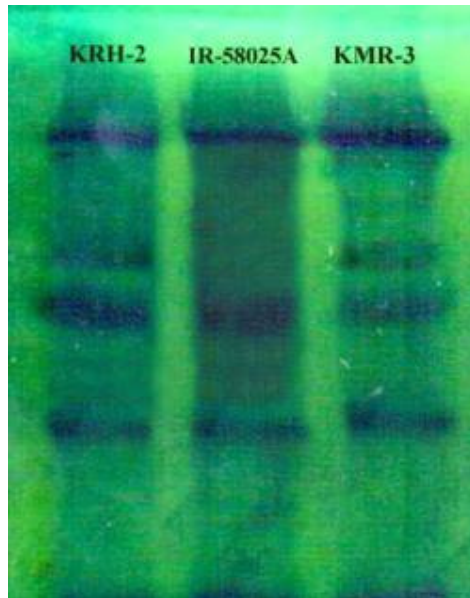
Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C							
G ₁ C ₁	87.78 (69.51)	85.20 (67.42)	83.73 (66.19)	79.83 (63.30)	74.47 (59.64)	74.82 (59.86)	72.33 (58.27)
G ₁ C ₂	87.94 (69.65)	86.56 (68.47)	84.99 (67.19)	82.09 (64.94)	77.21 (61.47)	76.54 (61.02)	74.97 (59.96)
G ₂ C ₁	88.24 (69.92)	86.78 (68.66)	85.19 (67.38)	82.29 (65.11)	81.68 (64.64)	79.34 (62.94)	77.86 (61.91)
G ₂ C ₂	88.42 (70.08)	86.88 (68.74)	86.05 (68.04)	84.60 (66.93)	84.14 (66.60)	80.64 (63.88)	78.16 (62.11)
G ₃ C ₁	90.19 (71.72)	87.83 (69.56)	86.32 (68.29)	83.42 (65.96)	81.62 (64.59)	78.14 (62.12)	74.35 (59.59)
G ₃ C ₂	90.28 (71.81)	88.39 (70.05)	87.49 (69.26)	84.59 (66.86)	83.21 (65.80)	79.53 (63.08)	78.55 (62.43)
Mean	88.81 (70.45)	86.94 (68.82)	85.63 (67.72)	82.80 (65.52)	80.39 (63.79)	78.17 (62.15)	76.04 (60.71)
SEm _±	0.06	0.40	0.32	0.40	0.47	0.30	0.74
CD at 1%	NS	NS	NS	NS	NS	NS	NS
C x T							
C ₁ T ₁	88.68 (70.33)	85.70 (67.81)	84.33 (66.67)	80.76 (63.98)	78.50 (62.44)	76.66 (61.11)	73.30 (58.91)
C ₁ T ₂	88.79 (70.43)	87.51 (69.28)	85.83 (67.90)	82.93 (65.60)	80.01 (63.47)	78.21 (62.17)	76.39 (60.93)
C ₂ T ₁	88.84 (70.47)	87.24 (69.06)	85.57 (67.67)	82.67 (65.39)	80.06 (63.52)	78.18 (62.15)	76.35 (60.89)
C ₂ T ₂	88.92 (70.55)	87.30 (69.11)	86.78 (68.66)	84.84 (67.10)	82.98 (65.73)	79.62 (63.16)	78.11 (62.11)
Mean	88.81 (70.45)	86.94 (68.82)	85.63 (67.72)	82.80 (65.52)	80.39 (63.79)	78.17 (62.15)	76.04 (60.71)
SEm _±	0.05	0.32	0.26	0.32	0.39	0.24	0.60
CD at 1%	NS	NS	NS	NS	NS	NS	NS
G x T							
G ₁ T ₁	87.80 (69.53)	85.03 (67.28)	83.78 (66.22)	79.88 (63.33)	74.35 (59.56)	74.87 (59.89)	72.35 (58.26)
G ₁ T ₂	87.91 (69.63)	86.73 (68.61)	84.94 (67.15)	82.04 (64.91)	77.33 (61.55)	76.50 (60.98)	74.95 (59.97)
G ₂ T ₁	88.28 (69.96)	86.47 (68.39)	84.71 (66.96)	81.81 (64.73)	81.67 (64.64)	79.50 (63.06)	77.85 (61.90)
G ₂ T ₂	88.38 (70.04)	87.19 (69.00)	86.53 (68.46)	85.08 (67.31)	84.16 (66.60)	80.48 (63.77)	78.17 (62.12)
G ₃ T ₁	90.19 (71.72)	87.91 (69.63)	86.36 (68.32)	83.46 (66.00)	81.83 (64.74)	77.90 (61.94)	74.27 (59.54)
G ₃ T ₂	90.28 (71.80)	88.31 (69.98)	87.45 (69.22)	84.55 (66.83)	83.01 (65.64)	79.77 (63.25)	78.62 (62.47)
Mean	88.81 (70.45)	86.94 (68.82)	85.63 (67.72)	82.80 (65.52)	80.39 (63.79)	78.17 (62.15)	76.04 (60.71)
SEm _±	0.06	0.40	0.32	0.40	0.47	0.30	0.74
CD at 1%	NS	NS	NS	NS	NS	NS	NS

Treatment	Storage (months)						
	0	2	4	6	8	10	12
G x C x T							
G ₁ C ₁ T ₁	87.69 (69.44)	83.18 (65.82)	83.64 (66.11)	78.74 (62.52)	72.70 (58.48)	74.40 (59.58)	70.61 (57.15)
G ₁ C ₁ T ₂	87.87 (69.59)	87.21 (69.02)	83.83 (66.26)	80.93 (64.08)	76.25 (60.81)	75.25 (60.14)	74.05 (59.39)
G ₁ C ₂ T ₁	87.91 (69.63)	86.88 (68.74)	83.92 (66.34)	81.02 (64.15)	76.01 (60.65)	75.34 (60.20)	74.09 (59.38)
G ₁ C ₂ T ₂	87.96 (69.67)	86.24 (68.20)	86.05 (68.04)	83.15 (65.74)	78.41 (62.29)	77.74 (61.83)	75.85 (60.54)
G ₂ C ₁ T ₁	88.19 (69.87)	86.42 (68.35)	83.99 (66.40)	81.09 (64.21)	81.27 (64.33)	78.93 (62.66)	77.62 (61.74)
G ₂ C ₁ T ₂	88.29 (69.96)	87.14 (68.96)	86.39 (68.36)	83.49 (66.02)	82.10 (64.94)	79.75 (63.23)	78.10 (62.07)
G ₂ C ₂ T ₁	88.38 (70.04)	86.52 (68.43)	85.42 (67.53)	82.52 (65.26)	82.07 (64.94)	80.07 (63.46)	78.07 (62.05)
G ₂ C ₂ T ₂	88.47 (70.12)	87.23 (69.04)	86.67 (68.56)	86.67 (68.59)	86.22 (68.26)	81.22 (64.31)	78.25 (62.18)
G ₃ C ₁ T ₁	90.16 (71.69)	87.48 (69.26)	85.36 (67.50)	82.46 (65.23)	81.54 (64.53)	76.66 (61.09)	71.67 (57.84)
G ₃ C ₁ T ₂	90.22 (71.75)	88.18 (69.87)	87.28 (69.08)	84.38 (66.69)	81.70 (64.65)	79.63 (63.15)	77.02 (61.34)
G ₃ C ₂ T ₁	90.23 (71.75)	88.34 (70.00)	87.36 (69.15)	84.46 (66.76)	82.11 (64.95)	79.14 (62.80)	76.88 (61.25)
G ₃ C ₂ T ₂	90.33 (71.86)	88.44 (70.10)	87.62 (69.37)	84.72 (66.96)	84.31 (66.64)	79.91 (63.35)	80.22 (63.61)
Mean	88.81 (70.45)	86.94 (68.82)	85.63 (67.72)	82.80 (65.52)	80.39 (63.79)	78.17 (62.15)	76.04 (60.71)
SEm _±	0.09	0.56	0.45	0.56	0.67	0.42	1.05
CD at 1%	NS	NS	NS	NS	NS	NS	NS

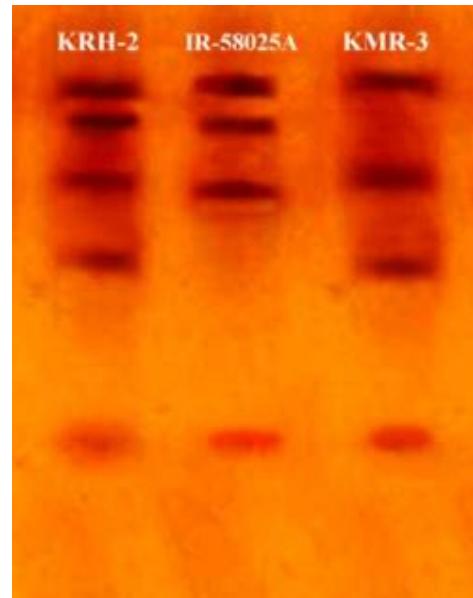
NS – Non-significant

Table 29. Isozyme pattern of catalase, polyphenol oxidase and peroxidase in seedlings of KRH-2 hybrid and its parental lines

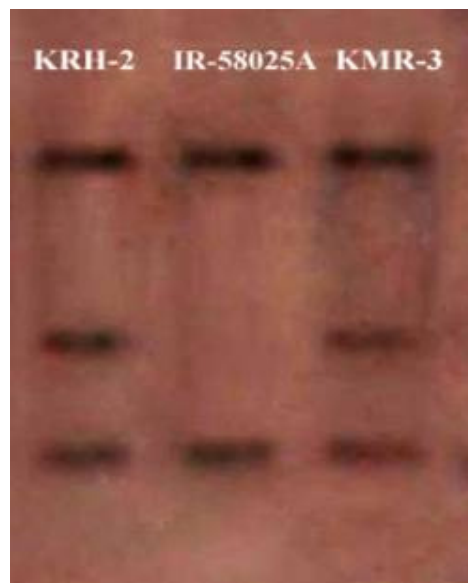
Lane No.	Treatment	Catalase					Peroxidase					Poly phenol oxidase			
		No. of bands	Rm value				No. of bands	Rm value				No. of bands	Rm value		
			1	2	3	4		1	2	3	4		1	2	3
1	KRH-2	4	0.18	0.36	0.54	0.72	4	0.16	0.32	0.52	0.71	3	0.18	0.59	0.74
2	IR58025A	3	0.16	0.32	-	0.71	3	-	0.31	0.50	0.72	2	0.18	-	0.79
3	KMR-3	4	0.14	0.33	0.57	0.70	3	0.15		0.50	0.69	3	0.16	0.50	0.69



Catalase



Peroxidase



Polyphenol oxidase

Plate 1: Isozyme banding pattern of KRH 2 hybrid and its parental lines

The seeds treated with vitavax powder (carboxin + thiram @ 3 g/kg) recorded significantly higher field emergence in all the months of storage. At the end of 12th month of storage, the seeds treated with vitavax powder (carboxin + thiram @ 3 g/kg) recorded significantly higher field emergence (77.25%) compared to untreated seeds (74.82%).

4.5 Experiment-V: Characterization of KRH-2 hybrid and its parents using isozymes

Isozyme pattern of catalase, peroxidase and poly Phenol oxidase in seedlings of KRH-2 hybrid and their parental lines are represented below.

4.5.1 Catalase

The catalase isozymes were visualized on polyacrylamide gels. It was revealed from the Table 29 that KRH-2 hybrid produced four bands with Rm value 0.18, 0.36, 0.54, 72. IR58025A produced three bands with Rm values of 0.16, 0.32, and 0.71. KMR-3 produced four bands with Rm value 0.14, 0.33, 0.57, 0.70.

4.5.2 Peroxidase

The enzyme peroxidase could be visualized on poly acryl amide gels. PAGE results presented in the Table 29 revealed that banding pattern differed in different treatments. KRH-2 hybrid produced four bands with Rm value 0.16, 0.32, 0.52, 0.71. IR58025A produced three bands with Rm values of 0.31, 0.50, 0.72. KMR-3 produced three bands with Rm value 0.15, 0.50, 0.69.

4.5.3 Polyphenol oxidase

Data presented in the Table 29 revealed that banding pattern of Poly Phenol Oxidase changed due to intensity of banding pattern of the genotypes. KRH-2 hybrid produced three bands with Rm value 0.18, 0.59, 0.74. IR58025A produced two bands with Rm values of 0.18, 0.79. KMR-3 produced three bands with Rm value 0.16, 0.50 and 0.69.

5. DISCUSSION

The successful development of hybrid maize in 1957's provided an impetus for the breeders of the other crops including self pollinated cereals such as rice, wheat and often cross pollinated crops like sorghum to exploit the phenomenon of hybrid rice in India.

Jones (1926) was the first scientist to report the heterosis in rice. Periodically suggestions of developing F1 hybrids to exploit heterosis commercially have been initiated by rice scientists in India, China, USA and Philippines. But China happened to be the first country to exploit heterosis by developing hybrid rice. The success of hybrid rice in China led to initiate the research on hybrid rice by other countries like India, Vietnam and Philippines. Efforts to develop hybrid rice technology in India, though initiated in 1970 which have been systematically intensified since 1989. And so far, few hybrids have been released for cultivation. To obtain the benefits of hybrid rice cultivation, it is essential to develop effective techniques of hybrid rice seed production.

As rice crop being traditionally the crop having high water requirement, there is a need to search for alternate methods to reduce water requirement of rice without reduction in the yield. In recent years, with the introduction of new aerobic rice technology in rice cultivation, it has become possible to get reasonably good yields with two to three irrigations, thus resulting in saving of 30-40 per cent of water. System of Rice Intensification (SRI) is another emerging water saving technology, with many fold increase in crop yield (Laulanie, 1993).

System of rice intensification (SRI) is the method, developed in Madagascar. SRI method of cultivation is said to promote greater root growth and higher soil biological activity in the rhizosphere. By adopting this system of cultivation we could save water, protect soil productivity, save environment by checking methane gas from water submerged paddy cultivation practices, bring down the input cost, besides, increasing the production. Hence an attempt was made to reduce the cost of cultivation and improve soil conditions by adopting hybrid rice seed production under system of rice intensification. However, the reports on hybrid rice seed production are scarce and hence the literature citation directly pertaining to hybrid rice cultivation under SRI is less in this chapter. Nevertheless, tangential reports on various growth and yield parameters are cited here.

5.1 Screening of selected promising rice hybrids under modified SRI method in upland eco system

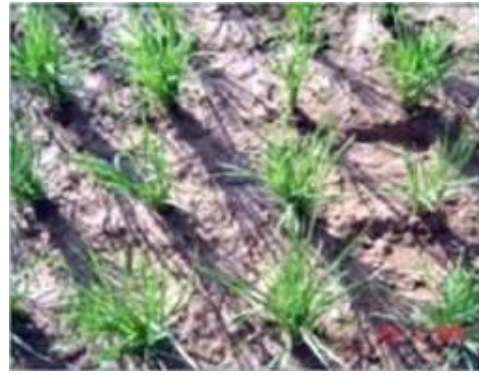
5.1.1 Growth parameters

Plant height was significantly influenced by methods of cultivation. Higher plant height was obtained under SRI method of cultivation (64.20 cm) as compared to normal method of cultivation (57.31cm). Planting of seedlings in clumps reduced the plant height. The spacing 20 × 20 cm significantly increased the plant height. Optimum plant population density and geometry under SRI led to availability of more resources to the plants that resulted in increased plant height. These findings are in conformity with the observations of Koma and Sinv (2003), Uphoff (2004) and Sheng *et al.* (2004.)

The plant height differed significantly with respect to hybrids. Among the 11 different hybrids and a check variety MGD-101 recorded the highest plant height (80.13 cm). The lowest plant height was recorded by CORH-3 (51.74 cm) and DRRH-2 (50.55 cm) which were on par with each other. This might be mainly due to influence of genotypic character with respect to plant height. Interaction M₁H₁₂ recorded the highest plant height (81.27 cm) followed by M₂H₁₂ (79.00 cm). The lowest plant height was recorded by M₂H₁₀ (50.60 cm). Wider spacing and application of RDF making the plants availability of resources for better crop growth lead to increase in the plant height. Several workers have reported instances of increase in plant height due to increased application of inorganic fertilizers (Hedge., 1996, Singh *et al.*, 1995 and Krupakar Reddy., 2004).



Traditional method



SRI method



Root growth



Traditional method



SRI method

Plate 2: Comparison between SRI and traditional method

Considerable amount of variability in number of tillers per plant was established by methods of cultivation and hybrids. SRI method of cultivation recorded significantly higher number of tillers per plant (25.49) as compared to the traditional method of cultivation (13.04). Planting in square methods with wider spacing might have resulted in profused tillering under SRI method, which might have facilitated the plants for better utilization of the resources. This advantage of SRI method in enhancing tiller number has been reported earlier by Gani *et al.* (2002) and Udaykumar (2005) in rice.

Among the hybrids screened for suitability under SRI method in upland eco system under Mugad region, KRH-2 hybrid recorded higher number of tillers (23.15). This may be due to adaptability of particular hybrid to the climatic condition hence produced more number of tillers. Interaction M_1H_{11} registered the highest number of tillers per plant (31.43) followed by M_1H_{10} , M_1H_8 , M_1H_7 (29.87, 29.73, 26.27), respectively. Whereas, M_2H_{12} recorded lower number of tillers per plant (10.37). The effect of SRI method with RDF application facilitated the plants to grow profusely because of wider spacing and better nutrition availability, thus leading to better growth parameters.

There was significant effect on days to 50 per cent flowering due to methods of cultivation. Flowering was early under SRI method of cultivation as compared to the traditional method. Hybrids under SRI method took lesser days (89.11) for 50 per cent flowering as compared to the traditional method (92.58). Plants grown under SRI method with recommended doses of fertilizers flowered and matured early compared to the traditional method. Supply of more P and K fertilizers in RDF, might have helped the plants to flower early, (Biradar patil 1999; Hussain *et al.* 2009) in rice. Hybrids showed significant difference with respect to 50 per cent flowering. Among the 11 hybrids, DRRH-2 recorded less number of days to 50 per cent flowering (83.33) and resembled it to be early maturing and short duration hybrid. Interaction effect revealed that M_1H_6 significantly took less number of days to 50 percent flowering (80.67) as compared to all other interaction effects, M_2H_9 took more days to 50 percent flowering (108.67). Similar findings were reported by Krupakar reddy., (2004) and Udaykumar (2005) who have noticed that SRI method plots recorded significantly lesser days by (4-5 days) for flowering and maturity as compared to the traditional method of planting in BPT-5204 variety and MTU-1010 rice variety.

5.1.2 Yield and yield parameters

The yield ultimately depends on better expansion of yield attributing characters. In the present investigation the productive tillers per plant were significantly higher in SRI method (23.13) as compared to the traditional method (10.07). Significant difference was observed in hybrids for the number of productive tillers per plant. Among the different hybrids, GK-5003 and KRH-2 recorded higher number of productive tillers per plant (19.37 and 19.07, respectively). The interaction effect between the methods of cultivation on 11 hybrids for productive tillers per plant showed significant difference. Interaction M_1H_{11} , M_1H_8 , M_1H_7 , recorded the highest number of productive tillers per plant (27.27, 26.27, 26.00, respectively) which were found on par with each other. Productive tillers per plant were significantly higher in SRI method as compared to the traditional method. The increase in the productive tillers per plant might be due to the better spacing provided to the plants by planting in square method. This might have facilitated better utilization of resources by the plants converting majority of the tillers in to productive tillers. Similar research findings were reported by Gani *et al.* (2002), Thiagarajan and Selvaraju (2002), Sarath and Thilak (2004) in rice.

Method of cultivation differed significantly for panicle length (cm). SRI method recorded significantly higher panicle length (21.51 cm) compared to the traditional method (19.59 cm). These results are in contradictory to results of Abu Yameb (2002) and Sarath and Thilak (2004), who have suggested that panicle length did not vary significantly neither due to planting methods nor due to fertilizers in variety BPT-5204. Among different hybrids including check, Hybrid GK-5003 recorded the highest panicle length (23.45 cm). This may be due to genotypic effect of the hybrid. Interaction effect between the methods of cultivation and hybrids showed significant difference with respect to panicle length (cm). Treatment combination of M_1H_7 , M_1H_{11} recorded the highest panicle length (24.00, 23.93 cm) and were found on par with each other, M_2H_8 recorded the lowest panicle length (16.33 cm) among all the treatment combinations.

Higher panicle weight was noticed in SRI method of cultivation (3.61g), when compared to the normal method of cultivation (3.23 g). The wider spacing to the plants in SRI method, might have resulted in better growth of the plants, leading to the longer panicles and accommodate more spikelets per panicle, which tends to increase the panicle weight, as reported earlier by Thakur *et al.* (2009). Among the different hybrids including check variety, GK-5003 recorded the highest panicle weight (4.00 g). This might be due to genotypic effect and influence of method of cultivation. Interaction effect differed significantly for panicle length. Interaction M₁H₇ recorded the highest panicle weight (4.24 g). M₂H₄ recorded the lowest panicle weight (2.93 g) which found on par with treatment M₂H₂ and M₂H₁ (2.95, 2.94, respectively).

The seed weight per plant (g) was significantly influenced by methods of cultivation. SRI method of cultivation recorded significantly higher seed weight per plant (34.27 g) as compared to normal method of cultivation (20.93 g). Seed weight per plant is a cumulative effect of seed attributing characters. The decreased plant density with SRI management was compensated by increased yield per-plant productivity. The higher seed yield per panicle or plant recorded with these treatments might be attributed to higher spikelet filling. Similar observations were also reported by Raju *et al.* (1989) and Udayakumar (2005).

Hybrids showed significant difference with respect to seed weight per plant. Of all the hybrids Gk-5003 differed significantly by recording higher seed weight per plant (33.96g). Interaction effect was found significant. M₁H₇ interaction recorded significantly higher seed weight per plant (42.34g) followed by M₁H₁₁, M₁H₈, M₁H₆ (40.29g, 39.41g, 38.86g) and were on par with each other. Whereas M₂H₁₂ recorded the lowest seed weight per plant (13.75g).

Methods of cultivation did not influence significantly on thousand seed weight. However, SRI method has recorded numerically higher seed weight (22.96 g) as compared to the normal method of cultivation (22.09 g). Among the different hybrids, GK-5003 recorded the higher 1000 seed weight (24.66 g). 1000 seed weight differed among the hybrids due to genotypic effect. Due to increase in 1000 grain weight under SRI method may be due to the edge effect uniformly over the whole field along with integrated effects of fertilizers and better soil aeration. These findings are in conformity with reports of Thakur *et al.* (2009) and Krishna *et al.* (2008) in rice.

The difference in yield components could be traced back to the difference in physiological characters both in vegetative and reproductive phases of the crop growth. The methods of cultivation differed significantly for total spikelets per panicle. SRI method has recorded significantly higher number of spikelets per panicle (183.29) as compared to the traditional method (139.85). The longer panicles produced in SRI carried more number of grain compared to panicles obtained from the traditional method of cultivation. With SRI management, each centimeter of increase in panicle length could accommodate 12 grains, whereas with traditional method of cultivation only 6 grains could be accommodated by each additional centimeter. The alternative sets of management practices thus produced a difference in the branching of panicles, so that the structure of SRI panicles could accommodate more grains. (Thakur *et al.*, 2009). Among the hybrids, GK-5003 differed significantly for total number of spikelets and recorded highest number of spikelets per panicle (189.17). Interaction M₁H₇ registered the highest number of spikelets per panicle (212.67) M₂H₁₂ recorded the lowest spikelets per panicle (119.99). Hills with single plants were found to have deeper and better-distributed root systems, higher xylem exudation rates, more open plant architecture with more erect and larger leaves, and more tillers than did the traditional system. Helps in better photosynthesis process, easy transport of reserve food material which in turn helps in production of more number of spikelets per plant, as reported by Thakur *et al.* (2009) Krishna *et al.*, (2008) in rice.

The number of filled spikelets per panicle differed significantly due to the method of cultivation. SRI method of cultivation recorded significantly higher number of filled spikelets (144.44) compared to the traditional method. In the traditional method of rice cultivation having fewer hills and fewer tillers per unit area, the leaf area index (LAI) with the SRI practice was greater due to larger leaves. These together with altered plant architecture, contributed to more light interception by SRI plants.

The higher leaf chlorophyll content at the ripening stage reflected delayed senescence and the greater fluorescence efficiency associated with the SRI method of practices contributed to more efficient utilization of light and a higher rate of photosynthesis, which was probably responsible for the observed increase in the grain filling and heavier grains compared to the plants grown in the traditional system. Similar findings were reported by Thakur *et al.* (2009).

GK-5003 recorded significantly highest number of filled spikelets per panicle (166.14). Lower number of filled spikelets was recorded by PA-6129 (114.14). Interaction effect was found to be significant, Among the interaction M_1H_7 interaction differed significantly by recording the higher number of spikelets (180.00). Where as the lowest number of filled spikelets was recorded by interaction treatment of M_2H_9 (96.97), which was on par with M_2H_3 (96.62) and M_2H_{10} (99.30). This might be due to ready availability of nutrients from the inorganic fertilizers to the plants resulting in higher yield parameters. The higher number of filled spikelets obtained in this experiment under SRI method are in conformity with the results of Abu Yameb (2002) and Sarath and Tilak (2004) in rice.

SRI method of cultivation recorded significantly lower number of unfilled spikelets per panicle (37.21) compared to the traditional method (46.33). The SRI method provided the plants better growth conditions such as wider spacing, better aeration and better utilization of resources, which enabled them to grow vigorously. This has been exhibited in terms of higher leaf area and ultimately higher dry matter production. These enhanced growth parameters might have helped in better filling of spikelets and reduced the number of unfilled spikelets per panicle. These results are in agreement with the findings of Nayak *et al.* (1998) and Barison (2002) in rice. Among the hybrids, Gk-5003 differed significantly by recording lower number of unfilled spikelets per panicle (34.57), which might be due to more number of filled spikelets per panicle. The interaction effect between the method of cultivation and hybrids were found significant. M_1H_7 recorded lower number of unfilled spikelets (27.00), followed by M_1H_{12} and M_1H_{11} (28.56, 29.33) which were found on par with each other. While interaction effects M_2H_9 differed significantly by recording more number of unfilled spikelets per panicle (69.63).

Root depth or penetration differed significantly due to method of cultivation. SRI method of cultivation recorded significantly higher root depth (31.64 cm) as compared to the traditional method of cultivation (19.50 cm). Root growth was markedly greater in plants raised under SRI method than in the traditional system of cultivation, root dry matter and root depth were also more in SRI method as compared to the traditional rice cultivation as reported by Tao Longxing *et al.* (2002). Hills with single plants were found to have deeper and better-distributed root systems, higher xylem exudation rates, more open plant architecture with more erect and larger leaves and more tillers per plant than the traditional system, helped in better photosynthesis process, easy transport of reserve food material. by adopting deeper root growth. These results are in agreement with the findings of Thakur *et al.* (2009), Tao Longxing *et al.* (2002), Zheng *et al.* (2004) in rice. Among the 11 different hybrids GK-5003 differed significantly by recording higher root depth (26.55 cm). The interaction effect between the method of cultivation and hybrids were found significant. M_1H_7 recorded the highest root depth (32.70 cm) and was found on par with M_1H_{11} (32.40 cm), M_1H_8 (32.20 cm). While the M_2H_{12} recorded lower root depth (18.70 cm).

Root dry weight (g) differed significantly due to method of cultivation. SRI method of cultivation recorded significantly higher root weight (11.55 g) as compared to the traditional method (5.16 g). Among the 11 different hybrids, GK-5003 differed significantly by recording higher root weight (8.77g). Planting single seedling per hill with a wider spacing, provided better aeration and less competition which enabled the roots to grow to greater depth and grow vigorously, having higher root weight (g). These results are in agreement with the findings of Tao Longxing *et al.* (2002) and Thakur *et al.* (2009) in rice.

The percent increase in grain yield per plot under SRI method was 2973g and 1879g respectively over the traditional method. These results are in conformity with the findings of Mchungu *et al.* (2002), Rafaralahy. (2002) who reported that SRI method of cultivation increases the yield levels by 147 per cent over the traditional method. Among the Hybrids, GK-5003 differ significantly for grain yield and recorded higher grain yield (2923g). Interaction M_1H_7 recorded significantly higher grain yield (3544 g).

This might be due to better supply of NPK nutrients through RDF, enabling the plants for higher production and better portioning of dry matter, resulting in higher number of unfilled spikelet's and decreased spikelet sterility. These results are in conformity with findings of Raju *et al.* (1989), Abu Yameb (2002) and Sarath and Tilak (2004).

SRI method recorded significantly higher grain yield per hectare (9.91t) compared to the traditional method (6.27t). Among the Hybrids GK-5003 differed significantly for grain yield, recorded higher grain yield (9.74t). The optimum level of plant population coupled with better yield parameters might have resulted in higher seed yield per plot with 30 x 30 cm spacing. These findings are in conformity with the findings of Ceesay and Uphoff (2003) and Zhang *et al.* (2004).

The data obtained on straw weight revealed significant difference on both the methods of cultivation. SRI method of cultivation recorded significantly higher straw weight (4.08kg) as compared to the traditional method of cultivation (3.50kg). KRH-2 significantly recorded higher straw weight (4.51 kg). This might be due to more number of tillers per plant having wider leaf area. Strong seedlings for SRI method produced stronger and profuse tillers supported by a prolific and deeper root system which resulted in higher grain yield and straw yield as reviewed by Hussain *et al.* (2009.) Interaction effect M₁H₁₁ recorded higher straw weight (5.01Kg). Strong seedlings for SRI method produced stronger and profuse tillers supported by a prolific and deeper root system resulted in higher grain yield and straw yield as reviewed by Hussain *et al.* (2009.). The greater straw weight at harvest from SRI method was due to number of tillers produced in each hill, which was almost double than that of traditional method, even though the traditional methods contained three plants instead of one. These results are in agreement with Thakur *et al.* (2009).

5.2 Evaluation of suitable seed treatment to improve seedling vigour under SRI method

Plants have evolved various biochemical and physiological mechanisms to combat water stress. One such mechanism that is ubiquitous in plants is the accumulation of certain organic metabolites of lower molecular weight especially during seed germination and at early stages of growth (Posmyk and Janas, 2007). Exogenous application of some of these compounds such as proline and glycine betaine to enhance stress tolerance ability of different crop plants has got attention of many researcher since many years (Bukhari, 2007) but the information regarding the role of exogenous glycine betaine or proline on germination and early seedling vigour growth is scanty. Hence, the study was conducted to investigate the role of exogenous application of some osmo-protectants such as glycine betaine, proline, PEG, calcium chloride and potassium nitrate as seed treatments in rice to overcome a biotic stress prevailed during crop growth. Due to scanty of research findings on influence of proline on seedling vigour, reference to the findings have been quoted from foliar applications of proline to mitigate salt and drought stress and correlated to the experimental findings.

Germination percentage varied significantly with respect to genotypes. Hybrid showed higher germination (96.77 %) as compared to the restorer line KMR-3 (94.68 %) and female line IR 58025A (91.69 %). These findings confirm in agreement with the findings Garg (2003) who have opined that genotypes of the same species may vary in their response to exogenous application of proline. Seeds treated with proline @ 0.1% recorded higher germination (94.96%) over control (93.61%). Proline is a compatible solute involved in cell osmo regulation and protection of proteins during dehydration. It acts as a free radical scavenger and may be more important in overcoming stress than in acting as a simple osmolyte. Increase in seed germination may be due to water potential between the seeds and surrounding media. The physical process of water uptake lead to activation of metabolic activity which in turn trigger germination process. The findings of research can be related to some earlier studies in which it has been observed that exogenous application of glycine betaine or proline counteracts the growth inhibition caused by salt stress or cold stress in different crop plants (Cha-um *et al.*, 2006). In rice, exogenous application of 30 mM proline counteracted the adverse effects of salinity on early seedling growth and enhanced germination (Roy *et al.*, 1993). Like wise, in rice exogenous application of proline increased the salt-tolerance of the seedlings by improving plant water status Cha-um *et al.* (2006). Bukhari (2007) reported that, proline application proved helpful in enhancing the growth of plants under drought stress. Proline treatments of 20 m mol L⁻¹ and 30 m mol L⁻¹ proved to

be the most effective levels for increasing germination percentage and growth of wheat plants. The main reason for poor performance of rice treated with glycine betaine is that rice is the only important cereal crop that does not accumulate glycine betaine as that of proline. (Sakamoto and Alia 2000).

The genotypes differed significantly with respect to speed of germination. KRH-2 hybrid recorded higher speed of germination (26.48). Proline @ 0.1% recorded higher speed of germination (24.05) than control (22.99). Interaction effect between the genotypes and seed treatments were found significant. Interaction P_3T_1 recorded higher speed of germination (26.95). Hydration of seed with proline permits early DNA replication increased RNA and protein synthesis greater ATP availability enhances the faster embryo growth, repair of deteriorated seed parts. These help radical protrusion through the seed coat and shorten the time to seed germination. These results are in conformity with the findings of Bray *et al.* (1989) and Saha *et al.* (1990) in wheat.

Higher shoot length was recorded by KRH-2 (12.67 cm) followed by the male parent KMR-3 (11.97 cm). The lowest was recorded by IR-58025A (11.08 cm). These findings confirm the argument of Garg (2003) who opined that genotypes of the same species may vary in their response to exogenous application of proline. Among the seed treatments, proline differed significantly and recorded higher shoot length (12.28 cm). The lowest shoot length was recorded by control (11.41 cm). Interaction effect between genotypes and chemical treatment were found significant. P_3T_1 recorded higher shoot length (12.95 cm). These findings are in contradictory to the findings of Kamran *et al.* (2009) who have reported that exogenous application of proline as a pre-sowing seed treatment (control, 20 mM and 40 mM) on 5 wheat cultivars viz., SARC-I, InqLab-91, MH-97, Bhakkar and S-24, improved shoot length under both non-stress and stress conditions and total leaf area per plant only under stress conditions which may be due to exogenously applied proline as a pre-sowing seed treatment did not affect the shoot and root K^+ , Ca^{2+} .

Proline in plants provides energy for their growth and stress tolerance. Proline also plays an important role in protection of membrane organelles, proteins and enzymes. Root length was significantly influenced by genotypes and seed treatment. Higher root length was recorded by KRH-2 (13.34 cm). The present findings are in conformity with the research results of Kamaran *et al.* (2009) who have observed differential effect of pre sowing seed treatment of proline on different cultivars under study. Interaction effects between the genotypes and seed treatment were found significant. Interaction P_3T_1 recorded higher root length (13.62 cm). Exogenous application of proline as a pre-sowing seed treatment (control, 20 mM and 40 mM) on 5 wheat cultivars viz., SARC-I, InqLab-91, MH-97, Bhakkar and S-24, improved shoot and root fresh and dry weights, shoot length and grain yield under both non-stress and stress conditions and total leaf area per plant only under stress conditions. Kamran *et al.* (2009) reported that this might be due to exogenously applied proline as a pre-sowing seed treatment did not affect the shoot and root K^+ , Ca^{2+} and P and root N,

Proline helps in accumulation of macronutrients (N.P.K) under salt stress condition. KRH-2 recorded higher seedling dry weight (152.64 mg) followed by KMR-3 (146.03mg). The lowest was recorded by IR58025A (141.15 mg). Proline recorded significantly higher vigour index (156.37 mg over the control. P_3T_1 interaction recorded higher seedling dry weight (160.33 mg). The research findings are controversially to the findings of Naseem (2007) Kamran *et al.* (2009). who have reported that exogenous application of proline 40 mM as a pre-sowing treatment improved the shoot fresh and dry weights of wheat cultivars under both non-stress and drought stress conditions. This may be due to exogenous application of proline as a pre-sowing seed treatment with varying levels of proline ameliorated the adverse effects of water deficit conditions on the growth of wheat cultivars.

The genotype differed significantly for vigour index, KRH-2 differed significantly and recorded higher vigour index (2385), Among the seed treatment proline recorded significantly higher vigour index (2289) over the control (2066). Interaction effect between genotype and seed treatment found significant with P_3T_1 interaction recorded higher vigour index (2484), which might be due to osmotic potentiality of proline to accommodate higher mineral nutrients in cell cytoplasm, which enhanced germination and improved shoot and root growth in turn recorded higher vigour index (Bukhari, 2007; Saha *et al.*, 1990) in wheat.

5.3 Standardization of hybrid rice seed production techniques in KRH-2 hybrid under SRI method

Application of gibberlic acid at various concentrations increased the plant height and the number of productive tillers per plant significantly. Remarkable increase in the growth and yield characteristics with the exogenous application of gibberlic acid and other growth hormones were also reported by earlier workers such as Govino *et al.* (2008). Better vegetative growth of the plant is largely responsible for higher seed yield because of number of photosynthesizing sites *i.e.* number of vegetative branches is affected by initial growth stages. The significant increase in plant height was observed by a treatment combination of exogenous application of GA₃. Among the treatment GA₃ alone recorded highest plant height (71.21 cm). The increase in the plant height may be due to the plant hormones promoted vegetative growth by active cell division, cell enlargement and cell elongation. Thus helped in improving growth characteristics and also facilitated reproductive growth (Pareek *et al.* 2000). These findings are in closely associated with previous results of Dunad (1998) and Virmani *et al.* (2007) who reported the differential application of GA₃ also increase the relative height of pollen parent over the seed parent.

Days to 50 per cent flowering was not influenced by any of the chemical sprays and planting ratios. However, numerically flowering was earlier in the plants sprayed with GA₃, female took (97.17 days) for 50 percent flowering, where as male took less days (93.5 days). The probable reason for early flowering with GA₃ spray may be due to the induction of higher total dry matter production at early stages of growth, which might have been more conducive for the flowering. Naturally occurring hormones play an important role in flowering. This is the fact that exogenously application of growth regulators like Gibberlic acid are commonly used to promote flowering. The flower forming hormone florigen is supposed to contain gibberellins and anthesins and thus exogenous application of GA₃ might have regulated this balance of gibberellins and anthesins and resulted in early flowering. These findings are in conformity with Lingaraju *et al.* (1998) who suggested that 50 per cent flowering in IR58025A by three days and five days respectively with application of 60 ppm GA₃ at boot leaf stage.

Maximum number of tillers per plant are believed to be closely associated with high seed yield per plant resulting high productivity. Hybrid yield relies mainly on tillers to obtain the desirable population, as of congenial method two to three seedlings per hill reduce the total number of tillers per plant. Significant difference in tillers was noticed with techniques, such as gibberlic acid spray and was ranged from 41.46-38.25. This may be mainly due to increased metabolic activity of GA₃ which increases the growth rate of secondary and tertiary tillers so that they bear panicles (Virmani and Sharma, 1993). single plants were found to have deeper and better-distributed root systems, higher xylem exudation rates, more open plant architecture with more erect and larger leaves, This advantage of SRI method in enhancing tiller numbers has been reported earlier by Gaini *et al.* (2002), Narayana Reddy (2002) and Udaykumar. (2005) and Krishna *et al.* (2008).

Of the total number of tillers about 80-90% were productive tillers and ranged from 36.18 to 29.21 and the highest number of tillers was recorded by GA₃ coupled with rope pulling (36.18) followed by GA₃ spray alone (35.06) which were found on par with each other, Increased number of productive tillers per plant obtained may be due to increased metabolic activity which inturn enhanced vegetative growth. These results are in accordance with Xu and Li (1988), Jagadeshwari *et al.* (1998) and Govino (2008). Planting ratio and interaction effects were found non significant. Planting ratio did not have any influence on total number of tillers.

Regulating total spikelets is necessary to gain high hybrid rice yields. The number of spikelets per panicle ranged from 183.57 to 182.27. All the treatment combinations showed non significant difference in spikelet number. This agrees with Chen (1995), who stated that the number of total spikelets per panicle were the stable inherited characters in rice variety and were influenced by parental genes.



IR 58025A



KMR 3

Plate 3: KRH-2 parents

Number of filled spikelets was highest in treatment combination of GA₃ coupled with rope pulling (52.67), followed by GA₃ alone (50.21). The increase in filled spikelets with GA₃ spray may be due to modification of panicle and spikelets characters, such as higher panicle exertion, wider opening of spikelets and increased flag leaf angle (Yuan and Viramni 1988, Virmani and Maruyama 1991). Increase in the number of vascular bundles and size of phloem in the young penduncles with the spray of GA₃ might have facilitated better translocation of metabolites from source to sink, resulting in higher number of filled spikelets per panicle. Similar results of increased filled spikelets per panicle with GA₃ application was also reported by Xu and Li (1988) and Bong *et al.* (1994) in rice. Row ratio of 6:2 recorded highest filled spikelets (54.44), followed by 3:1 (47.47) and 4:1 (43.39). GA₃ at boot leaf stage helps in better panicle exertion, provided with supplementary pollination, rope pulling makes the sufficient available of pollen for pollination and helps in better seed set and increase the number of filled seeds per panicle. These findings are in conformity with Ganagadharaiah *et al.* (2008) and Bong *et al.* (1992).

Generally larger panicle is associated with higher number of seeds per panicle resulting into higher productivity, therefore significant increase in panicle length is desirable. The highest panicle length was recorded with GA₃ coupled rope pulling (23.88 cm) followed by GA₃ spray alone (22.88 cm) and were found on par each other. Lowest panicle length was noticed in boron spray (15.16 cm). The lower concentration of GA₃ (25g/ha) in combination with urea, boric acid, NAA or arrapu leaf extract powder proved better for increased panicle length and such results were also reported by Bong *et al.* (1994), Ponnuswamy *et al.* (1998) and Biradar Patil and shekargouda (2007). Planting ratio and interaction effects were found non significant.

Panicle weight was highest in GA₃ + rope pulling (1.43g), Lowest was recorded by flag leaf clipping (1.15 g). Planting ratio and interaction effects were found non significant and such results were also reported by Bong *et al.* (1994).

In hybrid rice seed production seed yield mainly depends on floral traits of CMS lines *i.e.* panicle exertion, panicle length, panicle weight, out crossing rate and also agro morphological traits of pollen parents. Therefore to achieve higher yields improvements in this traits is a necessary requirement. The application of GA₃ influenced panicle exertion which increases out crossing rate. Higher panicle exertion was noticed in GA₃ spray (86.33) and the lowest was observed in boron spray (73.34). Gibberlic acid being a growth promoter, might have triggered the metabolic activities involved in cell division and cell elongation in the upper most internode to grow taller, resulting in increased panicle length and panicle exertion. Similar results were reported by Buu and Huang (1980), Duan and Ma (1992), Jagadeesha (1997) and Jagadeeshwari *et al.* (1988) in hybrid rice. Planting ratio and interaction effects were non significant.

Seed set (%) is very important in hybrid seed production because this trait has a direct effect on seed yield. The successful utilisation of CMS in development of hybrids is not possible unless the effective restorer lines are identified. Seed set (%) was greatly influenced by GA₃ spray and row ratio. GA₃ spray + rope pulling recorded higher seed set (27.08%). GA₃ application greatly influenced the plant height, panicle and spikelet exertion, stigma exertion, stigma longevity and receptivity, which improved the out crossing condition and directly affected the per seed set as reported by Tian and Zhou (1991). Row ratio of 6:2 recorded more seed set (30.90%), which is significantly superior than other row ratios. Interaction effect P₃T₂ recorded higher seed set (31.46%). Increase in seed set (%) of 6:2 ratio was due to sufficient supply of pollen from R-line to A-line, aided by the favorable weather conditions during flowering of both the parents, as reviewed by Ramos *et al.* (2004).

Spikelet sterility decreased with the GA₃ spray. Spikelet sterility was the lowest in GA₃+ rope pulling (71.03) followed by GA₃ alone (72.39). Sterility was the highest in flag leaf clipping (75.71). This may be mainly due to more number of spikelets enclosed in the flag leaf, deviated them from getting better exposed from pollination. Similar findings were reported by Yuan (1991); percent spikelet sterility decreased by GA₃ application as low as possible in the seed production which ensures maximum spikelet's exposure from leaf sheath for pollination. Row ratio of 6:2 recorded lowest spikelet sterility (70.22), followed by 1:3 (73.97). Poor development of spikelets on basal branches resulted in a high percentage of degeneration and spikelet sterility consequently grain yields was poor. Application of GA₃ improved development and seed yield on all branches (Patel and Mohapatra., 1992).

Filled seed weight per panicle was greatly influenced by GA₃ spray provided with supplementary pollination by rope pulling which enhanced the out crossing rate, due to availability of sufficient pollen to female parent resulting increased the seed set. Higher filled seed weight per panicle was recorded by a combination of GA₃ spray coupled with rope pulling (0.72g) as reported by Bong *et al.* (1994), Ponnuswamy *et al.* (1998). Planting ratio and interaction effects were found non significant.

Seed yield per plant is a very complex trait. It is a multiplicative end product of several basic compounds of yield. *i.e.* panicle exertion, panicle length, panicle weight, productive tillers, seed set (%), 1000 seed weight. In hybrid rice seed production seed yield mainly depends on floral traits of CMS line. Under SRI more number of productive tillers may be obtained per hill and GA₃ spray influences panicle exertion, spikelet opening angle and other floral traits which increases out crossing rate of CMS lines leading to higher seed yield. Xu and Li (1998) reported 13% higher seed yield with application of GA₃ in rice. Similarly Elanki *et al.* (2005), observed up to 50-52% increase in seed yield over control. In the present study GA₃ + rope pulling recorded higher seed yield per plant (22.51g) followed by GA₃ spray (21.47g). Lowest yield per plant was observed with flag leaf clipping (19.09 g). Planting ratio of 6:2 recorded highest seed yield per plant (24.50 g), 3:1 (23.34 g). 4:1 recorded lower seed yield per plant (14.61 g). Similar findings of increase in seed yield with 6:2 ratio was noticed by Ramos *et al.* (2004).



GA₃ and Boron spray



Rope pulling

Plate 4a: Techniques



3:1



4:1



6:2

Plate 4b: Planting ratio

The 1000 seed weight is one of the important common trait which influence the yield. All the treatment combinations were on par with each other and found non significant. Chen (1995), stated that the weight of 1000 seeds was the stable inherited characters in rice variety and was influenced by parental genes.

Seed yield composed of number of hills/ha x number of productive panicles/hill x number of spikelets/panicle x seed set rate x weight of 1000 grains. Seed set rate was only one component affected by GA₃ application in five components. In hybrid rice seed production, the highest/lowest percent seed set corresponds to highest or lowest seed yield. Seed yield per plot showed significant difference among the treatments. It's a combination of all the quantitative traits which enhance the hybrid seed yield and also depends on planting ratio. seed yield per plot was highest with GA₃ + rope pulling (1965.67g) followed by GA₃ alone (1822). The ratio of 6:2 recorded higher seed yield (2156.92g). Seed yield per hectare ranged between 21.84-16.11. Highest seed yield per hectare was recorded by GA₃+ rope pulling (21.84 q), GA₃ spray (20.24 q). Planting ratio of 6:2 recorded higher seed yield (23.97 q), 1:3 (19.05 q). Lowest yeild was recorded by 4:1 (14.55 q). The increase in the yield with the application of growth regulators might be due to increased yield attributes, which in turn resulted from effective translocation of photosynthesis and also depends on pollen availability and supplementary pollination at right time. Supplementary pollination using rod driving and rope pulling during peak anthesis has proven very important for increasing the hybrid rice seed yield, this activity was carried out at 30 min interval 3-5 times daily until no pollen remained in the hybrid restorer line. While Gangadhariaha *et al.* (2008) reported that flag leaf clipping, rope pulling and gibberlic acid application increased seed yield and seed set in IR-58025A during *kharif* season. These results were in conformity with a number of workers such as Bong *et al.* (1992), Monila *et al.* (2003), Annon (2005), Annon (2009).

5.3.1 Effect of techniques of seed production on seed quality

In general the seed quality was significantly influenced by chemical sprays. The application of GA₃ increased the seed quality parameters over the rest of other treatments. Significantly higher seed quality parameters were recorded with GA₃ @ 90g/ha and GA₃+ rope pulling.

The seed germination was highest with GA₃ alone (97.06%) followed by GA₃ coupled with rope pulling (97.03 %), Speed of germination (31.35), shoot length (13.06 cm), root length (13.79), vigour index (2616) and seedling dry weight (161 mg) the increase in seed quality with GA₃ may be due to increased seed weight and better filled seeds. This is in accordance with the findings of Deshpande (1993), Biradar patil (1999) in hybrid rice. Beneficial effect of GA₃ (seed treatment or foliar spray) in improving the seed quality of rice have been reported by earlier workers (Pian and Basu, 1985, Dunand, 1993).

Lowest seed quality parameters was recorded by boric acid spray. Boric acid at 1 per cent concentration significantly reduced the seed quality parameters compared to flag leaf clipping. Germination (91.58), speed of germination (28.76), shoot length (10.32 cm), root length (11.79 cm), vigour index (2019) and seedling dry weight (143.50 mg). The earlier studies have indicated beneficial effect of boron on seed quality (Tufail *et al.*, 1990. Shivaraju, 1993). In the present investigation, the high concentrating of boric acid (2%) might have adversely affected the seed germination and other quality parameters. Deshpande (1993) and Biradar patil (1999) observed decrease in seed quality in hybrid rice with 1.0 per cent boric acid spray compared to 0.5 per cent concentration.

5.4 Studies on storability of Karnataka rice hybrid-2 and their parental lines

Maintenance of seed quality especially during storage has become most important in the present context. Since agriculture is season bound, the storage of seed has become inevitable for an ordinary farmer, seed producer and a breeder as the case may be. Several intrinsic and extrinsic factors influence the viability of seeds during storage. Among intrinsic factors, seed moisture content, relative humidity, temperature of storage, pest and diseases are important. Deterioration of seed is a natural process which is inevitable, inexorable and irreversible but the rate of deterioration of seed may differ due to genetic factors (Roberts, 1973), seed treatment *etc.* Maintenance of seed viability in parental lines is a major concern because the harvested product is not stored properly and it is exposed to humid climate

during rainy season. Higher relative humidity in storage condition influences the faster spread and development of storage fungi. The seed treatment may act as physical barrier, which has been reported to reduce the leaching of inhibitors from the seed coverings and may restrict oxygen diffusion to embryo to enhance the rapid germination (Vanagamudi *et al.* 2003 ; Simon, 1974). Therefore use of different seed treating fungicides to reduce the spread, development and infestation of storage mycoflora and thereby reduce the deterioration of seeds. The results pertaining to seed quality parameters during storage are discussed here.

5.4.1 Behavior of genotype during storage

Seed germination was found to differ significantly among the genotypes throughout the storage period. There was gradual decrease in germination with the increase in the storage period in all the genotypes, irrespective of storage containers and seed treatments. The hybrid KRH-2 recorded higher seed germination initially (94.23%) and maintained the same up to eight months of storage, while the KMR-3 recorded the higher germination percentage from tenth month of storage till the end of the storage (83.33%). The female parent IR58024A recorded the lowest germination throughout the storage period. This variation in storability among the genotypes was obviously due to the genetic control to resist deterioration during storage. Such difference in storability among the rice genotypes were also reported by Gomez *et al.* (1986) and Juliano *et al.* (1990).

Significant difference in the shoot length and root length was observed with the genotypes. The hybrid KRH-2 recorded higher shoot and root length throughout the storage period, whereas the lowest values for these parameters were observed with IR58025A. The shoot length and root lengths decreased steadily in all the genotypes with the progress in storage period. These findings are in agreement with the results of Deshpande (1996) and Tungsawaara (1996) in rice genotypes.

The dry weight of the seedlings declined with the progress in storage in all the genotypes. The hybrid KRH-2 recorded higher seedlings dry weight in all the months over the rest of the genotypes, whereas the lowest seedlings dry weight (106.7) was observed with IR58025A. Variation in genotypes for seedling dry weight was also observed by Yogalakshmi *et al.* (1996).

Assessment of vigour index is also relevant since germination alone may be an incomplete assessment, since the root and shoot length is a measure of synthesis, mobilization and quality. The vigour index generally declined with the progress in storage period in all the genotypes studied (1129), but the extent of reduction varied with the genotypes. The hybrid KRH-2 recorded higher vigour index in all the months over the rest of the genotypes by Gomez *et al.* (1986) and Deshpande (1993).

The loss of viability and vigour during storage is attributed to hygroscopic nature of the seeds. During ambient storage conditions, seed moisture content fluctuates with concomitant changes in atmospheric relative humidity and temperature (Deshpande, 1993). In the present study also significant fluctuations in seed moisture content (9.22-10.26%) were noticed in all the months of storage. Seeds stored under cloth bag recorded higher moisture content (10.65%). This variation in seed moisture depends on hygroscopic nature of particular genotypes, temperature and relative humidity of storage. The genotype which have maintained better viability and vigour did not show much fluctuations in seed moisture content as compared to IR58025A. KRH-2 and KMR-3 which showed numerically lower moisture content. Similar fluctuations in seed moisture content and loss in viability and vigour due to varied relative humidity and temperature under ambient or artificial conditions have been reported by Deshpande (1993), Lakshmipathi (1995).

As deterioration progress during storage, cellular membranes loose their selective permeability, permitting the cytoplasmic metabolites to leach into the inter cellular spaces. Membrane degradation occurs due to both hydrolysis of phospholipids by phospholipase and phospholipid auto-oxidation, therefore, in strict sense, it might be considered as a result of ageing rather than a cause. It is widely accepted that loss of membrane permeability unfavorable condition of storage leading to increased leaching out of seed constituents and thus loss in viability (Sen, 1977). The leachate exudates measured by electrical conductivity indicate the loss of viability and vigour. Increased leachate was related to slow metabolic activity of seed (Abdu Baki and Anderson 1972).

The EC values varied with the genotype significantly. The restorer line KMR-3 recorded the lowest EC throughout the storage period (274.3 dsm^{-1}). The female line IR58025A recorded highest EC values (314.2 dsm^{-1}) in all the months of storage. Electrical conductivity of seed leachate is inversely proportional to quality. The KMR-3 which showed lowest EC value was having lower viability and vigour. The results are in conformity with the findings of Deshpande (1993) and Yogalakshmi (1996). The increase in EC of seed leachate values recorded could be due to the loss in membrane permeability during seed ageing. However disruption of membrane permeability may not be the same from all the genotypes and hence it causes differences in EC values among the genotypes.

The field emergence before and after storage varied significantly due to genotypes. The hybrid KRH-2 recorded higher field emergence from the beginning of storage up to the end of sixth month of the storage. During eight, tenth and twelfth months, higher field emergence was observed with KMR-3. The lowest field emergence was recorded by Female line IR58025A throughout the storage. Irrespective of genotypes, the field emergence decreased with the increase in storage period. This might be due to ageing induced reduction of germination during storage accompanied by reduction in seed vigour in terms of seedling length, vigour index and increased electrical conductivity of seed leachate. Similar reduction in field emergence had been reported in stored seeds of rice genotypes by Deshpande (1993) and Lakshminpathi (1995), Biradar Patil and Shekargouda (2007).

Among the genotypes hybrid KRH-2 and the restorer line KMR-3 exhibited as a good storers and female line as poor storers. The reduced storability of female line might be due to sterile cytoplasm and was restorer line may be attributed to the genetic make up of the genotype (Kalavathi *et al.*, 1994)

5.4.2 Effect of storage container

Seed storage package influence the seed storability at different storage environments. Generally seeds stored in moisture impervious containers store better compared to moisture pervious containers under ambient condition with low seed moisture. The results of the present study revealed that seeds stored in polythene bag (700 gauge) were significantly superior in maintaining viability and vigour compared to the seeds stored in cloth bag throughout the storage period. The seeds stored in polythene bag recorded higher germinability (83.46%) throughout the storages of cloth bag (80.86%). The seeds stored in polythene bag showed slow reduction in germination as compared to seeds stored in cloth bag.

The shoot and root length was higher in seeds stored in polythene bag as compared to cloth bag. The EC was higher in seeds stored in cloth bag (298.9). The seeds stored in polythene bag recorded higher vigour index (1258) throughout the storage period compared to cloth bag (1059). Field emergence decreased in seeds stored in cloth bag than in polythene bag in all the months of storage (Biradar Patil and Sekhargouda, 2007 and Raiker *et al.*, 2011).

The superiority of seeds stored in polythene bag for seed quality parameters were due to slow rate of deterioration as the polythene bags are moisture impervious containers which might not have allowed the moment of moisture from the environment and hence the seeds did not deteriorate at faster rate. The quality parameters declined in the polythene bag with the increase in the storage period, which might be due to influence of other factors such as temperature. The superiority of polythene bag over the cloth bag in prolonging the storage life of the seed was also reported by Siddalingappa, (1991), Angamathu (1996), Yogalakshmi (1996), Biradar Patil and Shekargouda (2007) and Raiker *et al.* (2011).

5.4.3 Effect of seed treatment

Rice is subjected to the degradation by various fungal pathogens (Sharma *et al.*, 1990) and storage pest (Sukprakaran, 1985). Importance of seed treatment against pathogen has also been well documented by Asokan *et al.* (1980). Vitavax (3g/kg of seed) maintained higher seed germinability through the storage. At the end of the 12th month of storage the germination recorded with treated and untreated seeds was 83.36 and 80.96 percent respectively. The gap between in these two maintaining viability was narrow initially and widened latter (Deshpande 1993). This shows the superiority of seed dressing fungicide like vitavax in protecting the seeds from hazards of storage fungi and maintaining the viability against seed deterioration.

Reduction in shoot and root lengths, another face of seed deterioration was more pronounced in the untreated seed lot than in the treated seeds through the storage period. The treated seeds recorded higher shoot and root lengths in all the months of storage.

These results are in accordance with the findings of Pawar *et al.* (1985), Gora *et al.* (1987) and Thungeshwara (1996). The dry weight of the seedlings reduced significantly with the untreated seeds till the end of storage period. The dry weight of the seedlings recorded at the end of the storage with treated and untreated seeds was 114.98mg and 110.85mg, respectively. This is in conformity with the findings of (Thungeswara, 1996). The electrical conductivity of seed leachates of treated seeds was significantly lower (287.2) than untreated seeds (300) throughout the storage. Increased leakage of exudates during storage deterioration might be due to reduced metabolic activity of untreated seeds, which was preceded by low enzymatic activity (Biradar Patil and Shekargouda 2007) decreased ATP production, accumulation of free radicals and toxic substances like coumarin and ferulic acid and lead it to the loss of germinability and vigour (Bapuayangouda Patil and Asok Sajjan 2011).

The seeds treated with vitavax maintained significantly higher seedling vigour throughout the storage. At the end of the 12th month of storage. The vigour index recorded with the treated and untreated seeds was 1282 and 1036, respectively. The reduction in the seedling vigour during storage was rapid in untreated seeds. This could be attributed to the lower germination and seedling length. The higher vigour of treated seeds was reflected with higher field emergence during storage. The treated seeds recorded significantly higher field emergence (77.25%) as compared to untreated seeds (74.82%) at the end of storage. These results are in accordance with the findings of Pawar *et al.* (1985), Gora *et al.* (1987) and Thungeshwara (1996). Biradar Patil and Sekhargouda (2007) when seeds treated with Thiram.

5.4.4 Interaction effects

Interaction effects of genotypes, container and seed treatment was significant for some of the seed quality parameters. The interaction between the container and the seed treatment were significant for germination and vigour index during the later period of seed storage.

The seeds germination was significantly higher with the vitavax treated seeds when stored in polythene bag and the lowest seed germination was recorded with the untreated seeds stored in cloth bag during 10th and 12th month of storage. Similar effect of container and seed treatment was observed for vigour index during 8th, 10th and 12th month of storage.

Such differential action of container and seed treatments during storage has been observed by Thungeswara (1996). The treated seeds could maintain high vigour and viability when stored in polythene bag, indicating the importance of seed treating and storing the seed in moisture impervious containers for better storability. The untreated seeds might have been affected by the storage fungi as the seeds stored in cloth bag was more susceptible for the variation in surrounding humidity. The other two way interactions and all the three way interactions were non significant for seed quality parameters.

5.5 Characterization of hybrid and its parents of rice using isozymes

Isozymes are the products of genes through transcription and translation processes, therefore their expressions depend on the stage of plant growth as well as plant tissues. Being gene products, isozymes show band intensity that is proportional to the dosage of the encoding gene. In a diploid, heterozygous for an isozyme locus, the two allozymes will have balanced band intensity (Wu, 1987). In contrast, a trisomic heterozygote will show higher band intensity for the allozymes encoded by the allele.

Present in two dosages. Using trisomic, analysis by dosage effect permits chromosomal location of isozyme loci (Nielsen and Frydenberg, 1971). However, isozyme markers are very limited than that of molecular markers. As biochemical markers, isozymes have advantages compared to morphological markers. The alleles (allozymes) at most isozyme loci are co-dominant. This codominant caused no deleterious changes in plant phenotype through recessiveness or pleiotropy and allows heterozygous to be distinguished from homozygous. Isozymes rarely exhibit epistatic interaction so that a genetic stock containing an infinite number of markers could be constructed (Tanksley and Rick, 1980).

In the present study, an attempt was made to assay the variation of activity of a couple of isozyme patterns; catalase, peroxidase and poly phenol oxidase to determine the genetic pairing between hybrids and that of parental lines. The process is nondestructive since only small amounts of plant tissue are needed. Any plant tissue can be used as samples, including leaves, roots, pollen, and callus, so that the technique is very versatile. It is also possible to screen plant at seedling stage and retains only desirable genotypes, thus, save time and money. The leaves crude extract was used for measuring enzyme activities since seeds is not desirable not only because F₁ seeds are limited on account of crossing barrier, but also the seeds are destroyed when used for analysis.

Variations in number and activity of bands are shown in Tables 29. A complex of sub-patterns was observed among the various rice genotypes tested. Description of catalase isozyme patterns of the hybrid line with its female and restorer line which showed that some bands were present in hybrid line while absent in others. KRH-2 hybrid produced four bands with R_m value 0.18, 0.36, 0.54, 0.72 were as IR58025A produced three bands with R_m values of 0.16, 0.32, and 0.71. KMR-3 produced four bands with R_m value 0.14, 0.33, 0.57, 0.70. Isozyme approach was identified as a valuable means of distinguishing the genotype through determination of polymorphism in the electrophoretic profiles. The electrophoretic banding pattern based on catalase isozyme from leaf to distinguish the hybrids and respective parents as they shared common bands. These results are in conformity with the findings of Shivananda (1995) and Agrawal *et al.*, (1988). On the basis of alcohol dehydrogenase (ADH) isozyme the genotypes could be differentiated as in cotton DH-2.

Banding pattern for peroxidase differed with respect to genotypes. KRH-2 hybrid differed from both the parents having an extra band. KRH-2 produced four bands, while IR58025A produced three bands with R_m values of 0.31, 0.50, 0.72 and KMR-3 also produced three bands with R_m value 0.15, 0.50, 0.69. An interesting finding was observed when a specific band was detected in the restorer line as well as in hybrid. The same band disappeared in CMS line. This band may be a result of the expression of a gene (s), that play an important genetic role in the maintaining process and could be used to identify the genetic purity of CMS line with its restorer line. These results indicated that a common monomorphic pattern for peroxidase was appeared in this CMS line IR58025A, its restorer line and the hybrid. CMS line and its restorer could be distinguished on the basis of the number of bands. These results are in conformity with the findings of Abo Youssef *et al.* (2011) in rice.

The KRH-2 hybrid produced three bands of polyphenol oxidase with R_m value 0.18, 0.59, 0.74. IR58025A produced two bands with R_m values of 0.18, 0.79. KMR-3 produced three bands with R_m value 0.16, 0.50, 0.69. The hybrid resembled closely to the male parent and could be distinguished from the female parent on the basis of poly phenol oxidase at R_m 0.50. Banding patterns of the hybrids and their respective male parents were almost similar. However, the banding patterns of most of the hybrids could be easily distinguished from those of their respective female parents. These findings are correlated to the studies of Diwakar *et al.* (2009) who studied the identification of rice varieties through isozyme analysis and found that peroxidase, catalase, and poly phenol oxidase isozymes were useful for identification of varieties as well as parents and hybrid and maybe served as molecular markers for identification of hybrids and parents of KRH-2 and thus these isozymes can be used for identification of genetic purity.

Practical utility of research

1. Out of 11 promising rice hybrids tested for their suitability, GK-5003 followed by KRH-2 performed better under modified SRI method in upland ecosystem of Mugad. The performance of all the hybrids under SRI method excelled the performance under normal method of rice cultivation.
2. Seed treatment with proline (0.1%) found to increase the seed germination (96.77 %) and seedling vigour index (2385) as compared to rest of the chemicals under study.
3. Planting ratio of 6:2 combined with GA₃ spray @ 90 g/ha + rope pulling enhanced F₁ hybrid rice seed yield (21.84 q) of KRH-2 under SRI method at Mugad region.

4. One year storage study revealed that male parent KMR-3 maintained higher germinability (83.33%) and was on par with F₁ hybrid KRH-2 (82.35%). The female parent was found to be inferior (80.80%). However, all the three genotypes maintained satisfactory germinability above minimum seed certification standards.
5. Seed stored in polythene bag recorded higher germinability (83.46%) and vigour index (1258) as compared to cloth bag (80.86% and 1059, respectively).
6. Seed treated with vitavax maintained higher germinability (83.36) and vigour index (1282) than untreated seeds (80.96 and 1036, respectively) at the end of 12th month of storage.
7. Assessment of genetic purity through isozyme studies found most reliable.

Future line of work

1. Evaluation of different promising hybrids under SRI method can be done and best performed one may be tested for seed production.
2. Testing of different chemicals to overcome drought situation under aerobic can be tested or evaluated either through seed treatment or foliar spray.
3. Standardization of planting ratio in combination with different hybrid seed production techniques can be tried at different regions for region specific hybrids, under SRI method.
4. Parents and hybrids of different rice hybrids can be tested for their storability with new generation chemical under agro-ecological conditions.

6. SUMMARY AND CONCLUSIONS

Hybrid Rice is gaining importance in view of 10-15 per cent increased yield advantage over the high yielding varieties. The seed production of hybrid rice is not an easy task in view of several problems like improper panicle exertion, poor seed set, differential behavior of parental lines at different locations and seasons, poor storability of parental lines and hybrid seed encountered during seed production and storage and the prevailing environmental stresses either biotic or abiotic which hinders the plant growth, and reduce the seed yield.

Owing to increasing water scarcity, a shifting trend towards less water demanding crops against rice is noticed in most part of the India and this warrants alternate methods of rice cultivation that aims at lower water utility and higher crop productivity. System of Rice Intensification (SRI) is the method developed in Madagascar in the early 1980's, where, it has been shown that yields can be enhanced by suitably modifying certain management practices such as controlled supply of water, planting of younger seedlings and providing wider spacing. SRI method of cultivation is said to promote greater root growth and higher soil biological activity in the rhizosphere.

To overcome the adverse effect of water stress by gaining maximum seed yield, opting of hybrid rice seed production under SRI method would be a better alternative. System of Rice Intensification (SRI) is slowly gaining momentum all over the world including India. Farmers of southern states are showing keen interest in this system and already substantial area is coming under SRI method of rice cultivation. There is ample scope to increase the productivity of rice by modifying microclimate and soil conditions. The System of Rice Intensification is also one such type of methodology, which revolves around this concept in view of this the present investigation entitled "Standardization of hybrid seed production techniques under SRI method in upland eco system" was carried out with two field and two laboratory experiments during 2010-2012 at University of Agricultural Sciences, Dharwad.

Eleven promising hybrids of public and Private organizations grown under different Agro ecological regions were obtained from the Directorate of Rice Research Hyderabad. These were evaluated in comparison with the local check for their adoptability under modified SRI method in Agricultural Research Station, Mugad area. Hybrids selected from different regions were PRH-10, Sahyadri-2 PA-6122, PSD-3, Indam 200-017, DRRH-2, GK-5003, CORH-3, Sahyadri- 3, Sahyadri-4, KRH-2 along with local Check variety-MGD101 These were screened for yield attributing characters under modified SRI method.

All the selected hybrids showed significant difference for yield attributing characters. Among them MGD-101 showed the highest plant height (80.13 cm), DRRH-2 took less number of days to 50 per cent flowering and proved to be an early maturing and short duration hybrid. KRH-2 recorded the highest number of total tillers per plant (22.25), GK-5003 recorded the highest productive tillers (19.37), panicle length (23.45 cm), panicle weight (4.00g), seed weight per plant (33.96g), higher 1000 seed weight (24.68g), total Number of spikelets (189.17), number of filled spikelets (166.14).lower unfilled spikelet (34.57), grain yield (2923 g/plot) grain yield (9.74t/ha).Gk-5003 showed excellence by contributing higher yield and proved to best suited for Mugad region, But as it was private hybrid its parental lines were not available for further seed production. Hence the next best local hybrid KRH-2 was selected to take up seed production under SRI method.

To over come the water stress under upland eco-system the seeds were pre treated with osmoprotectant such as proline @ (0.1%). Hydration of seed with proline permits early DNA replication increased RNA and protein synthesis, greater ATP availability enhances faster embryo growth, repair of deteriorated seed parts. These help radical protrusion through the seed coat and shorten the time to seed germination. Proline increased seed quality attributes compared to other osmoprotectants. Seed germination (96.77%), speed of germination (24.05), shoot length (12.28 cm), root length (13.34 cm), seedling dry weight(156.3 mg) and vigour index (2289).

Hybrid rice seed production of KRH-2 was taken up by imposing techniques which enhances seed yield, such as GA₃ alone @ 90g/ha, GA₃ coupled with rope pulling, boric acid @ 1% and flag leaf clipping on both parental lines of KRH-2 hybrid *i.e.* IR 58025A and KMR-3 with a planting ratio of 3:1, 4:1 and 6:2. Seeds were pretreated with proline @ 0.1% to overcome stress under SRI method. The significant increase in growth and yield contributing characters were observed by a treatment combination of exogenous application of GA₃ alone @ 90g/ha which was found on par with GA₃ coupled with rope pulling.

Gibberellic acid is commonly used to promote flowering. Days to 50 per cent flowering was not influenced by any of the chemical spray and planting ratio. However numerically flowering was earlier in the plants sprayed with GA₃, female took more (97.17 days) for 50 per cent flowering, where as male took less number of days (93.5 days) Maximum number of tillers per plant (41.46). The flower forming hormone florigen is supposed to contain gibberellins and anthesins and thus exogenous application of GA₃ might have regulated this balance of gibberellins and anthesins and resulted in early flowering.

GA₃ coupled with rope pulling recorded higher productive tillers per plant (36.18). GA₃ did not have any impact on total number of spikelets. The number of spikelets per panicle ranged from 183.57 to 182.27. All the treatment combinations showed non significant difference in spikelet number. Number of filled spikelets was the highest in treatment combination of GA₃ coupled with rope pulling (52.67), followed by GA₃ alone (50.21). The highest panicle length was recorded with GA₃ coupled with rope pulling (23.88 cm), panicle weight was the highest in GA₃ + rope pulling (1.43g). The application of GA₃ influenced panicle exertion which increased out crossing rate. Higher panicle exertion was noticed in GA₃ spray (86.33) and the lowest was observed in Boron spray (73.34). Spikelet sterility was the lowest in GA₃+ rope pulling (71.03) followed by GA₃ alone (72.39). Filled seed weight per panicle was greatly influenced by GA₃ spray provided with supplementary pollination by rope pulling.

Seed set (%) is very important in hybrid seed production because this trait has a direct effect on seed yield. GA₃ spray + rope pulling recorded higher seed set (27.08%). Spikelet sterility decreased with the GA₃ spray. Spikelet sterility was the lowest in GA₃+ rope pulling (71.03) followed by GA₃ alone (72.39). Higher filled seed weight per panicle was recorded by a combination of GA₃ spray coupled with rope pulling (0.72 g).

In the present study GA₃ + rope pulling recorded higher seed yield per plant (22.51 g) followed by GA₃ spray (21.47 g). The lowest was observed with the flag leaf clipping (19.09 g). Planting ratio of 6:2 recorded the highest seed yield per plant (24.50 g), followed by 3:1 (23.34 g). 4:1 recorded lower seed yield per plant (14.61 g). seed yield per plot was highest with GA₃ + rope pulling (1965.67g) followed by GA₃ alone (1822 g). 6:2 ratio recorded higher seed yield (2156.92g). seed yield per hectare ranged between 21.84-16.11. Highest seed yield per hectare was recorded by GA₃ + rope pulling (21.84q), GA₃ spray (20.24 q). Planting ratio of 6:2 recorded higher seed yield (23.97 q), 1:3 (19.05 q). The lowest was recorded by 4:1 (14.55 q).

In general, the seed quality was significantly influenced by chemical spray. The application of GA₃ increased the seed quality parameters over the rest of other treatments. Significantly higher seed quality parameters were recorded with GA₃ @ 90g/ha and GA₃+ rope pulling. The germination percentage of hybrid seeds was the highest with GA₃ @ 90 g/ha (97.06%) and GA₃+ rope pulling (97.03%). Similar trend was also observed with Speed of germination (31.35), shoot length (13.06 cm), root length (13.79cm), vigour index (2616) and seedling dry weight (161 mg).

Storage of seeds till the next sowing season is an essential segment of seed industry. The seed deterioration begins immediately after the physiological maturity and it is reflected in terms of loss in viability and vigour. The seed viability and vigour largely depends on the genotypes, production location, mechanical injury to the seed, initial seed quality, and seed treatment, packaging material and storage conditions. The knowledge of seed storability is very essential to avoid the huge financial losses due to non selling of the seeds and to carry over the seed stock for the use in next season. Among the genotypes hybrid KRH-2 recorded higher seed germination initially (94.23%) and maintain the same up to eight months of storage, while the KMR-3 recorded the higher germination percentage from tenth month of storage till the end of the storage (83.33%). The Female parent IR58024A recorded the lowest

germination throughout the storage period. All the quality parameters were higher with hybrid KRH-2 (shoot, root length, dry weight of the seedlings, vigour index) followed by KMR-3 in all the months over the female parent. The maintainer line exhibited poor storability. The seeds stored in polythene bag (700 gauge) were superior over cloth bag for all the seed quality parameters throughout the storage period.

The untreated seeds lost the viability and vigour at a faster rate during storage compared to vitavax (captan + thiram @ 3.0 g/kg) treated seed. Molecular characterization of KRH-2 hybrid and its parental line IR58025A and KMR-3 was done by polyacrylamide gel electrophoresis (PAGE) for some of the enzymes such as catalase, peroxidase and poly phenol oxidase. Of these PAGES of catalase was found to be more useful than that of peroxidase and poly phenol oxidase isozymes in differentiating the hybrids from their respective parents. Banding patterns of the hybrids and their respective male parents were similar. However, the banding patterns of most of the hybrids could be easily distinguished from those of their respective female parents, which is of practical importance to test the genetic purity of hybrids.

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**Appendix I: Monthly meteorological data during the research period (2011-2012)
recorded at ARS, Mugad**

Months	Rainfall (mm)		Rainy days	
	2011	2012	2011	2012
January	0.00	0.00	0	0
February	2.20	0.00	0	0
March	0.00	0.00	0	0
April	65.40	69.40	3	6
May	86.20	21.00	5	2
June	231.90	-	15	-
July	226.60	-	17	-
August	205.20	-	19	-
September	78.80	-	9	-
October	218.00	-	12	-
November	21.60	-	2	-
December	0.00	-	0	-
Total	1135.90	90.40	82.00	8.00

Appendix II: Monthly meteorological data during the research period (2010-11) recorded MARS Dharwad

Months	Temperature (°C)				Rainfall		Relative humidity (%)		Rainy days	
	Max.		Min.		2010	2011	2010	2011	2010	2011
	2010	2011	2010	2011						
January	28.2	29.2	15.4	12.5	0.8	0	63	59	-	-
February	32.4	30.8	17.3	14	0.4	21.6	50	48	-	1
March	35.6	35.2	20.3	18.6	Trace	0.8	49	44	-	-
April	37.6	34.9	22	20.2	43.8	77.4	55	57	5	3
May	35.7	34.7	22.4	21.3	63.1	66.6	63	61	5	6
June	31.2	27.5	4.8	21.3	63.4	194	15	84	8	14
July	27.6	26.9	20.8	20.6	155	131	84	85	14	14
August	27.7	26.2	20.7	20.7	190.7	124.2	84	87	10	13
September	27.9	28.1	20.2	19.9	164.9	82.8	83	80	10	11
October	29	29.9	19.5	19.5	177	219.7	77	73	10	8
November	28.4	29.8	19	15.8	92.8	4.6	79	55	07	1
December	27.4	29.6	14.1	13.7	0.6	0	65	57	-	--
Total					952.5	922.7				71

STANDARDIZATION OF HYBRID RICE SEED PRODUCTION UNDER SRI METHOD IN UPLAND ECOSYSTEM

HALESH KUMAR H. B.

2012

DR. V. K. DESHPANDE
MAJOR ADVISOR

ABSTRACT

An investigation entitled “Standardization of hybrid rice seed production through SRI method in upland eco-system” was carried out during *kharif* seasons of 2010 and 2011 at Agricultural Research Station, Mugad, with two field and two laboratory experiments. Eleven promising hybrids of public and Private organizations viz., PRH-10, Sahyadri-2 PA-6122, PSD-3, Indam 200-017, DRRH-2, GK-5003, CORH-3, Sahyadri- 3, Sahyadri-4, KRH-2 were evaluated in comparison with the local check variety-MGD 101 for their adoptability under modified SRI method in upland eco-sytem. Among the hybrids screened, GK-5003 showed the best field performance under SRI followed by KRH-2. Due to non availability of parental seeds of GK-5003 as it was private hybrid, the next best local hybrid KRH-2 was selected to standardize the techniques of hybrid seed production.

Among the Stress tolerance inducing chemicals proline @ 0.1% was proved to be the best and same was imposed during hybrid rice seed production of KRH-2 under SRI. Planting ratio of 6:2 recorded the highest seed set (30.90%) and seed yield (23.97 q) with spraying of GA₃ 90 g/ha followed by GA₃ + rope pulling. During storage experiment under ambient conditions the hybrid KRH-2 followed by KMR-3 (Male) showed the higher quality parameter in all the months over IR-58025A and Maintainer line. The seeds stored in polythene bag (700 gauge) were superior over cloth bag throughout the storage period.

Molecular characterization of KRH-2 hybrid and its parental lines IR58025A and KMR-3 was done by PAGE for enzymes like catalase, peroxidase and poly phenol oxidase, revealed difference in banding patterns of the hybrid and its male parent . But it could be easily distinguished from their respective female.