HYBRID SEED YIELD MAXIMISATION THROUGH SUPPLEMENTAL NUTRITION, HYBRID VIGOUR ASSESSMENT AND SEED QUALITY ENHANCEMENT BY POLYKOTE COATING IN ADTRH 1 AND CORH 2 RICE HYBRIDS AND THEIR PARENTS

Thesis submitted in part fulfillment of the requirements for the degree of
DOCTOR OF PHILOSOPHY (AGRICULTURE) IN SEED SCIENCE AND TECHNOLOGY to
the Tamil Nadu Agricultural University, Coimbatore – 641 003

By
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DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
TAMIL NADU AGRICULTURAL UNIVERSITY
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CERTIFICATE

This is to certify that the thesis entitled "**HYBRID SEED YIELD MAXIMISATION THROUGH SUPPLEMENTAL NUTRITION, HYBRID VIGOUR ASSESSMENT AND SEED QUALITY ENHANCEMENT BY POLYKOTE COATING IN ADTRH 1 AND CORH 2 RICE HYBRIDS AND THEIR PARENTS"** submitted in part fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) IN SEED SCIENCE AND TECHNOLOGY** to the Tamil Nadu Agricultural University, Coimbatore, is a record of *bonafide* research work carried out by **Mr. A. SABIR-AHAMED** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

HYBRID SEED YIELD MAXIMISATION THROUGH SUPPLEMENTAL NUTRITION, HYBRID VIGOUR ASSESSMENT AND SEED QUALITY ENHANCEMENT BY POLYKOTE COATING IN ADTRH 1 AND CORH 2 RICE HYBRIDS AND THEIR PARENTS

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Key words : Hybrid rice, Fertilizer, GA_3, spentwash, heterosis, polykote seed coating

The application of 25 kg N and 15 kg K each at panicle initiation and 10 days after panicle initiation in addition to the normal recommended dose of NPK @ 150 : 60 : 60 kg ha^{-1} increased the plant height, number of total tillers, productive tillers and 1000 seed weight of both the parents. Application of additional dose of N and K at panicle initiation and 10 days after panicle initiation recorded the highest N, P and K uptake. This additional N and K dose exerted an increase of 13.7 and 12.3 per cent hybrid seed yield in ADTRH 1 (2,061 kg ha^{-1}) and CORH 2 (1,663 kg ha^{-1}) respectively. The increase in grain yield was 15.0 and 11.5 per cent in R lines of ADTRH 1 (1,623 kg ha^{-1}) and CORH 2 (1,488 kg ha^{-1}) respectively. The foliar spraying of GA_3, brassinolide and spentwash was also effective in increasing the plant height, panicle length and panicle exsertion while, brassinolide advanced the 50 per cent flowering and GA_3 increased the seed set in seed parent. Foliar spraying of DAP + KCl either alone or along with $ZnSO_4$ + Boric acid had positive response in both the parents for production of more number of tillers, spikelets $panicle^{-1}$ and increased 1000 seed weight. GA_3 in A line and DAP + KCl as sole or combined with $ZnSO_4$ + Boric acid in R line increased the N, P and K uptake. Foliar spraying of GA_3 or spentwash maximized the hybrid seed yield upto 2,282 and 1,993 kg ha^{-1} in ADTRH 1 and 1,855 and 1,623 kg ha^{-1} in CORH 2, respectively. The R lines applied with DAP + KCl either alone or along with $ZnSO_4$ + Boric acid recorded maximum grain yield of 1,757 and 1,625 kg ha^{-1} in ADTRH 1 and 1,596 and 1,583 kg ha^{-1} in CORH 2 respectively. However, the seed quality of hybrid seed was not influenced either by fertilizer dose or foliar spray treatments. According to the present study, application of additional dose of 25 kg N and 15 kg K ha^{-1} at panicle initiation and 10 days after panicle initiation along with foliar spraying of GA_3 @ 75 g ha^{-1} thrice at flowering maximized the hybrid seed yield of ADTRH 1 and CORH 2. However, there is a scope for combined use of GA_3 along with spentwash, a cheap industrial by-product or brassinolide, a new group of plant hormone to substitute the quantity of GA_3 and economise the hybrid seed production

Hybrid seeds of ADTRH 1 and CORH 2 and their parental lines subjected to various vigour tests brought out a clear evidence for differences among the hybrids and their parental lines with respect to physiological and biochemical behaviour of seed vigour. Both the hybrids, ADTRH 1 and CORH 2 exhibited a significant positive relative heterosis (mid-parent heterosis) for most of the physiological and all the biochemical attributes. The fresh seeds of hybrids, that have outperformed the other lines and exhibited superior hybrid vigour under normal – optimal growing conditions have failed to excel under sub-optimal or stress condition. There was a clear distinction for each stress test in terms of degree of stress they imposed on the genotypes and with respect to the response the genotypes exerted upon such stress. Therefore, for predicting hybrid vigour on seedling growth attributes under stress condition, instead of comparison among multiple vigour tests, comparison of genotypes under a specific stress situation would be a realistic proposition. The rice hybrids, ADTRH 1 and CORH 2 and their female parent, IR58025A suffer with a peculiar problem of occurrence of split husk seed. The split husk seeds suffered with a loss of 11.8 per cent physical quality, 21.0 per cent germination, 34.1 per cent seedling growth rate and 33.7 per cent enzyme activity with an over all loss of 29.8 per cent as a mean of all the physical, physiological and biochemical seed quality attributes. The split husk seed occurrence in bulk seed incurred a direct loss upto 17.4 per cent in seed quality of hybrid and female parent seeds. A dosage of polykote @ 5 g diluted with 70 ml of water kg^{-1} was found to be optimum for effective coating of

rice seeds. Diluting polykote beyond the prescribed level reduced the positive effect of seed coating. Coating rice seeds with polykote enhanced water uptake, thereby promoted early sprouting, enhanced germination and seedling growth. While, hybrid seeds were found to be highly responsive at the early stage of germination, the R lines dominated at the later part of germination in responding to polykote coating. Among different colours of polykote tested, clear and pink found to be superior with no adverse effect on seed germination and seedling growth. Therefore, apart from increasing the germinability, coating seeds of each parent with a particular colour of polykote would enable easy identification and precision sowing of parental lines in hybrid seed production programmes.

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RESEARCH FINDINGS

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chapter I

introduction

Rice (***Oryza sativa*** *L.*) is the major food for one out of every three persons on earth. In the Asia and Pacific region, 90 per cent of rice is produced and consumed and will remain the life line of the people. Demand for rice is expected to grow faster than production in most countries (Swaminathan, 1998), so much so that by 2025, 800 million tonnes of it will be needed annually. Rice occupies a pivotal position in relation to food security in India.

It is estimated that India's population by 2010 will increase to 1.2 billion from today's billion mark and the country would need 103.6 million tonnes of rice to balance the food budget (Kumar, 1998). India produced 89.5 million tonnes of rice from an area of 43 million hectares during the year 1999-2000. Rice production had steadily increased during the green revolution, but recently, its growth has slowed down substantially.

The yield ceiling of rice varieties of green revolution era must be lifted again to meet the increased food demand. Among the many genetic approaches available to break the yield barrier in rice, hybrid rice technology appears to be the most feasible and adaptable one amongst the farmers (Singh ***et al.***, 2001). China's success in commercial hybrid rice production clearly demonstrated that hybrid rice at present is the only practical tool for increasing World production (Tran and Nguyen, 1998).

An yield advantage of 15-20 per cent over the best high yielding varieties proved to be the key factor for wide adoption of the hybrid technology. At present, 20 countries besides China are involved in developing and using this technology (Mahadevappa, 2001). In India, as a result of systematic evaluation, 14 public bred

and 3 private bred rice hybrids have been released. At present, about 2 lakh hectares are under hybrid rice cultivation in India, primarily in Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Uttar Pradesh, Orissa and West Bengal.

Although, several rice hybrids have been released in India for commercial cultivation, the coverage under hybrid rice is far below the projections. Of a host of factors that affect hybrid rice production, low level of exploitable heterosis and non-availability of quality seeds of released hybrids at reasonable price have been identified as the key impediments in adoption of hybrid rice technology (Mahadevappa, 2001).

For economic feasibility and commercial viability of the hybrid rice technology, development of an efficient seed production package is a pre-requisite. Hybrid rice seed production involves several intricacies which have to be tackled satisfactorily to obtain an acceptable seed yield of 1.5-2.0 tonnes ha^{-1}. The inherent yield potential of a crop gets expressed to its maximum extent, if the crop is provided with the required nutrients in abundance. Variation in the mother crop nutrition will have profound impact on the seed yield and its quality.

Application of major nutrients like N, P and K in required doses at the optimum stages of the crop growth can improve the yield of hybrid seed. Among the major nutrients, N is the most crucial nutrient limiting rice yield. Though, the modern rice varieties show excellent response to N application, the efficiency of utilization of applied N by rice is low due to various losses from soil-plant system and is estimated to range from 18-40 per cent (Natarajan and Pushpavalli, 1994).

Among the various techniques of N management, split application of N is perhaps one of the simplest agronomic solution for improving the N use efficiency since N demand is not same throughout the plant growth period (Manjappa ***et al.***, 1994). Eventhough, K comes next to N in terms of quantity used, it

plays a significant role in increasing the seed yield by activating enzymes involved in the plant growth and development.

Premature floral abscission and failure to set seeds are common symptoms of micronutrient deficiencies such as boron, zinc, copper etc. For an effective male genetic transformation, the pollen need to have the full compliment accomplished by balanced nutrition and associated with viability, without which the purpose will not be fulfilled. It has now been established fact that plants can be allowed to utilize water soluble nutrients in the form of foliar sprays (Gorbe and Kibe, 1993) with aqueous solutions of N, P, K and micronutrients during flowering and seed set.

The poor panicle exsertion in CMS lines is another major problem which is associated with a physiological mechanism due to cytoplasm i.e., male sterility (Duan and Ma, 1992). To overcome this problem, different approaches were tried earlier, such as splitting open the leaf sheath manually, spraying GA_3, urea, boric acid singly and in combination along with practices such as leaf clipping and rope pulling. Of all these practices, application of GA_3 was found to be most effective. Since GA_3 is the costliest input in hybrid seed production, there is an urgent need to find out various substituting chemicals to maximize seed yield which is economical to Indian farmer in hybrid seed production.

Hybrid vigour is the basis for the yield advantage of hybrids over conventional varieties. Seed or seedling vigour at the initial growth stage is the principal trigger of hybrid vigour (Hamid Miah and Sharma, 2000). In rice, a number of agronomic traits, including yield is reported to be significantly affected by seed vigour. It is generally agreed that the most important component which determines seed quality is the genetic potential of the seed.

The plant breeders recognized that the single most important factor which dictates seed vigour is the inherent capacity of the seed to resist both mechanical and

environmental alterations of seed quality. Seed vigour is positively related to the ability of a seed population to establish an optimum plant stand, in both optimum and sub-optimum soil environment and therefore, to maximize yield (Dornbos, 2002).

Thus, crop performance is entirely determined by a complex genotype / environment interaction whose outcome can be radically altered by quality of the seed representing the genotype (Matthews, 1990). Therefore, it is imperative to understand the physiological and biochemical basis of seed vigour of rice hybrids and their parental lines in order to enumerate the underlying mechanisms of seed vigour attainment and deterioration.

The successful establishment of crop seeds depends on a broad array of factors including species sown, inherent vigour of seed, soil conditions and presence or absence of antagonistic or beneficial organisms. Farmers have an opportunity to control only some of these factors. Many factors remain uncontrolled and can cause a delay or reduction in establishment. Farmers can overcome some of these adverse conditions by applying seed enhancement techniques performed on a given seed lot.

Seed enhancement is a value added technique given to the seed after harvest, but prior to sowing that improves germination or seedling growth or facilitate the delivery of required materials at the time of sowing (Taylor ***et al.***, 1998). Of the several seed enhancement techniques, seed coating provides an opportunity to package effective quantities of material in such a way that they affect the seed or soil at the seed soil interface. Seed coating with hydrophilic polymer has been seen by many (Scott, 1989; Dadlani ***et al.***, 1992; Joshi ***et al.***, 1998; Johnson ***et al.***, 2002) to offer exiting opportunity to promote the rapid and complete germination of seeds.

Only recently have people started looking at adding coating to the seed in the form of polymers. The original use of the polymers was to help the protection of the seed by keeping the fungicide / insecticide treatment on the seed longer. However, the

use of polymers has been taken a turn. It can be expected that an increased use and market demand for coated seeds can create a substantial interest in seed coating technology. The application of polymers to seed serves as an extra exterior shell in order to give the seed characteristics, that could be beneficial for germination in certain environment (Clayton, 1988; Taylor ***et al.***, 1998).

Since, the film coating is the wave of the future for production agriculture, specific formulations are needed to broader the range of environmental conditions in which a desired stand may be established. As only a limited research has been performed on the addition of polymer compounds (Taylor ***et al.***, 1992; Ni, 1997), seed coating should the developed to rice seeds as a management tool to be an integral component to enhance seedling establishment under a wide range of environmental conditions.

With this insight in view, comprehensive studies were taken up with rice hybrids ADTRH 1 and CORH 2 and their parental lines to elucidate information on the following objectives.

1. To study the effect of additional dose of N and K on growth and yield of parental lines in ADTRH 1 and CORH 2 rice hybrid seed production.
2. To determine the influence of supplemental foliar application of organic and inorganic nutrients on growth and yield of parental lines in ADTRH 1 and CORH 2 rice hybrid seed production.
3. To quantify the nutrient uptake of parental lines in relation to applied nutrients.
4. To enumerate the physiological and biochemical basis of hybrid vigour in rice hybrids on seed quality attributes.
5. To estimate the quality loss on occurrence of split husk seeds in rice hybrids and female parent.
6. To standardize the dose and dilution of polykote for rice seed.

7. To study the effect of seed coating with different colours of polykote in rice hybrids and parental lines.

Chapter II
Review Of Literature

Literature pertaining to effect of additional and split doses of N and K, foliar sprayings of organic and inorganic nutrients on growth and yield of rice, seed vigour attributes of rice hybrids and their parental lines and seed enhancement through polymer seed coating are reviewed and presented in this chapter.

2.1. EFFECT OF ADDITIONAL DOSE OF N AND K ON GROWTH AND YIELD OF RICE

Mother crop nutrition greatly influence the seed yield and quality characteristics (Roberts, 1972) and of which the micronutrients also occupy the key position (Agarwal, 1980). Balanced application of both macro and micronutrients improved the seed yield and quality (Krishnasamy and Ramasamy, 1979). The demand for nutrients may vary with the advancement in growth stages until maturity. Adequate nutrient supply is necessary for maximum growth during the vegetative period. Avoidance of nutrient stress is essential during translocation of nutrients from vegetative to reproductive parts to achieve higher seed yields (Munda ***et al.***, 1983).

2.1.1. Nitrogen

Nitrogen is the most essential element determining the yield potential in rice and nitrogenous fertilizer is one of the major inputs to agriculture system. Nitrogen (N) accounts for 67 per cent of the total amount of fertilizers applied to rice (Prasad and DeDatta, 1979). The total N uptake by hybrid rice shoot is greater than that of conventional cultivars, especially from transplanting to tillering and from panicle emergence to grain filling stage (Yang, 1987). Hybrid rice takes upto 15-20 per cent of the total amount of N accumulated in the plant after heading and responds well to late application of N at flowering.

2.1.1.1. Effect of N levels on growth and yield of rice

The N application had no significant effect on grain number whereas, it increased the grain yield significantly. With regard to plant height, it increased with increasing doses of N and maximum height was recorded by 200 kg N ha^{-1} which was on par with 150 and 100 kg N ha^{-1}. With regard to tiller number, though 200 kg N ha^{-1} recorded the maximum number it was on par with 150 kg N ha^{-1} (Sadayappan ***et al.***, 1974). Pillai and De (1980) found increased plant height and number of tillers with increased N levels.

Maximum leaf area index was observed at 120 kg N ha^{-1} and the N uptake in rice was proportionate to the level of N applied (Shivaraj, 1981; Shanmugam, 1983). Levels of N had significant influence on dry matter production (Maskina ***et al.***, 1985). Chlorophyll content and nitrate reductase activity were found to be increasing with an increase in N level. N application increased the panicle weight, number of grains $panicle^{-1}$, 1000 grain weight and the grain yield of rice (Sudhakara ***et al.***, 1987).

Average grain yield obtained at 120 kg N ha^{-1} was higher over the grain yield obtained at 60 kg N ha^{-1} and the percentage of filled grains (22.57 per cent), produced at 120 kg N ha^{-1} was significantly higher than that of 60 kg N ha^{-1} (Padmakanta Dhal and Misra, 1992). N at 160 kg ha^{-1} recorded highest dry matter and yield (Murali and Reddy, 1994). Grain yield is the product of mean individual grain weight and grain number which were significantly higher when more N was applied. Hence, rice yield was higher in high N condition (Sarkar ***et al.***, 1996).

2.1.1.2. Effect of split application of N

Split application of N proved better than single whole dose application (Pande and Singh, 1970). Application of N beyond four splits and after panicle initiation was not advantageous (Patel, 1982). Wagh and Thorat (1987) reported that the number of panicles per unit area and grain and straw yields ha^{-1} were significantly higher when N was applied in four splits at eight days after transplanting, tillering, primordial initiation and flowering stages. Application of N in five equal

splits – basal, at tillering, one week before panicle initiation, at booting stage and at panicle emergence produced highest grain yield (Pandey ***et al.***, 1989).

Application of N in four equal splits, viz., basal or at seedling stage, at tillering, panicle initiation and heading stage gave higher panicle weight, grain yield and N uptake, but could not influence on plant height, tiller and panicle production (Bhattacharya and Singh, 1992). Split application of N at sowing and tillering, produced greater increase in leaf area, biomass yield and total N uptake than single application (Ramazanova, 1993). Tyagi ***et al.*** (1994) reported split application need to be phased at transplanting, maximum tillering and panicle initiation corresponding to the needs of rice.

The N applied at tillering or panicle initiation was more effective in producing rice grain than basal N application (Dhyani and Mishra, 1994). Similarly, when N supply to rice crop was delayed upto 16 days after transplanting (DAT), higher grain yield was obtained due to increased tiller production and leaf N content (Thiyagarajan ***et al.***, 1993). Shi ***et al.*** (1995) in a field experiment using three line F_1 hybrid, Sanyou 63 obtained the highest yield with the application of 100 kg N ha^{-1} applied in 2 equal proportions at 10 and 40 DAT.

Recent studies by Shi ***et al.*** (1998) in hybrid rice recorded highest leaf area and yield with the application of 60 per cent N as basal and 40 per cent of N in seed development stage and the lowest being recorded with 60 per cent basal plus 30 per cent at flowering and 10 per cent at seed development. Asif ***et al.*** (1997) reported highest grain yield when N was applied in 3 equal splits at transplanting, tillering and panicle initiation as compared to 1 or 2 splits. Application of N in 3 splits as basal, at tillering and panicle initiation to rice hybrid CORH 1 recorded maximum productive tillers, number of grains and grain yield (Venkitaswamy ***et al.***, 1997).

Hybrid rice CORH 1 recorded higher plant height and number of tillers with 3 splits as basal, active tillering and the last split either at panicle initiation or panicle emergence at 150 kg N ha^{-1}. However, maximum number of spikelets, filled grains and yield were observed in 200 kg N ha^{-1} applied in 4 equal splits (Selvaraju ***et al.***, 1999). Similarly application of N in 3 splits gave yield on par with 4 splits in hybrid rice variety PAC – 803 (Anon., 1999).

Saha ***et al.*** (1998) recommended equal split application of N at early tillering (7 DAT), active tillering, neck node differentiation and active meiosis stages for efficient rice production. The superiority of 4 split application of N expressed in terms of total dry matter accumulation, filled grains and yield of rice were also observed by Pillai ***et al.*** (1999) and Sanbagavalli ***et al.*** (1999). In rice hybrid (MGR-1, KRH-1, APRH-1, APRH-2) also, 4 equal split application of N improved filled grains percentage, 1000 grain weight and grain yield as compared to 3 splits (Surekha ***et al.***, 1999a; Surekha ***et al.***, 1999b). All the growth parameters and yield attributes of rice hybrid CORH 2 were superior with the application of N in four splits (Edwin Luikham, 2001).

Sanbagavalli and Kandasamy (1998) reported that 5 split application of recommended dose of N was superior to 4 splits. In contrast, Singh ***et al.*** (1998) did not find significant difference in yield with 3, 4 and 5 split application of N in rice hybrid (KRH-1, Pro Agro 103, MGR-1). Dheebakaran and Ramasamy (1999) also confirmed the higher grain yield of rice with 5 split application of N (basal, active tillering, week after active tillering, panicle initiation and heading) as compared to 4 split application at Coimbatore under lowland situation.

2.1.2. Potassium

A good supply of K increases the tolerance of the plant and resistance to pests and diseases (Singh and Tripathi, 1979). It was reported that potassium was absorbed

by the plants in larger amount than any other essential nutrients especially by the starch storing species (Reddy ***et al.***, 1981).

2.1.2.1. Effect of K levels on growth and yield of rice

Significant increase in number of tillers was recorded by Singh and Singh (1972) and Biswas (1976). Seetharam (1981) stated that application of K in combination with N improved the Leaf Area Index (LAI). Premkumar (1981) observed that the LAI was increased upto 100 kg K_2O ha^{-1} and further increase in K decreased the LAI. Application of K increased the number of panicles per unit area, percentage of filled grains, thousand grain weight and thereby the grain yield (Majumder and Ghosh, 1981).

A significant positive influence on the plant height was reported by Venkatasubbiah ***et al.*** (1982) and Nannabatcha (1984). Prohit ***et al.*** (1986) observed no difference in panicle length towards application of K. The application of K increased the percentage of filled grains as reported by Venkatasubbiah ***et al.*** (1982). Senthilvel (1984) and Purushothaman (1985) observed that combined application of N and K influenced the plant height positively. Prohit ***et al.*** (1986) reported that K had no influence on plant height at different levels. Devasenapathy (1997) reported that application of K significantly increased the number of panicles m^{-2}.

2.1.2.2. Effect of split application of K

Application of K in three equal splits at tillering, preflowering and flowering resulted in better yield and had no adverse effect in skipping the basal application of potash (Biswas, 1976). The effectiveness of split application was also reported by Agarwal (1980). Application of K to rice at four splits with 40 per cent as basal, 20 per cent at effective tillering, 30 per cent at maximum tillering and 10 per cent at panicle initiation stages, recorded good yield (Mahapatra ***et al.***, 1980). Majumder and Ghosh (1981) indicated split application had better effect on yield and yield components.

Mahapatra and Patnaik (1982) also found that split application of K increased the number of filled grains panicle^{-1} significantly. Nannabatcha (1984) reported that application of K in three equal splits at transplanting, maximum tillering and panicle initiation stages of growth in rice increased panicle length significantly. Purushothaman (1985) observed a better effect on number of panicles per unit area when N and K were applied together at transplanting, maximum tillering and panicle initiation stages. Devasenapathy (1997) reported that split application of K found to increase the plant height, dry matter production, LAI and yield.

2.2. EFFECT OF FOLIAR SPRAYING OF ORGANIC AND INORGANIC NUTRIENTS ON GROWTH AND YIELD OF RICE

It is a well established fact that plants utilize water soluble nutrients when fed through foliage and utilize for better yield and quality in many crops. Foliar application of nutrients and hormones had increased the yield and quality of seeds in many agricultural and horticultural crops. Singh ***et al.*** (1978) reported that foliar application of chemical nutrients was better than any other method in improving yield, yield parameters and other desirable quality characters of rice. Such foliar application could be used to avoid the depletion of the nutrients in the leaves and the resulting reduction in photosynthetic rate during the period due to poor nutrient uptake from soil and translocation of these elements from the leaves to the developing seeds (Ramon Garcia and Hanway, 1976).

2.2.1. Effect of macronutrients

Foliar application of N and P in the form of diammonium phosphate (DAP) was recommended by Ramachandran ***et al.*** (1980) for the improvement of yield in rice. Foliar spraying of 2 per cent DAP thrice during boot leaf stage, 50 per cent flowering and post milk stage registered increased seed yield and improved the quality of rice (Manonmani, 1990). The parental line, IR 54752 A when sprayed with urea, KNO_3 and boric acid registered seed yield as that of GA_3 and suggested that these could be cheap substitutes for GA_3 in hybrid rice seed production

(Prasad ***et al.***, 1988). Virmani ***et al.*** (1993) found that 2 per cent urea or 1.5 per cent boric acid or both could be substituted for GA_3.

Urea sprays (1.5-2.0 per cent) at booting and at two per cent flowering during seed production of female parent of rice, increased the panicle exsertion, panicle length, filled spikelets plant^{-1} and the seed yield (Deshpande, 1993). Spraying 1 per cent urea at two per cent flowering stage increased the hybrid seed yield in rice by 12.7 per cent over unsprayed control (Bong ***et al.,*** 1994). Similar effect of urea in seed production of cytosterile lines of rice has been reported by Mishra and Pandey (1994). According to Bhaskaran (1995) foliar spraying of 1 per cent DAP increased the seed yield and quality attributes.

The seed yield of IR 58025 A increased to the extent of 14 and 19 per cent at Mandya and Karnal, respectively, when sprayed with urea at 2.0 per cent (Anon, 1996). Jayaraj and Chandrasekharan (1997) observed significant increase in germinability, seedling length and seedling dry weight with foliar spray of 2 per cent DAP thrice during panicle initiation, boot leaf and 50 per cent flowering stage in rice cv. ADT 36 and ADT 39. The studies on supplementary foliar nutrition on resultant seed and seedling quality parameters in hybrid rice carried out at Coimbatore revealed that the 2 per cent DAP spray recorded 33.6 per cent seed set which was 7.7 per cent higher over control and was on par with urea and potassium chloride spray (Anon, 1998).

Supplementary foliar nutrition of 2 per cent DAP or 1 per cent urea at panicle initiation (PI) stage and one week after PI could enhance seed set, seed recovery and 100 seed weight thereby significantly increased the hybrid seed yield of DRRH-1 (Anon, 1998). Similarly, spraying 2 per cent urea and 2 per cent DAP at PI and one week after PI significantly preponed flowering of parents, increased seed set and seed yield (Anon, 2000).

2.2.2. Effect of micronutrients

2.2.2.1. Boron

In general, monocotyledons have lower requirement for boron than dicotyledons (Wear, 1957). The role of boron appears to be associated with uptake of calcium by root and its efficient utilization in the plant (Russell, 1960). Boron application at 20 and 50 ppm concentrations reduced the plant height, tiller number, yield and 1000 grain weight in rice (Ishaque ***et al.***, 1983). However, Xiong (1987) observed that application of boron at 0.8 to 1.2 ppm resulted in early heading and increased 1000 grain weight.

Spraying of 1.5 per cent boric acid at full booting, initial heading or 20 per cent heading was as effective as GA_3 (90 ppm) in increasing the seed yield of hybrid rice. However, it did not increase the plant height (Prasad ***et al.***, 1988). According to Singh and Sahoo (1988), GA_3 (60 ppm) + boric acid (1.5%) spraying was the most effective for panicle exsertion in rice. Application of 0.2 per cent boron was adjudged the best by Manonmani (1990) as it gave high seed germination, dry matter and vigour when applied through foliage. Application of 0.05, 0.10, 0.50 per cent boron at tillering increased the number of spikelets panicle^{-1}, decreased the spikelet sterility and increased the grain yield in rice. The optimum concentration of boron was found to be 0.10 per cent (Sheudzhen, 1991).

Desphande (1993) noticed increased panicle length, panicle exsertion, filled spikelets plant^{-1}, seed set percentage, seed yield and seed quality of hybrid rice with the application of boric acid either at 0.5 or 1.0 per cent. Shivaraju (1993) observed that foliar spray of boron (2 kg ha^{-1}) increased the germination, dry weight of seedling and vigour index. Boron (1.0 ppm) increased the plant height and recorded significantly higher yield in IR 36 rice variety when grown in acid lateritic soils of Kharagpur (Subbaiah and Mittra, 1997).

Spraying of boric acid @ 0.5 and 1 per cent was very effective to enhance the seed yield of CMS line Pusa 5A. Boric acid application @ 1 per cent recorded yield of 2.6 t ha^{-1} which was significantly higher as compared to GA_3. Thus, boric acid appeared to be a potential substitute or a supplement to GA_3 application for economizing 'A' line seed production (Anon, 1998). Foliar spray of 0.1 per cent boric acid was the most effective for increasing seed yield, 1000 seed weight and germination (Sharma ***et al.***, 1999). Application of boron @ 0.1 per cent combined with KH_2PO_4 @ 0.2 per cent as foliar sprays at 5-10 per cent heading produced highest seed yield compared to control at Hyderabad (Anon, 2000).

2.2.2.2. Zinc

According to Yoshida ***et al.*** (1970) soil or foliar application of $ZnSO_4$ was as effective as dipping seedlings before planting in a zinc oxide suspension for correcting Zn deficiency and Zn has a stimulatory effect on growth and activity of nitrogen fixing organisms (Mishusting and Shilnikova, 1973). Varied varietal response to supplemental application of Zn was noticed in seed yield of rice varieties (Forno ***et al.***, 1975). Zn had a marked effect in increasing the yield by promoting its growth, increasing the number of tillers, panicle and well filled seeds and preventing early withering (Dong ***et al.***, 1982).

Balakrishnan and Natarajarathinam (1986) observed that applied Zn increased the number of productive tillers $plant^{-1}$, panicle length, number of total and filled grain $panicle^{-1}$ and 1000 seed weight. Foliar application of 0.1 per cent Zn at tillering stage of rice increased the number of spikelets $panicle^{-1}$, decreased spikelet sterility and thus increased grain weight $plant^{-1}$ (Sheudzhen, 1991). Soil or foliar application of $ZnSO_4$ in rice hybrid seed production increased the pollen viability and germination per cent (Vimala, 1997). Foliar spraying of 0.5 per cent $ZnSO_4$ three weeks after transplanting was the most effective post transplanting treatment in maximizing the grain yield (Kumar and Singh, 1997; Manoharan ***et al.***, 2001).

2.2.3. Effect of organic compounds

2.2.3.1. Spentwash

The distillery spentwash is primarily a plant extract and a rich source of organics, and hence plant nutrients can be effectively utilized when applied (Samvel, 1986). Somashekar ***et al.*** (1984) found that the distillery spentwash was alkaline in nature and contained variable amount of plant nutrients like N, K, P, Na, Ca, Mg, B, Fe, Cu and need based mineral nutrients in varying concentration.

Khruslova and Kolomiets (1974) stated that spentwash application in grasses, maize and fodder has increased the yield by 45-100 per cent. Arbatti (1976) also reported that application of spentwash was found to increase yield in bajra. Positive influence of distillery waste water on sorghum yield has been reported by Zalawadia and Raman (1994). Devarajan and Oblisami (1995) reported that the distillery spentwash application in rice increased the availability of N, P, K, Ca, Mg, micronutrients and organic matter content in soil.

Application of spentwash with 50 times dilution in rice CO 43 resulted in normal yield (Rajannan ***et al.***, 1998). The grain yield and biomass yield of maize was significantly higher due to spentwash application. The spent wash also increased the N, P, K, Ca, Mg and Na content in all the parts of the maize crop (Mallika, 2001). The maximum grain yield was recorded in rice variety ADT 42 due to 75 times diluted distillery spentwash treatments which was on par with 100 times diluted spentwash application (Chinnusamy ***et al.***, 2001).

2.2.3.2. Humic acid

Humic acid is extracted from lignite or low rank coals. It is a complex with high molecular weight humic constituents, containing plant growth stimulating substances. Humic acid typically contains herterocyclic compounds with carboxylic, phenolic, alcoholic and carbonyl functions (Khungar and Manoharan, 2000). Humic acid (HA) is known to influence the physiological and biochemical processes and

improve growth and yield in many crops, particularly in cereals and millets, since long as reported by Cincerova (1964) in wheat, Forton and Polo (1982) and Yadava (1989) in maize and Balasubramaniam ***et al.*** (1989) in rice.

Application of HA solutions enhanced the dry matter production of maize (Yadava, 1989), sorghum (Mallikarjuna Rao ***et al.***, 1987) and rice (Ravindraprasad ***et al.***, 1989). Govindasamy and Chandrasekaran (1989) obtained higher grain and straw yields of rice due to application of HA solution. Mandal ***et al.*** (1989) indicated that root dipping of rice seedlings and soil application of HA produced highest number of fertile tillers, filled grains, grain yield and straw yield in rice.

Govindasamy and Chandrasekaran (1990) observed an increase in the plant growth and yield of rice due to application of HA. Dhanasekaran ***et al.*** (1992) obtained higher dry matter production and yield in rice due to application of HA in a calcareous soil. Similarly, Durairaj (1993) on combined application of 20 ppm HA and 25 ppm $ZnSO_4$ got highest plant height, number of tillers $hill^{-1}$, grain and straw yield and dry matter production in rice. Meera Nair (1995) reported that foliar application of HA along with micronutrients increased the rice yield. The number of productive tillers, number of filled grains $panicle^{-1}$ and grain yield were significantly and positively influenced by HA application in rice (Senthil Kumar, 2001).

2.2.4. Effect of plant growth hormones

2.2.4.1. GA_3

Role of GA_3 in hybrid rice seed production is evident by several experiments carried out at different research stations in China, Philippines, India and Japan. Takahashi ***et al.*** (1972) suggested that GA_3 treatment in rice triggered the metabolic activity involved in cell division and cell elongation in internodes which are normally accelerated at panicle initiation. Using higher dosage of GA_3 @ 75 g ha^{-1} favoured the whole panicle to grow taller than flag leaf to avoid leaf clipping. Spraying of GA_3

three to four times at a higher concentration at early heading stage increased the seed set on female parent upto 65 per cent (Lin and Yuan, 1980). Chinese scientists recommended a higher dosage of GA_3 @ 150-225 g ha^{-1} to increase panicle exsertion (Yuan, 1985).

A study on outcrossing rate with growth regulators which influenced morphological and floral traits indicated that GA_3 increased the duration of floret opening (Anon, 1986), filled spikelets and 1000 seed weight (Kaur and Singh, 1986). Quian (1987) reported a positive correlation between seed yield and the amount of GA_3 applied. Yield could be doubled by spraying GA_3 as compared to control (Sahai ***et al.***, 1987). It was again confirmed by Yuan and Virmani (1988) that a dose of 75 g ha^{-1} of GA_3 was sufficient to make panicle growth longer than flag leaf to avoid clipping.

Spraying GA_3 three or four times at a higher concentrations of 40-60 ppm (150 g kg^{-1}) improved seed set of female parent upto 65 per cent in China (Shengqui, 1988). However, Xu and Li (1988) recommended two or three sprayings of a lower dose of 75 g GA_3 ha^{-1} to increase the panicle exsertion. Sharma (1991) observed that two sprays of GA_3 at 60 ppm and 30 ppm concentration applied at 10 and 30 per cent heading stage respectively aided in enhancing the panicle exsertion and caused the late tillers to grow faster.

Duan and Ma (1992) reported that increasing GA_3 significantly increased plant height and ear exsertion values of hybrid Zhenghshan 97 A x IR 26. They suggested that foliar application of GA_3 at the start of panicle emergence was one of the important techniques for promoting panicle exsertion and obtaining higher seed set. Mao and Deng (1992) recommended the application of GA_3 at the rate of 75-100 g ha^{-1} at five to ten per cent panicle exsertion stage. They also suggested the use of ultra low volume sprayer for economising the amount of GA_3.

Application of GA_3 at 60 ppm in combination of flag leaf clipping and rope pulling yielded higher out crossing rate (Bui Ba Bong ***et al.***, 1992). Deshpande (1993) observed the beneficial effects of GA_3 (60 ppm) in increasing the plant height, productive tillers plant^{-1}, panicle length, panicle exsertion percentage, filled spikelets plant^{-1}, seed set percentage and higher seed yield. The test weight also increased significantly with GA_3 application. Viraktamath (1993) recommended an extra dose of GA_3 on pollen parent to increase height by 10.5 cm if height of both CMS line and pollen parent are same. Virmani (1994) reported that response of GA_3 is genotype specific and male sterile lines respond better than the fertile lines. GA_3 helps in keeping the spikelets open for longer time which increases the receptivity of stigma upto seven days in CMS lines. Ruggeri and Branca (1994) reported that GA_3 at 400 ppm improved flower induction, flowering percentage and seed yield. According to Angamuthu (1996), application of GA_3 at the rate of 100 g ha^{-1} at 5 per cent flowering stage synchronized 50 per cent flowering, increased seed set and seed yield.

GA_3 spraying at 15-20 per cent panicle emergence stage recorded maximum panicle emergence, seed set and yield (Prabhagaran, 1996). Revansiddappa (1996) observed marginal increase in germination, field emergence and vigour index with the spray of GA_3 (100 ppm) over control at panicle initiation stage in upland rice cv. Amrut. Beneficial effect of GA_3 in seed production of rice hybrids for increasing yield and yield attributing characters were observed by Jagadeesha (1997), Jagadeeshwari ***et al.*** (1998) and Ponnuswamy ***et al.*** (1998). Application of GA_3 @ 120 g ha^{-1} at 5 per cent flowering stage, synchronized 50 per cent flowering, seed set per cent and seed yield (Indira, 1998). Increased panicle exsertion, seed set percentage and seed yield were achieved in hybrid rice seed production when GA_3 was applied @ 45 g ha^{-1} along with 2 per cent leaf extract of ***Albizia amara*** (Kalavathi ***et al.***, 2000).

2.2.4.2. Brassinolide

Brassinolide (BR) are the new group of plant hormones with a regulatory function in cell elongation and cell division (Mandava, 1988). In plant kingdom, brassinosteroids are widely distributed and they possess all properties necessary for classification as a plant hormone (Zurek and Clouse, 1994). They have been detected and isolated from almost all plant parts ranging from seeds, fruits, leaves, flower buds and pollen (Creelman and Mullet, 1997).

Foliar spraying of BR increased the thickness of the 3rd leaf by increasing the fresh and dry weight of leaf (Braun and Wild, 1984) and leaf area (Sairam, 1994) in wheat. BR application @ 0.05 ppm caused an increase in chlorophyll content in wheat (Sairam, 1994). Homobrassinolides at 5 ppm was effective in increasing plant height in rice (Hebbalkar ***et al.***, 1997).

BR have a significant role in reproductive development of plants (Clouse and Sasse, 1998). Krishnan ***et al.*** (1999) reported that foliar application of BR increased the number of fertile tillers hill^{-1} in rice. Similarly, in wheat also BR increased the number of flowers (Ikekawa and Zhao, 1991), grain number ear^{-1} and seed weight (Sairam, 1994). Jin and Chen (1999) reported that application of natural BR at tillering and ear emergence increased rice yield significantly. BR-120 foliar application increased the number of effective panicles and effective number of grains panicle^{-1} in rice (Wang ***et al.***, 1996).

Similarly, Krishnan ***et al.*** (1999) also obtained increased number of filled spikelets hill^{-1} and grain weight due to application of BR in rice. Ikekawa and Zhao (1991) reported application of epibrassinolide increased the yield of rice by 11 per cent and corn by 10-20 per cent. Ramaraj ***et al.*** (1997) reported that 28-homobrassinolide treatment significantly increased the grain yield in many crops including wheat and rice. Application of 0.1 ppm homobrassinosteroid in hybrid seed production of rice increased the seed set and seed yield (Thirthalingappa ***et al.***, 1999).

BR spray recorded highest percentage of spikelet fertility, number of spikelets panicle^{-1} and grain yield in rice (Maibangsa ***et al.***, 2000).

2.3. PHYSIOLOGICAL AND BIOCHEMICAL BASIS OF HYBRID VIGOUR ON SEED QUALITY ATTRIBUTES

2.3.1. Hybrid vigour on initial seed quality attributes

Seed vigour is defined by ISTA as the sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence (Hampton and Tekrony, 1995). High seed vigour i.e., rapid, uniform and complete emergence of vigourous seedling leads to high grain yield potential (Soltani ***et al.***, 2001). The effectiveness of selection is dependent upon the variability present in the germplasm and the extent to which it is heritable (Dudley, 1997). Further, for a rational improvement of seed vigour, knowledge of the inter-relationship among characters is important.

Several studies have reported genotypic and phenotypic variability and simple correlation among seed vigour traits (Krishnasamy and Seshu, 1989; Yamauchi and Winn, 1996; Lopez – Castaneda ***et al.***, 1996). Pollock and Roos (1972) divided seed and seedling vigour into two components; genetic and physiological. The genetic component includes differences between two or more genetic lines, whereas, the physiological component includes differences between seed lots within one genetic line.

Perry (1972) stated that seed vigour is determined by the genotype and modified by the environment. Ashby (1930, 1932) had proposed the so called initial capital theory to explain hybrid vigour on the basis of observations in maize hybrids. Takahashi (1956) in studying cultivar differences in germination speed of rice seeds, concluded that O_2 uptake and imbibition rate were parallel to germination speed. Heterosis for amylase and amylase activity in the endosperm providing energy and

assimilates for embryo development, which in turn was expressed in heterosis for germination speed (Anon, 1977).

According to Dale and his associates (Dale ***et al.***, 1972; Metivier and Dale, 1977) vigour in productivity of crop plants may be established at as early as seedling stage and the higher photosynthetic rates in the first leaf lead to a more rapid growth and unfolding of second and subsequent leaves. A significant superiority of hybrid over the better parent for total chlorophyll, chlorophyll a and chlorophyll b in seedlings has also been reported (Badwal ***et al.***, 1979). Li ***et al.*** (1982) showed that germination speed of the hybrid Nan-you 2 was superior to its three parental lines viz., R>B>A. In a study conducted by Akita ***et al.*** (1986) all the 15 F_1 rice hybrids derived from CMS and restorer lines showed heterosis for embryo weight and the embryo weight was closely related with that of seedling weight at 16 days after seeding.

Growth in terms of shoot length, fresh weight and dry weight along with the chlorophylls revealed better parental and / or mid parental heterosis in the pearlmillet hybrids over their respective parents (Joshi ***et al.***, 1986). Deng (1988) reported differences between rice hybrids and their parental lines with regard to amylase and α-amylase activity in germinating seeds, RNA content of young roots, glycolic acid oxidase (related to photorespiration) and catalase and peroxidase enzyme. Major enzymes were also screened in maize by Rood and Larsen (1988), who revealed that amylase activity of seedlings was higher in hybrids than in inbreds. Oxygen uptake and dehydrogenase activity also contributed to germination rate variability and the cultivar differences were also evident for germination rate (Krishnasamy and Seshu, 1989).

Genetic variations for early growth and reproductive stage dry matter yield have been shown to be related with early seedling vigour (Hebert, 1990). In maize, seedling emergence was more rapid in hybrids than in inbreds (Rood ***et al.***, 1990).

Leaf appearance rate and elongation were also found to be heterotic (Hebert, 1990). In a later study, it was concluded that factors between germination and the appearance of the second leaf must be responsible for the greater vigour (Lopez-Castaneda ***et al.***, 1995). It was also suggested that the breadth of the first seedling leaf as an indirect estimate of early vigour that integrates embryo size and specific leaf area and could be used in a breeding programme to increase the vigour of cereals (Lopez-Castaneda ***et al.***, 1996).

Similarly, the hybrid maize seeds exhibited superior physiological (germination, vigour) and biochemical quality compared to the maize lines under laboratory conditions (Gomes ***et al.***, 2000). In sorghum, the heterosis had favourable effect on emergence, emergence index, leaf number, vigour and dry weight when the parental lines and hybrids were evaluated under early and normal planting conditions in the field (Yu and Tuinstra, 2001). Soltani ***et al.*** (2001) reported that the important seed vigour traits such as germination rate, uniformity, seedling growth rate, electrical conductivity (membrane integrity), seed reserve depletion ratio and seed reserve utilization efficiency are under genetic control.

2.3.2. Loss of hybrid seed vigour on ageing

According to the classification of Delouche ***et al.*** (1973), rice seeds are classified as good storer. Though, the reduction in the germination and seedling vigour was certain, the rate and extent of reduction varied due to many factors which include cultivar difference (Agarwal, 1980; Tomer and Singh, 1986). Varietal differences in the seed viability period of rice seed during storage under different conditions have been reported by several workers (Sridhar Dronavalli, 1985; Vijayalakshmi, 1987; Sikder, 1988; Murugesan ***et al.***, 1989; Juliano ***et al.***, 1990).

Murugesan ***et al.*** (1989) observed higher values for germination, coleoptile length, seedling length, vigour index, dry matter production and dehydrogenase activity in medium bold seeds than long slender seeds of rice. Ray ***et al.*** (1990)

studied the mechanism of seed deterioration of late and early maturing rice varieties under accelerated ageing condition and observed rapid loss of viability in low vigour seeds. Sharma ***et al.*** (1990) observed genetic variability among rice varieties and noted long roots with high fresh weight and vigour index in bold seeded varieties. Younis ***et al.*** (1990) predicted the varietal differences in seed vigour and viability under accelerated condition and found rapid decline in storability in "Amber 33" compared to "Hybrid 2".

In sorghum, the female parental lines were genetically superior than male and CSH 2 hybrid was dominant than CSH 5 in storability (Agrawal ***et al.***, 1981). It appeared that maternal parent was dominant in storability in pearlmillet, when the seeds were subjected to accelerated ageing test (Singh ***et al.***, 1988). Similar report of female inbred lines dominance in storability was observed in maize by Ramamoorthy ***et al.*** (1989). Chen and Zhou (1990) recorded reduction in germination and increase in solute conductivity, soluble sugar and amino acids with ageing of rice hybrids than cultivars. F_1 hybrids had better germination, root length and vigour index compared to their parents in rice as reported by Li ***et al.*** (1990).

The vigour indices of fresh hybrids were superior over cultivars, which however, reduced rapidly under storage (Cheng, 1993). Bilia ***et al.*** (1994) concluded that seed quality of hybrid corn maintained better under controlled temperature and humidity. On testing six CMS and restorer lines of rice for physiological parameters after accelerated ageing, V20A, IR58025A, Pushpa A and IR 46R were found to be better storers (Deshpande and Mahadevappa, 1994).

In an another similar study, Pusa 150 R and IR 10198-66-2R were found to be the best storers compared to IR 58025 A and their hybrids (Kalavathi ***et al.***, 1994). In pearlmillet and sorghum, germination declined slowly irrespective of varieties, hybrid and parental lines (Premalatha and Vadivelu, 1994). In maize, the hybrid Trishulate and its female parent lost the viability in 7 months whereas, its male parent

stored well (Sinha ***et al.***, 1994). Studies on hybrid rice parental lines evinced the superiority of AS 89044 and inferiority of IR10198-66-2R-C20 (Prabhagaran, 1996).

However, in an another study, parental lines of rice hybrids, IR 10198-66-2R, C22R, Pusa 150 R followed by B lines IR 58025B and IR 62829B found to be superior and the line C 20R was identified as poor storer (Vimala, 1997). According to Kalavathi ***et al.*** (1999), R lines of rice hybrids TNRH1, TNRH 2 and TNRH3 were good storers than the other line and hybrids. Positive correlation in germination between accelerated aged and naturally aged seed indicated that accelerated ageing test can be employed to predict the storability of rice genotypes (Padma and Muralimohan Reddy, 2000).

2.4. EFFECT OF SEED COATING WITH POLYMER ON GERMINATION AND SEEDLING VIGOUR

Hydrophilic seed coating has been found to offer exciting opportunity to promote the rapid and complete germination of seeds (Scott, 1989). The use of such seed coating materials in lettuce or pasture seeds have shown no effect on germination (Sharples and Gentry, 1980). Such coatings on cowpea seeds resulted in delayed and reduced germination and emergence whereas, similar coating on corn seed produced better emergence in only one cultivar out of four (Baxter and Waters, 1986).

Reduced imbibition rate could be achieved by coating the seeds with hydrophobic polymers (West ***et al.***, 1985; Priestly and Leopold, 1986). Soybean seeds coated with ethyl cellulose recorded reduced imbibition damage and improved germination (Hwang and Sung, 1991). Ruban ***et al.*** (1983) reported that cotton seed coated with Penthiuram and polymer initially inhibited the activity of catalase and peroxidase and rate of seedling growth, but stimulated them later on. Markrov (1987) observed that sorghum seeds pelleted with polymer film coating, fungicide and growth regulator registered normal germination and accelerated crop maturity by 9-21 days.

Seeds coated with polymer film coating, fungicides and micronutrients registered good germination energy and germination per cent in lucerne (Konstantinov and Kolarova, 1988). Seeds of ***Phalaris aquatica*** coated with monocalcium phosphate suffered little emergence injury whereas, ***Medicago sativa*** was damaged during emergence. However, coating seeds with a polymer prior to applying the monocalcium phosphate resulted in substantial protection against injury (Scott, 1991). Angamuthu (1991) observed that seeds pelleted with polymer and ***Albizia amara*** leaf powder registered higher field emergence potential in minor millets.

Dadlani ***et al.*** (1992) observed faster field emergence of rice seeds coated with 50 g aqueous emulsion of sodium alginate litre^{-1} and dipping in 10 g calcium oxide litre^{-1} than non coated seeds under moisture stress conditions and also coated seeds absorbed more moisture when compared to non-coated seeds. Polymers in combination with captan were as effective as captan alone in increasing the rate of emergence and improving seedling height at early planting (Rivas ***et al.***, 1998). The seedling establishment rate was enhanced by treament with Daran 8600, Sepiret and Sacrust, which are the recommended polymers for direct sown rice (Song Dongseod and Lee Sheong Chun, 1998).

Joshi ***et al.*** (1998) reported that sorghum seeds treated with 10-50 g of hydrophilic polymer kg^{-1} seeds, improved seed germination and emergence rate at the lowest available soil moisture level. Arantes ***et al.*** (2000) reported that seed germination and seedling growth were best and fungal infection lowest with encapsulation or coating with gypsum + bentonite or the polymer Sepiret 6182 combined with fungicides carboxin + thiram. The fuzzy cotton seed coated with the Easiflo polymer and fungicide mixture did not significantly affect germination and emergence (Williams ***et al.***, 1999). Tony Vyn (2000) reported that the biodegradable

polymer seed coating delays soybean germination for about two weeks, a period that accommodates the wheat harvest.

Coating with a hydrophobic polymer can reduce rates of water uptake, lower solute leakage and improve vital tetrazolium chloride staining and partially improve germination or emergence of soybean seedlings. Prochaska (2001) observed that soybean seeds with polymer coatings A and C emerged about one and two weeks later than the untreated control, respectively. Seeds coated with 0.5 g sodium alginate kg^{-1} of seeds recorded the longest plumular axis of plants and largest increase in dry matter weight (Wang Hongyan and Liu Shuyu, 2001).

Tony Vyn (2001) reported a frost that seriously damaged a corn stand from uncoated seed had little effect on a stand that emerged due to seed coating. Crowley (2001) reported that Intellicoat coatings can provide protection to hybrid corn seed under cold stress conditions. Coated hybrid seed can retain its viability for a normal stand establishment in near saturated soil, while uncoated seed showed significant stand loss under the same conditions.

Rasu ***et al.*** (2001) reported that complex coating preparations with polymers which delay emergence, enabled emergence to occur when the best temperature for maize germination was reached in the soil. Coating with 24 mg of polymer $seed^{-1}$ (Vinamul 3650) regulated the rate of water uptake, reduced imbibition damage and improved germination and seedling emergence rate of soybean (Chachalis and Smith, 2001). Johnson ***et al.*** (2002) reported that germination of corn seeds coated with Intelimer polymer was significantly improved than uncoated seeds.

Chapter III

Materials and Methods

With a view to realize the objectives enumerated in the introduction chapter, the field and laboratory experiments were carried out in the wetlands farm and Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore during 2001-03. The experimental details, materials used and methods adopted are given in this chapter.

3.1. EFFECT OF ADDITIONAL DOSE OF N AND K AND FOLIAR SPRAYING OF ORGANIC AND INORGANIC NUTRIENTS ON GROWTH AND YIELD OF PARENTAL LINES IN ADTRH 1 AND CORH 2 RICE HYBRID SEED PRODUCTION

Field experiments were conducted in the wetland farm of Tamil Nadu Agricultural University, Coimbatore for two consecutive seasons during July – November 2001 with ADTRH 1 and January – May 2002 with CORH 2 to study the effect of additional dose of N and K and foliar spraying of organic and inorganic nutrients on growth and yield of parental lines (A x R) in hybrid seed production of rice hybrids ADTRH 1 and CORH 2.

3.1.1. Materials

3.1.1.1. Field location

Field experiments were conducted in the field No E4 and G11 of the wetland farm of Tamil Nadu Agricultural University, Coimbatore with A x R production of ADTRH 1 and CORH 2 respectively. The farm is situated at 11°N latitude and 77°E longitude and at an attitude of 426.72 m above the mean sea level. The soil type of the experimental fields was moderately drained, deep clay loam, haplustalf with a pH range of 7.6 to 7.8.

3.1.1.2. Weather and climate

Normal weather conditions of Coimbatore (mean of 25 years) recorded a mean annual rainfall of 674.2 mm received in 49 rainy days. The mean maximum and minimum temperature are 31.5°C and 21°C respectively. Mean relative humidity ranges from 58 to 63 per cent. Mean bright sunshine hours day^{-1} is 7.3 h with a mean solar radiation of 429.2 cal cm^{-2} day^{-1} (17.68 MJ m^2 day^{-1}). Minimum required agro-meteorological variables recommended for fundamental research in rice by the World Meteorological Organization and the International Rice Research Institute (IRRI, 1980) were considered in the present study.

3.1.1.3. Parental seed material

Genetically pure parental seeds of ADTRH 1 (IR58025 A x IR66 R) and CORH 2 (IR58025 A x C20 R) obtained from the Department of Rice, Tamil Nadu Agricultural University, Coimbatore formed the material for this research. The seed samples were cleaned, graded and utilized for the experiments. The characteristics of the parental lines are furnished in the Annexure I.

3.1.2. Methods

3.1.2.1. Experimental design and layout

The experiments were laid out in split plot design with two replications. Individual sub plots were formed with a buffer spacing of 0.5 m width all around each plot and irrigation channel of 0.75 m was left in between the main plot treatments. The treatments were allotted at random using random number tables. The layout plan of the experiment is given in Figure 1. The net size of each sub plot of this experiment was 6.4 m^2 (3.2 x 2.0 m) (Plate 1a and 1b).

3.1.2.2. Treatment details

The details of the treatments and symbols used are presented below.

Main plot treatments

M_1 – Recommended Dose of Fertilizer (RDF) @ 150:60:60 kg NPK ha^{-1} in four equal splits at basal, active tillering (AT), panicle initiation (PI) and 10 per cent flowering stages.

M_2 – M_1 + 25 kg N and 15 kg K ha^{-1} extra at PI stage

(Total NPK of 175 : 60 : 75 kg ha^{-1})

M_3 – M_1 + 25 kg N and 15 kg K ha^{-1} extra at 10 days after PI (10 DAPI) stage

(Total NPK of 175 : 60 : 75 kg ha^{-1}).

M_4 – M_1 + 25 kg N and 15 kg K ha^{-1} extra at both PI and 10 DAPI stages

(Total NPK of 200 : 60 : 90 kg ha^{-1})

Sub-plot treatments

S_1 – GA_3 @ 75 g ha^{-1} sprayed thrice at flowering,

1^{st} spray : 20 g ha^{-1} at 10-15 per cent flowering (1^{st} day)

2^{nd} spray : 30 g ha^{-1} at next day (2^{nd} day)

3^{rd} spray : 25 g ha^{-1} at one day after second spray (4^{th} day)

S_2 – Spent wash sprayed thrice as in S_1

1^{st} spray : diluted spent wash to 112.5 times

2^{nd} spray : diluted spent wash to 75 times

3^{rd} spray : diluted spent wash to 90 times

S_3 – Humic acid (0.1%) thrice at AT, PI and 10 DAPI

S_4 – Brassinolide (0.3 ppm) thrice as in S_3.

S_5 – $ZnSO_4$ (0.5%) + Boric acid (0.2%) thrice as in S_3.

S_6 – DAP (2.0%) + KCl (1.0%) thrice as in S_3

S_7 – DAP (2.0%) + KCl (1.0%) + $ZnSO_4$ (0.5%) + Boric acid (0.2%) thrice as in S_3.

3.1.3. Crop management

3.1.3.1. Nursery management

3.1.3.1.1. Nursery bed preparation

The nursery field was thoroughly puddled and perfectly leveled. Female and male (A and R lines) seedlings were raised in separate seed beds. DAP was applied @ 50 g sqm^{-1} as basal application in the nursery to ensure robust seedlings.

3.1.3.1.2. Seed rate

The A and R line seeds were sown at a seed rate of 20 kg and 10 kg ha^{-1} respectively. The seeds were first soaked in water for 12 h and then incubated for 24 h. The sprouted seeds were sown sparsely in the seed beds @ 25 g sqm^{-1}.

3.1.3.1.3. Staggered sowing for synchronization

Keeping in view the difference in growth duration of parental lines and to extend the pollen supply time, sowing of male seeds was delayed and staggered thrice at 12, 15 and 18 days in case of IR 66R (ADTRH 1) and 3, 6, 9 days in case of C20R (CORH 2) after female sowing @ 3.5, 3.5 and 3.0 kg ha^{-1} respectively at each sowing.

3.1.3.2. Preparation of main field

The main field was ploughed twice with a tractor drawn disc plough and then water was let into the field for puddling. The field was puddled thrice by a puddler and leveled with a wooden plank.

3.1.3.3. Transplanting

The entire A, first sown R and 50 per cent of second sown R seedlings were transplanted on the same day with a row ratio of 8:2 (A:R) with single seedling $hill^{-1}$. The R line seedlings of remaining 50 per cent of second sown nursery and the entire third sown nursery were transplanted two days after first transplanting. The row spacing maintained between two A lines, two R lines and between A and R line were 15, 30 and 20 cm respectively. The spacing maintained within the row of either

parents was 15 cm. Gap filling was done in all the treatments within a week to obtain desired density of plant population.

3.1.3.4. Fertilizer application

The recommended dose of 150 kg N, 60 kg P and 60 kg K ha^{-1} was applied through urea, superphosphate and muriate of potash respectively. $1/4^{th}$ dose of N and K along with entire P were applied at the time of transplanting. The remaining N and K were applied in three equal splits at active tillering and panicle initiation and 10 per cent flowering. The additional dose of N and P was top dressed along with the regular dose as per the treatment schedule detailed in section 3.1.2.2.

3.1.3.5. Irrigation

A thin film (1-2 cm) of water maintained at the time of transplanting was later on increased to 2-3 cm and this water level was maintained till the establishment of seedlings. Subsequently, the water level was maintained at 5±1 cm depth upto dough stage. Later on, the water was gradually drained off the field.

3.1.3.6. Weed control

Weeds were controlled by the application of Butachlor @ 1.5 kg a.i. ha^{-1} at three days after transplanting. Two hand weedings were taken up at 20^{th} and 40^{th} day after transplanting.

3.1.3.7. Isolation

The experimental field was isolated by using physical barrier (polythene sheet of 2 m height) from the other fields with rice.

3.1.3.8. Rouging

Periodical roguing was done by removing offtypes and pollen shedders from both the parental rows before the commencement of flowering.

3.1.3.9. Supplementary pollination

Supplementary pollination was done by shaking the male rows with the help of a rope. Rope pulling was done twice a day at half an hour interval during peak anthesis time between 10.00 AM and 11.30 AM and it was continued for 10 days.

3.1.3.10. Plant protection measures

Need based application of pesticides and fungicides based on economic threshold level (ETL) was carried out to keep the pest and diseases under check.

3.1.3.11. Harvesting

The male and female lines in each plot were harvested separately with sickles. To avoid mechanical admixture, the male lines were harvested 3-5 days earlier to female lines.

3.1.3.12. Threshing

Threshing of male and female lines was done separately plot wise. Care was taken to avoid admixtures.

3.1.4. Biometric observations

The following biometric characters were recorded at different growth stages on randomly selected five plants in each plot from both the parents except for days to 50 per cent flowering, panicle exsertion and seed set percentage which were recorded only on A line. The methods followed in recording of each of these parameters are described below.

3.1.4.1. Plant height

The height of the main tiller from the ground level to the tip of the matured earhead was measured and expressed in cm.

3.1.4.2. Number of total tillers

The total number of tillers in each hill was counted and the mean was expressed as number of tillers plant^{-1}.

3.1.4.3. Number of productive tillers

The number of panicle bearing tillers in each hill at maturity was counted and recorded.

3.1.4.4. Days to 50 per cent flowering

The number of days taken for attaining 50 per cent flowering in a population was observed and recorded.

3.1.4.5. Panicle length

The distance between the base and tip of the ten randomly selected panicles was measured with linear scale and the mean was expressed in cm.

3.1.4.6. Panicle exsertion

The total length of entire panicle and the length of exserted portion of the panicle were measured with linear scale in randomly selected ten panicles from A line plants and the mean panicle exsertion was calculated using the following formula and expressed in per cent.

$$\text{Panicle exsertion per cent} = \frac{\text{Length of the panicle emerged outside the flag leaf}}{\text{Total length of panicle}} \times 100$$

3.1.4.7. Number of spikelets panicle^{-1}

The number of matured seeds in each randomly selected ten panicles were counted and the mean number of seeds panicle^{-1} was recorded.

3.1.4.8. Seed set

The matured seeds and unfilled – chaffy seeds from randomly selected panicles were separated and counted individually. The mean matured seed set per cent was calculated using the following formula and expressed in per cent.

$$\text{Seed set per cent} = \frac{\text{Total number of filled spikelets in panicle}}{\text{Total number of spikelets in panicle}} \times 100$$

3.1.4.9. 1000 seed weight (ISTA, 1999)

Eight replicates of 1000 seeds were counted in each treatment and weighed in precision balance and the mean 1000 seed weight was expressed in g.

3.1.4.10. Seed yield plant^{-1}

The panicles from ten randomly selected plants of A and R lines from each treatment were threshed and the cleaned seeds were weighed and the mean of 10 plants was expressed in g plant^{-1}.

3.1.4.11. Seed yield ha^{-1}

The seeds from A line and R line were harvested separately plot wise, weighed and computed for unit area and expressed in kg ha^{-1}.

3.1.5. Chemical analysis

3.1.5.1. Plant analysis

The whole plants samples were collected carefully at the harvest stage. The roots of the plant samples were then washed thoroughly with clean water, air dried in shade and finally oven dried at 70°C for two days. The dry weight of whole plant sample was recorded. Then the intact plant samples were finely ground in Willy mill and used for chemical analysis to find out the uptake of nutrients. For calculating nutrient uptake, the nutrient content of seed / grain and straw (analysed separately) was multiplied with the respective dry weights and expressed in kg ha^{-1}. The anlaysis was done as per the standard procedures furnished below.

Particulars		Method Author adopted
Nitrogen	Kjeldahl method	Humphries (1956)
Phosphorus	Triacid digestion and colorimetric estimation	Jackson (1973)
Potassium	Triacid digestion and flame photometry	Jackson (1973)

3.1.5.2. Soil analysis

Soil samples were taken from surface layer (15 cm) before the commencement of the experiment and immediately after the harvest of each crop from each plot. The samples were shade dried, powdered to pass through 2 mm sieve and used for analysis of available N, P and K nutrients. The methods of analysis adopted are as detailed below.

Particulars	Method adopted	Author
Available N ($KMnO_4$-N)	Alkaline permanganate	Subbiah and Asija (1956)
Available P (Olsen-P)	0.5 M sodium bicarbonate	Olsen ***et al.*** (1954)
Available K	Neutral normal ammonium acetate	Standford and English (1949)

3.1.6. Seed quality analysis

3.1.6.1. Germination (ISTA, 1999)

In each treatment, 4 x 100 seeds were selected at random and kept for germination in roll towel medium. The test was carried out in a germination room maintained with 25 ± 2°C temperature, 95 ± 3 per cent RH. On 14th day, evaluation was carried out and all the normal seedlings were counted and expressed in per cent.

3.1.6.2. Root length

Ten normal seedlings were selected at random in each replication and the length of the root was measured from the collar region to tip and the mean value was expressed in cm seedling^{-1}.

3.1.6.3. Shoot length

From the above seedlings, the length of the shoot was measured from the collar to tip of the primary leaf and the mean value was expressed in cm seedling^{-1}.

3.1.6.4. Seedling dry matter production

After measuring the root and shoot length, the ten normal seedlings were shade dried for 24 h and then in a hot-air-oven maintained at 85 ± 1°C for 24 h. Then, they were cooled in a desiccator which contained calcium chloride for 30 min. and weighed. The mean weight was expressed in mg seedling^{-1}.

3.1.6.5. Vigour index (Abdul-Baki and Anderson, 1973)

The vigour index was computed using the following formula and expressed in whole number.

Vigour index = Germination percentage x mean length of seedling

3.2. PHYSIOLOGICAL AND BIOCHEMICAL BASIS OF HYBRID VIGOUR ON SEED QUALITY ATTRIBUTES

The laboratory experiments were conducted to enumerate the physiological and biochemical basis of hybrid vigour in rice hybrids on seed quality attributes. The details of the material and methods adopted during the course of investigation are described hereunder.

3.2.1. Seed material

Fresh seeds of two rice hybrids viz., ADTRH 1, CORH 2 and their parental lines viz., IR58025A and IR58025B of both the hybrids, IR66R of ADTRH1 and

C20R of CORH 2 were collected from Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore. All the seeds were produced in same location in isolation during June – October, 2002.

3.2.2. Experimental methods

The seeds of the above hybrids and parental lines were dried further to bring down the moisture content to less than 13 per cent. Then, they were cleaned with the help of suitable sieve and winnowed to obtain uniform sized seeds. Seed samples of 500 g each from all the parental lines and hybrids were stored in the deep freeze at 10°C till they were subjected to various vigour tests detailed below.

3.2.3. Imbibition rate (Takahashi, 1961)

Randomly selected 2 x 25 seeds in each sample were placed in between moistened filter paper and incubated at 25° ± 1°C to avoid the possible effect of temperature variations on water absorption during imbibition. Seeds were incubated for 0 to 20 h. At 4 h interval, the seeds were taken out, and the surface moisture on the seed was removed by gently pressing between 2 to 3 layers of filter paper and the fresh weight was recorded. Then, the seeds were dried to a constant weight at 103°C ± 1°C for 16 h. The seed moisture was estimated and expressed in percentage on wet weight basis (ISTA, 1999).

3.2.4. Seedling growth rate tests

3.2.4.1. Time taken for sprouting

Randomly selected 20 x 4 seeds in each of the parents and hybrids were surface sterilized with 0.1 per cent mercuric chloride solution for 10 minutes, washed

well in water and placed on the moist filter paper placed inside a petriplate and covered with a lid. Observation on the sprouting of seeds was recorded at an interval of four hours till such time that radicle emerged from 50 per cent of the seeds.

3.2.4.2. Radicle length on time bound germination (Whittington and Fierlinger, 1972)

Four replicates of 20 seeds were allowed to germinate using the top of the paper medium in the petriplates. At the expiry of 48 h, the length of radicles were measured using linear scale and the mean length of the radicle was expressed in cm.

3.2.4.3. Rate of germination (Maguire, 1962)

A total of 4 x 100 seeds from each treatment were placed on wet germination paper and allowed to germinate. The emergence was counted daily from 4^{th} day of sowing until 14^{th} day. From the mean per cent germination recorded on each counting date, speed of germination was calculated employing the following formula.

$$\text{Rate of germination} = \frac{X_1}{Y_1} + \frac{X_2 - X_1}{Y_2} + \ldots\ldots\ldots + \frac{Xn - X(n-1)}{Yn}$$

where,

Xn = Per cent germination on n^{th} day

Yn = Number of days from sowing to n^{th} count.

3.2.4.4. Germination as detailed in 3.1.6.1.

3.2.4.5. Root length as detailed in 3.1.6.2.

3.2.4.6. Shoot length as detailed in 3.1.6.3.

3.2.4.7. Seedling dry matter production as detailed in 3.1.6.4.

3.2.4.8. Vigour index as detailed in 3.1.6.5.

3.2.4.9. Field emergence

In each treatment 4 x 100 seeds were sown in the nursery bed and the normal seedlings that had emerged were recorded on 25^{th} day and expressed in per cent.

3.2.5. Enzyme activity

3.2.5.1. Dehydrogenase activity (Kittock and Law, 1968)

A representative seed sample from each treatment was taken and pre-conditioned by soaking them in water for 16 h at room temperature. Out of this, 4 x 10 seeds were taken at random and prepared by removing the seed coat. Then, the seed coat removed seeds were steeped in 0.5 per cent of 2, 3, 5 – Triphenyl tetrazolium chloride solution and kept in the dark at 40°C for 4 h for staining. After staining, the stained seeds were soaked in methyl cellosolve solution, 5 ml 10^{-1} seeds for 4-6 h with occasional stirring till the extraction of red colour formazon was completed. The extract was decanted and the intensity of colour was read in spectrophotometer at 470 nm. The OD values were reported as dehydrogenase activity.

3.2.5.2. Total ATPase activity (Unbreit *et al.*, 1964)

Seeds were allowed to pregerminate for 48 h. Four replicates of 1 g pregerminated seeds were homogenized with 0.125 M sucrose solution and cold centrifuged at 4°C for 15 min. The supernatant from each sample was collected and the volume made upto 10 ml with distilled water in a test tube. A test tube with 10 ml of distilled water served as the blank. Then 0.2 ml of solution from sample and blank tubes was taken and to this 9 ml of 0.25 M sucrose solution was added. Then 0.3 ml of 0.02 M magnesium chloride and calcium chloride solutions were poured one after other into both the sample and blank tubes respectively. The aggregate solutions were kept for incubation at 37°C under water bath. Eventually, the reaction was terminated by adding 1 ml of TCA and the activity of ATPase expressed in µmol of P g^{-1} h^{-1}.

3.2.5.3. Peroxidase activity (Malik and Singh, 1980)

Four replicates of 250 mg of seeds in each sample were first allowed to pregerminate for 48 h and then homogenized in 5 ml of 0.25 M Tris buffer (pH 6.0) and centrifuged at 10,000 rpm for 10 min. at 5°C. Enzyme activity was measured colorimetrically using pyrogallol as substrate. The reaction mixture consisted of 0.4 ml of enzyme extract, 0.5 ml of 1 per cent H_2O_2 pyrogallol. This was incubated for 10 min. at 25°C after which the reaction was stopped by adding 0.5 ml of 5 per cent (v/v) H_2SO_4. The OD values at zero time and at the expiry of 10 min. were measured in spectrophotometer at 420 nm with suitable blank. Then the peroxidase activity was expressed as difference in OD 10 min^{-1}.

3.2.5.4. Catalase activity (Povolotskaya and Sedenka, 1956)

Catalase activity was assayed in the crude extract of intact seeds, pre-germinated for 48 h. Four replicates of 250 mg of seeds in each sample were homogenized in 0.066 M sodium phosphate buffer (pH 6.8) and centrifuged at 2000 rpm for 10 min. The reaction mixture consisted of 5 ml of phosphate buffer (pH 6.8), 4 ml of 0.3 N hydrogen peroxide (substrate) and 0.2 ml of enzyme extract. The reaction was stopped after 15 min. of incubation by addition of 10 ml of 2 N H_2SO_4. The blank was maintained for each set in which 0.2 ml of enzyme extract was added after the addition of $2NH_2SO_4$. The contents were titrated against 0.1 N $KMNO_4$ and titre values were noted down. Difference between the titre values, gives the volume of permanganate equivalent to enzyme activity in ml of 0.01 N $KMnO_4$ min^{-1} ml^{-1}.

3.2.5.5. α-amylase activity (Simpson and Naylor, 1962)

Twenty gram of agar shreds and ten gram of potato starch were mixed together in water to form a paste and the volume was made upto 1000 ml. The homogenous solution of agar starch mixture after boiling was poured into

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

3.2.6. Stress tests

3.2.6.1. NH_4Cl soak test (Vanderlip *et al.*, 1973)

A total of 4 x 20 seeds were soaked in eight per cent ammonium chloride (NH_4Cl) solution for 8 h under room temperature. The seeds after soaking were germinated in roll towel adopting standard germination test as detailed in 3.1.6.1. and the germination, root length, shoot length and vigour index were measured by adopting the methods detailed elsewhere in this chapter.

3.2.6.2. D-mannitol soak test (Lad, 1986)

Circular pieces of cotton roll with even thickness along with Whatman No. 1 filter paper were placed in petridishes and 4 x 20 seeds were placed in each petriplate over the filter paper. To which 20 ml of 20 mM D-mannitol solution was added. After 120 h of sowing, the germination, root and shoot length and vigour index were measured using the methods detailed elsewhere in this chapter.

3.2.6.3. Anaerobic germination

Four replicates of 10 seeds each were uniformly placed in 100 ml beakers containing water upto 5 cm. The beakers were placed in germination room maintained at 25 ± 2°C and 95±3% RH. The seeds were allowed to germinate under anaerobic

condition for 14 days. On 14th day, germination, root and shoot length of seedlings and vigour index were measured using the methods detailed elsewhere in this chapter.

3.2.6.4. Exhaustion test

Twenty seeds of four replicates were placed on a seed placement line drawn on a roll towel medium and placed in a glass jar to prevent evaporation. The entire set up was placed in a refrigerator maintained at 10°C for ten days (Plate 2). Then, they were transferred to germination room maintained at 25 ± 3°C temperature and 95 ± 3 per cent RH. After 14 days, roots and shoots extended beyond root line and shoot line drawn at 5.0 cm below and 3.75 cm above the seed placement line respectively, were considered and counted as vigourous seedlings and expressed in percentage. In addition, the mean root and shoot length and vigour index were measured and expressed as suggested elsewhere in this chapter.

3.2.6.5. Bioassay test (Basu *et al.*, 1990)

Four replicates of 25 seeds each of rice hybrids and parental lines and high – vigour seeds of finger millet (***Eleusine coracana***) were germinated simultaneously in an air – tight, 2.30 litre capacity (outside dia. 16 cm, height 16 cm) desiccator. Rice seeds (stock material) were placed on a moist blotter (20 cm x 13 cm), which was wrapped on the outer surface of an empty 250 ml capacity glass bottle (outside dia. 5 cm, height 14.5 cm). Before placing on the blotter, rice seeds were sterilized with 0.1 per cent mercuric chloride solution for 30 min. followed by thorough washing and imbibition in distilled water for 2 h. Finger millet seeds (bioassay material) for each treatment were placed in one row on a moist blotting paper (size 44.5 cm x 15.5 cm) in a straight line leaving a margin of 2.5 cm from the upper edge of the blotter (Plate 3).

High - vigour finger millet seeds were used for the bioassay to enable seeds to germinate very quickly and to record seedling growth after 48 h which would coincide with the major phase of volatile gas production by stock material. The blotter with the finger millet seeds was introduced into the desiccator in such a way that the inner wall of the desiccator was uniformly lined by the blotting paper sheet. 30 ml of water was added to the bottom of the desiccator so that about 1 cm of the blotter with finger millet seeds could be immersed in the standing water to ensure adequate moisture supply to the germinating finger millet seeds. The glass bottles containing the blotter with rice seeds of different parental lines and hybrids were carefully placed inside the desiccator on a 6.5 cm diameter petridish containing 30 ml of water for the germinating rice seeds.

The desiccators were then securely closed air tight by glass lids which were lined with vaselline. There was also a blank set (control) in which only finger millet seeds were placed. The desiccators were kept in a temperature controlled room at 23 ± 1°C and after 48 h, the germination percentage and seedling growth of rice and finger millet were recorded. This experiments was repeated thrice and the mean germination, root length, shoot length and vigour index of both rice and fingermillet were recorded as detailed elsewhere in this chapter.

3.2.6.6. Accelerated ageing (Delouche and Baskin, 1973)

The sufficient quantity of seeds were subjected to accelerated ageing by incubating seeds at 40 ± 1°C and 92 +2 % RH. Seeds were kept in a single layer on a perforated wire mesh in the desiccator containing distilled water. These desiccators were incubated in a thermostatically controlled oven at a temperature of 40 ± 1°C. The seed samples in each variety were removed at an interval of 3, 6 and 9 days and shade dried until original weight was obtained. Again, they were kept in a

desiccator over fused calcium chloride for five days to equilibrate the seed moisture (Basu ***et al.***, 1979). These aged seeds along with non-aged seed were evaluated for the following seed quality parameters.

3.2.6.6.1. Germination as detailed in 3.1.6.1.

3.2.6.6.2. TZ-viability per cent (ISTA, 1999)

After staining the seeds as detailed in 3.2.5.1, the stained seeds were critically evaluated and the normally stained seeds were counted and expressed in per cent.

3.2.6.6.3. Root length as detailed in 3.1.6.2.

3.2.6.6.4. Shoot length as detailed in 3.1.6.3.

3.2.6.6.5. Seedling dry matter production as detailed in 3.1.6.4.

3.2.6.6.6. Vigour index as detailed in 3.1.6.5.

3.2.6.6.7. Dehydrogenase enzyme activity as detailed in 3.2.5.1

3.2.5.6.8. Electrical conductivity test (Presley, 1958)

2 x 50 seeds from each treatment were taken at random and soaked in 100 ml of deionised water for 16 h at room temperature and decanted to obtain the leachate and the electrical conductivity of leachate was measured using digital conductivity meter with an electrode possessing a cell constant of 1.0. The electrical conductivity of the seed leachate was expressed in dSm^{-1}.

3.2.6.6.9. Free sugars content (Somogyi, 1952)

To one ml of the seed leachate, one ml of copper reagent was added in a test tube and boiled for 15 min. After cooling in running water, one ml of Nelson's arseno molybdate reagent was added and the volume made up to 10 ml with distilled water. The colour complex developed was measured with an spectrophotometer at 620 nm.

The OD values were referred to a glucose standard curve and expressed in µg 50 seeds^{-1} 50 ml^{-1} of distilled water.

3.2.6.6.10. Free amino acid content (Ching and Ching, 1964)

One ml of 0.2 per cent ninhydrin was added to one ml of seed leachate and boiled for 15 min. in boiling water bath. Then, it was cooled in running water and diluted to 10 ml. The intensity of colour developed was read against a leusine standard in spectrophotometer at 620 nm and expressed in µg 50 seeds^{-1} 50 ml^{-1} of distilled water.

3.3. ESTIMATION OF QUALITY LOSS ON OCCURRENCE OF SPLIT HUSK SEEDS IN RICE HYBRIDS AND FEMALE PARENT

A laboratory experiment was conducted to estimate the quality loss on occurrence of split husk seed in rice hybrids ADTRH 1, CORH 2 and their female parent IR 58025 A. The details of the materials used and methods adopted during the course of investigation are described below.

3.3.1. Seed material

From the bulk seeds of IR58025 A, ADTRH 1 and CORH 2, normal and split husk seeds were separated and subjected to various quality evaluation along with bulk (unseparated) seeds. Samples of sufficient quantity of each fraction were stored in the deep freeze at 10°C till they were evaluated for the following seed quality attributes.

3.3.2. Seed quality attributes

3.3.2.1. Imbibition rate as detailed in 3.2.3.

3.3.2.2. 1000 seed weight as detailed in 3.1.4.9.

3.3.2.3. Seed to husk ratio

Eight replicates of 100 seeds each were randomly selected, the husk including lemma and palea and caryopsis were separated manually and their respective weights were recorded in a sensitive electronic balance in grams. The seed to husk ratio was calculated based on mean weight.

3.3.2.4. Time taken for sprouting as detailed in 3.2.4.1.

3.3. 2.5. Radicle length on time bound germination as detailed in 3.2.4.2.

3.3. 2.6. Rate of germination as detailed in 3.2.4.3.

3.3. 2.7. Germination as detailed in 3.1.6.1.

3.3. 2.8. Root length as detailed in 3.1.6.2.

3.3. 2.9. Shoot length as detailed in 3.1.6.3.

3.3. 2.10. Seedling dry matter production as detailed in 3.1.6.4.

3.3. 2.11. Vigour index as detailed in 3.1.6.5.

3.3. 2.12. Exhaustion test as detailed in 3.2.6.4.

3.3.2.13. Electrical conductivity test **as detailed in 3.2.6.6.8.**

3.3.2.14. Enzyme activity

3.3.2.14.1. Dehydrogenase as detailed in 3.2.5.1.

3.3.2.14.2. Total ATPase as detailed in 3.2.5.2.

3.3.2.14.3. Peroxidase as detailed in 3.2.5.3.

3.3.2.14.4. Calatase as detailed in 3.2.5.4.

3.3.2.14.5. α-amylase as detailed in 3.2.5.5.

3.4. EFFECT OF SEED COATING WITH POLYKOTE POLYMER IN RICE HYBRIDS AND PARENTAL LINES

A laboratory experiment was conducted to study the bioefficacy of polymer coating on rice. The materials used and methods adopted in this experiment are furnished below.

3.4.1. Standardisation of dose and dilution of polykote for rice seeds

3.4.1.1. Seed coating polymer

The seed coating polymer 'POLYKOTE' obtained from Little's Oriental Balm & Pharmaceutical Ltd., Chennai was used for this experiment.

3.4.1.2. Treatment details

Standardization for fixing optimum dosage was carried out using B line (IR58025B) seeds. Different dosage and water dilution tried are detailed below.

Polykote 5g + 90 ml water kg^{-1}	Polykote 3g + 90 ml water kg^{-1}
Polykote 5g + 70 ml water kg^{-1}	Polykote 3g + 70 ml water kg^{-1}
Polykote 5g + 50 ml water kg^{-1}	Polykote 3g + 50 ml water kg^{-1}
Polykote 5g + 30 ml water kg^{-1}	Polykote 3g + 30 ml water kg^{-1}
Polykote 5g + 15 ml water kg^{-1}	Polykote 3g + 15 ml water kg^{-1}

The required quantity of polykote was diluted with respective amount of water for each treatment and the polykote solution was then poured over the rice seeds at a constant rate and mixed well to achieve uniform coating. After coating, the seeds were shade dried until original moisture content was obtained. After drying, the seeds were tested for the following seed quality attributes along with uncoated seeds.

3.4.1.3. Seed quality attributes

3.4.1.3.1. Imbibition rate as detailed in 3.2.3.
3.4.1.3.2. Time taken for sprouting as detailed in 3.2.4.1.
3.4.1.3.3. Radicle length on time bound germination as detailed in 3.2.4.2.
3.4.1.3.4. Rate of germination as detailed in 3.2.4.3.
3.4.1.3.5. Germination as detailed in 3.1.6.1.
3.4.1.3.6. Root length as detailed in 3.1.6.2.
3.4.1.3.7. Shoot length as detailed in 3.1.6.3.
3.4.1.3.8. Seedling dry matter production as detailed in 3.1.6.4.
3.5.1.3.9. Vigour index as detailed in 3.1.6.5.

3.4.1.3.10. Germination in conventional method

From each treatment 4 x 100 seeds were packed in cloth bags and soaked in water for 12 h and then, they were incubated in dark for 24 h. At the expiry of 24 h, the seeds were sown in nursery beds and the number of seeds germinated in each treatment were counted and the mean of all replications was expressed in percentage.

3.4.2. Effect of seed coating with different colours of polykote in rice hybrids and parental lines

The best dosage standardised in the previous experiment was applied to treat all the parental and hybrid seeds in order to test the bio-efficacy of different colours of polykote on seeds of rice hybrids and their parental lines (Plate 4a and 4b). The seed materials and polykotes colours tried in this experiment are given below.

Parental lines / Hybrid	Polykote treatment
IR58025A	Pink
IR58025B	Red
IR66R	Green
C20R	Blue
ADTRH 1	Black
CORH 2	Clear

The seeds of parents and hybrids were coated with different colours of polykote @ 5 g diluted with 70 ml of water kg^{-1}. The coated seeds along with uncoated seeds were evaluated for the following seed quality attributes.

3.4.2.1. Seed quality attributes
3.4.2.1.1. Time taken for sprouting as detailed in 3.2.4.1.
3.4.2.1.2. Radicle length on time bound germination as detailed in 3.2.4.2.
3.4.2.1.3. Rate of germination as detailed in 3.2.4.3.
3.4.2.1.4. Germination as detailed in 3.1.6.1.
3.4.2.1.5. Root length as detailed in 3.1.6.2.
3.4.2.1.6. Shoot length as detailed in 3.1.6.3.
3.4.2.1.7. Seedling dry matter production as detailed in 3.1.6.4.
3.4.2.1.8. Vigour index as detailed in 3.1.6.5.

3.5. STATISTICAL ANALYSIS

3.5.1. Analysis of variance

The analysis of variance for all the characters were worked out as suggested by Panse and Sukhatme (1999). Wherever necessary, the per cent values were transformed to angular (Are sine) values before analysis. The critical difference (CD) was worked out at 5 per cent probability level.

3.5.2. Estimation of heterosis (Fonseca and Patterson, 1968)

The mean values of parents as well as hybrids were used to estimate heterosis per cent under two categories.

3.5.2.1. Relative heterosis (di)

Deviation of hybrid from mid-parent expressed in per cent.

$$di = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

3.5.2.2. Heterobeltiosis (dii)

Deviation of hybrid from best parent expressed in per cent.

$$dii = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

where,

$\overline{F_1}$ = Mean value of hybrid

$\overline{MP}$ = Mean of the parental value of the corresponding parents.

$\overline{BP}$ = Mean of the better parent of the cross.

Test of significance (t)

Significance of relative heterosis and heterobeltiosis was worked out by using the formula of Wynne ***et al.*** (1970).

$$t = \frac{\overline{F_1} - \overline{D}}{\sqrt{3/8\ V_E}}$$

where,

$\overline{F_1}$ = mean value of hybrids

$\overline{D}$ = mean of mid-parent and better parent of di and dii respectively.

V_E = Error variance

Chapter IV

Results

The experimental results on response of various growth and yield attributes of A and R lines to the additional dose of N and K application and various foliar spray treatments in ADTRH1 and CORH 2 rice hybrid seed production are presented in this chapter. Besides, results on estimation of hybrid vigour, quality loss on occurrence of split husk seeds and effect of polykote seed coating on performance of rice seeds are also presented in this chapter.

4.1. EFFECT OF ADDITIONAL DOSE OF N AND K AND FOLIAR SPRAYING OF ORGANIC AND INORGANIC NUTRIENTS ON GROWTH AND YIELD OF PARENTAL LINES IN ADTRH 1 AND CORH 2 RICE HYBRID SEED PRODUCTION

All the biometric observations on growth and yield attributes and nutrient uptake were recorded in both A and R lines of ADTRH 1 and CORH 2 except for a few parameters viz., days to 50 per cent flowering, panicle exsertion per cent and seed set per cent which were recorded in A line only.

4.1.1. Biometric observations on growth and yield attributes

4.1.1.1. Plant height

A line (Table 1)

On application of additional dose of N and K at both panicle initiation (PI) and 10 days after PI (DAPI), plant height was predominantly higher with 79.7 cm in ADTRH 1 and 84.3 cm in CORH 2. A phenomenal rise in plant height was noted due to additional dose given only at PI with 78.4 cm and 82.8 cm respectively in ADTRH 1 and CORH 2. Foliar spraying of GA_3 produced tallest plants of 91.2 cm and 90.7 cm in ADTRH 1 and CORH 2 respectively followed by brassinolide and DAP + KCl + $ZnSO_4$ + Boric acid. The shortest plants of 75.0 and 79.0 cm were

recorded in humic acid in both the hybrids respectively. However, the synergistic effect of fertilizer doses with foliar spray treatments seems to be negligible.

R line (Table 2)

Plant height was remarkably higher due to application of additional dose of N and K both at PI and 10 DAPI stages with 87.6 cm in ADTRH 1 and 106.2 cm in CORH 2. The plant height recorded by additional fertilizer dose applied at PI was comparable to additional dose applied at 10 DAPI stage with 84.9 and 83.7 cm in ADTRH 1 and 103.7 and 102.4 cm in CORH 2 respectively. Similar to A line, R line also responded well to GA_3 with profound increase in plant height in ADTRH 1 (108.1 cm) and CORH 2 (111.2 cm).

Foliar spraying of DAP + KCl + $ZnSO_4$ + Boric acid also increased the plant height appreciably with 83.8 and 103.7 cm respectively in ADTRH 1 and CORH 2. Humic acid recorded the least values for this parameter. The interaction effect of GA_3 with additional dose of N and K both at PI and 10 DAPI was pivotal in production of tallest plants of 103.2 cm in ADTRH 1 and 113.8 cm in CORH 2. Foliar spraying of DAP + KCl with or without $ZnSO_4$ + Boric acid found to have the next best interaction with the aforesaid fertilizer dose treatments.

4.1.1.2. Number of total tillers

A line (Table 3)

The additional dose of N and K both at PI and 10 DAPI predominated with highest number of total tillers in ADTRH 1 (12.0) and CORH 2 (10.7) followed by additional dose of N and K at PI with 10.8 and 10.2 tillers respectively in the above hybrids. Whereas, application of recommended dose of fertilizer (RDF) resulted in least number of total tillers in ADTRH 1 (9.0) and CORH 2 (8.7).

The foliar spray treatments, DAP + KCl + $ZnSO_4$ + Boric acid followed by DAP + KCl increased the number of total tillers in both ADTRH 1 (11.5 and 11.0) and in CORH 2 (10.4 and 10.1 respectively). Humic acid in ADTRH 1 (9.20) and spentwash in CORH 2 (9.1) recorded the lowest number of total tillers. The additive effect of fertilizer dose with foliar spray treatments was not evident conspicuously.

R line (Table 4)

The superior effect of additional N and K both at PI and 10 DAPI was much pronounced in R lines of ADTRH 1 (15.9) and CORH 2 (11.5) also and that was comparable with additional dose of N and K at PI in ADTRH 1 (15.1). The RDF produced only 12.8 and 10.1 number of total tillers in R lines of ADTRH 1 and CORH 2.

Spraying DAP + KCl with or without $ZnSO_4$ + Boric acid resulted in higher number of total tillers in ADTRH 1 (16.1 and 16.3) and CORH 2 (12.3 and 11.7) respectively. Spraying of $ZnSO_4$ + Boric acid in ADTRH 1 (15.5) and brassinolide in CORH 2 (10.8) found to follow the foreseen treatments. Humic acid spray produced remarkably lower number of total tillers in ADTRH 1 (12.2) and CORH 2 (9.4). The interaction effect did not set an impact on total tillers.

4.1.1.3. Number of productive tillers

A line (Table 5)

In ADTRH 1, highest number of tillers was productive due to additional N and K both at PI and 10 DAPI (9.3) followed by additional dose either at PI (8.7) or at 10 DAPI (7.7). Similarly, the aforesaid trend was adhered in CORH 2 also. The effect of RDF was not commendable as it recorded only 6.8 and 6.1 number of productive tillers in ADTRH 1 and CORH 2 respectively.

Among the foliar spray treatments, dominating effect of DAP + KCl with the highest (8.8) number of productive tillers was comparable with DAP + KCl + $ZnSO_4$ + Boric acid (8.7) in ADTRH1. Conversely, the trend was reverse in CORH 2 with

the maximum values of 7.7 and 8.1 among the foreseen treatments. Humic acid in ADTRH 1 (7.4) and spentwash in CORH 2 (6.3) turned remarkably lower number of tillers productive. The effect of interaction was found to be inconsistent as its significant existence in CORH 2 was not evident in ADTRH 1.

R line (Table 6)

A profound increase in the number of productive tillers was registered due to additional dose of N and K both at PI and 10 DAPI in ADTRH 1 (13.1) and CORH 2 (9.0). Application of additional N and K either at PI or at 10 DAPI stages also found to be notable with 12.2 and 10.9 productive tillers in ADTRH1 and 8.4 and 8.1 in CORH 2 in the same order. RDF converted only 9.6 and 7.6 number of tillers productive in the aforesaid hybrids respectively.

Superior effect of DAP + KCl + $ZnSO_4$ + Boric acid foliar spray was evident as more number of tillers were productive in both ADTRH 1 (14.3) and CORH 2 (10.2). DAP + KCl (13.3) followed by $ZnSO_4$ + Boric acid (12.4) in ADTRH 1 and DAP + KCl (9.5) followed by Brassinolide (8.6) in CORH 2 established next best superiority. Whereas, the additive effect of fertilizer dose with foliar spray failed to convert number of tillers productive significantly.

4.1.1.4. Days to 50 per cent flowering (Table 7)

A line (Table 7)

Application of additional dose of N and K both at PI and 10 DAPI advanced the 50 per cent flowering by 3.4 days (89.5 DAS) in ADTRH1 and by 3.8 days (89.9 DAS) in CORH 2 as compared to RDF (92.9 and 93.71 DAS respectively) in the above hybrids. Application of additional N and K at 10 DAPI was also comparable to the aforesaid treatment for earliness in 50 per cent flowering.

Brassinolide was the only foliar spray treatment significantly advanced the 50 per cent flowering at 90.5 days in ADTRH 1 and 91.1 days in CORH 2. There was no appreciable variation among rest of the foliar spray treatments. There was no significant interactive effect influenced on the days to 50 per cent flowering in both the hybrids.

4.1.1.5. Panicle length

A line (Table 8)

Panicle length was found to sway over different fertilizer dose treatments only in ADTRH 1. There was a marked increase in the panicle length when additional dose of N and K applied both at PI and 10 DAPI (23.95 cm) followed by additional dose at 10 DAPI (23.41 cm) and additional dose at PI (22.96 cm). The RDF managed to put up a panicle length of 22.54 cm.

Whereas, the foliar spray treatments exerted profound effect in both ADTRH 1 and CORH 2. The effect of GA_3 was predominated with the longest panicles of 24.15 and 24.25 cm respectively in ADTRH 1 and CORH 2. Brassinolide with 23.29 and 23.48 cm and spentwash with 23.26 and 23.43 cm respectively in ADTRH 1 and CORH 2 were found to be the next best foliar spray treatment with regard to panicle length. However, the interaction had no astounding effect on panicle length.

R line (Table 9)

Similar to A line, in R line also appreciable changes in panicle length was notable due to the fertilizer doses only in ADTRH 1. Longest panicles (22.10 cm) were recorded due to additional dose of N and K applied at PI and 10 DAPI which was comparable with additional N and K applied at 10 DAPI (22.06 cm). RDF put forth panicles of 21.24 cm long.

Variation due to foliar spray treatment was significant in both the hybrids. Among the foliar spray treatments, GA_3 found to be dominating by producing longest panicles (23.05 and 22.21 cm) followed by brassinolide (21.95 and 21.71 cm) in ADTRH 1 and CORH 2 respectively. However, the interaction of fertilizer doses with foliar spray treatments failed to exist.

4.1.1.6. Panicle exsertion

A line (Table 10)

Remarkably higher panicle exsertion was achieved when the additional dose of N and K was applied both at PI and 10 DAPI in ADTRH 1 (79.1%) and CORH 2 (75.8%). The next best exsertion was evident due to additional dose at PI to a tune of 78.0 and 74.4 per cent followed by additional dose at 10 DAPI with 77.0 and 73.4 per cent in ADTRH 1 and CORH 2 respectively. In RDF, 75.9 and 70.7 per cent of panicles got exserted in ADTRH 1 and CORH 2 respectively.

Foliar spraying of GA_3 exemplies in registering a marked increase in panicle exsertion in ADTRH 1 (90.0%) and CORH 2 (81.5%) followed by spentwash (78.0 and 76.2%) and brassinolide (77.0 and 74.4%) in the aforesaid hybrids respectively. Panicle exsertion was remarkably lower in humic acid (73.3 and 70.0%) in both the hybrids. The interaction of fertilizer doses and foliar spray treatments did not set an impact on panicle exsertion.

4.1.1.7. Total number of spikelets panicle^{-1}

A line (Table 11)

While foliar spray treatments had astounding effect on total number of spikelets panicle^{-1}, the fertilizer dose and its possible interaction with foliar spray treatments failed to impart differences in both the hybrids. Foliar spraying of DAP + KCl + $ZnSO_4$ + Boric acid promoted a phenomenal rise in number of total spikelets panicle^{-1} in ADTRH 1 (141.0) and CORH 2 (130.0). Marginal increase was evident in

both the hybrids due to DAP + KCl (140.0 and 129.1) followed by Brassinolide (130.7 and 129.1) respectively.

R line (Table 12)

While, the fertilizer doses failed to impart variation in ADTRH 1, its effect was conspicuous in CORH 2 on total number of spikelets panicle^{-1}. A profound increase in number of spikelets due to the additional dose of N and K both at PI and 10 DAPI (118.1) followed by additional dose at PI (115.6) and at 10 DAPI (111.4) was noted. The RDF recorded the least (107.5) number of spikelets panicle^{-1}.

Appreciable variation due to foliar spray treatments predominated in both ADTRH 1 and CORH 2. Maximum number of spikelets panicle^{-1} was recorded in DAP + KCl + $ZnSO_4$ + Boric acid in ADTRH 1 (123.6) and CORH 2 (119.4). DAP + KCl was found to be comparable with the above treatment by recording 122.6 and 116.9 number of spikelets panicle^{-1} in ADTRH 1 and CORH 2 respectively. The synergistic effect of fertilizer doses with foliar spray treatments failed to impart significant variations.

4.1.1.8. Seed set

A line (Table 13)

The additional N and K applied at PI and 10 DAPI resulted in highest seed set of 29.8 and 27.6 per cent in ADTRH 1 and CORH 2 respectively, which was almost comparable to additional dose of N and K at PI with 29.4 and 27.2 per cent respectively in the aforesaid hybrids. Application of additional dose of N and K at 10 DAPI not varied much from RDF (28.6 and 26.7) in both ADTRH 1 and CORH 2 respectively.

Among the foliar spray treatments, GA_3 established its superiority over the other treatments by recording remarkably higher seed set of 39.7 and 34.3 per cent in

ADTRH 1 and CORH 2 respectively. Spentwash, as the next best treatment recorded marginally higher seed set of 31.8 and 28.6 per cent in the above hybrids respectively. However, the additive effect of fertilizer doses with foliar spray treatments was found to be non significant.

4.1.1.9. 1000 seed weight

A line (Table 14)

The additional dose of N and K applied either at PI or at 10 DAPI or at both the stages recorded 19.07, 19.06 and 19.23 g respectively which were comparable to each other in ADTRH 1. Though, a similar trend was observed in CORH 2 also, additional dose of N and K at PI recorded slightly lower seed weight (20.33 g) compared to the other two additional doses (20.47 and 20.50 g respectively). The RDF, however, recorded the lowest 1000 seed weight of 18.71 g and 19.91 g in the aforesaid hybrids respectively.

Among the foliar spray treatments, DAP + KCl with or without $ZnSO_4$ + Boric acid recorded the predominantly higher 1000 seed weight of 19.57 and 19.34 g in ADTRH 1 and 20.65 and 20.34 g in CORH 2, of which the values of ADTRH 1 were on par with each other. The positive interaction effect in CORH 2 did not sustain in ADTRH 1.

R line (Table 15)

There was a considerable influence on the weight of 1000 grains due to fertilizer dose and foliar spray treatments in both the hybrids. Irrespective of stage of application of additional dose of N and K, the weight of 1000 grains ranged between 22.80 and 22.97 g in ADTRH 1 and 23.82 and 24.32 g in CORH 2 which were comparable with each other. The RDF recorded lowest weight of 21.67 and 23.61 g in ADTRH 1 and CORH 2 respectively.

Foliar spraying of DAP + KCl, either sole or in combination with $ZnSO_4$ + Boric acid produced heavier seeds at a range of 23.02 to 23.31 g in ADTRH 1 and 24.13 to 24.48 g in CORH 2. The seed weight of rest of the treatments were on par and ranged from 22.13 to 22.48 g in ADTRH 1 and 23.79 to 23.93 g in CORH 2. Whereas, the combined effect of fertilizer doses with foliar spray treatment had no profound impact on seed weight.

4.1.1.10. Seed / grain yield plant^{-1}

A line (Table 16)

Variation in hybrid seed yield plant^{-1} harvested from A line was remarkable among fertilizer doses and foliar spray treatments. The additional dose of N and K at PI and 10 DAPI registered marked increase in seed yield plant^{-1} of ADTRH 1 (5.52 g) and CORH 2 (4.75 g). The yield increase was phenomenal due to additional dose at PI (5.24 and 4.62 g) and additional dose at 10 DAPI (4.91 and 4.45 g) respectively in the above hybrids. The RDF recorded the lowest hybrid seed yield plant^{-1} in both ADTRH 1 (4.75 g) and CORH 2 (4.17 g).

GA_3 which recorded 6.09 g of ADTRH 1 and 5.30 g of CORH 2 seed yield plant^{-1} excelled over the other foliar spray treatments. Considerably higher seed yield of 5.34 g and 5.20 g of ADTRH 1 and 4.64 g and 46.1 g of CORH 2 recorded by spentwash and DAP + KCl + $ZnSO_4$ + Boric acid respectively adjudged as the next best treatments in the same order. Whereas, the synergistic effect of fertilizer doses with foliar spray treatments did not set an impact on seed yield plant^{-1}.

R line (Table 17)

Application of additional dose of N and K both at PI and 10 DAPI resulted in predominantly higher grain yield plant^{-1} (18.55 g) followed by additional dose applied at PI (17.57 g) and at 10 DAPI (17.47 g) in ADTRH 1. Similarly, in CORH 2 also, additional dose of N and K at both PI and 10 DAPI appreciably increased grain yield

(17.01 g) which was comparable with additional dose at PI (16.51 g). The RDF managed to yield only 15.75 g of IR66R and 15.65 g of C20R grains and that was comparable with additional dose of N and K at 10 DAPI in CORH 2.

The foliar spraying of DAP + KCl or DAP + KCl + $ZnSO_4$ + Boric acid found to increase the grain yield of R line with 20.08 and 18.57 g respectively in ADTRH 1. Similar effect was observed in CORH 2 also with 18.25 and 18.09 g of R line yield respectively due to above treatments. The foliar spraying of humic acid registered the lowest grain yield of 15.23 and 13.40 g in ADTRH 1 and CORH 2 respectively.

In ADTRH 1, the individual effect found to comply with their interaction and the combination of additional dose of N and K at both PI and 10 DAPI and foliar spraying of DAP + KCl + $ZnSO_4$ + Boric acid excelled with the remarkably higher grain yield of 21.91 g $plant^{-1}$. Whereas, the interaction had no significant effect on CORH 2.

4.1.1.11. Seed / grain yield ha^{-1}

A line (Table 18)

The additional dose of N and K applied at PI and 10 DAPI established its superiority by recording the highest seed yield of 2,061 and 1,663 kg ha^{-1} in ADTRH 1 and CORH 2 respectively. A comparatively higher seed yield of 1,955 and 1,618 kg ha^{-1} registered by additional dose of N and K at PI stage and a marginally higher seed yield of 1,832 and 1,558 kg ha^{-1} obtained by additional dose of N and K at 10 DAPI adjudged the second and third best treatments in ADTRH 1 and CORH 2 respectively. In both the hybrids, the RDF yielded relatively lower seed yield of 1,779 and 1,459 kg ha^{-1}.

GA_3 established its supremacy by recording predominantly higher seed yield of 2,282 and 1,855 kg ha^{-1} in ADTRH 1 and CORH 2 respectively over the other foliar spray treatments. The yield increase was conspicuous due to spentwash

(1,993 and 1,623 kg ha^{-1}) followed by DAP + KCl + $ZnSO_4$ + Boric acid (1,941 and 1,615 kg ha^{-1}) in ADTRH 1 and CORH 2 respectively. The seed yield was remarkably lower with 1,271 and 1,353 kg ha^{-1} due to humic acid spray. Whereas, the combined effect of fertilizer dose with foliar spray treatment appeared to be non-significant.
R line (Table 19)

A phenomenal increase in yield upto 1,623 kg ha^{-1} was noticed in additional dose of N and K applied at both PI and 10 DAPI stages in ADTRH 1. Additional dose of N and K applied either at PI or at 10 DAPI resulted in 1,537 and 1,529 kg ha^{-1} of grain yield respectively which were comparable with each other. A similar trend was resembled in CORH 2 also. In the aforesaid hybrids, RDF yielded considerably less grain yield of 1,379 and 1,317 kg ha^{-1} respectively.

Foliar application of DAP + KCl out yielded other treatments, by recording 1,757 kg ha^{-1} in ADTRH 1 and 1,596 kg ha^{-1} in CORH 2. Grain yield was also influenced by DAP + KCl + $ZnSO_4$ + Boric acid with 1,625 kg ha^{-1} in ADTRH 1 and 1,583 kg ha^{-1} in CORH 2, which was on par with the former foliar spray treatment in CORH 2.

Among the hybrids, the interaction effect did not sustain as the combination of additional dose of N and K applied both at PI and 10 DAPI stages along with foliar spraying of DAP + KCl either with or without $ZnSO_4$ + Boric acid found to be promising with highest yield of 1,625 and 1,757 kg ha^{-1} respectively in ADTRH 1. Whereas, this interaction had no worth mentionable impact on CORH 2.

4.1.2. Chemical analysis

4.1.2.1. Plant analysis

4.1.2.1.1. N uptake in straw

A line (Table 20)

The N uptake in straw was highest due to additional dose of N and K at both PI and 10 DAPI stages with 33.54 kg ha^{-1} as against the lowest uptake due to RDF in A line of ADTRH 1. The additional N and K applied either at PI or 10 DAPI found to be comparable with 30.48 to 31.11 kg ha^{-1}. Foliar spraying of GA_3 followed by spentwash increased the N uptake to a tune of 32.73 and 31.15 kg ha^{-1} respectively. DAP + KCl with or without $ZnSO_4$ + Boric acid also recorded a higher rate of N uptake (30.50 to 30.85 kg ha^{-1}) in ADTRH 1. A similar trend was observed in CORH 2 also.

R line (Table 21)

N uptake in straw by R lines of both the hybrids increased due to additional N and K application at PI and 10 DAPI stages (12.84 to 13.69 kg ha^{-1}) as compared to RDF (9.26 to 10.97 kg ha^{-1}). The single additional dose at PI found to be marginally superior to 10 DAPI stage in increasing the N uptake in R lines of both the hybrids. Foliar spraying of DAP + KCl with or without $ZnSO_4$ + Boric acid enhanced the N uptake in R lines.

4.1.2.1.2. N uptake in seeds

A line (Hybrid seed) (Table 22)

The N uptake was highest in seeds due to additional N and K applied at PI and 10 DAPI (26.13 kg ha^{-1}) as compared to RDF (17.89 kg ha^{-1}). Plants received GA_3 spray accumulated higher N in seeds (25.46 kg ha^{-1}) followed by DAP + KCl + $ZnSO_4$ + Boric acid foliar spray (23.44 kg ha^{-1}). Eventhough, a slightly lower uptake was recorded in CORH 2 as compared to ADTRH 1, the uptake pattern was found to be similar.

R line (Grain) (Table 23)

The N uptake in R line seeds did not differ due to fertilizer dose treatments. However, foliar spraying of DAP + KCl with or without $ZnSO_4$ + Boric acid increased uptake to a tune of 16.30 to 16.66 kg ha^{-1} in ADTRH 1 and 14.03 to 14.48 kg ha^{-1} in CORH 2. The interaction had no sustained effect.

4.1.2.1.3. P uptake in straw

A line (Table 24)

In A line of ADTRH 1, the P uptake in straw was enhanced significantly due to additional N and K at PI and 10 DAPI stages (6.86 kg ha^{-1}) as against the lowest P uptake due to RDF (25.65 kg ha^{-1}). DAP + KCl with or without $ZnSO_4$ + Boric acid increased the P uptake as compared to rest of the foliar spray treatments. However, both the treatments had no significant effect on P uptake in straw by A line of CORH 2. Conversely, the interaction exerted significant influence on P uptake in straw.

R line (Table 25)

The highest P uptake in straw was recorded due to application of additional N and K at PI and 10 DAPI with 2.30 kg ha^{-1} as against 1.59 kg ha^{-1} in A line of ADTRH 1. However, additional dose did not influence P uptake in CORH 2. Foliar spraying of either GA_3 or DAP + KCl + $ZnSO_4$ + Boric acid increased the P uptake followed by spentwash. The additive effect of individual factors found to be significant.

4.1.2.1.4. P uptake in seeds

A line (Hybrid seed) (Table 26)

While there was significant difference due to fertilizer dose in ADTRH 1, additional N and K at PI and 10 DAPI increased P uptake in seeds of CORH 2 at 4.81 kg ha^{-1} as compared to RDF with 3.72 kg ha^{-1}. Foliar spraying of GA_3 increased the P uptake in both ADTRH 1 (4.58 kg ha^{-1}) and CORH 2 (5.86 kg ha^{-1}). The interaction effect showed significant variation on P uptake of hybrid seed.

R line (Grain) (Table 27)

Fertilizer dose failed to alter P uptake of R line seeds significantly. However, foliar spraying of $ZnSO_4$ + KCl with or without DAP + KCl recorded a maximum uptake of 2.50 to 3.04 kg ha^{-1} in ADTRH 1 and 2.91 to 2.97 kg ha^{-1} in CORH 2. The additive effect exhibited significant variation in P uptake.

4.1.2.1.5. K uptake in straw

A line (Table 28)

The K uptake was maximum due to application of additional N and K at PI and 10 DAPI (22.44 kg ha^{-1}) as compared to RDF (17.28 kg ha^{-1}) in A line of ADTRH 1 and it was 11.03 and 8.42 kg ha^{-1} respectively in CORH 2 due to above treatments. Foliar spraying of DAP + KCl with or without $ZnSO_4$ + Boric acid enhanced the K uptake in straw by the A line of both the hybrids. There was no reliability of additive effect among the hybrids.

R line (Table 29)

The additional dose of N and K exerted a profound impact on the K uptake in R lines of ADTRH 1 and CORH 2, especially when applied at both PI and 10 DAPI, with 6.02 and 3.76 kg ha^{-1} respectively. When the additional dose of N and K applied at PI stage, K uptake increased marginally. A similar trend as that of A line was

observed in foliar spray treatments in R lines of both the hybrids also. The interaction effect of individual factors found to be significant.

4.1.2.1.6. K uptake in seeds

A line (Hybrid seed) (Table 30)

The K uptake increased due to additional N and K dose applied at both, PI and 10 DAPI in ADTRH 1 (4.33 kg ha^{-1}) and CORH 2 (11.12 kg ha^{-1}) as compared to RDF with 3.31 and 9.83 kg ha^{-1} in the above hybrids respectively. Foliar spraying of GA_3 increased the K uptake followed by brassinolide in ADTRH 1 and spentwash followed by brassinolide in CORH 2. The interaction exerted significant variation.

R line (Grain) (Table 31)

The K uptake increased due to additional N and K dose applied at both PI and 10 DAPI in both the R line seeds as compared to RDF. Foliar spraying of DAP + KCl or $ZnSO_4$ + boric acid either sole or in combination recorded higher K uptake with 2.61 to 2.85 kg ha^{-1} in ADTRH 1 and 7.89 to 8.62 kg ha^{-1} in CORH 2. The interaction had significant effect on K uptake in seed.

4.1.2.2. Soil analysis

4.1.2.2.1. Available N ($KMnO_4$-N) content (Table 32)

The initial available N content of 320 and 308 kg ha^{-1} increased by 3.3 and 13.5 per cent to 320 and 356 kg ha^{-1} in the post harvest soil of ADTRH 1 and CORH 2 respectively. The available N content of post harvest soil did not vary due to fertilizer doses. Significantly varied available N content due to foliar spray in ADTRH 1 did not differ in CORH 2.

4.1.2.2.2. Available P (Olsen P) content (Table 33)

The initial available P content of 28.40 and 23.22 kg ha^{-1} increased by 24.8 and 28.3 per cent to 37.75 and 32.40 kg ha^{-1} in post harvest soil of ADTRH 1 and CORH 2. Variation due to fertilizer dose and foliar spray treatment was significant in ADTRH 1 while, it was not in CORH 2. The available P of the post harvest soil in spentwash and humic acid foliar spray was higher at 40.1 kg ha^{-1}.

4.1.2.2.3. Available K (NH_4OAc-K) content (Table 34)

The initial available K content of 338 and 627 kg ha^{-1} increased by 5.6 per cent to 358 kg ha^{-1} in ADTRH 1 and decreased by 8.6 per cent to 573 kg ha^{-1} in CORH 2. There was no variation in available K content except for foliar spray and its interaction with fertilizer dose in ADTRH 1.

4.1.3. Seed quality analysis

As the seeds harvested from A line are utilised as hybrid seeds, seed quality analysis was done only in the hybrid seeds.

4.1.3.1. Germination (Table 35)

The fertilizer dose, foliar spray treatments and their interactions failed to influence the germination per cent of hybrid seeds of both the hybrids.

4.1.3.2. Root length (Table 36)

The foliar spray treatment in ADTRH 1 and fertilizer dose treatment in CORH 2 significantly influenced the root length. While, the additional N and K dose both at PI and 10 DAPI produced longest root (20.01 cm) in CORH 2 and foliar

spraying of DAP + KCl as sole or along with $ZnSO_4$ + Boric acid recorded longest roots to a tune of 19.57 to 19.72 cm in ADTRH 1. However, there was no significant effect of interaction noticed in both the hybrids.

4.1.3.3. Shoot length (Table 37)

Variation due to fertilizer dose, foliar spray treatment and their interaction was not significant for shoot length of both the hybrids.

4.1.3.4. Dry matter production (Table 38)

Dry matter production of resultant F_1 seeds of both the hybrids was not influenced significantly due to fertilizer dose, foliar spray treatments and their interaction.

4.1.3.5. Vigour index (Table 39)

Except for fertilizer dose treatment in CORH 2, rest of the treatments and interaction failed to influence vigour index of hybrid seeds of ADTRH 1 and CORH 2. The additional dose of N and K both at PI and 10 DAPI (2951) followed by additional dose at 10 DAPI (2925) recorded highest vigour index of CORH 2 seeds.

4.2. PHYSIOLOGICAL AND BIOCHEMICAL BASIS OF HYBRID VIGOUR IN RICE HYBRIDS ON SEED QUALITY ATTRIBUTES

4.2.1. Imbibition rate (Table 40)

Imbibition rate exerted appreciable change due to genotypes, period of incubation and their interaction. Irrespective of period of incubation, moisture absorbed by both the hybrids was remarkable to a tune of 31.7 per cent followed by A line (31.1 per cent) and B line (29.1 per cent). Though, both the R lines were found to be slow in moisture absorption, C20R was slowest with the least moisture of 21.4 per cent compared to 23.4 per cent of IR66R.

As the incubation period increased from 0 to 20 h, there was a progressive increase in moisture content from 12.5 to 40.5 per cent irrespective of genotypes. A rapid absorption was noticed at 4 h with 16.9 per cent increase and from then on, the increase in moisture reduced gradually from 5.8 per cent at 8 h to 0.5 per cent at 20 h.

The rapidity in moisture absorption of both the hybrid seeds was notable from 4 h of incubation and accumulated maximum moisture content of 44.0 and 44.3 per cent at 20 h in ADTRH 1 and CORH 2 respectively, followed by A and B lines with 43.6 and 41.5 per cent. During this period, both the R lines absorbed a lowest moisture content of only 35.9 (IR 66R) and 34.0 (C20R) per cent.

4.2.2. Seedling growth rate tests (Table 41a and b)

4.2.2.1. Time taken for sprouting

In general, the hybrids were faster in sprouting as they took only 25 to 26 h followed by A line which required 28 h, while C20R, one of the R lines had taken a maximum of 34 h for sprouting, and the other R line IR 66 R required slightly lower time of 31 h, which was comparable with B line that consumed 30 h for sprouting.

4.2.2.2. Radicle length in time bound germination

The hybrid seeds of CORH 2 putforth the longest radicle of 19.1 mm while the other hybrid ADTRH 1, that produced relatively long radicle (15.7 mm) which was comparable with C20R (15.6 mm). The B line which putforth only 13.2 mm of radicle found to be inferior with regard to radicle length in time bound germination.

4.2.2.3. Rate of germination

The hybrid seeds of CORH 2 were found to be rapid in germination (34.5) followed by ADTRH 1 (28.3), A (27.7) and B lines (27.5). Among the R lines, C20R was much slower (22.0) as compared to IR66R (23.8).

4.2.2.4. Germination

Difference in germination was more evident due to the hybrids and their parental lines. The hybrids CORH 2 and ADTRH 1 with highest germination of 96.0 and 95.0 per cent respectively established their supremacy. Though, the germination of R lines ranged between 93.0 and 94.0 per cent, they were comparable with B line (92.0 per cent).

4.2.2.5. Root length

Appreciably longer root length of 21.93 cm recorded by CORH 2 was followed by C20R with 20.15 cm. The root length of the other hybrid ADTRH 1 was marginally shorter with 18.40 cm followed by its R line IR 66R with 16.88 cm. The A and B lines with almost similar roots of 15.15 and 15.93 cm respectively happened to be the shortest among all.

4.2.2.6. Shoot length

Not withstanding the variations existed for shoot length, both the hybrids, A and B lines were comparable as their shoot length ranged from10.63 to 11.33 cm. Similarly, both the R lines were at par by recording a slightly longer shoots of 12.55 and 12.28 cm in IR 66R and C20R respectively.

4.2.2.7. Dry matter production

The R line, C20R predominated with a maximum dry matter production of 16.13 mg seedling^{-1}. While, the other R line IR66R recorded a fairly low dry matter of 13.66 mg seedling^{-1}. However, IR66R was found to be superior to the hybrids, A and B lines, in which dry matter ranged between 12.18 and 12.60 mg seedling^{-1}.

4.2.2.8. Vigour index

The vigour index was profusely higher in CORH 2 (3192) followed by its R line C20R (3093). The other hybrid, ADTRH 1 and its R line registered vigour

index of 2815 and 2737 respectively which were on par with each other. Similarly, A and B lines registered remarkably lower vigour index to a tune of 2417 to 2444.

4.2.2.9. Field emergence

The hybrid CORH 2 emerged superior with 89.0 per cent of field emergence followed by the other hybrid ADTRH 1. The field emergence of 83.5 to 84.5 per cent recorded by R lines was comparable with each other. Similarly, the A and B were also at par and the field emergence was relatively lower with of 80.5 to 81.0 per cent.

4.2.3. Enzyme activity (Table 42)

4.2.3.1. Dehydrogenase

Dehydrogenase enzyme activity expressed as OD value was remarkably higher in CORH 2 (0.124) followed by ADTRH 1 (0.114). A line had least activity (0.079) as compared to rest of the lines. Among R lines, C20R had higher dehydrogenase enzyme activity (0.106) as against IR66R (0.096).

4.2.3.2. Total ATPase

The total ATPase enzyme activity was higher with 3.417 µ mol of p g^{-1} h^{-1} in CORH 2 and the lowest activity of 2.476 µ mol of p g^{-1} h^{-1} in B line. In general, the hybrids followed by R lines recorded higher total ATPase enzyme activity.

4.2.3.3. Peroxidase

Peroxidase enzyme activity of hybrids and parental lines expressed as OD value differed significantly with highest activity in hybrids CORH 2 (0.095) followed by ADTRH 1 (0.092). The R lines and B line recorded next best enzyme activity and the A line had a least activity (0.072).

4.2.3.4. Catalase

The highest and lowest catalase activity equivalent to 2.73 and 2.13 ml of 0.01N $KMnO_4$ min^{-1} ml^{-1} respectively, were recorded in CORH 2 and A line.

The other hybrid ADTRH 1 followed by C20R recorded the next highest enzyme activity equivalent to 2.53 and 2.34 ml of 0.01N $KMnO_4$ min^{-1} ml^{-1} respectively.

4.2.3.5. α-amylase

α-amylase enzyme activity was influenced significantly by parental lines and hybrids to the tune of 7.52 mm of halo zone in B line to 13.90 mm of halo zone in CORH 2. In general, the hybrids followed by R lines recorded the highest α-amylase enzyme activity. Among R lines, C20R (12.34 mm) had higher activity compared to IR66R (10.69 mm).

4.2.4. Stress tests

4.2.4.1. NH_4Cl soak test (Table 43)

4.2.4.1.1. Germination

The R line, IR66R followed by its hybrid ADTRH 1, registered the highest germination of 58.0 and 56.5 per cent respectively. Similarly, CORH 2 and its male parent, C20R were comparable to each other by recording 47.5 and 45.5 per cent of normal seedlings respectively. B line followed by its counter part, A line recorded the lowest germination of 44.5 and 42.5 per cent respectively.

4.2.4.1.2. Root length

Hybrids and parental lines had astounding effect on root length. Maximum root length was recorded in C20R (19.21 cm) followed by its hybrid CORH 2 (18.93), which were on par with each other. Root length recorded by ADTRH 1 and its R line were almost identical with 18.02 and 18.01 cm respectively. Moreover, these values were comparable with root length registered by B line (17.40 cm). Root of A line was shortest among all with 15.15 cm.

4.2.4.1.3. Shoot length

The maximum shoot length of CORH 2 (9.38 cm) was comparable to its R line C20R (8.99 cm). Similarly, ADTRH 1 and its R line, IR 66R were on par and produced slightly shorter shoots of 8.56 cm. The shortest shoots of 6.58 cm was recorded by B line.

4.2.4.1.4. Vigour index

Vigour index of rice hybrids and their parental lines subjected to NH_4Cl soak test differed remarkably with maximum vigour in IR66R (1499) followed by its offspring hybrid ADTRH 1 (1469). A and B lines exhibited poor vigour of 1008 and 1068 respectively in NH_4Cl soak test.

4.2.4.2. D-mannitol soak test (Table 43)

4.2.4.2.1. Germination

IR66R established its superiority with the highest germination of 80.5 per cent followed by C20R with 77.5 per cent, when subjected to D-mannitol soak test. While, the hybrids and the B line had the germination between 69.5 and 73.5 per cent, A line could germinate only upto 62.5 per cent.

4.2.4.2.2. Root length

D-mannitol soaking of hybrids and their parental seeds exhibited significant variation on root length which ranged from 1.91 cm in B line to 3.69 cm in C20R. The root length of other R line, IR66R and its hybrid ADTRH 1 were on par by recording 3.10 and 3.16 cm, respectively.

4.2.4.2.3. Shoot length

While, the shoot length of R lines and the hybrids ranged from 2.03 to 2.27 cm, the A and B lines recorded 1.83 and 1.46 cm of shoots respectively.

4.2.4.2.4. Vigour index

In D-mannitol soak test also, the vigour index of R lines exhibited highest values of 422 and 458 in IR66R and C20R respectively. Among the hybrids, ADTRH 1 recorded higher vigour index (399) as compared to CORH 2 (338). A line performed poorly with a vigour index of 211 as against 296 of B line.

4.2.4.3. Anaerobic germination test (Table 44)

4.2.4.3.1. Germination

Germination of hybrids and parental lines varied significantly with the highest value of 45.0 per cent in A line and IR66R. While, B line germinated only upto 5.0 per cent and C20R and both the hybrids failed to germinate normally under anaerobic condition.

4.2.4.3.2. Root length

Hybrids and parental lines influenced the root length profoundly due to anaerobic condition and registered a maximum root length of 1.83 cm in IR66R followed by IR58025 A and B which were comparable with shortest roots ranging from 1.03 to 1.14 cm.

4.2.4.3.3. Shoot length

Highly significant variation was noticed with shoot length as it ranged from 0.0 cm in C20R and hybrids to 3.71 cm in IR66R. The A and B line had a shoot length of 2.47 and 1.08 cm respectively.

4.2.4.3.4. Vigour index

Vigour index of hybrids and parental lines was influenced appreciably due to anaerobic germination. The R line, IR66R exhibited the highest vigour of 248 followed by A line with 164. While, B line recorded a far low vigour index of 16 and the rest of the lines obtained nil value.

4.2.4.4. Exhaustion test (Table 44)

4.2.4.4.1. Seedlings crossed root – shoot line

IR66R and ADTRH 1 emerged vigourous by registering 95.0 and 80.0 per cent of seedling crossing root-shoot line respectively. ADTRH 1 and C20R with 65.0 and 55.0 per cent of their seedlings crossed root-shoot line adjudged the next best. A and B lines observed to be inferior in exhaustion test as only 35.0 and 15.0 per cent of their seedlings respectively crossed the root-shoot line.

4.2.4.4.2. Root length

Remarkable differences to a tune of 9.68 cm in B line to 19.93 cm in C20R were observed in root length due to exhaustion test. ADTRH 1 and its R line IR66R were comparable with 17.95 and 17.58 cm respectively followed by CORH 2 with 16.08 cm and A line with 12.95 cm.

4.2.4.4.3. Shoot length

Similar to root length, shoot length also differed to a range of 4.65 (B line) to 11.18 cm (C20R). While, root length of ADTRH 1 (10.10 cm) was on par with its R line, IR66R (9.63 cm), CORH 2 (10.75 cm) was also at par with its R line C20R.

4.2.4.4.4. Vigour index

In exhaustion test also, the vigour index was convincingly highest in IR66R (2585) followed by its hybrids ADTRH1 (2246). The other hybrid CORH 2 and its male parent C20R exhibited next best vigour index of 1743 and 1714 respectively

which were on par with each other. Though, A and B lines were far behind rest of the lines, B line was poorest (144) as compared to A line (765).

4.2.4.5. Bioassay test (Table 45)

4.2.4.5.1. Germination

Rice (stock material)

There was no commendable change noticed among the parental lines and hybrids with regard to germination.

Finger millet (Bioassay material)

Germination of bioassay material tested as blank without stock material was prominently higher (90.5 per cent) than those tested with stock material. However, there was no worth mentionable change among the bioassay material tested with different parental lines and rice hybrids (85.0 to 87.5 per cent).

4.2.4.5.2. Root length

Rice

As in the normal test, in bioassay test also the difference among parental lines and hybrids was conspicuous in root length. The longest roots were produced by C20R (7.17 cm) followed by the hybrids and IR66R (5.33 to 5.37 cm). Root length of A line (4.90 cm) followed by B line (4.28 cm) found to be shortest among all.

Finger millet

Root length of bioassay material (finger millet) reduced significantly to a tune of 0.23 to 0.86 cm, when tested with various stock material (rice) as compared to blank (3.99 cm). Among the stock material, shortest root length of bioassay material was recorded in B line (3.13 cm) followed by A line (3.34 cm), R lines (3.50 – 3.52 cm) and hybrids (3.73-3.76 cm).

4.2.4.5.3. Shoot length

Rice

As in the normal test, shoot length in bioassay test considerably varied among parental lines and hybrids. The hybrids were on par with highest shoot length of 3.54 to 3.63 cm followed by R lines and A line with 3.31 to 3.41 cm. The shoot length of B line was least with 2.58 cm.

Finger millet

Shoot length of bioassay material (finger millet) declined drastically to a tune of 0.23 to 0.55 cm when tested with stock material (rice) as compared to blank (1.97 cm). Among the stock materials, shortest shoot length of bioassay material was recorded in B line (1.42 cm) followed by A line (1.48 cm), R lines (1.47 – 1.50 cm) and hybrids (1.66-1.68 cm).

4.2.4.5.4. Vigour index

Rice

Rice hybrids and parental lines subjected to bioassay test exhibited highly significant variation in vigour index with a highest vigour in C20R (995) and the lowest in B line (624). Both the hybrids and IR66R were on par with a vigour index of 823 (ADTRH1), 841 (CORH 2) and 812 (IR66R). A line was slightly better (763) as compared to B line.

Finger millet

Vigour index of bioassay material subjected to gaseous emanations of germinating rice hybrids and parental lines differed appreciably with the highest and lowest values in blank (537) and B line (386) respectively. Both the hybrids and both

the R lines were on par with each other by recording vigour index to a tune of 472 to 476 and 421 to 438 respectively. A line exhibited superiority over B line with a vigour index of 421.

4.2.4.6. Accelerated ageing test

4.2.4.6.1. Germination (Table 46)

Irrespective of genotypes, a loss of 60.0 per cent in germination was noticed at the final ageing period of 9 days. The loss of germination was rapid in 6 and 9 days of ageing with 23.0 and 30.4 per cent compared to just 6.6 per cent loss in 3 days of ageing. Both the R lines, IR 66R and C20R sustained ageing stress compared to other lines by recording the highest germination of 77.0 and 73.5 per cent respectively irrespective of ageing period. Next to R lines, B line and ADTRH 1 resisted ageing stress and recorded 70.0 per cent of germination followed by A line and CORH 2 with 66.0 per cent.

Interaction effect of ageing period and genotypes revealed that except R lines, germination of all the other lines reduced below 40.0 per cent in 9 days of ageing. Among the R lines, loss in IR66R was lowest with only 42.0 per cent as compared to 48.0 per cent in C20R. Similarly, among hybrids, loss in CORH 2 was much pronounced with 76.0 per cent as compared to 68.0 per cent in ADTRH 1 in 9 days of ageing.

4.2.4.6.2. TZ-viability test (Table 47)

Irrespective of ageing periods, both the R lines maintained a viability level of 68.8 and 65.0 per cent in IR66R and C20R respectively. The other line which sustained ageing stress and maintained 60.0 per cent of viability was B line. However, both the hybrids and A line reduced to below 60.0 per cent level by recording viability of 54.4 to 58.1 per cent. The interaction effect of genotypes with ageing period found to be non-significant.

4.2.4.6.3. Root length (Table 48)

Irrespective of ageing period, C20R produced longest roots of 16.58 cm followed by its hybrid CORH 2 with 15.60 cm. The other hybrid, ADTRH1 was on par with its R line by recording 14.43 and 14.15 cm of root length respectively. A line registered shortest roots of 11.00 cm due to accelerated ageing. Interaction effect of genotypes and ageing period revealed that reduction in root length was much higher at the rate of 54.9, 52.5, 49.2 and 46.6 per cent in CORH 2, A line, ADTRH 1 and B line respectively at the end of 9 days of ageing. Though, the reduction in R lines was less, C20R lost upto 42.2 per cent of root length as against 34.9 per cent in IR66R.

4.2.4.6.4. Shoot length (Table 48)

Irrespective of ageing period, shoot length of R lines, IR66R and C20R were higher with 11.75 and 11.38 cm respectively as against 9.38 to 9.58 cm in rest of the lines. The non-significant effect of interaction revealed that the reduction in shoot length of all the genotypes was similar over the ageing periods.

4.2.4.6.5. Dry matter production (Table 49)

Among the genotypes, the R lines maintained a higher dry matter of 13.99 and 12.03 mg seedling^{-1} in C20R and IR66R respectively. A slightly lower dry matter registered by A and R line (10.11 and 10.23 mg seedling^{-1}) was on par with each other. The hybrids were least among the genotypes with 9.90 to 9.99 mg seedling^{-1} of dry matter. The non-significant effect of interaction between genotypes and ageing period suggested the similarity in rate of reduction of dry matter production in all the genotypes.

4.2.4.6.6. Vigour index (Table 49)

Irrespective of ageing period, the R lines showed higher vigour index of 2047 and 2133 in IR66R and C20R respectively followed by hybrids with 1783 and 1801 in

ADTRH 1 and CORH 2. The A line was found to be less vigourous with a vigour index of 1453. Interaction effect of genotypes and ageing period revealed that the loss in vigour index due to accelerated ageing for 9 days was much higher in A line and hybrids ADTRH 1 and CORH 2 respectively at the rate of 88.5, 83.0 and 89.2 per cent. The male lines viz., B line (76.7 per cent) followed by R lines, C20R (68.7 per cent) and IR66R (61.0 per cent) lost vigour index relatively at a slower rate.

4.2.4.6.7. Dehydrogenase enzyme activity (Table 50)

Among the genotypes, R lines and hybrids had higher enzyme activity (0.064 to 0.069 of OD value) as against A and B lines (0.051 to 0.055) under accelerated ageing conditions. The interaction of genotypes with ageing period clearly revealed that the reduction in dehydrogenase activity was much higher in CORH 2 (88.0 per cent) and ADTRH 1 and A line (83.3 and 83.5 per cent) followed by B line (81.8 per cent). Though, the reduction in R lines was less compared to rest of the lines, reduction in C20R was higher (78.5 per cent) as compared to IR66R (73.2 per cent).

4.2.4.6.8. Electrical conductivity of seed leachate (Table 50)

Irrespective of genotypes, electrical conductivity increased 126.4 per cent in 9 days of ageing. Irrespective of ageing period, CORH 2 which was on par with A line recorded a higher electrical conductivity of 0.18 and 0.184 dSm^{-1} respectively followed by ADTRH1 and B line with 0.177 and 0.165 dSm^{-1}. Although, the electrical conductivity of R lines were much lesser as compared to other lines, C20R registered relatively higher value of 0.153 dSm^{-1} as against 0.137 dSm^{-1} of IR66R.

As revealed by the interaction effect, increase in the electrical conductivity was higher in CORH 2 since 3 days of ageing (35.4 per cent) to 9 days of ageing (145.1 per cent) followed by ADTRH 1 (34.5 and 137.3 per cent) during the same period. The R line, IR66R recorded very less increase in electrical conductivity of 1.0 per cent at 3 days of ageing increased to 119.6 per cent at 9 days of ageing.

4.2.4.6.9. Free sugars content (Table 51)

Among the genotypes, the highest free sugar content was recorded in CORH 2 (25.53 µg 50 seeds^{-1} 50 ml^{-1}) followed by A line and ADTRH 1 (24.73 and 24.13 µg 50 seeds^{-1} 50 ml^{-1} respectively). A free sugar content of 19.08 µg 50 seeds^{-1} 50 ml^{-1} recorded by IR66R was the least among all the genotypes. The interaction effect of genotypes with ageing period clearly indicated the rapid increase in free sugars content to the tune of 127.7, 114.0 and 113.2 per cent in CORH 2, A line and ADTRH1 respectively. Next to B line (98.2%), the increase in C20R (93.3%) was higher as compared to IR66R (75.6%).

4.2.4.6.10. Free amino acids content (Table 51)

There was an increase of 172.8 per cent in free amino acids content due to 9 days of accelerated ageing. Irrespective of ageing period, increase in free amino acid content was higher in CORH 2 (8.33 µg) followed by A line (7.95 µg), ADTRH 1 (7.93 µg) and B line (7.48 µg). Among R lines, IR66R registered a least increase in free amino acid content of 6.00 µg as against 6.86 µg registered in C20R. Interaction effect revealed that CORH 2 had highest accumulation of free amino acid content since 3 days of ageing (36.0%) to the final ageing period of 9 days (211.2%) as compared to rest of the genotypes.

4.3. ESTIMATION OF QUALITY LOSS ON OCCURRENCE OF SPLIT HUSK SEEDS IN RICE HYBRIDS AND FEMALE PARENT

4.3.1. Imbibition rate (Table 52)

There was a progressive increase in the moisture content from 12.5 per cent to 44.0 per cent over a period of 20 h. Among the three seed materials tested, split husk seeds registered higher rate of imbibition to a tune of 32.8 per cent followed by normal seeds (31.5 per cent) and bulk seeds (29.9 per cent). The interaction effect of seeds with imbibition period revealed that when the moisture content of split husk increased to 33.3 and 45.3 per cent at 4th and 20th h respectively, it was 31.5 and

43.9 per cent in normal and 32.5 and 42.6 per cent in bulk seeds during the same period.

4.3.2. 1000 seed weight (Table 53)

The weight of split husk seeds was the lowest (18.77 g) with a loss of 7.6 per cent. The bulk seeds (19.24 g) lost upto 5.3 per cent as compared to normal seeds (20.32 g). However, the additive effect of genotype with different seed materials failed to influence 1000 seed weight.

4.3.3. Seed to husk ratio (Table 53)

The split husk seeds had very poor seed to husk ratio of 3.83 incurring a loss of 16.0 per cent as against the higher value of 4.56 in normal seeds and the bulk seeds lost upto 5.5 per cent with a ratio of 4.31. The interaction of genotype with seed materials did not alter the seed to husk ratio appreciably.

4.3.4. Time taken for sprouting (Table 54)

The split husk seeds had taken a maximum of 35.7 h for sprouting as against 26.3 h of normal and 31.7 h of bulk seeds. Insignificant interaction effect implies that the seed materials behaved similarly among the genotypes.

4.3.5. Radicle length in time bound germination (Table 54)

The radicle length was shorter in the bulk (15.54 mm) and split husk seeds (14.08 mm) as compared to normal seeds (16.42 mm) with a reduction of 5.4 and 14.3 per cent respectively. However, the interactive effect of genotypes and seed material failed to influence radicle length.

4.3.6. Rate of germination (Table 55)

The normal seeds were superior (30.16) to bulk (25.28) and split husk (17.73) seeds. There was no significant interactive effect observed for rate of germination.

4.3.7. Germination (Table 55)

The normal seeds had 92.3 per cent germination as against 80.0 per cent in bulk and 71.3 per cent in split husk seeds. The interactive effect revealed that the split husk seeds of IR58025 A had lowest germination (61.5 per cent) followed by ADTRH 1 (71.0 per cent) and the CORH 2 recorded highest split husk seed germination (81.5 per cent). A similar variation was observed incase of bulk seeds also. However, the normal seeds of all the genotypes recorded higher and comparable germination ranging from 91.5 to 93.5 per cent.

4.3.8. Root length (Table 56)

The root length of split husk seeds was found to be reduced by 32.5 per cent (12.49 cm) as against normal seeds (18.49). The bulk seeds lost upto 20.1 per cent (14.78 cm). The interaction effect was found to be non-significant.

4.3.9. Shoot length (Table 56)

The shoot length differed significantly among seed materials with longest shoots in normal seeds (11.23 cm) as compared to split husk seeds (7.28 cm) and bulk seeds (7.80 cm) with a loss of 35.2 and 30.5 per cent. However, the genotypes and interaction of individual factors did not exert a significant impact on shoot length.

4.3.10. Dry matter production (Table 57)

The normal seeds excelled with 12.48 mg seedling^{-1} followed by 9.38 mg seedling^{-1} in bulk seeds with a loss of 24.8 per cent. The split husk seeds were proved to be inferior with only 8.29 mg seedling^{-1} of dry matter production and incurred a loss of 33.6 per cent. The synergistic effect of individual factors also found to influence dry matter production significantly.

4.3.11. Vigour index (Table 57)

The split husk seeds were inferior with a lowest vigour index of 1434 followed by bulk seeds with 1813. Normal seeds emerged highly vigorous with a vigour index of 2746. The split husk and bulk seeds suffered a loss of 47.8 and 34.0 per cent respectively in vigour index.

4.3.12. Exhaustion test

4.3.12.1. Seedlings crossed root shoot line (Table 58)

About 60.0 per cent of seedlings from normal seeds crossed root – shoot line. While about 37.1 per cent bulk seeds crossed the lines, only 20.0 per cent of split husk seeds crossed root-shoot lines. Interaction effect revealed that the seedlings of normal seeds of ADTRH 1 crossed root-shoot lines were as high as 80.0 per cent, while in split husk seeds of CORH 2, it was as low as 17.5 per cent.

4.3.12.2. Root length (Table 58)

The split husk seeds followed by bulk seeds registered smaller roots of 7.35 and 12.72 cm respectively as against longest roots of 15.66 cm in normal seeds. The significant interaction effect revealed that root length of normal seeds of ADTRH 1 was highest with 17.95 cm and lowest in split husk seeds of IR58025 A with 6.08 cm.

4.3.12.3. Shoot length (Table 59)

The length of normal and bulk seeds were on par with 9.87 and 9.55 cm respectively as against the far low length of 4.98 cm in split seed. Interactive effect of genotypes with their respective seed material revealed that both longest and shortest shoot length were recorded in CORH 2 with 10.75 and 4.05 cm respectively, in normal and split husk seeds.

4.3.12.4. Vigour index (Table 59)

The superiority of normal seeds was proved to be true with a vigour index of 1583 as compared to 248 of split husk and 849 of bulk seeds. The synergistic effect of individual factors existed to a significant level.

4.3.13. Electrical conductivity (Table 60)

In the split husk and bulk seeds the electrical conductivity (EC) increased by 17.4 and 12.3 per cent with 0.138 and 0.130 dSm^{-1} respectively as compared to normal seeds with 0.114 dSm^{-1}. However, the interaction of genotypes with seed material failed to influence EC significantly.

4.3.14. Enzyme activity

4.3.14.1. Dehydrogenase (Table 60)

The normal seeds were superior with higher enzyme activity followed by bulk seeds as expressed by their OD values 0.106 and 0.091 respectively. Split seeds recorded a lowest OD value of 0.083 with a loss of 21.7 per cent in dehydrogenase enzyme activity.

4.3.14.2. Total ATPase (Table 61)

The total ATPase enzyme activity was much lower in split seeds with 2.154 µ mol of P g^{-1} h^{-1} with a loss of 30.0 per cent as against normal seeds with 3.077 µ mol of P g^{-1} h^{-1} and the bulk seed incurred a loss of 13.6 per cent with an enzyme activity equivalent to 2.659 µ mol of P g^{-1} h^{-1}.

4.3.14.3. Peroxidase (Table 61)

Very low OD value of split husk seeds (0.047) denoted the poor peroxidase enzyme activity as compared to normal (0.086) and bulk seeds (0.071). There was a loss upto 45.4 and 17.4 per cent in split husk and bulk seeds.

4.3.14.4. Catalase (Table 62)

The normal seeds exhibited higher activity catalase enzyme equivalent to 2.46 ml of 0.01 N $KMnO_4$ min^{-1} ml^{-1} of enzyme extract as compared to 1.96 ml of bulk and 1.77 ml of split husk seeds which suffered a loss of 19.1 and 28.1 per cent in activity.

4.3.14.5. α-amylase (Table 62)

The halo zone of normal seeds was much larger measuring 11.50 mm followed by 8.56 mm of bulk and much smaller zone of split husk seeds measuring 6.52 mm. The reduction in activity zone was 25.6 and 43.3 per cent in bulk and split husk seeds as compared to normal seeds. Interaction effect revealed that the α-amylase enzyme activity of split husk seeds of CORH 2 was higher (8.48 mm) than that of normal and bulk seeds of IR58025 A (7.56 and 6.47 mm respectively).

4.4. EFFECT OF SEED COATING WITH POLYKOTE POLYMER IN RICE HYBRIDS AND PARENTAL LINES

4.4.1. Standardisation of dose and dilution of polykote for rice seeds

4.4.1.1. Imbibition rate (Table 63)

Among the polykote treatments, polykote 5 g + 70 ml water kg^{-1} absorbed a higher moisture content of 38.1 per cent followed by polykote 3 g + 50 ml water kg^{-1}. These two treatments have recorded 7.2 and 6.5 per cent higher moisture content over uncoated (control) seeds, which recorded a moisture content of 32.4 per cent irrespective of period of imbibition.

Interaction of polykote dosage with imbibition period revealed that at 20 h of imbibition, moisture content of 48.2 and 47.6 per cent was recorded by polykote 5 g + 70 ml and water kg^{-1} and polykote 3 g + 50 ml kg^{-1} respectively. During the same period, uncoated (control) seeds obtained only 41.1 per cent of moisture content.

The per cent increase in moisture content of above two polykote treatments was 36.1 and 35.3 per cent respectively as against 28.9 per cent in control.

4.4.1.2. Time taken for sprouting (Table 64)

Seeds coated with polykote 5 g + 70 ml water kg^{-1} sprouted earlier (25.3 h) followed by polykote 3 g + 50 ml water kg^{-1} (26.7 h). However, the uncoated seeds elapsed 32.0 h for sprouting. Polykote 5 g and 3 g diluted with 90 and 70 ml of water kg^{-1} respectively also consumed relatively lower time of 26.7 and 28.0 h for sprouting as compared to rest of the treatments. As the quantity of water used for dilution increased or decreased beyond 70 ml in 5 g and beyond 50 ml in 3 g, the time taken for sprouting increased.

4.4.1.3. Radicle length in time bound germination (Table 64)

Radicle length registered by polykote 5 g + 70 ml water kg^{-1} and polykote 3 g + 50 ml water kg^{-1} were on par with 18.8 and 18.2 mm respectively. Seeds coated with polykote @ 5 g as well as 3 g diluted with 15 ml of water kg^{-1} had similar effect as that of control by recording comparatively lower radicle length of 13.4, 13.7 and 13.8 mm respectively. Increasing or decreasing the quantity of water used for dilution beyond 70 ml in 5 g polykote and beyond 50 ml in 3 g polykote reduced the radicle length significantly.

4.4.1.4. Rate of germination (Table 64)

Rate of germination was highest in 5 g followed by 3 g of polykote when diluted with 70 and 50 ml of water kg^{-1} respectively. The rate of germination recorded by the above two treatments were 35.4 and 34.8 respectively as against 27.8 registered by control. This parameter also responded negatively to the dilution beyond 70 ml in 5 g dose and 50 ml in 3 g dose.

4.4.1.5. Germination (Table 64)

The highest germination of 86.7 per cent was recorded in both 5 g and 3 g of polykote diluted in 70 and 50 ml of water kg^{-1} respectively. The seeds coated with polykote @ 5 and 3 g after dilution in 90 and 70 ml of water kg^{-1} recorded the next highest germination of 85.3 per cent. The uncoated seeds had a lowest germination of 78.7 per cent.

4.4.1.6. Root length (Table 65)

The 5 g and 3 g of polykote diluted with 70 and 50 ml of water respectively promoted longer roots of 21.0 and 20.2 cm respectively. Dilution beyond the above mentioned level in the respective polykote dosages, decreased the root length at increasing rate. The control registered a lowest root length of 16.9 cm.

4.4.1.7. Shoot length (Table 65)

The highest shoot length of 11.8 cm was recorded in seeds coated with polykote @ 5 g + 70 ml of water kg^{-1} and 3 g of polykote + 50 ml of water kg^{-1} with 11.7 cm, and both were statistically on par. In general, seeds coated with 5 g polykote were superior to 3 g with regard to shoot length. The uncoated (control) seeds had a shoot length of 9.6 cm.

4.4.1.8. Dry matter production (Table 65)

The seeds coated with polykote @ 5 and 3 g, diluted with 70 and 50 ml respectively registered an equal dry matter production of 13.7 mg $seedling^{-1}$. The above doses, when diluted with additional 20 ml of water kg^{-1}, though had a slightly lesser dry matter production of 13.3 and 13.4 mg seedling, all the above four doses were at par. However, dilution beyond this limit had no effect of polykote coating. The uncoated seeds recorded a lower value of 12.3 mg $seedling^{-1}$.

4.4.1.9. Vigour index (Table 65)

A highest vigour index of 2846 followed by 2766 was recorded in 5 and 3 g of polykote diluted with 70 and 50 ml kg^{-1} respectively. As in the case of other parameters, the vigour index reduced at an increasing rate when the polykote doses were diluted beyond the above mentioned levels. The uncoated seeds poorly performed with a vigour index 2085.

4.4.1.10. Germination in conventional method (Table 65)

Influence of polykote coating was significant with regard to emergence of rice seeds incubated and sown in conventional method also. In this test, the seeds coated with polykote @ 5 g + 70 ml of water kg^{-1} emerged superior with 92.7 per cent followed by polykote 3 g + 50 ml water kg^{-1}. It was proved that as the water used for dilution increased or decreased beyond the above levels had decreased the effect of polykote coating. The uncoated seeds registered emergence as low as 81.3 per cent which was 11.4 per cent lower than the best treatment.

4.4.2. Effect of seed coating with different colours of polykote in rice hybrids and parental lines

4.4.2.1. Time taken for sprouting (Table 66)

In general, all the colours of polykote consumed lesser time for sprouting (27.7 to 30.0 h) as compared to uncoated control (31.0 h). Among different polykote colour tested, pink followed by clear promoted early sprouting at 27.7 and 28.0 h respectively. The impact on sprouting time by blue and black was found to be slightly less with 30.0 and 30.3 h as compared to others.

In general, both the hybrids ADTRH 1 and CORH 2 responded well to the polykote coatings by sporuting within a short span of 26.9 and 26.6 h respectively as against both the R lines IR66R and C20R which exhausted much longer time of 31.4 and 33.7 h respectively. There was no worth mentionable variation observed due to the interactive effect of genotypes with polykote coating.

4.4.2.2. Radicle length in time bound germination (Table 67)

The increase in the radicle length was evident in all the polykote coated seeds (16.46 to 16.84 mm) when compared to uncoated control (14.77 mm). However, the effect of various polykote colours appeared to be comparable statistically. The effect of polykote coating was found to be dominating in the hybrids especially in CORH 2 (17.21 mm) followed by ADTRH 1 (16.89 mm). It was in IR66R, the polykote coating could not bring about commendable change in radicle length (14.74 mm) in time bound germination. Conversely, there was no evidence of significant interactive effect.

4.4.2.3. Rate of germination (Table 68)

Polykote coatings resulted in a marked increase in the rate of germination to a tune of 30.93 to 31.27 as against 26.89 of uncoated control. Whereas, the effect found to be not much varying among different coloured polykotes. The polykote effect predominated in CORH 2 (33.43) and ADTRH 1 (32.04) and it was only marginal in the R lines, IR 66R (27.86) and C20R (26.41). The interactive effect found to comply with the individual effect.

4.4.2.4. Germination (Table 69)

Coating with clear, green and pink polykote excelled in registering a marked increase in germination (89.2, 89.2 and 88.8 per cent respectively) as compared to uncoated seeds (86.8 per cent), irrespective of the genotypes. The hybrids, ADTRH 1 and CORH 2 were found to be highly responsive to the polykote coatings by recording a maximum germination of 89.7 and 89.9 per cent respectively. The additive effect of individual factors was not conspicuous.

4.4.2.5. Root length (Table 70)

The effect of polykote coating was much pronounced in red (19.45 cm) followed by clear and pink (18.95 and 18.93 respectively) as against the uncoated control (17.01 cm). The response to coating with polykote among the genotypes also varied appreciably with the CORH 2 responding profusely (20.00 cm) and the A line, IR58025A responding marginally (17.43 cm). The interactive effect of individual treatments did not exert appreciable change in root length.

4.4.2.6. Shoot length (Table 71)

The role played by the polykote coating was pivotal in increasing the shoot length especially in red (12.21 cm), clear (12.13 cm) and pink (11.99 cm) polykote as compared to uncoated control (11.22 cm). Irrespective of colour of polykote, the shoot length was high in C20R followed by IR66R. As observed in root length, similar was the case for shoot length also with regard to interactive effect.

4.4.2.7. Dry matter production (Table 72)

The dry matter production was a predominantly higher in green and pink polykote to a tune of 13.93 and 13.91 mg seedling^{-1} as against a remarkably lower value of 12.77 mg seedling^{-1} in uncoated control. Irrespective of polykote treatment, C20R registered a higher dry matter of 15.71 mg seedling^{-1} followed by the other R line, hybrids and female parent (12.60 mg seedling^{-1}). The additive effect of individual factors failed to offer variation convincingly in dry matter production.

4.4.2.8. Vigour index (Table 73)

A conspicuous increase in vigour index values was noticed due to polykote coatings especially in red (28.07), clear (2771) and pink (2747) as compared to uncoated (2454). The blue and black polykotes could influence vigour index only to a marginal extent of 2574 and 2579 respectively. Irrespective of polykote treatment, C20R and its hybrid CORH 2 registered remarkably higher vigour index of 2850 and 2811 respectively, while the A and B lines registered far low vigour index of

2537 and 2525 respectively. There was no significant evidence exist for the interaction effect.

Chapter V

Discussion

Hybrid rice research in China, India and elsewhere during the past few years has established the superiority of hybrids over popular traditional varieties in respect of growth, vigour, grain yield and tolerance to stresses. Hybrid rice technology as the most feasible and readily adoptable option for increasing production has been demonstrated in China during the past two decades. The large scale adoption and future spread of the hybrid technology will, however, primarily depend on its economic attractiveness (Paroda, 1998). The requirement of fresh seed each time and low seed yield from the complex seed production procedures render this technology quite costly (Liang Manzhong and Zaman, 1999).

Therefore, the hybrid rice seed production technology should be refined further to obtain 1.5 – 2.0 t ha^{-1} of seed yield on sustainable basis. This would stabilize the cost of the hybrid seed. A well-established package of the technology for hybrid rice seed production would greatly boost the expansion of hybrid rice (Yuan, 1998). Therefore, the seed production technology should continue to be improved to attain higher seed yields. As gibberellic acid (GA_3) is the costliest input in hybrid seed production in India, research should focus on economizing the use of GA_3 and finding suitable alternatives to it. Considering the above, the present study was envisaged at developing comprehensive nutritional package involving cheaply and locally available organic and inorganic nutrients with a view to maximizing the yield of hybrid seed in rice. The results obtained in the present investigation are discussed hereunder.

5.1. EFFECT OF ADDITIONAL DOSE OF N AND K AND FOLIAR SPRAYING OF ORGANIC AND INORGANIC NUTRIENTS ON GROWTH AND YIELD OF PARENTAL LINES IN HYBRID SEED PRODUCTION OF RICE

Nitrogen is well recognized as a promoter of vegetative growth (Sadayappan ***et al.***, 1974; Pillai and De, 1980). A better effect has been observed in growth attributes when N and K were applied together at transplanting, maximum tillering and panicle initiation stages (Seetharam, 1981; Purushothaman, 1985). In the present study also various growth and yield attributes of both A and R lines exerted a profound response to the additional dose of N and K fertilizers applied in split doses at different growth stages. The impact of additional 25 kg N + 15 kg K ha^{-1} each applied in two stages viz., panicle initiation (PI) and 10 days after PI (10 DAPI) over and above the recommended dose of fertilizer (RDF) @ 150 : 60 : 60 kg NPK ha^{-1} was overwhelming by increasing the plant height, number of total tillers and productive tillers in both male (R) and female (A) lines.

Due to application of higher N and K at the aforesaid level, the plants grew taller by 4.0-4.2 cm in A line and 4.8 – 6.0 cm in R lines as compared to RDF. The increase in plant height was only upto 50 per cent of the above in A (2.7 cm) and R line (2.3-3.3 cm) when the additional dose was given only at PI stage and was about 25 per cent when applied only at 10 DAPI stage. N apart from being a substrate for protein synthesis, it also stimulates meristematic growth through protoplasmic biosynthesis (Yoshida and Oritani, 1974; Beringer, 1980). Thus, increased availability of N through additional N application resulted in higher values of plant height. Eventhough, K was not considered necessary for promoting the vegetative growth, it might be possible that this nutrient has an indirect influence in increasing the uptake

of N, which in turn might have contributed to increase in the plant height (Tisdale and Nelson, 1975). Eventhough, the increase in plant height was corresponding to the additional doses of N and K, the results clearly indicated that the stage of application was critical for the plants to respond significantly and positively. Therefore, it appears that the higher N application at earlier stage (PI) was highly beneficial in promoting vegetative growth, thus the increase in plant height was appreciable.

During certain critical stages of crop growth, the metabolic demand for mineral nutrients may temporarily exceed the capacity of root absorption. Such stress can be overcome by foliar feeding of fertilizers by which, nutrients are supplied to plant directly without spending energy for their transport and without any loss in transit. Plant height is one of the morphological parameters influenced by the application of growth regulators. In the present study, foliar spraying of GA_3 @ 75 g ha^{-1} thrice at flowering increased the plant height of both A and R lines remarkably in seed production of rice hybrids ADTRH 1 and CORH 2. Application of GA_3 at early stage of flowering might have caused elongation of top most internode thereby, increasing plant height (Pan and Liang, 1987). In the present investigation, R lines responded profusely to the GA_3 application and grew taller than the A lines. Foliar spraying of 0.2 ppm brassinolide in A line and spraying of DAP 2% + KCl 1% + $ZnSO_4$ 0.5% + Boric acid 0.2% in both A and R lines also increased the plant height to an appreciable level. Positive effect of brassinolide in increasing the plant height of rice was reported by Hebbalkar ***et al.*** (1997). Brassinosteroids are reported to regulate cell elongation, cell expansion and cell division (Adam, 1994; Creelman and Mullet, 1997) and that might have caused increase in plant height. Increase in plant height, especially in the pollen parent is very important for the increased out crossing

and seed set in seed parent which was accomplished by the above foliar spray treatments (Figure 2).

The additional dose of N and K given at both PI and 10 DAPI promoted 2.0 to 3.0 extra tillers in A line and of which 1.8 to 2.5 tillers become productive in both the hybrids. Similarly in R line also, 3.0 to 4.5 additional tillers were produced due to the above extra doses of N and K and 1.4 to 3.5 of them turned to be productive in both ADTRH 1 and CORH 2. Jiang ***et al.*** (1993) also reported that the content of NH_4-N in the soil solution was positively correlated with tillering ability in rice. In a study conducted by Ramakrishna Reddy (1984) also higher dose of K increased the number of productive tillers. K by promoting more dry matter production (Mengel ***et al.***, 1976) would have contributed to increased production and conversion of tillers more productive. Velu (1990) observed that the increase in fertility level had beneficial effect and recorded higher values in respect to tillers. The response to additional dose applied at single stage either at PI or 10 DAPI also positive with regard to production of tillers and converting them to be productive, but, the response was comparatively higher when applied at PI stage. As reported by Dhyani and Mishra (1994), N applied at PI was more effective in rice than top dressing at flowering stage (Figure 3).

Spraying of DAP + KCl with or without $ZnSO_4$ + Boric acid resulted in higher number of total tillers and converting them to be panicle bearing significantly in both the parents of ADTRH 1 and CORH 2. The additional dose of N, P and K received in the form of foliar spray could have attributed to increased number of total and productive tillers. Several studies indicated that similar responses were often

obtainable with foliar application (Manoharan and Subramanian, 1983; Rattan and Shukla, 1984). Besides, foliar spraying of $ZnSO_4$ + Boric acid or brassinolide in R lines of ADTRH 1 and CORH 2 respectively also exerted worth mentionable effect on production and promoting tillers more productive. Bhaskaran (1986) found higher number of productive tillers with the spraying of $ZnSO_4$. The increased activity of enzymes such as dehydrogenase, proteinase and efficient utilization of absorbed nutrients which might in turn increase the productive tillers (Dong ***et al.***, 1981) in rice. Similarly, Mai ***et al.*** (1989) reported that brassinolide increased the nitrate reductase activity in rice, which plays a key role in nitrogen metabolism and thereby, influence the plant growth and development (Eilrich and Hageman, 1973).

The A line enriched with additional dose of N and K at both PI and 10 DAPI stages was early by 3.4 to 3.8 days in attaining 50 per cent flowering at 89.5 to 89.9 days after sowing (DAS) in ADTRH 1 and CORH 2 respectively as compared to RDF which required 92.9 to 93.7 days. Earliness in flowering due to application of nitrogen has been reported by Vanangamudi and Ramasamy (1985) and Bhaskaran (1986) in bajra and Ram Sudhakar and Jayakumar (1996) in sorghum. The reduction in number of days required to complete 50 per cent flowering was related to the increase in nitrogen uptake. The early flowering due to higher fertilizer application may be attributed to the early attainment of C/N ratio, accompanied by induction of physiological systems such as enzymes necessary for early initiation of the reproductive phase in rice (Mitsui and Nishigaki, 1940).

It was indicated in the foreseen part of the discussion that the stage of application of additional fertilizer dose played a pivotal role. Now, it appeared to be

varying among the growth traits also. As it was evident in the present investigation that the additional dose of N and K applied in single stage at 10 DAPI promoted early 50 per cent flowering as that of additional dose applied in two stages viz. PI and 10 DAPI. Therefore, 10 DAPI appeared to be a critical stage for the application of additional dose of N and K in order to advance the 50 per cent flowering. Brassinolide was the only foliar spray treatment promoted early 50 per cent flowering. The enhanced uptake of nutrients and minimized nutrient depletion in leaves during critical stages due to brassinolide spraying (Alapat, 2001) might have promoted early flowering. In addition to more accumulation of photosynthetic pigments, brassinolide induces enzyme proteins and in turn increased photosynthetic rate and nitrogen metabolism leading to higher biomass production (Sasse, 1985). Moreover, increased translocation (Fujii ***et al.***, 1991) might have also resulted in early flowering.

The response of both the parents to the additional dose of N and K was not consistent in increasing the panicle length, as it was positive in ADTRH 1 and had no effect in CORH 2. Similar observation was reported by Hembram ***et al.*** (2001). The foliar spraying of GA_3 predominated in improving the length of panicles followed by the other plant growth hormone, brassinolide and the distillery by-product, spentwash in both the parents. The positive effect of brassinolide in increasing panicle length was mainly due to the ability of this chemical in increasing cell division and cell elongation (Anitha, 1993). Spentwash reported to contain appreciable amounts of plant growth hormones like GA (>4600 mg L^{-1}) and IAA (>50 mg L^{-1}) (Murugaragavan, 2002). Therefore, increase in panicle length due to spentwash spray is attributable to the effect of growth promoting substances present in the spentwash.

Panicle exsertion was higher by 3.2 to 5.1 per cent in A line of both the hybrids due to additional dose of N and K applied at both PI and 10 DAPI as compared to RDF. Application of additional N and K at 10 DAPI also improved the panicle exsertion marginally. The results indicated that top dressing of N and K at around panicle exsertion was a good cultural practice because it enhanced translocation of assimilates from the flag leaf to the panicle during ripening (Yong-Rui Wang and Ying-Jie Zhang, 1995). Foliar spraying of GA_3 exserted panicles remarkably higher upto 90.0 per cent in ADTRH 1 and 81.5 per cent in CORH 2. Increase in the number of vascular bundles and size of the phloem in young peduncles with the spray of GA_3, which facilitated better translocation of metabolites from source to sink (Kaur and Singh, 1986) and resulted in more exsertion of panicles. Superiority of GA_3 in enhancing panicle exsertion has been reported by many researchers (Yuan, 1985; Xu and Li, 1988; Sharma, 1991; Deshpande, 1993; Prabhagaran, 1996).

Foliar spraying of spentwash and brassinolide also promoted panicle exsertion to a reasonable level as compared to rest of the treatments. The poor panicle exsertion in rest of the treatments might be due to low concentration of available endogenous gibberellic acid in male sterile line resulted in reduced rate of cell division of the internode meristem (Yuan ***et al.***, 1994). Increase in plant height, panicle length and panicle exsertion to a considerable extent due to spentwash spray was the confirmation for the positive effect of growth promoting substances (GA and IAA) present in the spentwash that would have promoted the internode elongation, though not to the level of absolute GA_3 (Figure 4).

The fertilizer doses had no effect on the number of spikelets panicle^{-1}. This result is in agreement with that of Sadayappan ***et al.*** (1974). However, the foliar spraying of DAP + KCl + $ZnSO_4$ + Boric acid favoured more number of spikelets panicle^{-1} than the other chemicals and fertilizers. The increased and immediate availability of both macro and micronutrients at critical growth stages might have accumulated more dry matter and resulted in better performance of this treatment. Virmani (1996) also reported increased number of spikelets with higher accumulation of dry matter in hybrid rice. Eventhough, the seed set per cent in A line increased with the proportionate increase in the supply of fertilizer doses, the later application of fertilizers at 10 DAPI exhibited the effect only as that of RDF. Foliar spraying of GA_3 @ 75 g h^{-1} established its superiority by achieving a maximum seed set of 39.7 and 34.3 per cent in ADTRH 1 and CORH 2, respectively. GA_3 was able to manipulate many floral traits that have direct bearing on out crossing rate and the seed set in hybrid seed production (Viraktamath, 1995). The increased seed set could be due to better synchronization of A and R lines, better panicle exsertion and stigma exsertion as influenced by GA_3.

Though, the test weight of rice is a genetic character, the present study indicated that the fertilizer management could also influence this trait to considerable extent. As compared to RDF, additional dose of N and K applied irrespective of stages increased the 1000 seed weight of both the hybrids and R lines. Sufficient level of fertilizer nutrition lead to better growth and dry matter production, which might have caused higher production of photosynthates and efficient translocation to sink, thus resulting in better filling of the spikelets (Athmanathan, 1996). Similarly foliar spraying of DAP + KCl either alone or in combination with $ZnSO_4$ + Boric acid

increased the 1000 seed weight. Application of zinc plays a role in nucleic acid and protein synthesis and aids in the utilization of phosphorus and nitrogen with associated increase in seed formation (Gill and Singh, 1978); while the application of boron helps in lignin and protein synthesis and cell division in rice (Takkar and Randhawa, 1978).

Significantly varied seed yield, manifested with appropriate nutrient supply was very much evident in the present investigation. The application of additional dose of N and K at both PI and 10 DAPI resulting in greater plant height, productive tillers, panicle exsertion, seed set and efficient filling of more number of spikelets and 1000 seed weight cumulatively resulted in higher single plant yield and thereby, increased hybrid seed yield per unit area. The positive manifestation of these characters in general resulted in increase of 13.7 per cent in ADTRH 1 (2,061 kg ha^{-1}) and 12.3 per cent in CORH 2 (1,663 kg ha^{-1}) hybrid seed yield due to application of additional N and K at both PI and 10 DAPI stages. The additional dose supplied at PI stage alone could also achieve 9.0-9.8 per cent higher seed yield of both the hybrids. A similar trend was observed in R line also with the additional fertilizer dose at both PI and 10 DAPI enhancing the per plant and unit area grain yield to a tune of 15.0 and 11.5 per cent by recording 1,623 and 1,488 kg ha^{-1} in R lines of ADTRH 1 and CORH 2 respectively. The additional N and K at PI also maximized the grain yield by 10.3 and 9.8 per cent in R lines of ADTRH 1 and CORH 2 respectively (Figure 5).

Increase in leaf area, N uptake (Shivaraj, 1981 and Shanmugam, 1983), chlorophyll content and nitrate reductase activity (Sudhakara ***et al.***, 1987) proportionate to levels of N applied has been reported. Similarly, potassium is

essential for enzyme activation, cell division, photosynthesis, respiration and translocation in plants (Singh Balaram ***et al.***, 1977), These factors might have contributed significantly in increased growth and yield attributes and thereby, increase in seed / grain yield of both the parents. Among the foliar spray treatments, GA_3 retained its supremacy by recording a remarkably higher hybrid seed yield of 2,282 and 1,855 kg ha^{-1} in ADTRH 1 and CORH 2 respectively. The higher panicle length, panicle exsertion and increased plant height of pollen parent resulted in enhanced seed set which enabled to achieve a higher seed yield due to GA_3 spray. The superiority of GA_3 in enhancing the hybrid seed yield of rice has been reported by many scientists (Sahai ***et al.***, 1987; Deshpande, 1993; Ruggeri and Branca, 1994; Angamuthu, 1996; Ponnuswamy ***et al.***, 1998; Kalavathi ***et al.***, 2000 and Adarana Kumar, 2001).

The increase in hybrid seed yield was also conspicuous due to spentwash, a cheap industrial by - product by recording 1,993 and 1,623 kg ha^{-1} in ADTRH 1 and CORH 2 respectively. This could possibly be due to increased plant height, panicle length and panicle exsertion though not to the level of GA_3, resulted in higher seed set and seed yield. As it was indicated earlier that the positive effect of growth promoting substances such as GA and IAA present in spentwash would have resulted this yield increase. Being originated from plant source, the spentwash is rich in N, P, K, Ca, Mg and S. Relatively small amounts of micronutrients (Fe>Mn>Zn>Cu) were also present in the spentwash (Murugaragavan, 2002). Ray and Choudhuri (1981) while observing the function of growth hormones in improving seed filling of rice, attributed to an increase in longevity of leaves, thereby prolonging the period of remobilization of metabolites from leaves to seed. Inspite of appreciable amount of growth promoting substances available in spentwash, its inability to be effective as equivalent to

absolute GA_3 could probably be due to the presence of large amount of Cl > HCO_3 > SO_4 salts that might have hampered the positive effect of growth promoting substances of spentwash.

The R lines applied with DAP + KCl either alone or along with $ZnSO_4$ + Boric acid recorded a higher grain yield of 1,757 and 1,625 kg ha^{-1} in ADTRH 1 and 1,596 and 1,583 kg ha^{-1} in CORH 2. This yield increase due to the foliar spraying of above treatments obtained in R line as compared to A line clearly indicated the differential response of the parental lines to the applied nutrients. It was evident in the present investigation that the growth promoting substances played a major role in seed parent and it was inorganic chemical nutrients found to be effective in pollen parent.

The present results indicated a corresponding increase in the N, P and K uptake of both the straw and seed / grain of A and R lines with the progressive increase in the application of N and K fertilizer dose. The highest uptake of N, P and K was recorded with the application of additional dose of N and K at both PI and 10 DAPI. Increased uptake with the increase in dose of fertilizer application has been reported by Sahu ***et al.*** (1980) and Salam (1984). The lower nutrient uptake in RDF could be attributed to the reduced quantity of fertilizer supply. One way to achieve better use of the applied nutrients is to apply the fertilizer at a time to best meet the demand of the rice plant (De Datta, 1981). Accordingly, the application of additional dose of fertilizers at PI stage and additionally at 10 DAPI attributed to better uptake. Samantary ***et al.*** (1990) observed that N uptake was high between vegetative and reproductive stages.

The response to GA_3 spray in A line and DAP + KCl as sole or combined with $ZnSO_4$ + Boric acid in R lines was much pronounced with the increased uptake of N, P and K. This indicates the active role of GA_3 and other foliar spray treatments in the uptake, translocation, accumulation and utilization of applied mineral nutrients which resulted in a greater influence on the growth and yield of both A and R lines in the seed production of hybrid rice. In general, the additional dose of N and K fertilizers improved the available soil N, P and K contents at post harvest stage. Whereas, a minimum variation observed in the available soil nutrient contents among the fertilizer doses and foliar spray treatment indicated the better uptake and utilization of the applied nutrients by both A and R lines of both the hybrids.

To ascertain the relationship of various growth and yield parameters and nutrient uptake pattern of A and R lines with hybrid seed yield of ADTRH 1 and CORH 2, correlation co-efficient was worked out and presented in the Table 75. The hybrid seed yield was positively and significantly associated with plant height and panicle length of both the parents. The direct influence of panicle exsertion per cent, seed set per cent and total N, P and K uptake in seed parent (A line) exhibited positive and significant correlation with hybrid seed yield of both ADTRH 1 and CORH 2. This also indicated that the increase in the plant height and panicle length of R line had indirect influence on hybrid seed yield probably by increasing the out crossing and seed set in seed parent. Correlation coefficient revealed no significant contribution of days to 50 per cent flowering, number of spikelets and 1000 seed weight towards increase of hybrid seed yield.

The results of seed quality analysis of freshly harvested hybrid seeds of ADTRH 1 and CORH 2 revealed that both the fertilizer and foliar spray treatments failed to influence the seed quality attributes such as germination, root length, shoot length, dry matter production and vigour index consistently. According to the present investigation, application of additional dose of 25 kg N and 15 kg K ha^{-1} each at PI and 10 DAPI over and above the recommended dose of NPK @ 150 : 60 : 60 kg ha^{-1} along with foliar spraying of GA_3 @ 75 g ha^{-1} thrice at flowering maximized the hybrid seed yield of ADTRH 1 and CORH 2. However, there is a scope for combined use of GA_3 with spentwash, a cheap industrial by-product or brassinolide, a new group of plant hormone to substitute the quantity of GA_3 and economize the hybrid seed production in rice.

5.2. ASSESSMENT OF PHYSIOLOGICAL AND BIOCHEMICAL BASIS OF HYBRID VIGOUR IN RICE HYBRIDS ON SEED QUALITY ATTRIBUTES

Hybrid vigour is the basis for yield advantage of hybrids over conventional varieties. The development of hybrid rice involves evaluation of the degree of heterosis for yield and development of parental lines and techniques for seed production (Hamid Miah and Sarma, 2000). Hybrid vigour in plants has been pursued with great zeal by the Plant Breeders seeking enhanced crop productivity. However, at the conceptual level, a sense of stagnation tends to persist. Frankel (1983) stated that the causal factor for hybrid vigour at the physiological and biochemical level are almost as obscure as they were 30 years ago. Although, heterosis has been subject for multitude of scientific investigations, the genetical, physiological and biochemical basis of this phenomenon still remain largely unexplained (Stuber, 1994).

While, Plant Breeders and Agronomist have been utilizing hybrid vigour as a means of improving crop productivity, the biological basis of hybrid vigour remains largely unknown (Tasaftaris and Kafka, 1998). Seed or seedling vigour at the initial growth stage is the principal trigger of hybrid vigour (Hamid Miah and Sarma, 2000). Therefore, a comprehensive investigation was undertaken to understand the physiological and biochemical basis of hybrid vigour on germination and seedling growth of rice hybrids ADTRH 1 and CORH 2 in order to determine whether this phenomenon is fixable and / or predictable. In the present investigation, hybrid seeds of ADTRH 1 and CORH 2 and their parental lines IR58025 A, IR58025 B, IR66R and C20R were subjected to various vigour tests viz., imbibition rate, seedling growth rate, enzyme activity and stress tests (Plate 5a). The results of this study brought out a clear evidence for differences among the hybrids and their parental lines with respect to physiological and biochemical behaviour of seed vigour.

The germination of seed is influenced by various ‘intrinsic’ and ‘extrinsic’ factors. The first and foremost change when seeds are placed for germination is the imbibition of water. Beginning with moisture absorption, various physiological and biochemical changes immediately take place in seed and after then the seed germinates. Therefore, water absorption was the most important physiological phenomenon (Takahashi, 1961) influenced by genotype apart from many other factors. In the present study, the moisture absorbed by the hybrids was rapid and almost similar as that of their female parent, IR58025A with about 31.1 to 31.7 per cent irrespective of period of imbibition. The male lines, IR66R and C20R absorbed 8.0 to 10.0 per cent lesser moisture than the above seeds. This variation could be due to existence of variation in relative permeability of seed coat among the

genotypes. The existence of a very efficient semi-permeable membrane system in seed regulates the water uptake (Shull, 1913). The rapidity in moisture absorption in both the hybrid seeds was notable since the beginning of imbibition. Among the R lines, C20R was slowest as compared to IR66R. This clearly indicates the presence of efficient semi-permeability of seed coat in the hybrids and female parent as compared to their male parents (Figure 6).

The rapidity in moisture absorption resulted in quicker sprouting in the hybrid seeds within 25 to 26 h followed by IR58025A in 28 h. The R lines required 5 to 6 extra hours to sprout. The earliness in sprouting of hybrids seeds was earlier reported by Ramalingam (1994). Wanjura ***et al.*** (1969) were of the strong opinion that the time of sprouting could be a realistic indicator of vigour and yield potential. Genetic variability for the time to germinate in the field crops is considered very important particularly with regard to hybrid seed production, which involves synchronization of male and female lines at the time of flowering for obtaining maximum yield. Whittington ***et al.*** (1965) were not clear why differences occur in the time taken for germination in various genotypes. An immediate clarification for this could be that the increase in the amount of water entering the caryopsis, stimulating the α-amylase activity, which is the main factor governing starch breakdown (Jones, 1969). α-amylase is also sensitive to seed water potential (Jones and Armstrong, 1971) which might have resulted in variation for sprouting time. There are many factors contributing to such differences that the present study tried to elucidate some of them in the ensuing part of the discussion.

The hybrid seeds of CORH 2 exhibited a distinct superiority in producing relatively longer radicles of 19.1 mm in time bound germination as compared to other hybrid and its male parent C20R that produced only 15.6 mm of radicle. The superiority of hybrids CORH 2, followed by ADTRH 1 was clearly evident in rate of germination and standard germination tests also. Takahashi (1956) in studying cultivar differences in germination speed of rice seeds, concluded that O_2 uptake and imbibition rate were parallel to germination speed. The hybrid seeds of CORH 2 and ADTRH 1 which exhibited a predominantly higher enzyme activity, particularly the highest α-amylase activity in the endosperm could have provided energy and assimilates for embryo development, which in turn was expressed in hybrid vigour for germination and its speed. Similar results obtained by Li ***et al.*** (1982) showed superiority of rice hybrid Nan-you 2 to its three parental lines viz., R>B>A for germination speed.

Significant variations were noticed in root length, shoot length, dry matter production and vigour index of hybrids and their parental lines. It is interesting to note that root length of both the hybrids was slightly longer, but almost resembled their respective R lines. However, their shoot lengths were statistically comparable with their female parent (Plate 5b). According to earlier report of Karivaratharaju (1986) both root and shoot length had maternal influence on hybrid. Most of the seed vigour definitions indicated that the seed vigour is a product of interaction of genetic and environmental components during seedling emergence (Moore, 1963; Grabe, 1966 and Burris, 1975). Therefore, vigour is in part, an inherited trait has a genetic basis as observed in the root and shoot expression of present study.

As the shoot growth was pronounced in R lines, it resulted in higher dry matter production as compared to hybrids, A and B lines. Conversely, Joshi ***et al.*** (1986) reported that growth in terms of shoot length, fresh and dry weight revealed better parental and / or mid parental hybrid vigour in pearlmillet hybrids over their respective parents. Similarly, vigour index was also higher in the hybrids to a tune of 2.8 to 3.1 per cent over their R lines and 13.2 to 24.3 per cent over their A line. The increase in reverse mobilization, as a result of greater water uptake (Lieffering ***et al.***, 1993) in hybrids, is the major cause of increased seedling vigour in hybrids. Similar results of high hybrid vigour was obtained by Hebert (1990), Lopez-Castaneda ***et al.*** (1995) and Gomes ***et al.*** (2000). The germination ability and vigour are related indirectly to the performance in the field. In the present study, the field emergence potential of hybrids was comparatively higher than their parents.

When seeds germinate, it is essential that the stored reserves are degraded to provide nutrients at correct time during embryo growth. This is achieved through hormonal control mechanism which increases the activity of proteolytic enzymes, starch – degrading enzymes, nucleases, phytase etc., at appropriate time (Chesworth ***et al.***, 1998). The most sensitive tests for measuring seed vigour are those which measure activity of certain enzymes associated with germination process. In the present study, changes in enzyme activity exhibited by fresh seeds of rice hybrids and their parental lines brought out convincing evidence for superiority of hybrids and existence of hybrid vigour in seed germination. The total dehydrogenase enzyme activity was highest in hybrids with slightly more activity in CORH 2 (0.124) than ADTRH 1 (0.114) as expressed by their OD values, indicated in the parentheses. Among the R lines, C20R had higher dehydrogenase activity. Moreover, the energy

for biochemical reactions in living cells is stored in high energy compounds such as ATP. ATP content in imbibed seeds has been significantly correlated with seedling size (Ching, 1973; Ching and Danielson, 1972) and field emergence (Yaklich ***et al.***, 1979). The total ATPase enzyme activity was highest in CORH 2 and ADTRH 1 (32.08 to 34.17 µ mol of P g^{-1} h^{-1}) followed by R lines and lowest in B line (24.76 µ mole of P g^{-1} h^{-1}) ATPase are mainly involved in biochemical pathways (particularly those involving sugars) and accompanied by release of considerable amounts of energy which can be used to drive reactions (Chesworth ***et al.***, 1998).

The activity of dehydrogenase and ATP content of hybrid roots were reported to be much greater than those of conventional cultivars by Yang and Sun (1988). The higher activity of these enzymes have resulted in rapid and higher growth of roots and shoots in the hybrids and R lines. During very early stage of imbibition, energy releases or transfers are by the way of glycolysis using as substrate free sugars available in embryo tissue and catalysed by enzymes already present. Later, mitochondria drive the system by way of the Kreb cycle and the substrates are derived from breakdown of endosperm tissue. The initial breakdown of endosperm, in turn is catalysed by enzymes (Chen and Osborne, 1970). Vigorous seeds must be seeds with a high average performance in all of these processes. During the first few hours, the germinating seed needs available sugars, and efficient available enzymes (Kneebone, 1976). Stable but active alcohol dehydrogenases could improve early seed vigour involving glycolysis under temperature stress and low oxygen tensions (Schwartz and Laughner, 1969). Similarly, ATP, the major fuel for cell activities, is largely a function of quantity and efficiency of mitochondria (McDanial, 1973) related to higher total respiration. The qualitative differences in mitochondrial

efficiency associated with hybrid vigour and the genetic differences in seedling vigour are independent of seed size (Clements and Latter, 1974; Kneebone, 1972) (Figure 6).

The toxicity of H_2O_2 concentration in plants lead to many degradative process involving photo oxidation. Catalase and peroxidase enzymes act as protectants against accumulation of peroxide (Woodstock, 1973). They cause the decomposition of H_2O_2 into water and oxygen as per the equation, $2H_2O_2 \rightarrow 2H_2O + O_2$. These enzymes are more directly involved in the maintenance of better germination (Rame Gowda, 1992). Amylases are also key enzymes for starch catabolism during rice seed germination (Wang Sangen, 1997). Amylase hydrolyses starch to give reducing sugars like glucose, maltose and limit dextrins. In the present study, all these three enzymes were highly active in the hybrids followed by R lines. The seeds of IR58025 A and IR58025 B exhibited comparatively poor activity of the enzymes. Higher amylase activity in kernals would enhance seedling vigour (Wang Sangen, 1997). Decreased amylase activity results in reduced supply of readily assimilable sugars, which accounts for the poor seedling growth. Decrease in activity of α-amylase activity with decline in seed vigour in rice seeds was reported by Ghosh ***et al.*** (1981), Rame Gowda (1992) and Bhaskaran (1995). The aforesaid discussion explicitly brought out the evidence for the reliability of the biochemical measurements that have been tested for correlation with germinability and seed vigour are the manipulations of seed constituents, nature and level of enzymatic activity and metabolic processes initiated by each genotype during the early hours of germination (Plate 6 and Plate 7a).

In order to understand the level of hybrid vigour expressed in the (so far discussed) seed vigour attributes, the relative heterosis (di) and heterobeltiosis (dii) percentages were worked out and presented in the Table 76. Both the hybrids exhibited significant and positive relative heterosis for all the physiological and biochemical seed vigour attributes except for time taken for sprouting and dry matter production showing negative heterosis and shoot length exhibiting no heterosis. Significant, positive heterobeltiosis was observed for radicle length in time bound germination, root length and enzymes activity. For the vigour attributes viz., time taken for sprouting, shoot length and dry matter production both the hybrids showed significant, but, negative heterobeltiosis. In general, CORH 2 was found to be superior in terms of relative heterosis and heterobeltiosis for most of the physiological and biochemical seed vigour attributes.

Except imbibition rate, shoot length and dry matter production, rest of the physiological and biochemical vigour attributes had positive and significant relationship with field emergence according to Table 77 presented with the correlation coefficient among the seed vigour attributes. All the biochemical attributes found to be reliable and correlate well with most of the physiological vigour attributes. Among the physiological attributes, rate of germination and vigour index exhibited significant correlation with six out of ten physiological vigour attributes. After critically analyzing the multiple vigour tests so far discussed capable of resembling field emergence were rate of germination, vigour index and enzyme activity. Those vigour tests closely predicted the field emergence were time taken for sprouting, radicle length in time bound germination, germination and root length. However, shoot length and dry matter had no accurate predictability of field emergence. Therefore, by

employing the seedling growth rate tests, and enzyme activity early hybrid vigour was predictable and fixable.

Earlier studies on variability in seed vigour (Murugesan ***et al.***, 1989), seed germination rate and associated quality characteristics (Krishnasamy and Seshu, 1989), laboratory parameters and field emergence (Shenoy ***et al.***, 1990) in rice revealed the cultivar differences for seedling vigour and emergence potential. Usually, field conditions are less than optimum when seeds are sown. Under sub-optimum or stress conditions, high vigour seeds have a greater potential for emergence and stand establishment. Some vigour tests, therefore, were conducted under stress conditions which simulate certain stresses, seeds may encounter in the field. In these tests, seeds were stressed either prior to imbibition or during germination. However, seed germination remains the criterion for evaluation.

A vigorous seed can tolerate a more severe osmotic stress and consequently, the osmotic stress method has been suggested as a vigour test (Hadas, 1977). The hybrid and parental seeds, when subjected to osmotic stress created by NH_4Cl and D-mannitol, resulted in reduced germination and seedling growth. The rice seed were highly responsive to the NH_4Cl soaking rather than to D-mannitol. IR66R, excelled with 58.0 and 80.5 per cent germination in both the tests. Eventhough, the root length reduced considerably, the superiority of C20R and CORH 2 in production of long roots was retained under stress condition also. However, the results of osmotic stress tests did not bring out clear evidence for superiority of a particular genotype for shoot length and vigour index.

There is evidence, however, which indicates that the low molecular weight osmotic substances such as NH_4Cl and mannitol might have entered germinating seeds and induce a change in osmotic potential and cause toxicity (Anon, 1983). Moreover, the rate of germination under water stress condition is markedly reduced and plumule emergence is generally sensitive to reduced osmotic potential than radicle emergence (El-Sharkawi and Springnel, 1977). Due to this reason, in the present study also, growth of shoots was affected rather than the roots. According to Takahashi (1961), the water uptake in rice was inversely correlated with the concentration of osmoticum. The initial water absorption was rapidly increased until the osmotic pressure of the salt of the out side balances the internal force, and then the entrance of water stopped. Such a situation was tolerated by the R line, IR66R with higher germination and the other R line, C20R by maintaining their superiority in production of longest roots.

There was a wide variation exerted due to anaerobic germination among the hybrids and parental lines. Under anaerobic condition also 45.0 per cent of IR66R seeds germinated and produced longest roots (1.83 cm) and shoots (3.71 cm). The only other line germinated equal to above was IR58025A. The other R line, C20R and both the hybrid seeds unable to germinate normally under anaerobic condition. The higher values of germination and seedling growth maximized the vigour index of IR66R followed by A line. These results elucidate clear distinction on environmental responses of hybrids and parental lines. Similar genotypic differences to anoxia was reported by Aleman ***et al.*** (1981), De ***et al.*** (1981) and Balamurugan (1986). In general, it is recognized that coleoptile elongation is promoted under anaerobic condition. Elongation of the mesocotyle is controlled by CO_2 concentration, and that

of the coleoptile by both O_2 and CO_2 tension (Takahashi, 1984). However, under anaerobic condition, the coleoptiles of ***japanica*** cultivars elongated more markedly than the ***indica.*** The decreased coleoptile length might be caused by the anomalous accumulation of endogenous substances during seedling growth that suppresses this growth at higher concentrations (Takahashi, 1978). During seed germination under anaerobic condition in rice, the biosynthetic increase in the rate of glycolysis does not provide sufficient ATP for rapid germination. The ATP production inhibited by excessive ethanol production (Atwell ***et al.***, 1982) as much as this situation will over come in the seedling of the highly vigorous genotype, tolerant to anoxia.

Seeds of IR66R and ADTRH 1 tolerated extremely to low temperature of 10°C in the exhaustion test and recorded remarkably higher germination of 95.0 and 80.0 per cent respectively with their roots and shoots grown beyond the root-shoot lines. However, the root and shoot growth were the highest in C20R even under the low temperature conditions. ADTRH 1, IR66R and CORH 2 followed the above in the same order with regard to root and shoot growth (Plate 7b and Plate 8). The vigour index, an interactive factor of all the above parameters indicated the superiority of IR66R followed by its hybrid ADTRH 1 with the higher values of 2585 and 2246 respectively. Therefore, it becomes apparent that there is an inbuilt mechanism to respond or to withstand stress imposed by unfavourable weather condition which is specific to each genotype. Evidently, the sum total of all the seed attributes as reflected in seed germination under stress condition is an indirect indicator of the superiority of genotypes under such conditions.

Under bioassay test, the sensitive bioassay material (fingermillet seeds) was exposed to the gaseous emanations of germinating stock seeds (rice hybrids and their parental seeds). Harvest fresh, high vigour seeds of fingermillet were used as bioassay material for testing seed vigour of rice hybrids and parents. Maximum germination of fingermillet seeds was found in the blank (90.5 per cent) in which fingermillet seeds were not exposed to gaseous emanations of rice seeds as compared to exposed ones (85.0 to 87.5 per cent). The root / shoot growth of high vigour fingermillet seedlings exposed to the gaseous emanations of germinating rice seeds was adversely affected especially with the exposure to IR58025A (3.34 / 1.48 cm) and B lines (3.13 / 1.42 cm). Root / shoot growth of fingermillet seeds was not affected much due to both the hybrids (3.73-3.76 cm / 1.66-1.68 cm) followed by their R lines (3.50-3.52 cm / 1.47-1.50 cm). Similarly, the vigour index of the bioassay material was found to be corresponding to the vigour level of stock material (rice seeds). Although, seedling growth of fingermillet seeds was affected, the germination per cent of the bioassay material (fingermillet) was not significantly differed among the gaseous emanations of germinating seeds of hybrids and parental line. The bioassay results clearly demonstrated the superiority of hybrid seeds that might have produced lesser quantities of volatile growth inhibitory substances during germination than the A and B lines, while the R lines showed intermediate effect. Fielding and Goldsworthy (1982) suggested the possible relationship between the content of volatiles and the vigour of seeds. The variations in seedling growth and vigour of bioassay material (fingermillet) is attributed to differential levels of injurious effect caused by emanating gases (Harman ***et al.***, 1982; Wilson and McDonald, 1986) from the germinating rice hybrids and their parental line seeds.

Accelerated ageing is one of the vigour tests to predict the viability potential of crop seeds. It is developed to estimate the relative storage potential of crop seed lots which is related to vigour. Vigour implies ability to germinate under deleterious conditions. Besides many other uses, this vigour test helps in selection of superior parents based on seedling characteristics in Plant Breeding Programme. The present study with accelerated aged seeds evidently implicate, irrespective of the selected genotypes, with the increased period of ageing, a progressive decline in seed germination and seedling growth was observed. This has been exemplified by the decline in germination (60.0 per cent), TZ-viability (58.3 per cent), root length (47.0 per cent), shoot length (29.0 per cent), dry matter production (36.3 per cent), vigour index (77.8 per cent) and dehydrogenase enzyme activity (81.2 per cent) after 9 days of accelerated ageing. During the same period, there was an increase in electrical conductivity (126.4 per cent), free sugars content (103.6 per cent) and free amino acids content (172.8 per cent) in the seed leachate.

The genotypic variations in the decline of seed quality with progressive ageing have also been noticed. The decline in germination due to ageing was much slower in R lines, IR66R and C20R (73.5 – 77.0 per cent) followed by IR58025 B; whereas, the hybrids and IR58025A (66.0-70.0 per cent) lost germination relatively at higher rate. Similar results of genotypic differences in respect of the decline in germinability were reported by several workers in rice (Agarwal, 1980; Sridhar Dronavalli, 1985; Murugesan ***et al.***, 1989; Chen and Zhou, 1990; Kalavathi ***et al.***, 1999). In TZ-viability test also similar variations were noticed in the present study. Significant differences in root and shoot growth among the parental lines and hybrids were recorded with the increase in ageing period. The hybrids CORH 2 and ADTRH 1 suffered reduction

in root length at a higher rate of 54.9 and 49.2 per cent while it was 52.5 and 46.6 per cent in IR58025 A and B lines. Eventhough, the root length of C20R was higher after ageing which was due to higher initial values, the rate of reduction was comparatively higher (42.2 per cent) as compared to IR66R (34.9 per cent).

Similar deteriorative changes were observed in shoot length, dry matter production, vigour index and dehydrogenase enzyme activity also. Murugesan ***et al.*** (1989) observed similar higher values for the above parameters in medium bold seeds than the long slender genotypes. Sharma ***et al.*** (1990) also observed genetic variability among rice varieties and noted long roots with high fresh weight and vigour index in bold seeded varieties. This results indicated the existence of genetic variability among the genotypes as pointed out by Gorai (1976) in rice, Agrawal (1979) in wheat and Ravi (1985) in pearlmillet. Cultivar differences in vigour potential under accelerated ageing was reported by Rajendran (1976) and related this variation to genetic vigour.

Examination of seed leachate for electrical conductivity, free sugars and amino acids content also indicated the poor performance of hybrids and their female parent, IR58025A, as compared to better performance of their R lines under accelerated ageing condition. Chen and Zhou (1990) observed similar increase in electrical conductivity, soluble sugar and amino acids with ageing of rice hybrids. The superiority of R lines in storability was also been reported by Kalavathi ***et al.*** (1994), Vimala (1997) and Kalavathi ***et al.*** (1999) in rice. The present study clearly indicated that the high initial seed vigour of hybrids reduced rapidly under accelerated ageing. Whereas, the R lines could tolerate the ageing stress and

could be able to maintain vigour substantially. Among the hybrids, CORH 2 and among the R lines, C20R were found to be poor storers. The poor storability nature of CORH 2 could have possibly been inherited from its male parent C20R, that might have resulted in rapid vigour loss than that of ADTRH 1.

The correlation coefficient among the henceforth discussed stress test vigour attributes (Table 78) found not a particular stress test to have correlation with all the other stress tests. While, both the osmotic stress tests (NH_4Cl soak and D-mannitol soak tests) correlated well, rest of the stress tests were found to be independent of each other. This implies that there was a clear distinction for each stress test in terms of the degree of stress they imposed on the genotypes and with respect to the response the genotypes exerted upon such stress. Therefore, for predicting hybrid vigour on seedling growth attributes under stress condition, instead of comparison among multiple vigour tests, comparison of genotypes under specific / given stress situation would be a realistic proposition.

Based on the above discussion, it may be concluded that the performance of hybrids and parental lines varied in relation to the given environmental condition. Both the hybrids, ADTRH 1 and CORH 2 exhibited a significant positive relative heterosis (mid-parent heterosis) for most of the physiological and all the biochemical attributes. Heterobeltiosis was pronounced in radicle length of time bound germination, root length and enzyme activity. CORH 2 was found to be superior to ADTRH 1 in terms of heterosis for seedling vigour. The rate of germination, vigour index and enzyme activity were found to be capable of resembling field emergence and can be employed for prediction of hybrid vigour in seed emergence and seedling

growth attributes. The fresh seeds of hybrids, that have outperformed the other lines and exhibited superior hybrid vigour under normal – optimal growing conditions with early germination and vigorous seedling growth, have failed to excel under sub-optimal or stress condition. Under such unfavourable growing conditions, the R lines exhibited their superiority and sustained the stress imposed on them. There was a clear distinction for each stress test in terms of degree of stress they imposed on the genotypes and with respect to the response the genotypes exerted upon such stress. Therefore, for predicting hybrid vigour on seedling growth attributes under stress condition, instead of comparison among multiple vigour tests, comparison of genotypes under a specific stress situation would be a realistic proposition. In general, the hybrids resembled their respective male parents for various phenotypic expressions of seed vigour attributes.

5.3. ESTIMATION OF QUALITY LOSS ON OCCURRENCE OF SPLIT HUSK SEEDS IN RICE HYBRIDS AND FEMALE PARENT

The rice hybrids, ADTRH 1 and CORH 2 and their female parent, IR58025 A suffer with a peculiar problem of occurrence of split husk seed in which the lemma and the palea forming the husk do not properly close the caryopsis at different proportion of seeds and thereby giving an appearance of split husk. The occurrence of split husk seed may very due to the place of production and the pollinator involved (Kamaraj, 2001). The present study aims at thorough investigation of physical, physiological and biochemical vigour status of such split husk seeds in comparison with normal intact and unseparated bulk seeds. It would elucidate information on the level of reduction, the split husk seeds incur on the seed quality of precious hybrid seeds.

The results of imbibition rate revealed the rapidity of split husk seeds in moisture absorption. The split husk seeds were ahead with 1.8 and 0.8 per cent at 4 h of imbibition and with 1.4 and 2.8 per cent at 20 h of imbibition as compared to normal and bulk seeds. The split husk seeds of all the genotypes exhibited similar pattern of water uptake and hence, there was no genotypic influence on the behaviour of split husk seeds. This suggests that the split husk seeds might have lost selective permeability of seed coat and resulted in more influx of water. The permeability of membrane in the seed to both gases and water are important in the behaviour of the seed. Therefore, characteristics of the seed coat must be considered in a study of germination behaviour of seed (Crocker and Barton, 1957). Takahashi (1961) noticed that the intake of water was very quick and high in the deteriorated seeds as compared to normal (fresh) seeds, in which the water absorption followed the normal (sigmoidal) pattern.

It has been proposed that during the process of seed deterioration, biochemical deterioration or physical disruption causes membrane damage and that weakened membranes are more susceptible to the physical damage caused by the rapid in rush of water during imbibition (Powell, 1988). This physical damage to cell membrane may, in turn, affect α-amylase activity via changes in water uptake and decrease, the rate of reverse mobilization (Cookson ***et al.***, 2001). Split husk seeds exhibited rapid uptake of water and might have suffered loss in α-amylase activity. Besides, a decline in α-amylase activity (43.3 per cent), the results of present study indicated decline in activity of other enzymes viz., dehydrogenase (21.7 per cent), total ATPase (30.0 per cent), peroxidase (45.4 per cent) and catalase (28.1 per cent) also (Plate 9).

This reduction in major enzymes activity has manifested the poor physiological performance of split husk seeds.

Inspite of rapid absorption of moisture by the split husk seeds, the time taken for sprouting was higher by 4.0 to 9.3 h as compared to bulk and normal seeds. This delayed sprouting, regardless of rapid absorption was attributed to reduction in enzyme activity, particularly the α-amylase. The reduced activity of enzymes, potentially capable of contributing to starch breakdown might have resulted in impaired reverse mobilization may therefore, explain the delay in sprouting and seedling growth. As a result, the split husk seeds exhibited a slow rate of germination and poor radicle growth in time bound germination as compared to normal seeds which possessed high enzyme activities.

Split husk seeds recorded 21.0 per cent lesser germination than normal seeds. The occurrence of split husk seeds in bulk seeds resulted in 12.3 per cent reduction in germination. The split husk seeds exhibited extreme decline in the seedling growth attributes viz., root length (32.5 per cent), shoot length (35.2 per cent), dry matter production (33.6 per cent) and vigour index (47.8 per cent) compared to normal seeds. There was a reduction upto 20.1, 30.5, 24.8 and 34.0 per cent in the above parameters due to occurrence of split husk seeds in the bulk seed also. This clearly indicates that the occurrence of split husk seeds in hybrid and female parent would bring down the seed vigour considerably (Plate 10).

The reduction in seed vigour of split husk seeds could be attributed to the lower seed weight and seed to husk ratio. The 1000 seed weight of split husk seed

(18.77 g) was 1.55 g lesser than normal seeds (20.32 g). Such a lower seed weight of split husk seeds had direct bearing on bulk seed (19.24 g) also which lost 1.08 g. A similar trend was observed in the seed to husk ratio also. The lower seed to husk ratio of split husk seeds (3.83) indicated that reduction in caryopsis weight was more than the reduction in husk weight. Due to this, a concomitant reduction was apparent in bulk seeds also (4.31) as against the higher ratio of normal seeds (4.56). Seed size has been shown to be related to vigour and often expressed additive effects on germination (Maguire, 1980). Positive and significant correlation between seed size and seedling vigour were also reported by Murugesan ***et al.*** (1989) and Krishnasamy and Seshu (1989).

Under sub-optimal or stress conditions, high vigour seeds have a greater potential for emergence and stand establishment (Anon, 1983). On subjecting split husk seeds to low temperature during germination in exhaustion test, a drastic reduction in germination (40.0 per cent), root length (53.1 per cent), shoot length (49.5 per cent) and vigour index (84.3 per cent) was inevitable (Plate 11a). The poor state of split husk seed resulted in appreciable decline in the above seedling growth attributes (Plate 11b). The inferior vigour potential of split seeds was reflected in higher electrical conductivity of seed leachate also. Electrical conductivity of seed leachate as a measure of membrane integrity is considered as a good index for seed viability (Mathews and Bradnock, 1968) and vigour (Grabe, 1965). Therefore, a lower and higher electrical conductivity in normal seeds and split husk seeds respectively adjudged them as vigour and low vigour according to above index. The increase in electrical conductivity might be due to degradation of cell membrane and the resultant loss of permeability (Ching and Schoolcraft, 1968) or due to free radical damage

(Basu, 1976). Considering all the quality attributes henceforth discussed, the split husk seeds suffered with a loss of 11.8 per cent physical quality, 21.0 per cent germination, 34.1 per cent seedling growth rate and 33.7 per cent enzyme activity with a over all loss of 29.8 per cent as a mean of all the physical, physiological and biochemical seed quality attributes. The split seed occurrence in bulk seed incurred a direct loss upto 17.4 per cent in seed quality of hybrid and female parent seeds.

5.4. EFFECT OF POLYKOTE SEED COATING ON RICE HYBRIDS AND PARENTAL LINES ON GERMINATION AND SEEDLING VIGOUR

Seed coating is a mechanism of applying needed materials in such a way that they affect the seed or soil at the seed soil interface. Thus, seed coating provides an opportunity to package effective quantities of materials such that they can influence the microenvironment of each seed (Scott, 1989). Seed coating have evolved from those which protect the seed from fungal and insect attack to a diverse and new range of coatings such as polymer. Number of published results indicate positive (Konstantinov and Kolarova, 1988; Angamuthu, 1991; Dadlani ***et al.***, 1992; Song Dongseod and Lee Sheong Chun, 1998), negative (Baxter and Waters, 1986) and no effect (Sharples and Gentry, 1980) of polymer coating on germination and seedling establishment of various crop seeds. Therefore, it has been imperative to explore thoroughly the effect of seed coating on seed germination and seedling vigour precisely. In view of the above, a laboratory experiment was designed and conducted to assess the efficacy of seed coating polymer (polykote) on rice seeds.

As there were no reliable, earlier reports available on polymer seed coating for rice, initially an experiment was conducted to standardize the optimum dose of

polymer and the level of dilution required to coat rice seeds. For this purpose, a single genotype (IR58025 B) and single polykote colour (pink) were used. The results of imbibition rate of coated and uncoated seeds revealed an increased rate of moisture absorption when the seeds were coated with 5 g of polykote (name of the polymer used) diluted with 70 ml of water kg^{-1} of seed (48.2 per cent), followed by 3 g of polykote diluted with 50 ml of water kg^{-1} of seed (47.6 per cent) with an increase of 7.2 and 6.5 per cent over the uncoated seeds (41.1 per cent). The increase in imbibition may be due to the fine particles in the polymer coating acting as a 'wick' or moisture attracting materials or perhaps, to improved seed soil contact. The use of hydrophilic polymers as coating materials claimed to improve the movement of air and water to the seeds (Hedrick and Mowry, 1953) by aggregating soil clay particles adjacent to the seed (Figure 7).

In the absence of information on the ingredients and their exact specification used in the polymer, it could only be hypothised that the mixing of fatty alcohols with the polymers might have reduced the evaporation of absorbed water (Weaver ***et al.***, 1976; Hall, 1979). This increased rate of moisture absorption advanced the sprouting by 6.7 and 5.3 h respectively in the above coating doses. As it was already quoted elsewhere in this chapter that increase in the amount of water entering the caryopsis stimulated α-amylase enzyme activity, which is the main factor governing starch breakdown (Jones, 1969) and resulted in early sprouting. Advancement in sprouting in the above treatment led to a rapid rate of germination and corresponding increase in growth of radicles (Plate 12).

It was observed that coating rice seeds with 5 g and 3 g of polykote after dilution with 70 and 50 ml of water kg^{-1} respectively enhanced the germination by 6.6 to 8.0 per cent over uncoated control. Similar enhancement in germination due to coating with polymer was reported by Dadlani ***et al.*** (1992), Song Dongseod and Lee Sheong Chun (1998) in rice, Joshi ***et al.*** (1998) in sorghum and Johnson ***et al.*** (2002) in corn. Though, this enhancement in germination is partly attributable to an increased rate of imbibition, alternatively, the wetting and drying processes that the seeds have undergone during the coating process might have preconditioned the seeds for prompt germination. Such a condition, according to Lush ***et al.*** (1981) was achieved after controlled wetting and drying of ryegrass and resulted in an increased rate of germination.

In addition to improvement in germination the seed coating increased the seedling growth and vigour as discernable by the relative measures of shoot-root growth. The seed coating with 5 g of polykote diluted with 70 ml of water kg^{-1} increased the root and shoot length, dry matter production and vigour index @ 19.5, 18.6, 10.2 and 26.7 per cent over the uncoated seeds. When the polykote dose and dilution reduced to 3 g and 50 ml kg^{-1}, there was corresponding decrease in enhancement of above seedling growth attributes. Ruban ***et al.*** (1983) reported that polymer initially inhibited the activity of catalase and peroxidase and stimulated later on and thus, the seedling growth also.

Conventionally, the rice seeds are soaked in water over-night and incubated for 24 h before sown in the field. In order to ensure the sustainability of the positive effect of promising polymer coating treatments, polymer coated seeds were

germinated in the conventional method also. The test results established the sustainability and reproducibility of this coating treatments at farm level also. In the conventional method also the aforesaid dosage levels excelled and enhanced the germination. Therefore, beyond doubt it has been established that coating polykote @ 5 g diluted with 70 ml of water kg^{-1} followed by 3 g diluted in 50 ml water kg^{-1} enhanced water absorption, thereby advanced sprouting and seedling growth. The results also revealed that increasing or decreasing the quantity of water used for dilution beyond 70 ml in 5 g polykote dose and beyond 50 ml in 3 g polykote dose had no worth mentionable effect on seedling growth.

After standardization, the seeds of rice hybrids and parental lines were given coating with polykote @ 5 g diluted in 70 ml of water kg^{-1} of seed and seed quality evaluations were made to find out the genotypic response to the polykote treatment. The results found that the hybrids are highly responsive to polykote coating at early emergence stage by recording reduced sprouting time, rapid rate of germination, enhanced germination and more radicle growth in time bound germination. However, during the later stage of seedling growth, response of R lines was dominated over hybrids. Therefore, it may be ascribed that complimenting the seeds of R lines with polykote coating improved the seedling vigour as much as that of hybrids. Eventhough, there was a positive effect of polykote coating on IR58025A and B, the effect was marginal as compared to uncoated (Figure 8).

In the context of seed production in hybrid rice involving many parental lines, seed coating with different colours of polykote would fetch added advantages such as easy identification and precision sowing of parental lines, detection of admixtures and

attractive presentability. The results of the experiment involving six colours of polykote coated with all the six genotypes revealed that on most of the parameters tested, clear and pink coloured polykotes found to be effective followed by red and green. However, there was no worth mentionable variation observed among the colours of polykote for the rate of germination and radicle length. The response of seed coated with blue and black colour polykote was only marginal and it could probably be due to the inhibitory effect of the dyeing materials used in the polymers.

It may be concluded that a dosage of polykote @ 5 g diluted with 70 ml of water kg^{-1} was found to be optimum for effective coating on rice seeds. Diluting polykote beyond the prescribed level reduced the positive effect of seed coating. Coating rice seeds with polykote enhanced water uptake, thereby promoted early sprouting, enhanced germination and seedling growth. While, hybrid seeds were found to be highly responsive at the early stage of germination, the R lines dominated at the later part of germination in responding to polykote coating. Among different colours of polykote tested, clear and pink found to be superior with no adverse effect on seed germination and seedling growth. Therefore, apart from increasing the germinability, coating seeds of each parent with a particular colour of polykote would enable easy identification and precision sowing of parental lines in hybrid seed production programmes.

CHAPTER VI

Summary

Rice is the major food for one out of every three persons on earth. Demand for rice is expected to grow faster than production in most of the countries. Rice production had steadily increased during the green revolution, but recently, its growth has slowed down substantially. The yield ceiling of rice varieties must be lifted to meet out the increased food demand. Among the many genetic approaches available to break the yield barrier in rice, hybrid rice technology appears to be the most feasible. For economic feasibility and commercial viability of the hybrid rice technology, development of an efficient seed production package is a pre-requisite.

As gibberellic acid (GA_3) is the costliest input in hybrid seed production, research should focus on economising the use of GA_3 and finding a suitable alternative to it. Considering the above, the present study was envisaged at developing a comprehensive nutritional package involving cheaply and locally available organic and inorganic nutrients with a view to maximizing the yield of hybrid seed in rice. Under this study, field experiments were conducted in the wetland farm of Tamil Nadu Agricultural University, Coimbatore for two consecutive seasons during July – November 2001 with ADTRH 1 and January – May 2002 with CORH 2 to study the effect of additional dose of N and K and foliar spraying of organic and inorganic nutrients on growth and yield of parental lines (A x R) in hybrid seed

production of rice hybrids ADTRH 1 and CORH 2. The salient findings of this study are summarized below

The application of 25 kg N and 15 kg K each at panicle initiation and 10 days after panicle initiation in addition to the normal recommended dose of NPK @ 150 : 60 : 60 kg ha^{-1} increased the plant height, number of total tillers, productive tillers and 1000 seed weight of both the parents. This additional fertilizer dose advanced the days to 50 per cent flowering, improved the panicle exsertion and seed set in seed parent. Though, there was a progressive increase in most of the growth traits due to progressive increase in fertilizer dose, the stage of application was most critical and specific to certain growth traits. While the plant height, tiller production and seed set have responded well to the early application at panicle initiation, 50 per cent flowering and panicle exsertion responded to late application at 10 days after panicle initiation.

Conversely, the 1000 seed weight reciprocated irrespective of the stage of application and the growth traits viz., panicle length and number of spikelets $panicle^{-1}$ exerted no response to the additional dose of fertilizer. There was a corresponding increase in the N, P and K uptake in both straw and seed / grain of A and R lines with the progressive increase in the application of N and K fertilizer dose. Application of additional dose of N and K at panicle initiation and 10 days after panicle initiation recorded the highest N, P and K uptake. This additional N and K dose exerted an increase of 13.7 and 12.3 per cent hybrid seed yield in ADTRH 1 (2,061 kg ha^{-1}) and CORH 2 (1,663 kg ha^{-1}) respectively. The increase in grain yield was 15.0 and

11.5 per cent in R lines of ADTRH 1 (1,623 kg ha^{-1}) and CORH 2 (1,488 kg ha^{-1}), respectively.

While, the foliar spraying of GA_3, brassinolide and spentwash was effective in increasing the plant height, panicle length and panicle exsertion, brassinolide advanced the 50 per cent flowering and GA_3 increased the seed set in seed parent. Foliar spraying of DAP + KCl either alone or along with $ZnSO_4$ + Boric acid had a positive response in both the parents for the production of more number of tillers, spikelets $panicle^{-1}$ and increased 1000 seed weight. GA_3 in A line and DAP + KCl as sole or combined with $ZnSO_4$ + Boric acid in R line increased the N, P and K uptake. Foliar spraying of GA_3 or spentwash maximized the hybrid seed yield upto 2,282 and 1,993 kg ha^{-1} of ADTRH 1 and 1,855 and 1,623 kg ha^{-1} of CORH 2, respectively. The R lines applied with DAP + KCl either alone or along with $ZnSO_4$ + Boric acid recorded maximum grain yield of 1,757 and 1,625 kg ha^{-1} in ADTRH 1 and 1,596 and 1,583 kg ha^{-1} in CORH 2 respectively.

In general, the seed parent responded well to the growth hormones and organic substances, while the inorganic chemical nutrients played an effective role in pollen parent. Correlation coefficient of various growth as well as yield attributes and nutrient uptake of A and R lines with hybrid seed yield revealed a positive and significant contribution of plant height, panicle length, panicle exsertion, seed set and total NPK uptake of seed parent and plant height and panicle length of pollen parent in increasing the hybrid seed yield. However, the seed quality of hybrid seed was not influenced either by fertilizer dose or by foliar spray treatment. According to the present investigation, application of additional dose of 25 kg N and 15 kg K ha^{-1} at

panicle initiation and 10 days after panicle initiation along with foliar spraying of GA_3 @ 75 g ha^{-1} thrice at flowering maximized the hybrid seed yield of ADTRH 1 and CORH 2. However, there is a scope for combined use of GA_3 along with spentwash, a cheap industrial by-product or brassinolide, a new group of plant hormone to substitute the quantity of GA_3 and economize the hybrid seed production

Hybrid vigour is the basis for yield advantage of hybrids over conventional varieties. The causal factor for hybrid vigour at the physiological and biochemical level are almost as obscure as they were 30 years ago. Seed or seedling vigour at the initial growth stage is the principal trigger of hybrid vigour. Therefore, a comprehensive investigation was undertaken to understand the physiological and biochemical basis of hybrid vigour on germination and seedling growth of rice hybrids ADTRH 1 and CORH 2 in order to determine whether this phenomenon is fixable and / or predictable. In the present investigation, hybrid seeds of ADTRH 1 and CORH 2 and their parental lines IR58025 A, IR58025 B, IR66R and C20R were subjected to various vigour tests viz., imbibition rate, seedling growth rate, enzyme activity and stress tests.

The results of this study brought out a clear evidence for differences among the hybrids and their parental lines with respect to physiological and biochemical behaviour of seed vigour. The moisture absorbed by the hybrids was rapid and almost similar as that of their female parent, IR58025A with about 31.1 to 31.7 per cent irrespective of period of imbibition. The rapidity in moisture absorption resulted in quicker sprouting in the hybrid seeds within 25 to 26 h followed by IR58025A in 28 h. The R lines required 5 to 6 extra hours to sprout. Significant variations were noticed in root length, shoot length, dry matter production and vigour index of hybrids

and their parental lines. It is interesting to note that root length of both the hybrids was slightly longer, but almost resembled their respective R lines.

In the present study, changes in enzyme activity exhibited by fresh seeds of rice hybrids and their parental lines brought out convincing evidence for superiority of hybrids and existence of hybrid vigour in seed germination. Both the hybrids, ADTRH 1 and CORH 2 exhibited a significant positive relative heterosis (mid-parent heterosis) for most of the physiological and all the biochemical attributes. Heterobeltiosis was pronounced in radicle length, of time bound germination, root length and enzyme activity. CORH 2 was found to be superior to ADTRH 1 in terms of heterosis for seedling vigour. The rate of germination, vigour index and enzyme activity were found to be capable of resembling field emergence and can be employed for prediction of hybrid vigour in seed emergence and seedling growth attributes.

The fresh seeds of hybrids, that have outperformed the other lines and exhibited superior hybrid vigour under normal – optimal growing conditions with early germination and vigorous seedling growth, have failed to excel under sub-optimal or stress condition. Under such unfavourable growing conditions, the R lines exhibited their superiority and sustained the stress imposed on them. There was a clear distinction for each stress test in terms of degree of stress they imposed on the genotypes and with respect to the response the genotypes exerted upon such stress. Therefore, for predicting hybrid vigour on seedling growth attributes under stress condition, instead of comparison among multiple vigour tests, comparison of genotypes under a specific stress situation would be a realistic proposition. In general,

the hybrids resembled their respective male parents for various phenotypic expressions of seed vigour attributes.

The rice hybrids, ADTRH 1 and CORH 2 and their female parent, IR58025 A suffer with a peculiar problem of occurrence of split husk seed. To elucidate information on the level of reduction, the split husk seeds incur on the seed quality of precious hybrid seeds, a laboratory experiment was designed and carried out. The results of imbibition rate revealed the rapidity of split husk seeds in moisture absorption. The split husk seeds of all the genotypes exhibited similar pattern of water uptake and hence, there was no genotypic influence on the behaviour of split husk seeds. Besides, a decline in α-amylase activity (43.3 per cent), decline in activity of other enzymes viz., dehydrogenase (21.7 per cent), total ATPase (30.0 per cent), peroxidase (45.4 per cent) and catalase (28.1 per cent) was also noticed. This reduction in major enzymes activity has manifested the poor physiological performance of split husk seeds.

In spite of rapid absorption of moisture by the split husk seeds, the time taken for sprouting was higher by 4.0 to 9.3 h as compared to bulk and normal seeds. This delayed sprouting, regardless of rapid absorption was attributed to reduction in enzyme activity, particularly the α-amylase. As a result, the split husk seeds exhibited a slow rate of germination and poor radicle growth in time bound germination as compared to normal seeds. Split husk seeds recorded 21.0 per cent lesser germination than normal seeds. The occurrence of split husk seeds in bulk seeds resulted in 12.3 per cent reduction in germination. The split husk seeds exhibited extreme decline in the seedling growth attributes viz., root length (32.5 per cent),

shoot length (35.2 per cent), dry matter production (33.6 per cent) and vigour index (47.8 per cent) compared to normal seeds. There was a reduction upto 20.1, 30.5, 24.8 and 34.0 per cent in the above parameters due to occurrence of split husk seeds in the bulk seed also.

The reduction in seed vigour of split husk seeds could be attributed to the lower seed weight and seed to husk ratio. On subjecting split husk seeds to low temperature during germination in exhaustion test, a drastic reduction in germination (40.0 per cent), root length (53.1 per cent), shoot length (49.5 per cent) and vigour index (84.3 per cent) was inevitable. The inferior vigour potential of split seeds was reflected in higher electrical conductivity of seed leachate also. As a result, the split husk seeds suffered with a loss of 11.8 per cent physical quality, 21.0 per cent germination, 34.1 per cent seedling growth rate and 33.7 per cent enzyme activity with an over all loss of 29.8 per cent as a mean of all the physical, physiological and biochemical seed quality attributes. The split husk seed occurrence in bulk seed incurred a direct loss upto 17.4 per cent in seed quality of hybrid and female parent seeds.

Seed coating is a mechanism of applying needed materials in such a way that they affect the seed or soil at the seed soil interface. Number of published results indicate a positive, negative and no effect of polymer coating on germination and seedling establishment of various crop seeds. Therefore, it has been imperative to explore thoroughly the effect of seed coating on seed germination and seedling vigour precisely. As there were no reliable, earlier reports available on polymer seed coating

for rice, initially an experiment was conducted to standardize the optimum dose of polymer and the level of dilution required to coat rice seeds.

The results of imbibition rate of coated and uncoated seeds revealed an increased rate of moisture absorption when the seeds were coated with 5 g of polykote (name of the polymer used) diluted with 70 ml of water kg^{-1} of seed (48.2 per cent), followed by 3 g of polykote diluted with 50 ml of water kg^{-1} of seed (47.6 per cent) with an increase of 7.2 and 6.5 per cent over the uncoated seeds (41.1 per cent). This increased rate of moisture absorption advanced the sprouting by 6.7 and 5.3 h respectively in the above coating doses. Advancement in sprouting in the above treatment led to a rapid rate of germination and corresponding increase in growth of radicles. It was observed that coating rice seeds with 5 g and 3 g of polykote after dilution with 70 and 50 ml of water kg^{-1} respectively enhanced the germination by 6.6 to 8.0 per cent over uncoated control.

The seed coating with 5 g of polykote diluted with 70 ml of water kg^{-1} increased the root and shoot length, dry matter production and vigour index @ 19.5, 18.6, 10.2 and 26.7 per cent over the uncoated seeds. Conventionally, the rice seeds are soaked in water over-night and incubated for 24 h before sown in the field. In the conventional method also the aforesaid dosage levels excelled and enhanced the germination. The results also revealed that increasing or decreasing the quantity of water used for dilution beyond 70 ml in 5 g polykote dose and beyond 50 ml in 3 g polykote dose had no worth mentionable effect on seedling growth.

After standardization, the seeds of rice hybrids and parental lines were given coating with polykote @ 5 g diluted in 70 ml of water kg^{-1} of seed and seed quality evaluations were made to find out the genotypic response to the polykote treatment. The results found that the hybrids are highly responsive to polykote coating at early emergence stage by recording reduced sprouting time, rapid rate of germination, enhanced germination and more radicle growth in time bound germination. However, during the later stage of seedling growth, response of R lines was dominated over hybrids.

In the context of seed production in hybrid rice involving many parental lines, seed coating with different colours of polykote would fetch added advantages such as easy identification and precision sowing of parental lines, detection of admixtures and attractive presentability. The results of the experiment involving six colours of polykote coated with all the six genotypes revealed that on most of the parameters tested, clear and pink coloured polykotes found to be effective followed by red and green. Therefore, apart from increasing the germinability, coating seeds of each parent with a particular colour of polykote would enable easy identification and precision sowing of parental seeds in hybrid seed production programmes

Annexure I. Characteristics of parental lines of rice hybrids ADTRH 1 and CORH 2

Characteristics	IR58025 A	IR58025 B	IR 66 R	C 20 R
Duration (days)	125	125	115	125
Plant height (cm)	75	80	90	90
Panicle length (cm)	25	25	23	20
Panicle exsertion (%)	70	100	100	100
Anther sac	White or Pale	Light yellow	Yellow	Yellow
Pollen grains	Sterile	Fertile	Fertile	Fertile
1000 seed weight (g)	20.0	20.0	23.7	24.0
Seed length, width and thickness (mm)	10.6, 2.1, 1.9	10.6, 1.9, 1.8	9.2, 2.3, 1.8	6.8, 2.8, 2.1
Awn	Present	Present	Absent	Absent

Table 1. Effect of additional dose of N and K and foliar spraying on plant height (cm) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	84.9	87.9	86.9	91.2	87.7	87.9	91.6	89.7	93.8	90.7
Spentwash	73.4	76.8	75.7	77.8	75.9	76.6	81.2	78.5	81.5	79.4
Humic acid 0.1%	72.9	75.8	74.8	76.4	75.0	76.3	79.8	78.8	81.0	79.0
Brassinolide 0.2 ppm	75.5	77.4	76.4	78.5	76.9	81.7	82.2	81.7	83.7	82.3
$ZnSO_4$ 0.5% + BA 0.2%	73.9	76.4	74.9	78.2	75.8	77.9	81.5	79.2	80.6	79.8
DAP 2 % + KCl 1%	74.9	76.6	75.7	77.2	76.1	79.6	80.9	80.6	83.8	81.2
DAP+KCl+$ZnSO_4$+BA	74.2	77.7	76.5	78.9	76.8	80.6	82.8	82.0	85.3	82.7
Mean	75.7	78.4	77.3	79.7		80.1	82.9	81.5	84.3	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.171	0.362	0.692	0.704	0.594	0.495	1.092	0.990
CD (P=0.05)	0.543	0.747	NS	NS	1.891	1.021	NS	NS

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 2. Effect of additional dose of N and K and foliar spraying on plant height (cm) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	95.8	97.1	95.7	103.2	97.9	108.1	113.7	109.2	113.8	111.2
Spentwash	79.0	82.1	81.4	84.3	81.7	100.7	101.4	100.9	104.1	101.8
Humic acid 0.1%	77.5	82.7	80.3	85.0	81.4	97.9	100.0	99.1	102.5	99.9
Brassinolide 0.2 ppm	81.3	83.2	82.4	84.9	82.9	99.7	101.2	100.1	104.4	101.4
$ZnSO_4$ 0.5% + BA 0.2%	79.2	82.0	81.1	82.6	81.2	101.4	102.5	102.7	103.2	102.4
DAP 2 % + KCl 1%	80.2	81.6	81.6	85.8	82.3	101.6	102.8	102.4	107.8	103.7
DAP+KCl+$ZnSO_4$+BA	78.2	85.9	83.5	87.7	83.8	100.1	104.2	102.4	107.9	103.7
Mean	81.6	84.9	83.7	87.6		101.4	103.7	102.4	106.2	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.540	0.639	1.300	1.278	0.679	0.282	0.857	0.565
CD (P=0.05)	1.719	1.318	2.934	2.637	2.162	0.583	2.371	1.165

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 3. Effect of additional dose of N and K and foliar spraying on number of total tillers of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	8.6	10.3	9.2	12.0	10.0	8.7	10.2	9.1	10.1	9.5
Spentwash	9.0	9.9	9.7	11.8	10.1	8.0	9.9	8.4	10.1	9.1
Humic acid 0.1%	8.2	9.3	8.8	10.6	9.2	8.4	9.9	8.6	10.4	9.3
Brassinolide 0.2 ppm	9.3	11.2	10.0	12.3	10.7	8.5	9.9	9.5	10.9	9.7
$ZnSO_4$ 0.5% + BA 0.2%	9.1	11.1	9.7	12.1	10.5	9.0	10.3	9.1	10.5	9.7
DAP 2 % + KCl 1%	9.4	11.7	10.6	12.4	11.0	9.3	10.4	9.6	10.9	10.1
DAP+KCl+$ZnSO_4$+BA	9.9	12.2	11.1	12.8	11.5	9.1	11.0	9.8	11.7	10.4
Mean	9.0	10.8	9.8	12.0		8.7	10.2	9.2	10.7	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.420	0.423	0.888	0.846	0.507	0.887	1.718	1.774
CD (P=0.05)	1.336	0.873	NS	NS	1.613	1.830	NS	NS

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 4. Effect of additional dose of N and K and foliar spraying on number of total tillers of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	12.2	14.0	14.4	15.0	13.9	9.5	10.2	9.9	11.1	10.2
Spentwash	11.7	13.4	13.0	14.7	13.2	9.3	9.8	9.9	11.2	10.1
Humic acid 0.1%	12.2	12.5	11.2	13.2	12.2	9.0	9.6	9.4	9.5	9.4
Brassinolide 0.2 ppm	12.7	14.7	12.9	15.7	14.0	10.3	10.6	10.5	11.8	10.8
$ZnSO_4$ 0.5% + BA 0.2%	13.5	16.0	16.2	16.2	15.5	9.7	10.5	10.5	11.6	10.6
DAP 2 % + KCl 1%	13.0	18.0	15.4	18.8	16.3	11.0	12.0	11.5	12.5	11.7
DAP+KCl+$ZnSO_4$+BA	14.4	16.9	15.5	18.5	16.1	11.8	12.6	12.0	13.0	12.3
Mean	12.8	15.1	14.1	15.9		10.1	10.8	10.5	11.5	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.285	0.438	0.859	0.895	0.206	0.255	0.514	0.509
CD (P=0.05)	0.907	0.903	NS	NS	0.654	0.525	NS	NS

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 5. Effect of additional dose of N and K and foliar spraying on number of productive tillers of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	7.0	8.6	7.9	9.0	8.1	5.8	6.8	6.3	7.6	6.6
Spentwash	6.9	8.5	7.6	9.1	8.0	5.6	6.6	6.1	7.2	6.3
Humic acid 0.1%	6.2	7.9	6.9	8.7	7.4	5.8	6.4	6.1	7.4	6.4
Brassinolide 0.2 ppm	6.8	8.6	7.4	9.4	8.0	5.9	7.6	6.9	7.8	7.1
$ZnSO_4$ 0.5% + BA 0.2%	6.3	8.3	7.6	9.4	7.9	6.5	7.3	6.9	7.4	7.0
DAP 2 % + KCl 1%	7.7	9.8	8.2	9.8	8.8	6.7	8.1	7.5	8.5	7.7
DAP+KCl+$ZnSO_4$+BA	7.3	9.2	8.5	9.9	8.7	6.8	8.4	7.7	9.3	8.1
Mean	6.8	8.7	7.7	9.3		6.1	7.3	6.8	7.9	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.219	0.368	0.716	0.736	0.048	0.098	0.187	0.195
CD (P=0.05)	0.698	0.759	NS	NS	0.153	0.202	0.400	0.403

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 6. Effect of additional dose of N and K and foliar spraying on number of productive tillers of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	8.1	11.2	9.4	12.0	10.2	7.2	8.0	8.0	8.7	7.9
Spentwash	8.3	10.5	9.5	11.4	9.9	6.9	7.8	7.6	8.3	7.6
Humic acid 0.1%	7.3	9.1	8.4	10.1	8.9	6.2	6.9	6.9	8.1	7.9
Brassinolide 0.2 ppm	10.0	12.1	10.9	13.1	11.5	8.0	8.6	8.3	9.5	8.6
$ZnSO_4$ 0.5% + BA 0.2%	9.3	14.1	12.1	14.0	12.4	6.8	7.6	6.9	8.0	7.3
DAP 2 % + KCl 1%	11.6	14.1	12.4	14.9	13.3	8.9	9.9	9.3	10.2	9.5
DAP+KCl+$ZnSO_4$+BA	12.7	14.8	13.6	16.0	14.3	9.6	10.5	9.9	10.8	10.2
Mean	9.6	12.2	10.9	13.1		7.6	8.4	8.1	9.0	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.251	0.243	0.516	0.487		0.127	0.246	0.472	0.491	
CD (P=0.05)	0.799	0.503	NS	NS		0.405	0.507	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 7. Effect of additional dose of N and K and foliar spraying on days to 50 per cent flowering of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	93.0	92.5	90.0	89.5	91.3	94.0	93.0	90.5	90.0	91.9
Spentwash	93.0	92.5	89.5	90.0	91.3	93.5	93.5	90.0	90.5	91.9
Humic acid 0.1%	93.5	92.5	89.5	90.0	91.4	94.0	93.0	90.5	90.5	92.0
Brassinolide 0.2 ppm	92.5	92.0	89.0	88.5	90.5	93.0	92.0	90.5	89.0	91.1
$ZnSO_4$ 0.5% + BA 0.2%	92.5	93.0	90.0	89.5	91.3	94.0	93.0	90.5	90.0	91.9
DAP 2 % + KCl 1%	92.5	92.0	90.5	90.0	91.3	93.5	92.5	90.5	89.5	91.5
DAP+KCl+$ZnSO_4$+BA	93.0	92.5	89.5	89.0	91.0	94.0	93.0	90.0	90.0	91.8
Mean	92.9	92.4	89.7	89.5		93.7	92.9	90.4	89.9	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.290	0.225	0.508	0.450		0.184	0.270	0.533	0.540	
CD (P=0.05)	0.923	0.464	NS	NS		0.587	0.557	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 8. Effect of additional dose of N and K and foliar spraying on panicle length (cm) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	23.4	23.9	24.6	24.8	24.1	24.2	24.3	24.3	24.4	24.3
Spentwash	22.6	23.3	23.6	23.7	23.3	23.4	23.3	23.5	23.7	23.4
Humic acid 0.1%	21.9	22.3	22.7	23.1	22.5	22.7	22.7	23.1	22.7	22.8
Brassinolide 0.2 ppm	22.3	22.9	23.5	24.6	23.3	23.8	23.1	23.3	23.9	23.5
$ZnSO_4$ 0.5% + BA 0.2%	22.5	22.8	22.3	24.0	22.9	22.3	22.6	23.1	22.6	22.6
DAP 2 % + KCl 1%	22.5	22.8	23.8	23.9	23.2	22.4	23.7	22.9	23.5	23.1
DAP+KCl+$ZnSO_4$+BA	22.8	23.0	23.6	23.7	23.3	22.9	23.3	23.3	23.3	23.2
Mean	22.5	23.0	23.4	24.0		23.1	23.2	23.3	23.4	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.046	0.273	0.507	0.545	0.185	0.166	0.360	0.333
CD (P=0.05)	0.145	0.563	NS	NS	NS	0.343	NS	NS

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 9. Effect of additional dose of N and K and foliar spraying on panicle length (cm) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	22.5	23.2	23.3	23.8	23.1	21.7	21.9	22.7	22.7	22.2
Spentwash	21.0	21.5	21.7	22.3	21.6	21.2	21.1	21.5	21.7	21.3
Humic acid 0.1%	21.3	21.0	22.7	22.1	21.7	20.1	20.2	20.0	20.1	20.1
Brassinolide 0.2 ppm	21.4	22.0	22.2	22.3	22.0	21.5	21.4	21.8	22.2	21.7
$ZnSO_4$ 0.5% + BA 0.2%	21.3	21.5	21.8	21.0	21.4	20.1	20.5	20.7	21.2	20.6
DAP 2 % + KCl 1%	20.5	20.6	21.6	21.3	21.0	21.0	20.9	21.2	21.5	21.1
DAP+KCl+$ZnSO_4$+BA	20.8	20.1	21.4	22.6	21.7	21.2	21.3	21.4	22.1	21.5
Mean	21.2	21.7	22.1	22.1		21.0	21.0	21.3	21.6	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.091	0.261	0.491	0.522		0.387	0.323	0.713	0.646	
CD (P=0.05)	0.288	0.538	NS	NS		NS	0.667	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 10. Effect of additional dose of N and K and foliar spraying on panicle exsertion (%) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	87.6 (69.35)	91.0 (72.53)	90.2 (71.73)	91.4 (72.91)	90.0 (71.63)	79.9 (63.33)	82.5 (65.29)	80.2 (63.59)	83.3 (65.85)	81.5 (64.51)
Spentwash	76.4 (60.90)	78.9 (62.62)	77.2 (61.49)	79.5 (63.05)	78.0 (62.02)	74.1 (59.38)	77.1 (61.41)	76.5 (60.98)	77.3 (61.52)	76.2 (60.82)
Humic acid 0.1%	72.2 (58.15)	73.8 (59.18)	72.4 (58.28)	74.8 (59.84)	73.3 (58.86)	66.6 (54.67)	70.1 (56.82)	69.6 (56.15)	73.9 (59.25)	70.0 (56.81)
Brassinolide 0.2 ppm	75.4 (60.24)	77.9 (61.93)	76.8 (61.18)	78.1 (62.07)	77.0 (61.35)	72.1 (58.09)	75.3 (60.17)	74.0 (59.34)	76.3 (60.84)	74.4 (59.61)
$ZnSO_4$ 0.5% + BA 0.2%	72.8 (58.54)	73.1 (58.73)	73.5 (58.99)	74.8 (59.84)	73.5 (59.02)	67.6 (55.28)	70.9 (57.36)	72.1 (58.12)	72.7 (58.48)	70.8 (57.31)
DAP 2 % + KCl 1%	73.8 (59.18)	75.1 (60.04)	74.1 (59.38)	76.8 (61.17)	74.9 (59.94)	67.1 (54.97)	72.5 (58.38)	71.4 (57.64)	74.2 (59.48)	71.3 (57.62)
DAP+KCl+$ZnSO_4$+BA	73.3 (58.86)	76.7 (61.12)	74.8 (59.84)	78.5 (62.35)	75.8 (60.54)	67.6 (55.31)	72.5 (58.37)	70.3 (56.98)	72.9 (58.60)	70.8 (57.32)
Mean	75.9 (60.75)	78.0 (62.30)	77.0 (61.55)	79.1 (63.03)		70.7 (57.29)	74.4 (59.69)	73.4 (59.02)	75.8 (60.57)	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.190	0.409	0.781	0.818	0.218	0.316	0.625	0.633
CD (P=0.05)	0.606	0.844	NS	NS	0.694	0.653	NS	NS

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

(Figures in parentheses are arc-sine transformed values)

Table 11. Effect of additional dose of N and K and foliar spraying on total number of spikelets panicle^{-1} of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	127.9	129.8	128.1	131.3	129.3	121.5	126.3	122.7	126.7	124.3
Spentwash	127.4	129.4	129.6	130.0	129.0	123.5	127.0	125.0	126.9	125.6
Humic acid 0.1%	127.2	128.5	128.1	129.3	128.3	121.3	125.8	124.1	126.5	124.4
Brassinolide 0.2 ppm	130.0	131.0	130.2	131.7	130.7	127.2	130.3	127.2	131.9	129.1
$ZnSO_4$ 0.5% + BA 0.2%	129.5	130.9	130.6	132.3	130.8	125.2	126.8	125.2	128.7	126.4
DAP 2 % + KCl 1%	138.7	141.5	139.5	140.3	140.0	126.4	130.3	128.1	131.6	129.1
DAP+KCl+$ZnSO_4$+BA	139.9	141.4	140.8	142.0	141.0	127.1	130.4	128.6	133.9	130.0
Mean	131.5	133.2	132.4	133.8		124.6	128.1	125.8	129.4	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	1.769	1.363	3.082	2.726		1.729	2.091	4.241	4.183	
CD (P=0.05)	NS	2.813	NS	NS		NS	4.316	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 12. Effect of additional dose of N and K and foliar spraying on total number of spikelets panicle^{-1} of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	119.3	116.3	118.5	120.9	118.7	106.0	114.0	108.9	116.1	111.2
Spentwash	116.9	116.7	119.1	118.5	117.8	108.8	115.1	112.4	120.2	114.1
Humic acid 0.1%	118.1	116.7	117.1	119.0	117.7	101.3	110.2	100.5	113.2	106.3
Brassinolide 0.2 ppm	118.9	120.5	116.2	121.8	118.1	109.1	115.3	114.7	117.6	114.2
$ZnSO_4$ 0.5% + BA 0.2%	117.4	121.2	119.6	121.3	119.8	104.5	113.2	109.0	113.6	110.0
DAP 2 % + KCl 1%	120.6	123.8	122.3	123.9	122.6	109.9	119.7	116.2	122.0	116.9
DAP+KCl+$ZnSO_4$+BA	120.1	124.5	124.2	125.8	123.6	112.9	122.1	118.4	124.2	119.4
Mean	118.0	119.9	119.5	121.6		107.5	115.6	111.4	118.1	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	2.012	1.968	4.162	3.935		1.611	2.816	5.458	5.633	
CD (P=0.05)	NS	4.061	NS	NS		5.127	5.813	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 13. Effect of additional dose of N and K and foliar spraying on seed set (%) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	38.3 (38.21)	39.7 (39.03)	41.5 (40.08)	39.6 (38.97)	39.7 (39.07)	33.7 (35.46)	34.6 (36.00)	34.1 (35.70)	35.0 (36.24)	34.3 (35.85)
Spentwash	30.4 (33.42)	32.6 (34.82)	30.1 (33.24)	34.1 (36.00)	31.8 (34.30)	28.1 (31.98)	28.9 (32.49)	28.3 (32.11)	29.3 (32.74)	28.6 (32.33)
Humic acid 0.1%	20.5 (26.89)	23.1 (28.69)	21.0 (27.24)	21.4 (27.52)	21.5 (27.58)	22.0 (27.93)	22.3 (28.14)	22.2 (28.08)	22.3 (28.14)	22.2 (28.07)
Brassinolide 0.2 ppm	28.2 (32.04)	28.6 (32.30)	25.6 (30.36)	29.3 (32.78)	27.9 (31.87)	26.2 (30.76)	26.8 (31.14)	26.7 (31.08)	27.1 (31.34)	26.7 (31.08)
$ZnSO_4$ 0.5% + BA 0.2%	25.4 (30.23)	25.0 (30.00)	23.5 (29.00)	25.2 (30.10)	24.8 (29.83)	24.1 (28.69)	24.4 (29.57)	24.2 (29.47)	24.7 (29.77)	24.3 (29.38)
DAP 2 % + KCl 1%	27.5 (31.60)	28.9 (32.52)	28.0 (31.95)	28.4 (32.17)	28.2 (32.06)	26.1 (30.69)	27.1 (31.34)	26.5 (30.95)	27.3 (31.47)	26.7 (31.11)
DAP+KCl+$ZnSO_4$+BA	30.3 (33.37)	28.1 (31.98)	29.6 (32.93)	30.6 (33.55)	29.6 (32.96)	26.7 (31.08)	26.9 (31.21)	26.6 (31.02)	27.6 (31.66)	26.9 (31.24)
Mean	28.6 (32.25)	29.4 (32.76)	28.4 (32.11)	29.8 (32.97)		26.7 (30.94)	27.2 (31.41)	26.9 (31.20)	27.6 (31.62)	

	M	S	M at S	S at M	M	S	M at S	S at M
SEd	0.114	0.403	0.755	0.806	0.116	0.245	0.469	0.491
CD (P=0.05)	0.362	0.832	NS	NS	0.369	0.507	NS	NS

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

(Figures in parentheses are arc-sine transformed values)

Table 14. Effect of additional dose of N and K and foliar spraying on 1000 seed weight (g) of hybrid seeds of ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	18.85	18.98	18.83	19.02	18.92	19.99	20.53	19.91	20.27	20.18
Spentwash	18.14	18.82	18.88	18.87	18.68	19.82	20.49	20.62	20.57	20.37
Humic acid 0.1%	18.61	18.99	18.95	18.94	18.87	20.07	20.17	20.15	20.59	20.24
Brassinolide 0.2 ppm	18.63	18.93	18.95	19.08	18.90	19.44	20.52	20.72	20.43	20.27
$ZnSO_4$ 0.5% + BA 0.2%	18.97	18.69	18.88	18.94	18.87	19.16	20.03	20.68	20.37	20.06
DAP 2 % + KCl 1%	18.58	19.57	19.38	19.82	19.34	20.25	20.07	20.44	20.60	20.34
DAP+KCl+$ZnSO_4$+BA	19.24	19.55	19.54	19.97	19.57	20.68	20.49	20.76	20.70	20.65
Mean	18.71	19.07	19.06	19.23		19.91	20.33	20.47	20.50	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.180	0.146	0.324	0.291		0.035	0.098	0.185	0.196	
CD (P=0.05)	0.436	0.300	NS	NS		0.110	0.202	0.388	0.404	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 15. Effect of additional dose of N and K and foliar spraying on 1000 grain weight (g) of R lines in ADTRH1 and CORH2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	21.38	22.88	22.86	22.48	22.40	23.46	23.76	23.91	24.20	23.83
Spentwash	21.54	22.54	22.44	22.83	22.34	23.22	23.63	24.28	24.21	23.83
Humic acid 0.1%	21.90	22.40	22.63	22.58	22.37	23.65	23.55	24.24	24.30	23.93
Brassinolide 0.2 ppm	21.52	22.51	22.89	23.00	22.48	23.30	23.37	24.17	24.31	23.79
$ZnSO_4$ 0.5% + BA 0.2%	21.56	22.07	22.08	22.83	22.13	23.39	23.76	23.72	24.33	23.80
DAP 2 % + KCl 1%	21.83	23.34	23.83	23.10	23.02	24.04	24.12	24.16	24.21	24.13
DAP+KCl+$ZnSO_4$+BA	21.98	23.84	23.48	23.95	23.31	24.20	24.53	24.47	24.73	24.48
Mean	21.67	22.80	22.88	22.97		23.61	23.82	24.14	24.32	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.063	0.190	0.358	0.380		0.097	0.172	0.332	0.343	
CD (P=0.05)	0.199	0.392	NS	NS		0.307	0.354	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 16. Effect of additional dose of N and K and foliar spraying on hybrid seed yield plant^{-1} (g) of ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	5.95	6.10	6.05	6.35	6.09	4.89	5.39	5.25	5.66	5.30
Spentwash	4.95	5.60	4.95	5.85	5.34	4.26	4.69	4.66	4.93	4.64
Humic acid 0.1%	4.05	4.35	4.05	4.55	4.25	3.63	3.98	3.83	4.02	3.87
Brassinolide 0.2 ppm	4.35	5.35	5.10	5.55	5.09	4.05	4.69	4.35	4.75	4.46
$ZnSO_4$ 0.5% + BA 0.2%	4.45	4.85	4.40	5.15	4.71	3.89	4.39	4.06	4.40	4.18
DAP 2 % + KCl 1%	4.75	5.15	4.95	5.35	5.05	4.13	4.49	4.49	4.65	4.44
DAP+KCl+$ZnSO_4$+BA	4.85	5.25	4.85	5.85	5.20	4.34	4.74	4.53	4.85	4.61
Mean	4.75	5.24	4.91	5.52		4.17	4.62	4.45	4.75	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.065	0.140	0.267	0.280		0.017	0.057	0.107	0.114	
CD (P=0.05)	0.201	0.289	NS	NS		0.054	0.117	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 17. Effect of additional dose of N and K and foliar spraying on grain yield plant^{-1} (g) of R lines in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	14.73	16.32	15.87	17.78	16.18	13.57	14.99	14.05	15.47	14.52
Spentwash	14.93	17.47	15.62	18.41	16.61	13.70	15.47	14.76	15.50	14.86
Humic acid 0.1%	13.97	15.55	15.87	15.55	15.23	12.76	14.16	12.50	14.19	13.40
Brassinolide 0.2 ppm	15.23	16.51	16.50	16.83	16.27	15.59	16.66	16.55	17.02	16.45
$ZnSO_4$ 0.5% + BA 0.2%	18.36	19.05	19.05	18.73	18.41	15.96	17.37	16.79	17.98	17.02
DAP 2 % + KCl 1%	18.73	20.00	20.96	20.64	20.08	16.43	18.57	18.59	19.40	18.25
DAP+KCl+$ZnSO_4$+BA	15.87	18.10	18.41	21.91	18.57	17.38	18.33	17.14	19.52	18.09
Mean	15.75	17.57	17.47	18.55		15.65	16.51	15.77	17.01	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.105	0.337	0.633	0.674		0.356	0.314	0.681	0.628	
CD (P=0.05)	0.333	0.696	1.325	1.391		1.132	0.648	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 18. Effect of additional dose of N and K and foliar spraying on hybrid seed yield (kg ha^{-1}) of ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	2221	2277	2258	2371	2282	1713	1886	1838	1981	1855
Spentwash	1848	2091	1848	2184	1993	1492	1643	1632	1724	1623
Humic acid 0.1%	1512	1624	1512	1699	1587	1271	1893	1341	1407	1353
Brassinolide 0.2 ppm	1624	1997	1904	2072	1899	1416	1641	1523	1662	1561
$ZnSO_4$ 0.5% + BA 0.2%	1661	1811	1643	1923	1759	1360	1537	1419	1540	1464
DAP 2 % + KCl 1%	1773	1923	1848	1997	1885	1445	1570	1570	1628	1553
DAP+KCl+$ZnSO_4$+BA	1811	1960	1811	2184	1941	1518	1658	1584	1698	1615
Mean	1779	1955	1832	2061		1459	1618	1558	1663	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	26.47	51.85	99.59	103.69		5.89	19.91	37.3	39.8	
CD (P=0.05)	84.23	107.01	NS	NS		18.79	41.09	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 19. Effect of additional dose of N and K and foliar spraying on grain yield (kg ha^{-1}) of R lines in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	1289	1428	1389	1555	1415	1187	1312	1229	1354	1271
Spentwash	1306	1528	1367	1611	1453	1198	1354	1292	1356	1300
Humic acid 0.1%	1222	1361	1389	1361	1333	1117	1239	1094	1292	1185
Brassinolide 0.2 ppm	1333	1444	1444	1473	1424	1365	1458	1448	1489	1440
$ZnSO_4$ 0.5% + BA 0.2%	1473	1667	1667	1639	1611	1396	1520	1469	1573	1489
DAP 2 % + KCl 1%	1639	1750	1834	1806	1757	1438	1625	1626	1698	1596
DAP+KCl+$ZnSO_4$+BA	1389	1584	1611	1917	1625	1521	1604	1500	1708	1583
Mean	1379	1537	1529	1623		1317	1444	1379	1488	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	9.12	29.47	55.33	58.93		31.13	27.47	59.64	54.95	
CD (P=0.05)	29.03	60.81	115.85	121.63		99.07	56.70	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 20. Effect of additional dose of N and K and foliar spraying on N uptake in straw (kg ha^{-1}) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	30.09	32.80	32.14	35.89	32.73	37.67	38.00	34.01	38.63	37.08
Spentwash	28.62	31.44	30.57	33.95	31.15	30.97	33.05	32.31	36.19	33.13
Humic acid 0.1%	23.84	28.16	29.46	31.47	28.23	25.61	27.25	30.01	32.26	28.78
Brassinolide 0.2 ppm	26.46	30.54	30.18	32.62	29.95	28.44	29.00	33.15	32.55	30.78
$ZnSO_4$ 0.5% + BA 0.2%	25.26	29.39	30.24	31.41	29.08	30.13	31.15	33.28	34.73	32.32
DAP 2 % + KCl 1%	24.90	30.44	32.28	34.37	30.50	27.32	30.98	31.37	36.21	31.47
DAP+KCl+$ZnSO_4$+BA	24.90	30.57	32.88	35.06	30.85	29.84	34.67	32.42	33.72	32.66
Mean	26.29	30.48	31.11	33.54		30.00	32.01	32.36	34.90	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.08	0.30	0.56	0.60		0.18	0.71	1.32	1.41	
CD (P=0.05)	0.24	0.62	1.17	1.24		0.56	1.46	2.75	2.91	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 21. Effect of additional dose of N and K and foliar spraying on N uptake in straw (kg ha^{-1}) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	9.58	11.94	11.03	13.02	11.39	12.05	11.45	10.51	14.99	12.25
Spentwash	8.98	11.17	10.72	12.39	10.81	10.68	11.37	9.62	13.26	11.23
Humic acid 0.1%	9.14	11.00	10.47	12.07	10.67	10.11	9.90	10.47	13.72	11.05
Brassinolide 0.2 ppm	9.24	12.49	11.06	12.48	11.32	11.31	12.60	11.68	12.16	11.94
$ZnSO_4$ 0.5% + BA 0.2%	8.55	12.47	10.89	13.00	11.23	10.17	13.26	12.74	13.39	12.39
DAP 2 % + KCl 1%	9.87	12.61	11.25	13.05	11.69	10.83	12.25	14.79	15.30	13.29
DAP+KCl+$ZnSO_4$+BA	9.49	12.26	11.86	13.88	11.87	11.62	15.40	16.31	12.98	14.08
Mean	9.26	11.99	11.04	12.84		10.97	12.32	12.30	13.69	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.32	0.11	0.38	0.22		0.39	0.43	0.88	0.86	
CD (P=0.05)	1.02	0.23	1.09	0.46		1.24	0.88	2.01	1.77	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 22. Effect of additional dose of N and K and foliar spraying on N uptake in seeds (kg ha^{-1}) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	22.45	23.59	27.30	28.50	25.46	17.22	22.78	22.69	26.52	22.30
Spentwash	18.68	24.23	21.42	26.69	22.76	15.07	19.04	19.81	21.86	18.95
Humic acid 0.1%	16.96	19.63	18.28	22.21	19.27	14.36	16.83	15.73	18.26	16.30
Brassinolide 0.2 ppm	16.82	26.10	22.39	25.65	22.74	14.86	19.32	19.90	20.58	18.66
$ZnSO_4$ 0.5% + BA 0.2%	15.16	22.89	21.47	25.13	21.17	17.45	20.08	18.68	20.13	19.09
DAP 2 % + KCl 1%	18.37	25.13	22.31	26.16	22.99	18.13	18.95	20.50	22.45	20.01
DAP+KCl+$ZnSO_4$+BA	16.75	24.77	23.67	28.54	23.44	19.35	21.72	20.01	22.56	20.91
Mean	17.89	23.77	22.41	26.13		16.63	19.82	19.62	21.76	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.50	0.94	1.81	1.87		0.66	0.54	1.19	1.07	
CD (P=0.05)	1.58	1.93	NS	NS		2.09	1.10	2.86	2.21	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 23. Effect of additional dose of N and K and foliar spraying on N uptake in seeds (kg ha^{-1}) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	7.20	8.93	12.47	14.58	10.80	11.30	10.84	10.54	12.38	11.27
Spentwash	7.08	14.70	10.65	14.76	11.80	10.91	10.90	11.38	12.72	11.48
Humic acid 0.1%	9.79	10.41	12.33	13.09	11.41	7.43	10.58	9.17	12.24	9.85
Brassinolide 0.2 ppm	11.80	13.19	11.39	11.34	11.93	11.19	11.47	11.40	12.41	11.62
$ZnSO_4$ 0.5% + BA 0.2%	16.45	15.62	14.89	13.13	15.02	11.63	13.29	14.75	14.19	13.46
DAP 2 % + KCl 1%	16.98	15.10	17.64	16.92	16.66	12.80	13.70	15.60	15.85	14.48
DAP+KCl+$ZnSO_4$+BA	16.61	14.46	13.11	17.02	15.30	13.94	13.61	13.89	14.66	14.03
Mean	12.27	13.20	13.21	14.41		11.31	12.05	12.39	13.49	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.71	0.53	1.21	1.06		0.64	0.99	1.93	1.97	
CD (P=0.05)	NS	1.09	2.95	2.18		NS	2.03	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 24. Effect of additional dose of N and K and foliar spraying on P uptake in straw (kg ha^{-1}) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	6.10	6.69	6.51	6.98	6.57	6.00	4.67	5.12	6.02	5.45
Spentwash	5.69	6.45	6.16	6.81	6.27	5.61	5.28	5.09	5.52	5.37
Humic acid 0.1%	5.27	6.02	6.02	6.32	5.91	5.19	5.42	5.46	4.84	5.23
Brassinolide 0.2 ppm	5.16	6.41	6.45	6.89	6.23	4.80	5.88	5.21	5.53	5.35
$ZnSO_4$ 0.5% + BA 0.2%	5.26	6.15	6.46	6.46	6.08	5.66	4.99	5.64	5.28	5.39
DAP 2 % + KCl 1%	6.01	6.88	6.93	7.19	6.75	4.68	6.02	6.07	6.57	5.84
DAP+KCl+$ZnSO_4$+BA	6.10	7.10	6.84	7.35	6.85	5.02	5.28	5.64	6.53	5.62
Mean	5.65	6.53	6.48	6.86		5.28	5.36	5.46	5.76	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.05	0.07	0.13	0.13		0.20	0.21	0.44	0.42	
CD (P=0.05)	0.16	0.13	0.29	0.27		NS	NS	1.01	0.88	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 25. Effect of additional dose of N and K and foliar spraying on P uptake in straw (kg ha^{-1}) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	1.81	2.01	2.03	2.34	2.05	2.08	1.50	1.51	2.11	1.80
Spentwash	1.68	1.99	1.91	2.26	1.96	1.51	1.61	1.41	1.68	1.55
Humic acid 0.1%	1.50	1.78	1.79	2.17	1.81	1.57	1.34	1.35	1.72	1.50
Brassinolide 0.2 ppm	1.53	1.87	2.02	2.21	1.91	1.48	1.58	1.38	1.46	1.48
$ZnSO_4$ 0.5% + BA 0.2%	1.42	1.84	1.89	2.35	1.88	1.32	1.66	1.60	1.46	1.51
DAP 2 % + KCl 1%	1.45	1.98	2.10	2.33	1.97	1.17	1.63	1.47	1.89	1.54
DAP+KCl+$ZnSO_4$+BA	1.73	2.07	2.04	2.45	2.07	1.14	1.91	1.95	1.58	1.65
Mean	1.59	1.93	1.97	2.30		1.47	1.60	1.52	1.70	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.03	0.03	0.07	0.07		0.07	0.07	0.15	0.14	
CD (P=0.05)	0.10	0.07	0.16	0.14		NS	0.14	0.34	0.28	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 26. Effect of additional dose of N and K and foliar spraying on P uptake in seeds (kg ha^{-1}) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	5.00	4.36	4.26	4.69	4.58	5.48	6.24	5.66	6.08	5.86
Spentwash	2.72	3.81	4.14	4.46	3.78	4.19	4.37	3.90	4.60	4.27
Humic acid 0.1%	3.60	4.16	3.36	3.62	3.68	3.03	3.83	3.34	3.89	3.52
Brassinolide 0.2 ppm	2.99	4.28	4.39	4.35	4.00	3.29	3.69	3.37	4.62	3.74
$ZnSO_4$ 0.5% + BA 0.2%	3.99	3.68	4.31	4.23	4.05	3.26	4.19	3.38	4.91	3.93
DAP 2 % + KCl 1%	3.51	4.86	5.29	3.59	4.31	3.41	4.13	4.32	4.62	4.12
DAP+KCl+$ZnSO_4$+BA	3.28	3.59	4.17	4.33	3.84	3.40	4.64	4.47	4.92	4.36
Mean	3.58	4.10	4.28	4.18	4.04	3.72	4.44	4.06	4.81	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.16	0.13	0.29	0.26		0.06	0.12	0.24	0.25	
CD (P=0.05)	NS	0.27	0.70	0.54		0.20	0.25	0.50	0.51	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 27. Effect of additional dose of N and K and foliar spraying on P uptake in seeds (kg ha^{-1}) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	2.14	1.91	2.61	2.85	2.38	2.52	2.21	2.53	2.60	2.46
Spentwash	1.89	2.60	1.93	2.87	2.32	2.63	2.21	2.44	2.64	2.48
Humic acid 0.1%	2.38	2.56	2.40	2.40	2.43	1.61	2.33	2.03	2.24	2.05
Brassinolide 0.2 ppm	2.31	1.52	2.09	2.28	2.05	2.50	2.60	2.71	2.61	2.60
$ZnSO_4$ 0.5% + BA 0.2%	3.25	3.62	2.78	2.52	3.04	2.72	3.41	2.83	2.69	2.91
DAP 2 % + KCl 1%	3.25	2.70	2.99	2.37	2.82	2.84	3.21	2.65	2.94	2.91
DAP+KCl+$ZnSO_4$+BA	2.44	2.08	2.17	3.32	2.50	3.14	3.05	2.74	2.95	2.97
Mean	2.52	2.42	2.43	2.66		2.57	2.72	2.56	2.67	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.06	0.06	0.13	0.13		0.17	0.11	0.26	0.22	
CD (P=0.05)	NS	0.13	0.30	0.27		NS	0.22	0.67	0.43	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 28. Effect of additional dose of N and K and foliar spraying on K uptake in straw (kg ha^{-1}) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	17.03	19.50	21.12	23.42	20.27	8.77	10.16	8.12	11.43	9.62
Spentwash	16.49	18.90	20.12	22.26	19.44	7.65	10.56	10.23	10.41	9.71
Humic acid 0.1%	16.62	17.85	19.11	20.73	18.58	5.81	10.66	10.95	10.77	9.55
Brassinolide 0.2 ppm	16.90	19.54	21.70	22.31	20.11	8.38	10.67	7.95	12.39	9.85
$ZnSO_4$ 0.5% + BA 0.2%	16.64	18.71	19.76	20.92	19.01	8.71	10.41	8.86	9.93	9.48
DAP 2 % + KCl 1%	18.50	20.40	22.24	23.56	21.18	9.97	10.83	10.95	11.06	10.70
DAP+KCl+$ZnSO_4$+BA	18.77	21.31	22.43	23.89	21.60	9.63	11.91	10.60	11.21	10.84
Mean	17.28	19.46	20.93	22.44		8.42	10.74	9.67	11.03	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.21	0.32	0.64	0.65		0.02	0.08	0.15	0.16	
CD (P=0.05)	0.68	0.67	NS	NS		0.07	0.16	0.31	0.33	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 29. Effect of additional dose of N and K and foliar spraying on K uptake in straw (kg ha^{-1}) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	4.24	5.26	5.04	5.81	5.09	3.10	3.57	3.37	3.75	3.45
Spentwash	4.19	5.24	4.89	5.53	4.96	2.71	3.34	3.10	3.70	3.21
Humic acid 0.1%	4.17	5.14	4.69	5.63	4.91	2.88	3.14	2.94	3.31	3.07
Brassinolide 0.2 ppm	4.43	5.82	5.38	5.88	5.38	3.22	3.43	3.25	3.73	3.41
$ZnSO_4$ 0.5% + BA 0.2%	4.61	5.76	5.23	6.15	5.44	3.02	3.41	3.28	3.61	3.33
DAP 2 % + KCl 1%	4.93	6.11	5.69	6.51	5.81	3.10	3.33	3.30	4.25	3.50
DAP+KCl+$ZnSO_4$+BA	4.85	6.07	5.79	6.61	5.83	2.92	3.79	3.42	3.95	3.52
Mean	4.49	5.63	5.25	6.02		2.99	3.43	3.24	3.76	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.14	0.04	0.15	0.08		0.07	0.10	0.19	0.19	
CD (P=0.05)	0.43	0.08	0.45	0.17		0.15	0.21	0.41	0.39	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 30. Effect of additional dose of N and K and foliar spraying on K uptake in seeds (kg ha^{-1}) of A line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	4.15	4.51	3.73	4.96	4.34	13.48	14.22	12.02	14.81	13.63
Spentwash	3.05	4.37	3.86	4.32	3.90	11.10	11.57	10.36	11.73	11.19
Humic acid 0.1%	2.00	3.57	3.49	3.74	3.20	8.47	8.71	8.34	9.75	8.82
Brassinolide 0.2 ppm	3.39	4.61	4.19	4.33	4.13	9.35	10.19	9.64	11.06	10.06
$ZnSO_4$ 0.5% + BA 0.2%	3.65	3.98	3.80	4.23	3.92	8.63	9.51	9.22	10.40	9.44
DAP 2 % + KCl 1%	3.32	4.02	3.05	4.61	3.75	9.30	10.08	10.05	9.34	9.69
DAP+KCl+$ZnSO_4$+BA	3.59	3.88	3.39	4.08	3.73	8.47	10.37	10.37	10.77	9.99
Mean	3.31	4.14	3.64	4.33	3.85	9.83	10.66	10.00	11.12	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.05	0.11	0.20	0.21		0.10	0.21	0.39	0.41	
CD (P=0.05)	0.15	0.22	0.42	0.43		0.30	0.42	0.83	0.85	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 31. Effect of additional dose of N and K and foliar spraying on K uptake in seeds (kg ha^{-1}) of R line in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	1.47	2.57	2.14	2.29	2.12	6.11	7.98	6.97	8.02	7.27
Spentwash	2.52	2.66	2.59	2.18	2.49	6.26	7.86	7.50	8.54	7.54
Humic acid 0.1%	2.25	1.95	1.88	2.60	2.17	5.22	6.48	6.63	7.76	6.52
Brassinolide 0.2 ppm	2.23	2.05	2.75	2.86	2.47	7.24	7.80	7.56	8.93	7.88
$ZnSO_4$ 0.5% + BA 0.2%	3.12	2.16	2.57	2.59	2.61	7.25	7.86	7.60	8.83	7.89
DAP 2 % + KCl 1%	2.89	3.18	2.70	2.62	2.85	7.59	8.53	8.01	9.84	8.49
DAP+KCl+$ZnSO_4$+BA	2.09	2.53	2.29	2.30	2.30	8.17	8.60	8.42	9.28	8.62
Mean	2.37	2.44	2.42	2.49		6.83	7.87	7.52	8.74	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.02	0.05	0.10	0.10		0.33	0.27	0.59	0.53	
CD (P=0.05)	0.06	0.11	0.20	0.21		0.72	0.55	1.43	1.09	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 32. Effect of additional dose of N and K and foliar spraying on available N ($KMnO_4$-N) content (kg ha^{-1}) of post harvest soil in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	315	330	375	367	347	341	366	369	358	358
Spentwash	351	308	326	337	331	397	364	354	336	363
Humic acid 0.1%	357	300	252	360	317	345	381	370	344	360
Brassinolide 0.2 ppm	332	292	342	301	317	350	359	369	329	352
$ZnSO_4$ 0.5% + BA 0.2%	340	364	308	325	334	347	375	361	348	358
DAP 2 % + KCl 1%	344	375	325	319	341	344	331	374	342	348
DAP+KCl+$ZnSO_4$+BA	288	332	329	378	332	339	361	344	378	355
Mean	333	329	322	341		352	362	363	348	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	4.20	7.19	13.96	14.38		8.45	13.78	26.88	27.55	
CD (P=0.05)	NS	14.84	30.22	29.67		NS	NS	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid
Initial available N content (Before commencement of experiment) : ADTRH 1 – 320 kg ha^{-1} CORH 2– 308 kg ha^{-1}

Table 33. Effect of additional dose of N and K and foliar spraying on available P (Olsen-P) content (kg ha^{-1}) of post harvest soil in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	41.52	35.61	36.01	33.45	36.64	45.67	43.19	40.38	30.36	39.90
Spentwash	36.07	43.41	45.08	35.90	40.11	34.06	33.58	26.99	35.02	32.41
Humic acid 0.1%	39.24	34.09	47.97	39.35	40.16	36.34	39.15	28.56	37.31	35.34
Brassinolide 0.2 ppm	33.42	36.12	47.59	35.29	38.10	33.93	31.00	19.26	29.48	30.92
$ZnSO_4$ 0.5% + BA 0.2%	39.40	34.31	34.32	35.81	35.96	38.94	27.89	37.81	33.09	34.43
DAP 2 % + KCl 1%	27.97	35.79	38.56	38.97	35.32	25.26	36.14	25.26	31.91	29.64
DAP+KCl+$ZnSO_4$+BA	38.23	36.22	36.32	40.90	37.92	29.37	28.79	20.49	18.01	24.17
Mean	36.55	36.51	40.84	37.09		34.80	34.25	29.82	30.74	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.267	0.776	1.461	1.552		4.61	4.60	9.68	9.68	
CD (P=0.05)	0.850	1.602	3.071	3.203		NS	NS	22.40	18.97	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid
Initial available P content (Before commencement of experiment) : ADTRH 1 – 28.40 kg ha^{-1} CORH 2– 23.22 kg ha^{-1}

Table 34. Effect of additional dose of N and K and foliar spraying on available K (NH_4OAc-K) content (kg ha^{-1}) of post harvest soil in ADTRH 1 and CORH 2 rice hybrid seed production

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	356	341	363	348	352	522	570	618	550	565
Spentwash	362	354	364	352	358	560	587	603	572	580
Humic acid 0.1%	365	362	392	352	368	537	526	551	548	540
Brassinolide 0.2 ppm	353	346	355	344	349	550	568	594	542	563
$ZnSO_4$ 0.5% + BA 0.2%	354	356	357	358	356	607	541	543	602	573
DAP 2 % + KCl 1%	345	363	355	370	358	615	650	625	562	613
DAP+KCl+$ZnSO_4$+BA	354	363	359	375	363	580	574	545	598	574
Mean	355	355	363	357		567	574	582	568	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	4.03	4.13	8.65	8.26		27.80	20.91	47.67	41.83	
CD (P=0.05)	NS	8.53	19.95	17.06		NS	NS	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid
Initial available K content (Before commencement of experiment) : ADTRH 1 – 338 kg ha^{-1} CORH 2– 627 kg ha^{-1}

Table 35. Effect of additional dose of N and K and foliar spraying on germination (%) of hybrid seeds of ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	90.0 (71.57)	90.5 (72.06)	91.0 (72.57)	90.5 (72.06)	90.5 (72.06)	92.5 (74.18)	92.5 (74.12)	91.5 (73.06)	91.5 (73.06)	92.0 (73.60)
Spentwash	90.5 (72.06)	90.5 (72.06)	92.5 (74.12)	91.5 (73.06)	91.3 (72.82)	90.5 (72.10)	89.5 (71.14)	91.0 (72.57)	91.0 (72.65)	90.5 (72.11)
Humic acid 0.1%	91.0 (72.57)	90.5 (72.06)	91.0 (72.57)	91.0 (72.57)	90.9 (72.44)	91.5 (73.06)	91.5 (73.11)	92.0 (73.60)	91.5 (73.11)	91.6 (73.22)
Brassinolide 0.2 ppm	90.5 (72.06)	91.0 (72.57)	90.0 (71.57)	90.5 (72.06)	90.5 (72.06)	91.5 (73.23)	91.5 (73.11)	90.5 (72.10)	91.5 (73.06)	91.3 (72.88)
$ZnSO_4$ 0.5% + BA 0.2%	90.5 (72.06)	91.5 (73.11)	91.5 (73.05)	90.0 (71.57)	90.9 (72.45)	91.5 (73.06)	90.5 (72.10)	91.5 (73.11)	91.5 (73.11)	91.3 (72.85)
DAP 2 % + KCl 1%	90.5 (72.06)	91.0 (72.57)	90.5 (72.06)	90.5 (72.06)	90.6 (72.18)	91.5 (73.11)	91.5 (73.06)	89.5 (71.10)	91.5 (73.06)	91.0 (72.58)
DAP+KCl+$ZnSO_4$+BA	91.0 (72.57)	91.0 (72.57)	91.0 (72.57)	91.0 (72.57)	91.0 (72.57)	91.0 (72.65)	91.5 (73.11)	91.5 (73.06)	90.5 (72.10)	91.1 (72.73)
Mean	90.6 (72.13)	90.9 (72.43)	91.1 (72.64)	90.7 (72.28)		91.4 (73.06)	91.2 (72.82)	91.1 (72.66)	91.3 (72.88)	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.583	0.505	1.102	1.010		0.522	0.987	1.900	1.973	
CD (P=0.05)	NS	NS	NS	NS		NS	NS	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

(Figures in parentheses are arc-sine transformed values)

Table 36. Effect of additional dose of N and K and foliar spraying on root length (cm) of hybrid seeds of ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	17.92	19.25	18.19	19.20	18.64	19.07	19.29	19.38	19.51	19.31
Spentwash	17.56	18.52	18.37	19.39	18.46	18.65	18.46	20.19	20.12	19.35
Humic acid 0.1%	18.91	19.11	17.99	18.36	18.59	18.89	18.62	18.90	20.25	19.17
Brassinolide 0.2 ppm	18.82	19.86	18.76	19.39	19.21	19.61	19.37	20.20	20.17	19.84
$ZnSO_4$ 0.5% + BA 0.2%	18.21	17.92	19.90	19.22	18.81	19.32	19.41	19.70	20.06	19.62
DAP 2 % + KCl 1%	18.81	20.19	19.77	19.50	19.57	19.40	18.99	20.27	19.90	19.64
DAP+KCl+$ZnSO_4$+BA	19.71	19.98	19.36	19.85	19.72	19.77	19.98	20.13	20.04	19.98
Mean	18.56	19.26	18.90	19.27		19.24	19.16	19.82	20.01	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.369	0.448	0.907	0.895		0.192	0.379	0.727	0.757	
CD (P=0.05)	NS	0.924	NS	NS		0.610	NS	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 37. Effect of additional dose of N and K and foliar spraying on shoot length (cm) of hybrid seeds of ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	10.41	11.00	11.14	11.43	10.99	12.21	12.02	11.98	12.14	12.08
Spentwash	11.25	9.80	9.94	10.30	10.32	11.99	12.27	12.50	12.43	12.30
Humic acid 0.1%	10.02	11.22	10.26	9.98	10.37	12.14	12.03	12.12	12.39	12.17
Brassinolide 0.2 ppm	11.10	9.76	10.76	11.35	10.74	12.03	12.34	12.50	12.20	12.27
$ZnSO_4$ 0.5% + BA 0.2%	11.48	11.26	11.38	11.18	11.32	12.02	12.28	12.17	12.22	12.17
DAP 2 % + KCl 1%	10.11	10.85	11.39	11.43	10.94	11.84	12.39	12.18	12.54	12.24
DAP+KCl+$ZnSO_4$+BA	11.38	11.30	11.30	11.29	11.31	12.48	12.43	12.67	12.37	12.48
Mean	10.82	10.74	10.88	10.99		12.10	12.25	12.30	12.32	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	0.387	0.627	1.224	1.255		0.152	0.272	0.525	0.543	
CD (P=0.05)	NS	NS	NS	NS		NS	NS	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 38. Effect of additional dose of N and K and foliar spraying on dry matter production seedling^{-1} (mg) of hybrid seeds of ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	12.1	11.9	12.2	11.9	12.0	13.2	13.3	13.5	13.3	13.3
Spentwash	12.1	12.5	12.5	12.0	12.3	13.7	13.8	13.2	14.0	13.7
Humic acid 0.1%	11.7	11.8	11.9	12.0	11.8	13.2	13.4	13.2	13.3	13.3
Brassinolide 0.2 ppm	12.7	12.1	12.4	12.0	12.3	13.5	13.4	13.9	13.4	13.5
$ZnSO_4$ 0.5% + BA 0.2%	12.0	12.7	11.8	12.4	12.2	13.5	13.8	13.7	13.4	13.6
DAP 2 % + KCl 1%	12.3	11.8	12.7	12.1	12.2	14.0	13.5	14.1	14.0	13.9
DAP+KCl+$ZnSO_4$+BA	12.1	12.1	11.6	12.2	12.0	13.5	13.6	13.3	14.0	13.6
Mean	12.1	12.1	12.1	12.1		13.5	13.5	13.5	13.6	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	1.08	2.49	4.73	4.97		1.39	3.69	6.96	7.37	
CD (P=0.05)	NS	NS	NS	NS		NS	NS	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 39. Effect of additional dose of N and K and foliar spraying on vigour index of hybrid seeds of rice ADTRH 1 and CORH 2

Foliar spray treatments (S)	ADTRH 1					CORH 2				
	Fertilizer treatments (M)									
	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean	RDF	RDF + 25N + 15 K at PI	RDF + 25N + 15 K at 10 DAPI	RDF + 25N + 15 K at PI & 10 DAPI	Mean
GA_3 75 g ha^{-1}	2549	2738	2670	2772	2682	2895	2896	2870	2897	2889
Spentwash	2607	2563	2619	2717	2626	2772	2750	2976	2962	2865
Humic acid 0.1%	2633	2744	2569	2580	2631	2839	2804	2854	2986	2871
Brassinolide 0.2 ppm	2708	2696	2657	2783	2711	2894	2901	2960	2962	2929
$ZnSO_4$ 0.5% + BA 0.2%	2687	2666	2863	2736	2738	2867	2867	2915	2953	2900
DAP 2 % + KCl 1%	2618	2825	2822	2798	2766	2859	2873	2905	2969	2901
DAP+KCl+$ZnSO_4$+BA	2830	2846	2789	2832	2824	2934	2964	3001	2932	2958
Mean	2662	2725	2712	2745		2866	2865	2925	2951	
	M	S	M at S	S at M		M	S	M at S	S at M	
SEd	60.8	67.7	139.4	135.5		15.2	46.5	87.4	93.0	
CD (P=0.05)	NS	NS	NS	NS		48.5	NS	NS	NS	

RDF – Recommended dose of fertilizer (150 : 60 : 60 kg NPK ha^{-1}); PI – Panicle initiation; DAPI – Days after panicle initiation; BA – Boric acid

Table 63. Standardisation of dose of polykote and quantity of water for polykote dilution in rice seeds (IR 58025 B) – imbibition rate

Polykote dose and dilution (T)	Period (P) of imbibition (h)						Mean	Per cent increase over period	Per cent increase over control
	0	4	8	12	16	20			
Polykote 5 g + 90 ml water kg^{-1}	12.3 (20.51)	32.5 (34.74)	38.8 (36.70)	42.3 (40.54)	47.0 (43.27)	47.3 (43.43)	36.2 (36.53)	35.0	6.1
Polykote 5 g + 70 ml water kg^{-1}	12.2 (20.44)	34.5 (35.97)	40.3 (39.41)	45.4 (42.37)	48.0 (43.83)	48.2 (43.99)	38.1 (37.67)	36.1	7.2
Polykote 5 g + 50 ml water kg^{-1}	12.2 (20.45)	32.3 (34.61)	37.9 (37.93)	41.4 (40.04)	44.3 (41.70)	44.7 (41.97)	35.4 (36.12)	32.5	3.6
Polykote 5 g + 30 ml water kg^{-1}	12.3 (20.52)	32.2 (34.57)	37.6 (37.83)	41.0 (39.81)	42.8 (40.85)	43.8 (41.44)	35.0 (35.84)	31.5	2.6
Polykote 5 g + 15 ml water kg^{-1}	12.3 (20.55)	30.7 (33.67)	35.2 (36.39)	38.9 (38.56)	40.8 (39.70)	42.2 (40.50)	33.4 (34.89)	29.9	1.0
Polykote 3 g + 90 ml water kg^{-1}	12.3 (20.51)	30.5 (33.54)	36.5 (37.18)	41.2 (39.90)	44.2 (41.64)	44.8 (42.04)	34.9 (35.80)	32.6	3.7
Polykote 3 g + 70 ml water kg^{-1}	12.3 (20.49)	31.9 (34.37)	36.8 (37.33)	42.0 (40.39)	45.6 (42.45)	46.5 (43.01)	35.8 (36.34)	34.3	5.8
Polykote 3 g + 50 ml water kg^{-1}	12.3 (20.49)	33.5 (35.35)	39.9 (39.15)	44.3 (41.70)	46.2 (42.82)	47.6 (43.62)	37.3 (37.19)	35.3	6.5
Polykote 3 g + 30 ml water kg^{-1}	12.3 (20.52)	31.0 (33.81)	37.0 (37.44)	39.0 (38.62)	41.5 (40.12)	43.6 (41.34)	34.1 (35.31)	31.3	2.5
Polykote 3 g + 15 ml water kg^{-1}	12.2 (20.47)	30.0 (33.23)	35.6 (36.65)	39.2 (38.76)	40.7 (39.66)	41.3 (40.01)	33.2 (34.80)	29.1	0.2
Uncoated (control)	12.2 (20.44)	29.6 (32.97)	33.1 (35.14)	38.0 (38.06)	40.2 (39.36)	41.1 (39.87)	32.4 (34.31)	28.9	-
Mean	12.3 (20.49)	31.7 (34.26)	36.9 (37.38)	41.1 (39.89)	43.7 (41.40)	44.7 (41.93)			

	T	P	T x P
SEd	0.255	0.189	0.625
CD (P=0.05)	0.510	0.376	1.248

(Figures in parentheses are arc-sine transformed values)

Table 76. Correlation coefficient among physiological and biochemical seed vigour test attributes of rice hybrids and their parental lines

Characters	Imbibition rate	Sprouting time	Radicle length	Rate of germination	Germination	Root length	Shoot length	Dry matter production	Vigour index	Field emergence	Dehydrogenase enzyme	Total ATPase	Peroxidase	Catalase	α-Amylase
Imbibition rate	1.00														
Sprouting time	-0.83**	1.00													
Radicle length	0.29	-0.37	1.00												
Rate of germination	0.81**	-0.75**	0.61**	1.00											
Germination	0.10	-0.12	0.70**	0.35	1.00										
Root length	-0.11	-0.12	0.82**	0.25	0.56**	1.00									
Shoot length	-0.80**	0.56**	-0.01	-0.58**	0.15	0.28	1.00								
Dry matter production	-0.86**	0.70**	0.02	-0.68**	0.08	0.38	0.80**	1.00							
Vigour index	-0.28	0.04	0.76**	0.11	0.67**	0.95**	0.51**	0.53**	1.00						
Field emergence	0.12	-0.40*	0.72**	0.40*	0.68**	0.66**	0.07	-0.01	0.66**	1.00					
Dehydrogenase enzyme	0.06	-0.24	0.76**	0.31	0.78**	0.84**	0.17	0.14	0.84**	0.75**	1.00				
Total ATPase	0.19	-0.39*	0.84**	0.41*	0.74**	0.85**	0.15	0.11	0.84**	0.74**	0.90**	1.00			
Peroxidase	0.18	-0.35	0.77**	0.43*	0.70**	0.82**	0.12	0.02	0.80**	0.74**	0.92**	0.94**	1.00		
Catalase	0.27	-0.45*	0.85**	0.57**	0.72**	0.84**	0.02	-0.07	0.79**	0.78**	0.91**	0.92**	0.96**	1.00	
α-Amylase	-0.12	-0.15	0.73**	0.18	0.75**	0.84**	0.39	0.32	0.89**	0.77**	0.91**	0.89**	0.90**	0.88**	1.00

** Correlation significant at the (P=0.01) level; * Correlation significant at the (P=0.05) level

Table 77. Correlation coefficient among the seed vigour attributes of rice hybrid and parental lines subjected to stress tests

Stress tests		NH_4Cl soak test		D-mannitol soak test		Anaerobic germination		Exhaustion test		Bioassay test		Accelerated ageing				
		Germination	Vigour index	Germination	Vigour index	Germination	Vigour index	Germination	Vigour index	Germination	Vigour index	Germination	TZ-viability	Vigour index	Electrical conductivity	Dehydrogenase
NH_4Cl soak test	Germination	1.00														
	Vigour index	0.90**	1.00													
D-mannitol soak test	Germination	0.60**	0.68**	1.00												
	Vigour index	0.58**	0.77**	0.91**	1.00											
Anaerobic germination	Germination	0.10	-0.15	-0.13	-0.34	1.00										
	Vigour index	0.28	0.04	0.09	-0.14	0.97**	1.00									
Exhaustion test	Germination	0.80**	0.89**	0.56**	0.65**	0.14	0.31	1.00								
	Vigour index	0.78**	0.90**	0.62**	0.73**	0.05	0.22	0.99**	1.00							
Bioassay test	Germination	0.34	0.26	-0.17	-0.18	0.27	0.26	0.28	0.22	1.00						
	Vigour index	0.49*	0.65**	0.05	0.27	-0.19	-0.14	0.68**	0.66**	0.56**	1.00					
Accelerated ageing	Germination	0.31	0.28	0.78**	0.59**	0.32	0.47*	0.28	0.32	-0.22	-0.37	1.00				
	TZ- viability	0.35	0.30	0.73**	0.57**	0.29	0.44*	0.31	0.33	-0.23	-0.37	0.30	1.00			
	Vigour index	0.36	0.40*	0.85**	0.77**	0.22	0.39	0.39	0.43*	-0.22	-0.25	0.98**	0.91**	1.00		
	Electrical conductivity	0.49*	0.521**	0.73**	0.67**	0.16	0.32	0.51*	0.55**	-0.21	0.04	0.67**	0.54**	0.72**	1.00	
	Dehydrogenase	-0.38	-0.291	-0.79**	-0.56**	-0.32	-0.48*	-0.25	-0.28	0.22	0.39	-0.96**	-0.87**	-0.94**	-0.74**	1.00

** Correlation significant at the (P=0.01) level;

* Correlation significant at the (P=0.05) level

Table 74. Effect of additional N and K and foliar spraying on correlation coefficient of growth, yield attributes and nutrient uptake of A and R lines with hybrid seed yield of ADTRH 1 and CORH 2

Parameters	ADTRH 1		CORH 2	
	A line	R line	A line	R line
Plant height	0.816**	0.795**	0.777**	0.870**
Productive tillers	0.559**	0.307	0.261	0.276
Days to 50% flowering	-0.227	-	-0.209	-
Panicle length	0.796**	0.545**	0.637**	0.678**
Panicle exsertion	0.852**	-	0.745**	-
Number of spikelets panicle^{-1}	0.101	0.201	0.190	0.465*
Seed set	0.879**	-	0.729**	-
1000 seed weight	0.236	-	0.241	-
Total N uptake	0.727**	0.190	0.698**	0.164
Total P uptake	0.645**	0.224	0.628**	0.265
Total K uptake	0.427*	0.259	0.770**	0.339

** Correlation significant at (P=0.01) level

* Correlation significant at (P=0.05) level

Table 75. Heterosis percentage for physiological and biochemical seed vigour attributes in ADTRH 1 and CORH 2

Parameters	Relative heterosis (di)		Heterobeltiosis (dii)	
	ADTRH 1	CORH 2	ADTRH 1	CORH 2
Imbibition rate	6.41**	8.35**	0.63	0.97
Time taken for sprouting	-11.86*	-19.35**	-16.13**	-26.47**
Radicle length in time bound germination	9.17**	26.74**	7.39*	22.67**
Rate of germination	10.00*	38.49**	2.26	24.37**
Germination	4.12*	4.90**	3.27	3.22
Root length	14.91**	24.22**	9.04*	8.81**
Shoot length	-4.96	-5.23	-10.36**	-11.35**
Drymatter production	-6.39**	-12.12**	-10.24**	-21.86**
Vigour index	9.23**	15.87**	2.84	3.21
Field emergence	3.86*	8.61**	1.81	7.09**
Dehydrogenase enzyme activity	31.43**	35.14**	21.05**	19.05**
Total ATPase enzyme activity	20.63**	21.90**	18.30**	13.94**
Peroxidase enzyme activity	20.00**	22.58**	12.50**	11.76**
Catalase enzyme activity	14.71**	21.99**	10.87**	16.33**
α-amylase enzyme activity	42.82**	39.53**	21.94**	12.46**

** Significant at (P=0.01) level * Significant at (P=0.05) level

Table 40. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to imbibition rate test

Parents and hybrids (G)	Period (P) of imbibition (h)						Mean	Per cent increase
	0	4	8	12	16	20		
IR58025 A	12.5 (20.71)	30.3 (33.41)	37.0 (37.45)	39.7 (39.07)	42.9 (40.92)	43.6 (41.30)	34.3 (35.48)	31.1
IR58025 B	12.4 (20.64)	28.9 (32.53)	35.7 (36.71)	38.3 (38.26)	41.0 (39.80)	41.5 (40.09)	33.0 (34.67)	29.1
IR66 R	12.4 (20.65)	27.5 (31.60)	32.6 (34.83)	34.2 (35.78)	35.3 (36.46)	35.9 (36.80)	29.7 (32.69)	23.5
C20 R	12.7 (20.84)	25.3 (30.19)	29.3 (32.75)	31.6 (34.19)	33.6 (35.44)	34.0 (35.67)	27.7 (31.51)	21.4
ADTRH 1	12.3 (20.51)	31.4 (33.92)	37.6 (37.83)	40.5 (39.50)	43.7 (41.35)	44.0 (41.54)	34.9 (35.77)	31.7
CORH 2	12.5 (20.74)	33.0 (35.06)	38.9 (38.57)	40.9 (39.77)	43.9 (41.47)	44.3 (41.70)	35.6 (36.22)	31.7
Mean	12.5 (20.68)	29.4 (32.79)	35.2 (36.36)	37.5 (37.76)	40.1 (39.24)	40.5 (39.52)		

	G	P	G x P
SEd	0.193	0.193	0.473
CD (P=0.05)	0.392	0.392	0.959

(Figures in parentheses are arc-sine transformed values)

Table 41a. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to seedling growth rate tests

Parents and hybrids	Time taken for sprouting (h)	Radicle length in time bound germination (mm)	Rate of germination	Germination	
				%	Arc-sine value
IR58025 A	28.0	14.55	27.7	92.0	73.57
IR58025 B	30.0	13.15	27.5	92.0	73.57
IR66 R	31.0	14.08	23.8	93.0	74.80
C20 R	34.0	15.55	22.0	94.0	76.02
ADTRH 1	26.0	15.63	28.3	95.0	77.24
CORH 2	25.0	19.08	34.5	96.0	78.46
SEd	1.41	0.46	1.15	1.29	
CD (P=0.05)	2.97	0.97	2.41	2.71	

Table 41b. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to seedling growth rate tests (Contd.)

Parents and hybrids	Root length (cm)	Shoot length (cm)	Dry matter production (mg seedling^{-1})	Vigour index	Field emergence	
					%	Arc-sine value
IR58025 A	15.15	11.13	12.55	2417	81.0	64.20
IR58025 B	15.93	10.63	12.18	2444	80.5	63.82
IR66 R	16.88	12.55	13.68	2737	84.5	66.85
C20 R	20.15	12.78	16.13	3093	83.5	65.92
ADTRH 1	18.40	11.25	12.28	2815	86.0	68.05
CORH 2	21.93	11.33	12.60	3192	89.0	70.73
SEd	0.58	0.36	0.27	51.9	1.15	
CD (P=0.05)	1.21	0.75	0.56	108.9	2.41	

Table 42. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to enzyme activity test

Parents and Hybrids	Dehydorgenase (OD value)	Total ATPase (µmol of P g^{-1} h^{-1})	Peroxidase (OD value 10 min^{-1})	Catalase (ml of 0.01 N $KMnO_4$ min^{-1} ml^{-1})	α-amylase (mm of halo zone)
IR58025 A	0.079	2.607	0.072	2.13	7.56
IR58025 B	0.088	2.476	0.075	2.20	7.52
IR66 R	0.096	2.711	0.079	2.28	10.69
C20 R	0.106	2.999	0.084	2.34	12.34
ADTRH 1	0.114	3.208	0.092	2.53	13.03
CORH 2	0.124	3.417	0.095	2.73	13.90
SEd	0.004	0.068	0.002	0.021	0.282
CD (P=0.05)	0.008	0.142	0.004	0.043	0.592

Table 43. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to stress tests- NH_4Cl and D-mannitol soak test

Parents and hybrids	NH_4Cl soak test				D-mannitol soak test			
	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index
IR58025 A	42.5 (40.68)	15.15	8.56	1008	62.5 (52.24)	2.32	1.83	211
IR58025 B	44.5 (41.84)	17.40	6.58	1068	71.5 (57.74)	1.91	1.46	296
IR66 R	58.0 (49.61)	18.01	7.84	1499	80.5 (63.82)	3.10	2.14	422
C20 R	45.5 (42.42)	19.21	8.99	1282	77.5 (61.70)	3.69	2.23	458
ADTRH 1	56.5 (48.74)	18.02	7.97	1469	73.5 (59.02)	3.16	2.27	399
CORH 2	47.5 (43.57)	18.93	9.38	1344	69.5 (56.48)	2.83	2.03	338
SEd	0.897	0.36	0.29	40.8	0.66	0.06	0.05	7.95
CD(P=0.05)	1.885	0.77	0.60	85.7	1.38	0.13	0.11	16.7

(Figures in parentheses are arc-sine transformed values)

Table 44. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to stress tests - anaerobic germination and exhaustion test

Parents and hybrids	Anaerobic germination test				Exhaustion test			
	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index	Seedling crossed root-shoot line (%)	Root length (cm)	Shoot length (cm)	Vigour index
IR58025 A	45.0 (42.41)	1.14	2.47	164	35.0 (36.25)	12.95	8.75	765
IR58025 B	5.0 (11.49)	1.03	1.08	16	15.0 (18.15)	9.68	4.65	144
IR66 R	45.0 (42.41)	1.83	3.71	248	95.0 (78.79)	17.58	9.63	2585
C20 R	0.0 (04.06)	0.0	0.0	0.0	55.0 (47.88)	19.93	11.18	1714
ADTRH 1	0.0 (04.06)	0.0	0.0	0.0	80.0 (63.52)	17.95	10.10	2246
CORH 2	0.0 (04.06)	0.0	0.0	0.0	65.0 (58.76)	16.08	10.75	1743
SEd	2.82	0.11	0.37	13.0	2.88	0.44	0.28	92.8
CD (P=0.05)	5.93	0.23	0.78	27.3	6.05	0.92	0.58	195.0

(Figures in parentheses are arc-sine transformed values)

Table 45. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to stress tests - bioassay

Parents and hybrids	Stock material (Rice)				Bioassay material (Finger millet)			
	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index	Germination (%)	Root length (cm)	Shoot length (cm)	Vigour index
IR58025 A	93.5 (75.36)	4.90	3.31	767	87.5 (69.35)	3.34	1.48	421
IR58025 B	91.0 (72.57)	4.28	2.58	624	85.0 (67.77)	3.13	1.42	386
IR66 R	94.0 (75.92)	5.33	3.31	812	87.5 (69.35)	3.50	1.50	438
C20 R	94.0 (75.92)	7.17	3.41	995	85.0 (66.77)	3.52	1.47	421
ADTRH 1	93.0 (74.80)	5.34	3.54	823	87.5 (69.35)	3.73	1.66	472
CORH 2	93.5 (75.26)	5.37	3.63	841	87.5 (69.35)	3.76	1.68	476
Blank	-	-	-	-	90.5 (71.64)	3.99	1.97	537
SEd	0.14	0.09	0.09	18.8	1.30	0.08	0.05	11.1
CD (P=0.05)	NS	0.21	0.18	39.4	2.66	0.17	0.11	23.1

(Figures in parentheses are arc-sine transformed values)

Table 46. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to accelerated ageing test – germination (%)

Parents and hybrids	Germination (%)				
	0	3	6	9	Mean
IR58025 A	94.0 (76.02)	84.0 (66.59)	62.0 (51.95)	24.0 (29.26)	66.0 (55.95)
IR58025 B	92.0 (73.57)	88.0 (69.73)	64.0 (53.16)	36.0 (36.84)	70.0 (58.33)
IR66 R	94.0 (76.02)	90.0 (71.65)	72.0 (58.11)	52.0 (46.15)	77.0 (62.98)
C20 R	94.0 (76.02)	86.0 (68.08)	68.0 (55.55)	46.0 (42.71)	73.5 (60.59)
ADTRH 1	96.0 (78.47)	88.0 (69.73)	66.0 (54.34)	28.0 (31.89)	69.5 (58.61)
CORH 2	96.0 (78.47)	90.0 (71.65)	56.0 (48.46)	20.0 (26.46)	65.5 (56.26)
Mean	94.3 (76.43)	87.7 (69.57)	64.7 (53.60)	34.3 (35.55)	

	G	P	G x P
SEd	1.39	1.14	2.78
CD (P=0.05)	2.87	2.34	5.74

(Figures in parentheses are arc-sine transformed values)

Table 47. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to accelerated ageing test –TZ viability (%)

Parents and hybrids	TZ-viability (%)				
	0	3	6	9	Mean
IR58025 A	85.0 (67.50)	72.5 (58.40)	47.5 (43.57)	20.0 (26.39)	56.3 (48.96)
IR58025 B	82.5 (65.33)	77.5 (61.72)	52.5 (46.44)	27.5 (31.60)	60.0 (51.27)
IR66 R	87.5 (69.39)	80.0 (63.61)	65.0 (53.78)	42.5 (40.68)	68.8 (56.87)
C20 R	85.0 (67.22)	82.5 (65.33)	57.5 (49.32)	35.0 (36.22)	65.0 (54.52)
ADTRH 1	85.0 (67.50)	75.0 (60.11)	50.0 (45.00)	22.5 (28.22)	58.1 (50.23)
CORH 2	87.5 (69.39)	72.5 (58.40)	42.5 (40.68)	15.0 (22.50)	54.4 (47.74)
Mean	85.4 (67.72)	76.7 (61.26)	52.5 (46.47)	27.1 (30.95)	

	G	P	G x P
SEd	1.79	1.46	3.58
CD (P=0.05)	3.69	3.02	NS

(Figures in parentheses are arc-sine transformed values)

Table 48. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to accelerated ageing test – root length and shoot length (cm)

Parents and hybrids	Root length (cm)					Shoot length (cm)				
	0	3	6	9	Mean	0	3	6	9	Mean
IR58025 A	15.8	11.7	9.2	7.5	11.00	11.6	10.2	8.9	7.5	9.55
IR58025 B	16.3	12.5	10.5	8.7	11.95	11.1	10.3	9.1	7.8	9.58
IR66 R	17.2	15.5	12.9	11.2	14.15	12.9	12.5	11.5	10.1	11.75
C20 R	21.1	18.4	14.8	12.2	16.58	12.9	11.9	10.9	9.6	11.33
ADTRH 1	19.3	16.2	12.6	9.8	14.43	11.2	9.9	9.1	7.9	9.53
CORH 2	21.9	17.6	13.1	9.9	15.60	11.5	9.7	8.6	7.7	9.38
Mean	18.56	15.27	12.13	9.84		11.87	10.75	9.68	8.43	

	G	P	G x P	G	P	G x P
SEd	0.34	0.28	0.68	0.31	0.25	0.62
CD (P=0.05)	0.70	0.57	1.40	0.64	0.52	NS

Table 49. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to accelerated ageing test – dry matter production (mg seedling^{-1}) and vigour index

Parents and hybrids	Dry matter production (mg seedling^{-1})					Vigour index				
	0	3	6	9	Mean	0	3	6	9	Mean
IR58025 A	12.8	10.8	9.3	7.7	10.11	2566	1835	1118	294	1453
IR58025 B	12.5	10.9	9.5	8.1	10.23	2512	2002	1252	586	1588
IR66 R	14.1	12.6	11.4	10.2	12.03	2826	2509	1751	1102	2047
C20 R	16.3	13.9	12.7	10.8	13.39	3185	2604	1745	998	2133
ADTRH 1	12.6	10.4	9.3	7.8	9.99	2923	2288	1424	497	1783
CORH 2	12.8	10.2	9.0	7.3	9.90	3202	2447	1209	347	1801
Mean	13.50	11.43	10.23	8.60		2869	2281	1416	637	

	G	P	G x P	G	P	G x P
SEd	0.217	0.177	0.433	60.3	49.2	120.5
CD (P=0.05)	0.447	0.365	NS	124.4	101.6	248.9

Table 50. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to accelerated ageing test – dehydrogenase enzyme activity and electrical conductivity of seed leachate

Parents and hybrids	Dehydrogenase enzyme activity (OD value)					Electrical conductivity of seed leachate (dSm^{-1})				
	0	3	6	9	Mean	0	3	6	9	Mean
IR58025 A	0.085	0.066	0.040	0.014	0.051	0.118	0.151	0.192	0.266	0.184
IR58025 B	0.088	0.074	0.044	0.016	0.055	0.113	0.127	0.167	0.243	0.165
IR66 R	0.097	0.081	0.051	0.026	0.064	0.097	0.098	0.131	0.213	0.137
C20 R	0.107	0.091	0.047	0.023	0.067	0.108	0.117	0.146	0.233	0.153
ADTRH 1	0.114	0.082	0.049	0.019	0.066	0.110	0.148	0.170	0.261	0.177
CORH 2	0.125	0.092	0.043	0.015	0.069	0.113	0.153	0.196	0.277	0.187
Mean	0.101	0.081	0.046	0.019		0.110	0.132	0.168	0.249	

	G	P	G x P	G	P	G x P
SEd	0.003	0.003	0.006	0.002	0.001	0.003
CD (P=0.05)	0.006	0.005	0.011	0.004	0.003	0.007

Table 51. Assessment of hybrid vigour on seed attributes of rice hybrids subjected to accelerated ageing test – free sugar and free amino acid contents of seed leachate

Parents and hybrids	Free sugar (µg 50 $seeds^{-1}$ 50 ml^{-1})					Free amino acid (µg 50 $seeds^{-1}$ 50 ml^{-1})				
	0	3	6	9	Mean	0	3	6	9	Mean
IR58025 A	17.1	20.3	24.9	36.6	24.73	4.55	5.75	8.05	13.45	7.95
IR58025 B	16.4	18.5	22.5	32.5	22.48	4.35	5.45	7.55	12.55	7.48
IR66 R	15.6	15.9	17.4	27.4	19.08	3.95	3.95	5.85	10.25	6.00
C20 R	16.3	17.2	20.1	31.5	21.28	4.30	4.75	6.95	11.45	6.86
ADTRH 1	16.7	18.8	25.4	35.6	24.13	4.65	5.65	8.25	13.15	7.93
CORH 2	16.6	21.1	26.6	37.8	25.53	4.45	6.05	8.95	13.85	8.33
Mean	16.5	18.6	22.8	33.6		4.38	5.27	7.60	12.45	

	G	P	G x P	G	P	G x P
SEd	0.235	0.192	0.469	0.167	0.137	0.335
CD (P=0.05)	0.485	0.396	0.969	0.346	0.282	0.692

Table 52. Imbibition rate as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Seed material (S)	Period (P) of imbibition (h)						Mean	Per cent increase
		0	4	8	12	16	20		
IR58025 A	Normal	12.5 (20.71)	30.3 (33.41)	37.0 (37.45)	39.7 (39.07)	42.9 (40.92)	43.6 (41.30)	34.3 (35.48)	31.1
	Split	12.5 (20.71)	32.0 (34.46)	39.3 (38.82)	41.1 (39.86)	43.4 (41.20)	44.4 (41.79)	35.5 (36.14)	31.9
	Bulk	12.6 (20.77)	31.0 (33.84)	36.7 (37.29)	38.6 (38.40)	40.6 (39.58)	41.6 (40.15)	33.5 (35.00)	29.0
	Mean	12.5 (20.73)	31.1 (33.91)	37.7 (37.85)	39.8 (39.11)	42.3 (40.57)	43.2 (41.08)	34.4 (35.54)	30.7
ADTRH 1	Normal	12.3 (20.50)	31.4 (33.92)	37.6 (37.83)	40.5 (39.50)	43.7 (41.35)	44.0 (41.54)	34.9 (35.77)	31.7
	Split	12.5 (20.67)	33.3 (35.25)	40.5 (39.53)	43.1 (41.02)	44.9 (42.05)	45.6 (42.49)	36.6 (36.84)	33.2
	Bulk	12.7 (20.86)	32.9 (34.97)	36.5 (37.18)	39.7 (39.07)	42.8 (40.88)	42.7 (40.78)	34.6 (35.62)	30.0
	Mean	12.5 (20.68)	32.4 (34.71)	38.2 (38.18)	41.1 (39.86)	43.8 (41.43)	44.1 (41.60)	35.3 (36.08)	31.6
CORH 2	Normal	12.5 (20.74)	33.0 (35.06)	38.9 (38.57)	40.9 (39.77)	43.9 (41.47)	44.3 (41.70)	35.6 (36.22)	31.7
	Split	12.5 (20.70)	34.4 (35.91)	40.9 (39.76)	43.6 (41.32)	45.4 (42.34)	45.9 (42.67)	37.1 (37.11)	33.4
	Bulk	12.6 (20.81)	33.7 (35.47)	37.1 (37.53)	40.0 (39.24)	42.4 (40.60)	43.5 (41.26)	34.9 (35.82)	30.9
	Mean	12.6 (20.75)	33.7 (35.48)	39.0 (38.62)	41.5 (40.11)	43.9 (41.47)	44.6 (41.88)	35.9 (36.38)	32.0
	Normal	12.4 (20.65)	31.5 (34.13)	37.8 (37.95)	40.4 (39.45)	43.5 (41.25)	43.9 (41.51)	34.9 (35.82)	31.5
	Split	12.5 (20.69)	33.3 (35.21)	40.2 (39.37)	42.6 (40.73)	44.5 (41.87)	45.3 (42.32)	36.4 (36.70)	32.8
	Bulk	12.6 (20.81)	32.5 (34.76)	36.8 (37.33)	39.4 (38.91)	41.9 (40.35)	42.6 (40.73)	34.3 (35.48)	29.9
	Grand Mean	12.5 (20.72)	32.4 (34.70)	38.3 (38.22)	40.8 (39.70)	43.3 (41.16)	43.9 (41.52)		

	G	S	P	G x S	S x P	G x P	G x S x P
SEd	0.108	0.108	0.152	0.187	0.264	0.264	0.457
CD (P=0.05)	0.216	0.216	0.305	NS	0.529	0.529	NS

(Figures in parentheses are arc-sine transformed values)

Table 53. Thousand seed weight and seed to husk ratio as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	1000 seed weight (g)				Seed to husk ratio			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	19.88	18.60	18.98	19.15	4.51	3.69	4.27	4.16
ADTRH 1	20.33	18.75	19.33	19.47	4.53	3.80	4.31	.21
CORH 2	20.75	18.95	19.43	19.71	4.65	3.99	4.36	4.33
Mean	20.32	18.77	19.24		4.56	3.83	4.31	

	G	S	G x S	G	S	G x S
SEd	0.108	0.108	0.187	0.025	0.025	0.044
CD(P=0.05)	0.222	0.222	NS	0.052	0.052	NS

Table 54. Time taken for sprouting (h) and radicle length in time bound germination (mm) as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Time taken for sprouting (h)				Radicle length in time bound germination (mm)			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	28.0	39.0	34.0	33.7	14.55	13.23	14.28	14.02
ADTRH 1	26.0	36.0	31.0	31.0	15.63	13.65	14.80	14.69
CORH 2	25.0	32.0	30.0	29.0	19.08	15.35	17.53	17.32
Mean	26.3	35.7	31.7		16.42	14.08	15.54	

	G	S	G x S	G	S	G x S
SEd	2.29	2.29	3.97	0.325	0.325	0.563
CD(P=0.05)	NS	4.71	NS	0.667	0.667	NS

Table 55. Rate of germination and germination (%) as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Rate of germination				Germination (%)			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	27.70	15.78	21.70	21.73	92.0 (73.63)	61.5 (51.65)	76.5 (61.05)	76.7 (62.11)
ADTRH 1	28.33	16.63	25.05	23.33	91.5 (71.13)	71.0 (57.44)	80.5 (63.85)	81.0 (64.80)
CORH 2	34.45	20.80	29.08	28.11	93.5 (75.52)	81.5 (64.55)	83.0 (65.77)	86.0 (68.61)
Mean	30.16	17.73	25.28		92.3 (74.09)	71.3 (57.88)	80.0 (63.56)	

	G	S	G x S	G	S	G x S
SEd	0.533	0.533	0.923	0.92	0.92	1.59
CD(P=0.05)	1.094	1.094	NS	1.89	1.89	3.27

(Figures in parentheses are arc-sine transformed values)

Table 56. Root length and shoot length (cm) as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Root length (cm)				Shoot length (cm)			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	15.15	9.38	11.95	12.16	11.13	7.18	7.73	8.68
ADTRH 1	18.40	12.03	15.38	15.27	11.25	7.10	7.60	8.65
CORH 2	21.93	16.08	17.03	18.35	11.33	7.55	8.08	8.99
Mean	18.49	12.49	14.78		11.23	7.28	7.80	

	G	S	G x S	G	S	G x S
SEd	0.299	0.299	0.519	0.181	0.181	0.314
CD(P=0.05)	0.614	0.614	NS	NS	0.372	NS

Table 57. Dry matter production (mg seedling^{-1}) and vigour index as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Dry matter production (mg seedling^{-1})				Vigour index			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	12.55	7.28	8.60	9.48	2417	1018	1506	1647
ADTRH 1	12.28	7.73	8.98	9.66	2712	1358	1850	1973
CORH 2	12.60	9.88	10.55	11.00	3109	1925	2084	2372
Mean	12.48	8.29	9.38		2746	1434	1813	

	G	S	G x S	G	S	G x S
SEd	0.184	0.184	0.319	39.5	39.5	68.4
CD(P=0.05)	0.377	0.377	0.654	81.0	81.0	NS

Table 58. Seedlings crossed root-shoot line (%) and root length (cm) as influenced by split husk seeds in rice hybrids and their female parent under exhaustion test

Female parent and hybrids (G)	Seedling crossed root-shoot line (%)				Root length (cm)			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	35.0 (36.25)	20.0 (26.48)	27.5 (31.61)	27.5 (31.45)	12.95	6.08	10.23	9.75
ADTRH 1	80.0 (63.52)	22.5 (28.28)	50.0 (45.00)	50.8 (45.60)	17.95	8.28	15.58	13.93
CORH 2	65.0 (53.76)	17.5 (24.68)	33.8 (35.51)	38.8 (37.98)	16.08	7.70	12.35	12.04
Mean	60.0 (51.18)	20.0 (26.48)	37.1 (37.37)		15.66	7.35	12.72	

	G	S	G x S	G	S	G x S
SEd	0.96	0.96	1.66	0.179	0.179	0.310
CD(P=0.05)	1.96	1.96	3.40	0.367	0.367	0.636

(Figures in parentheses are arc-sine transformed values)

Table 59. Shoot length (cm) and Vigour index as influenced by split husk seeds in rice hybrids and their female parent under exhaustion test

Female parent and hybrids (G)	Shoot length (cm)				Vigour index			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	8.75	5.45	8.73	7.64	760	229	522	504
ADTRH 1	10.10	5.43	9.85	8.46	2246	308	1270	1275
CORH 2	10.75	4.05	10.08	8.29	1743	206	756	902
Mean	9.87	4.98	9.55		1583	248	849	

	G	S	G x S	G	S	G x S
SEd	0.179	0.178	0.308	35.2	35.2	61.0
CD(P=0.05)	0.365	0.365	0.631	72.2	72.2	125.1

Table 60. Electrical conductivity in leachate (dSm^{-1}) and dehydrogenase enzyme activity (OD value) as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Electrical conductivity in leachate (dSm^{-1})				Dehydrogenase enzyme activity (OD value)			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	0.118	0.141	0.131	0.130	0.079	0.069	0.074	0.074
ADTRH 1	0.111	0.140	0.135	0.129	0.114	0.083	0.092	0.097
CORH 2	0.113	0.134	0.125	0.124	0.124	0.096	0.109	0.109
Mean	0.114	0.138	0.130		0.106	0.083	0.091	

	G	S	G x S	G	S	G x S
SEd	0.001	0.001	0.002	0.002	0.002	0.003
CD(P=0.05)	0.003	0.003	NS	0.004	0.004	0.007

Table 61. Total ATPase (µmol of P g^{-1} h^{-1}) and peroxidase (OD value) enzyme activity as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Total ATPase (µmol of P g^{-1} h^{-1})				Peroxidase (OD value)			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	2.607	1.849	2.267	2.241	0.072	0.042	0.061	0.058
ADTRH 1	3.208	2.241	2.764	2.737	0.092	0.051	0.075	0.072
CORH 2	3.417	2.372	2.946	2.911	0.095	0.049	0.078	0.074
Mean	3.077	2.154	2.659		0.086	0.047	0.071	
	G	S	G x S		G	S	G x S	
SEd	0.044	0.044	0.076		0.002	0.002	0.003	
CD(P=0.05)	0.090	0.090	NS		0.003	0.003	NS	

Table 62. Catalase (ml of 0.01 N $KMnO_4$ min^{-1} ml^{-1} enzyme extract) and α-amylase (mm of halo zone) as influenced by split husk seeds in rice hybrids and their female parent

Female parent and hybrids (G)	Catalase (ml of 0.01 N $KMnO_4$ min^{-1} ml^{-1} enzyme extract)				α-amylase (mm of halo zone)			
	Seed material (S)							
	Normal	Split husk	Bulk	Mean	Normal	Split husk	Bulk	Mean
IR58025 A	2.13	1.66	1.94	1.91	7.59	4.54	6.47	6.19
ADTRH 1	2.53	1.81	1.94	2.09	13.03	6.53	8.76	9.44
CORH 2	2.73	1.85	2.08	2.22	13.90	8.48	10.45	10.94
Mean	2.46	1.77	1.99		11.50	6.52	8.56	
	G	S	G x S		G	S	G x S	
SEd	0.015	0.015	0.026		0.155	0.155	0.269	
CD(P=0.05)	0.031	0.031	0.053		0.319	0.319	0.552	

Table 64. Standardisation of dose of polykote and quantity of water for polykote dilution in rice seeds (IR 58025 B) – Germinability

Polykote dose and dilution	Time taken for sprouting	Radicle length in time bound germination (mm)	Rate of germination	Germination	
				%	Arc-sine
Polykote 5 g + 90 ml water kg^{-1}	26.7	17.2	32.3	85.3	67.53
Polykote 5 g + 70 ml water kg^{-1}	25.3	18.8	35.4	86.7	68.63
Polykote 5 g + 50 ml water kg^{-1}	29.3	15.7	31.3	84.0	66.42
Polykote 5 g + 30 ml water kg^{-1}	30.7	14.3	30.6	84.0	66.53
Polykote 5 g + 15 ml water kg^{-1}	30.7	13.4	27.4	81.3	66.43
Polykote 3 g + 90 ml water kg^{-1}	29.3	15.3	29.4	84.0	66.42
Polykote 3 g + 70 ml water kg^{-1}	28.0	16.4	32.4	85.3	67.53
Polykote 3 g + 50 ml water kg^{-1}	26.7	18.2	34.8	86.7	68.63
Polykote 3 g + 30 ml water kg^{-1}	30.7	14.1	28.8	82.7	65.43
Polykote 3 g + 15 ml water kg^{-1}	32.0	13.7	27.3	80.0	63.51
Uncoated (control)	32.0	13.8	27.8	78.7	62.51
SEd	1.87	0.32	1.07	1.58	
CD (P=0.05)	3.91	0.67	2.21	3.28	

Table 65. Standardisation of dose of polykote and quantity of water for polykote dilution in rice seeds (IR 58025 B) – Seedling growth rate

Polykote dose and dilution	Root length (cm)	Shoot length (cm)	Dry matter production (mg $seedling^{-1}$)	Vigour index	Germination in conventional method	
					%	Arc-sine
Polykote 5 g + 90 ml water kg^{-1}	19.2	11.4	13.3	2611	88.7	70.35
Polykote 5 g + 70 ml water kg^{-1}	21.0	11.8	13.7	2846	92.7	74.32
Polykote 5 g + 50 ml water kg^{-1}	17.8	10.6	12.9	2386	85.3	67.49
Polykote 5 g + 30 ml water kg^{-1}	17.1	10.1	12.5	2280	84.7	66.96
Polykote 5 g + 15 ml water kg^{-1}	16.5	9.7	12.2	2133	83.3	65.92
Polykote 3 g + 90 ml water kg^{-1}	18.7	10.7	12.9	2470	85.3	67.49
Polykote 3 g + 70 ml water kg^{-1}	19.1	11.0	13.4	2563	87.3	69.17
Polykote 3 g + 50 ml water kg^{-1}	20.2	11.7	13.7	2766	91.3	72.90
Polykote 3 g + 30 ml water kg^{-1}	16.9	9.9	12.6	2218	84.0	66.45
Polykote 3 g + 15 ml water kg^{-1}	17.2	9.1	12.0	2104	82.0	64.92
Uncoated (control)	16.9	9.6	12.3	2085	81.3	64.41
SEd	0.415	0.354	0.328	63.8	0.92	
CD (P=0.05)	0.861	0.735	0.680	132.4	1.90	

Table 66. Effect of seed coating with different colours of polykote on time taken for sprouting (h) in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	26	28	26	28	30	26	30	27.7
IR58025 B	26	28	28	30	30	28	32	28.9
IR66 R	30	32	30	32	32	30	34	31.4
C20 R	32	34	34	34	34	32	36	33.7
ADTRH 1	26	26	26	28	28	26	28	26.9
CORH 2	26	26	26	28	28	26	26	26.6
Mean	27.7	29.0	28.3	30.0	30.3	28.0	31.0	

	G	P	G x P
SEd	0.83	0.89	2.18
CD (P=0.05)	1.67	1.80	NS

Table 67. Effect of seed coating with different colours of polykote on radicle length (mm) in time bound germination in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	17.15	17.05	16.90	16.95	16.85	16.95	13.85	16.53
IR58025 B	17.30	17.00	17.15	16.75	16.95	16.85	12.95	16.42
IR66 R	15.15	14.85	14.85	14.90	14.75	14.95	13.75	14.74
C20 R	16.45	16.15	16.05	16.15	16.10	16.35	15.85	16.16
ADTRH 1	17.35	17.25	17.15	17.05	17.05	17.25	15.15	16.89
CORH 2	17.65	17.45	17.15	16.95	17.10	17.15	17.05	17.21
Mean	16.84	16.63	16.54	16.46	16.47	16.58	14.77	

	G	P	G x P
SEd	0.27	0.29	0.71
CD (P=0.05)	0.54	0.59	NS

Table 68. Effect of seed coating with different colours of polykote on rate of germination in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	32.7	32.5	32.1	32.8	32.4	32.8	26.8	31.69
IR58025 B	32.9	32.7	32.5	32.2	32.8	32.6	26.4	31.72
IR66 R	28.9	28.9	28.3	28.1	28.6	29.0	23.4	27.86
C20 R	27.4	27.0	27.3	27.1	26.5	27.3	22.5	26.41
ADTRH 1	32.1	32.8	33.0	32.4	32.7	32.5	29.1	32.04
CORH 2	33.6	33.2	34.4	33.2	33.9	33.6	33.3	33.43
Mean	31.24	31.14	31.08	30.93	31.11	31.27	26.89	

	G	P	G x P
SEd	0.31	0.33	0.82
CD (P=0.05)	0.62	0.67	1.65

Table 69. Effect of seed coating with different colours of polykote on germination (%) in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	88 (69.73)	89 (70.65)	87 (68.88)	86 (68.08)	85.0 (67.23)	89 (70.65)	85 (67.23)	87.0 (68.92)
IR58025 B	87 (68.88)	86 (68.03)	89 (70.65)	85 (67.23)	86.0 (68.03)	87 (68.88)	84 (66.46)	86.3 (68.31)
IR66 R	89 (70.65)	87 (68.88)	89 (70.65)	87 (68.88)	87 (68.88)	89 (70.65)	86 (68.08)	87.7 (69.53)
C20 R	88 (69.73)	89 (70.65)	89 (70.65)	87 (68.88)	87 (68.88)	89 (70.65)	87 (68.88)	88.0 (69.76)
ADTRH 1	90 (71.57)	91 (72.57)	90 (71.57)	88 (69.73)	89 (70.65)	90 (71.57)	90 (71.57)	89.7 (71.32)
CORH 2	91 (72.57)	90 (71.57)	91 (72.57)	89 (70.65)	88 (69.73)	91 (72.57)	89 (70.65)	89.9 (71.47)
Mean	88.8 (70.52)	88.7 (70.39)	89.2 (70.83)	87.0 (68.91)	87.0 (68.90)	89.2 (70.83)	86.8 (68.81)	

	G	P	G x P
SEd	0.46	0.49	1.21
CD (P=0.05)	0.92	0.99	NS

(Figures in parentheses are arc-sine transformed values)

Table 70. Effect of seed coating with different colours of polykote on root length (cm) in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	18.15	18.40	18.00	17.40	17.60	18.10	14.35	17.43
IR58025 B	17.90	19.25	17.85	17.85	18.05	18.60	15.40	17.84
IR66 R	18.50	18.95	18.45	18.00	18.10	18.35	16.45	18.11
C20 R	20.10	20.65	20.20	19.00	19.20	19.75	18.90	19.69
ADTRH 1	18.75	19.25	18.60	17.85	18.15	18.70	17.00	18.33
CORH 2	20.20	20.20	20.20	19.65	19.60	20.20	19.95	20.00
Mean	18.93	19.45	18.88	18.29	18.45	18.95	17.01	

	G	P	G x P
SEd	0.25	0.27	0.66
CD (P=0.05)	0.51	0.55	NS

Table 71. Effect of seed coating with different colours of polykote on shoot length (cm) in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	12.15	12.55	11.65	11.65	11.00	12.55	10.35	11.70
IR58025 B	11.95	11.65	11.65	10.95	11.45	12.45	9.95	11.44
IR66 R	12.25	12.65	11.85	11.05	11.65	12.15	11.95	11.94
C20 R	13.10	13.65	12.20	12.75	11.70	12.90	12.55	12.69
ADTRH 1	11.05	11.10	10.65	10.20	10.60	11.15	11.30	10.86
CORH 2	11.45	11.65	11.20	11.15	10.75	11.55	11.20	11.28
Mean	11.99	12.21	11.53	11.29	11.19	12.13	11.22	

	G	P	G x P
SEd	0.24	0.25	0.62
CD (P=0.05)	0.48	0.51	NS

Table 72. Effect of seed coating with different colours of polykote on dry matter production (mg seedling^{-1}) in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	12.75	12.75	13.00	12.45	12.45	12.75	12.05	12.60
IR58025 B	13.55	13.25	13.35	12.75	12.50	13.00	11.75	12.88
IR66 R	14.05	13.75	13.65	13.40	13.15	13.40	13.05	13.49
C20 R	15.50	16.10	16.00	15.70	15.80	15.95	14.90	15.71
ADTRH 1	13.35	12.85	14.15	12.60	12.85	13.35	12.05	13.03
CORH 2	14.25	13.50	13.45	12.60	13.15	13.25	12.80	13.29
Mean	13.91	13.70	13.93	13.25	13.32	13.62	12.77	

	G	P	G x P
SEd	0.24	0.23	0.57
CD (P=0.05)	0.44	0.47	NS

Table 73. Effect of seed coating with different colours of polykote on vigour index in rice hybrids and parental lines

Parents and Hybrids (G)	Polykote colour (P)							Mean
	Pink	Red	Green	Blue	Black	Clear	Uncoated	
IR58025 A	2667	2754	2580	2498	2432	2728	2100	2537
IR58025 B	2596	2658	2626	2450	2537	2702	2129	2528
IR66 R	2736	2749	2697	2526	2589	2715	2443	2636
C20 R	2922	3053	2884	2763	2688	2906	2736	2850
ADTRH 1	2682	2761	2633	2469	2559	2687	2547	2619
CORH 2	2880	2867	2857	2741	2671	2890	2772	2811
Mean	2747	2807	2713	2574	2579	2771	2454	

	G	P	G x P
SEd	28.2	30.4	74.5
CD (P=0.05)	56.8	61.4	NS

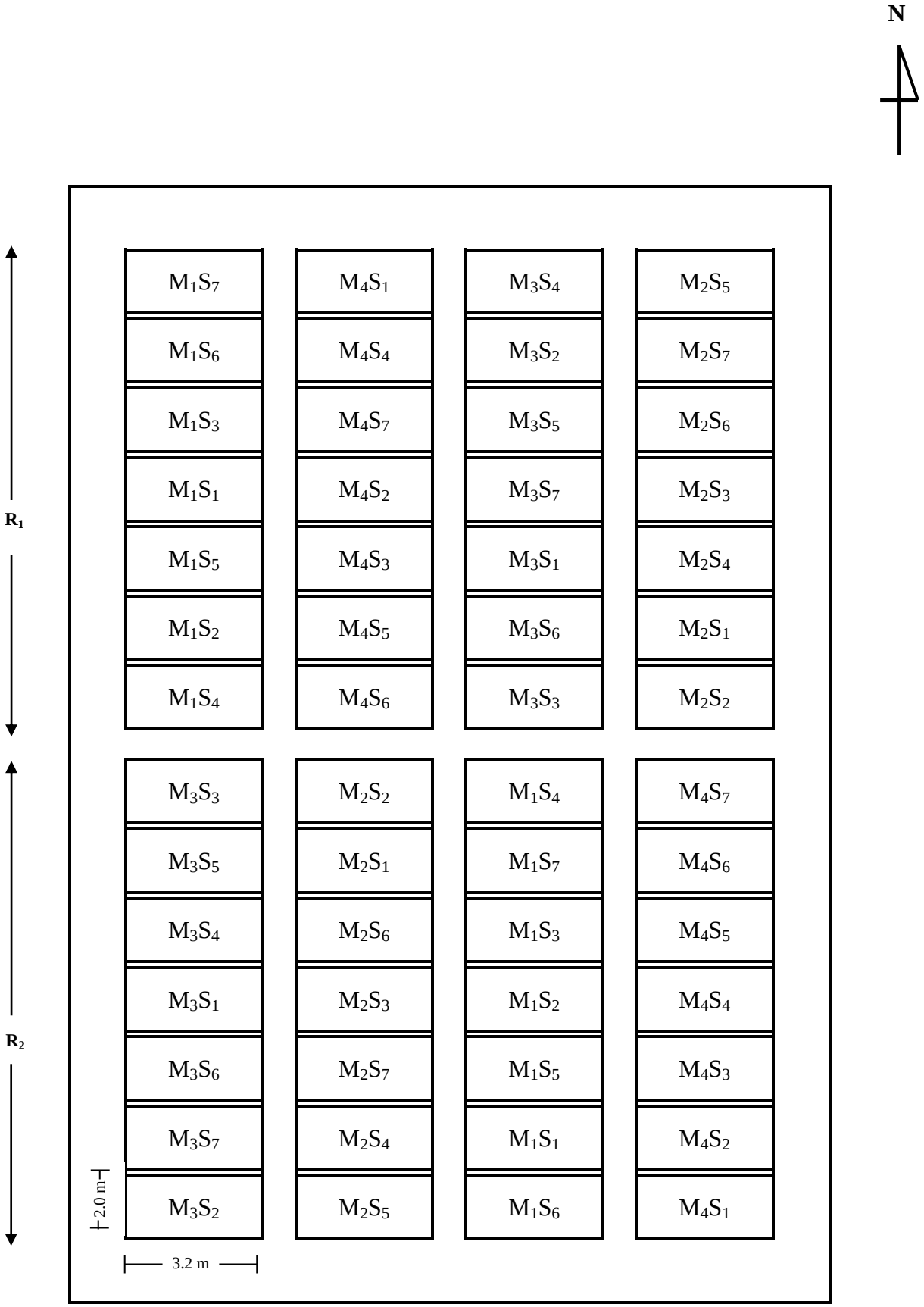
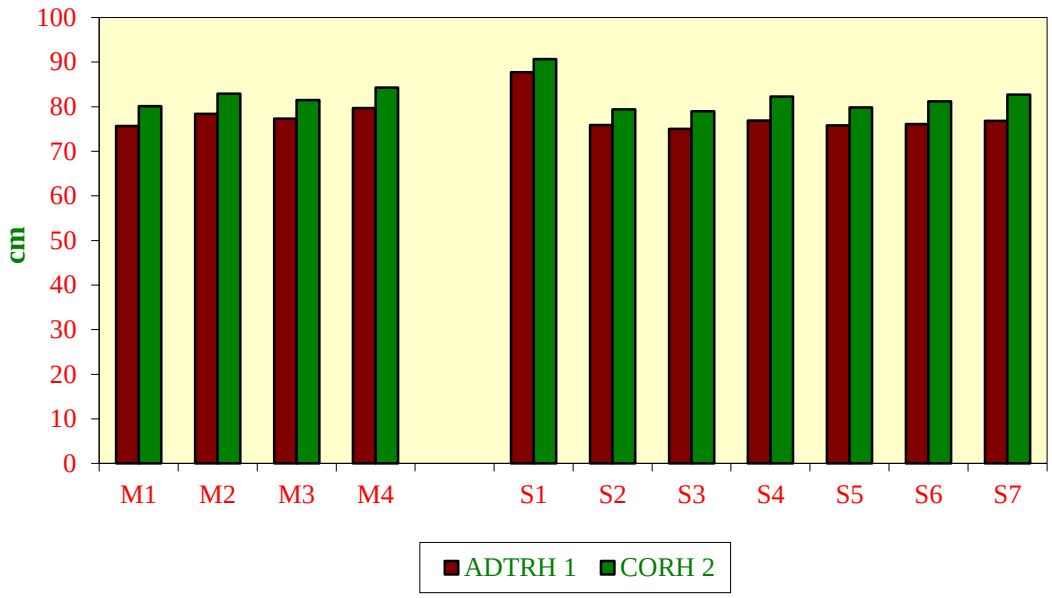
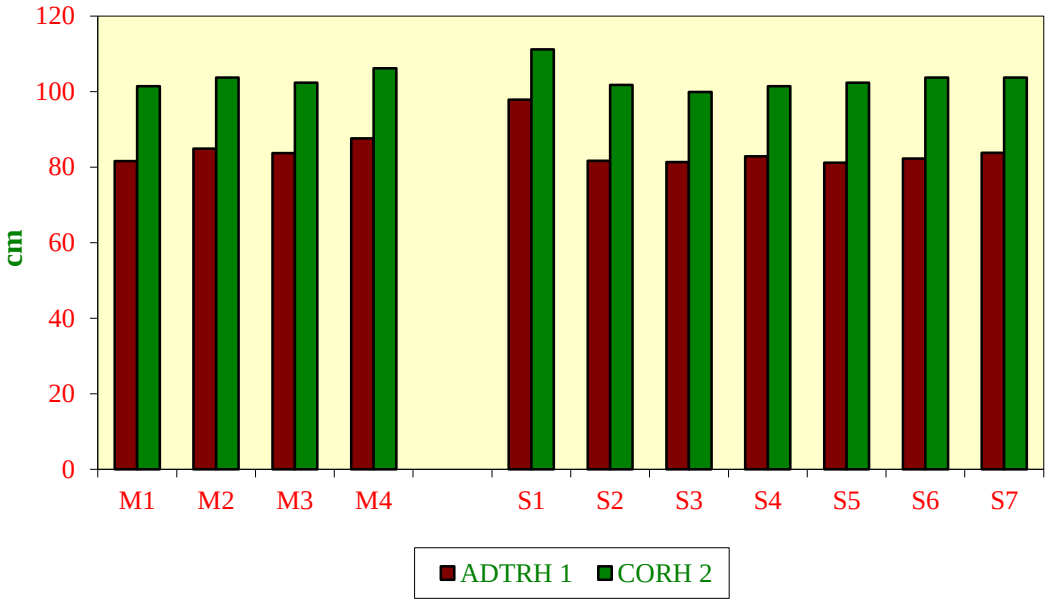


Figure 1. Layout plan of experimental field

a. A line


100
90
80
70
60
50
40
30
20
10
0
cm
M1
M2
M3
M4
S1
S2
S3
S4
S5
S6
S7
ADTRH 1
CORH 2

b. R line



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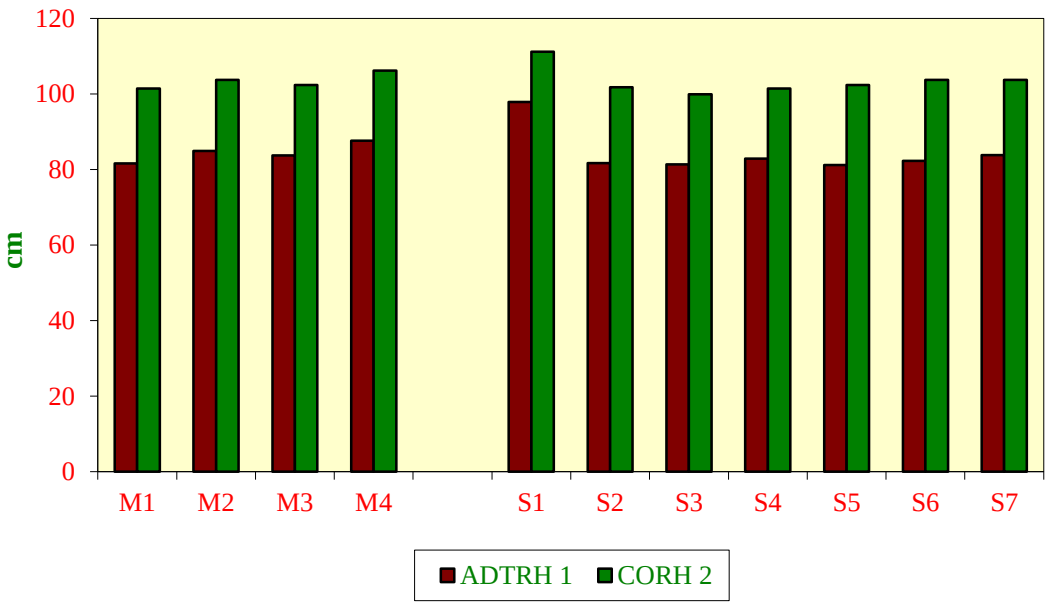
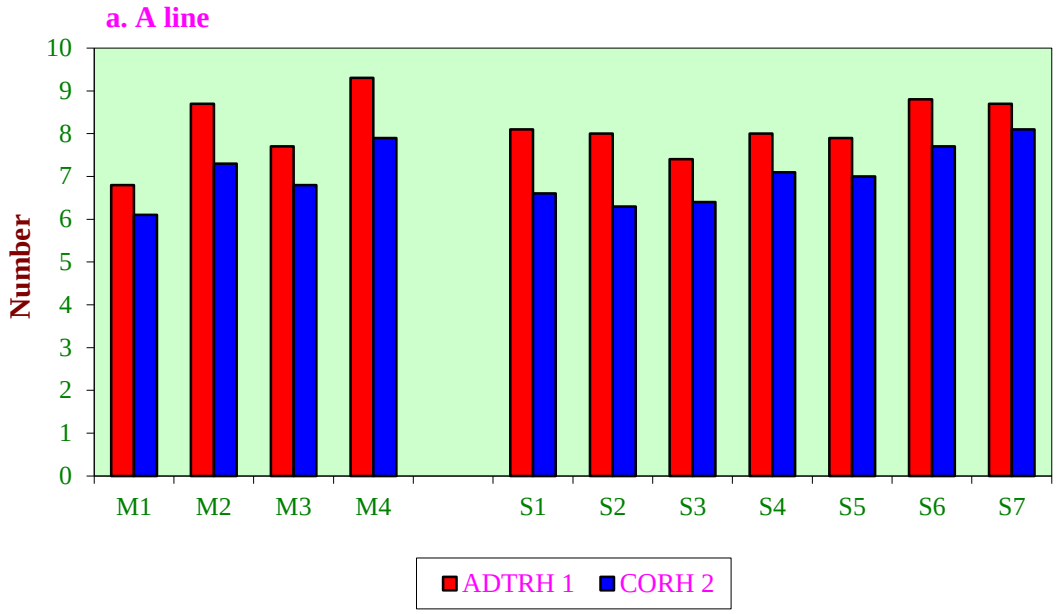
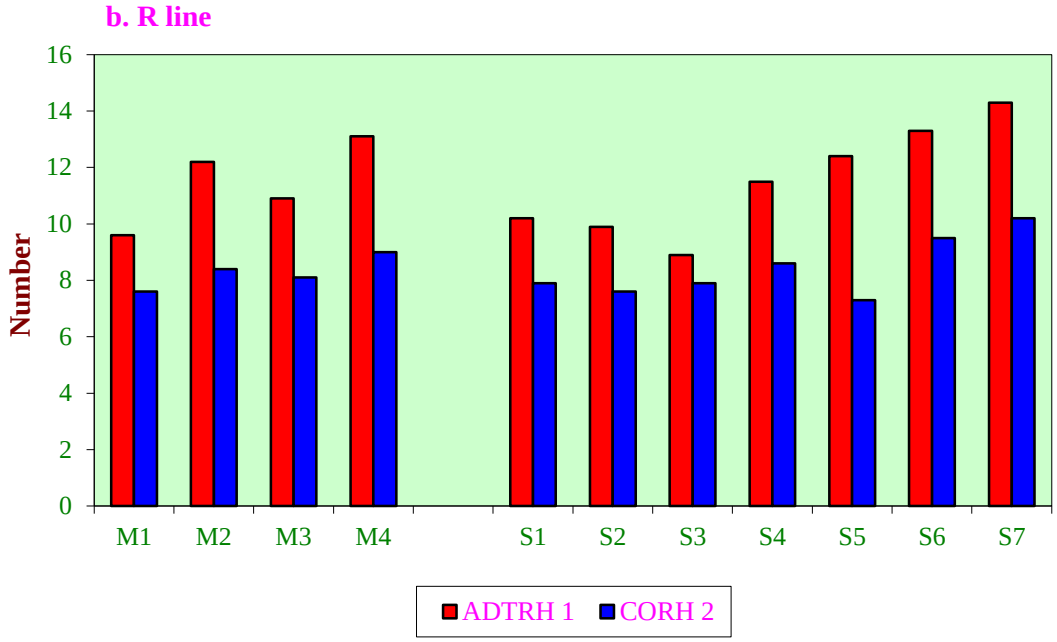
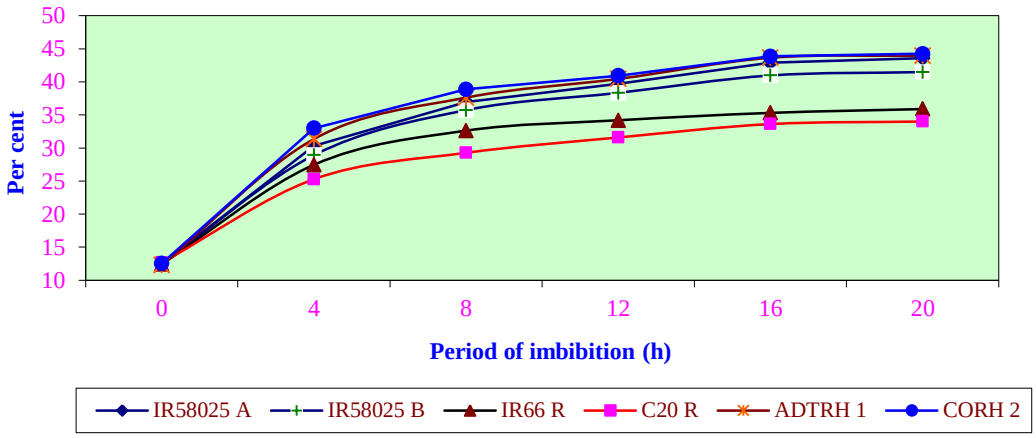


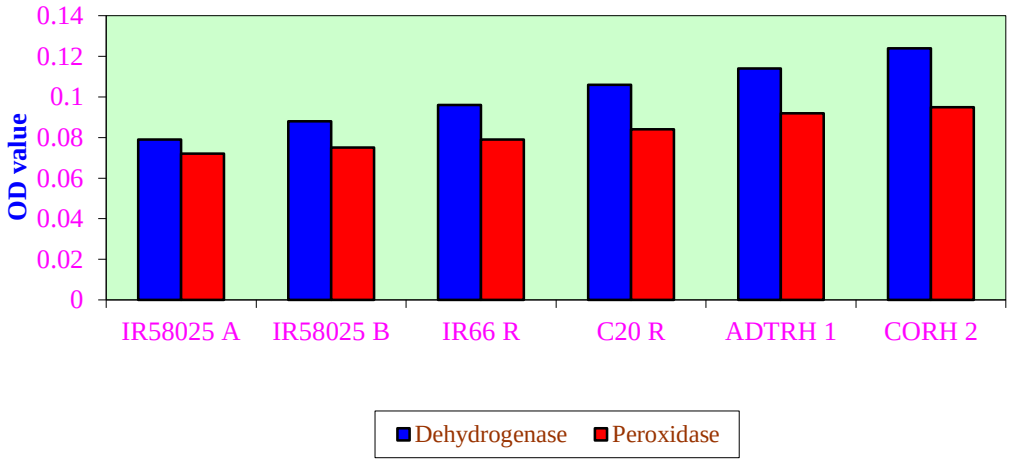

a. A line
Number
10
9
8
7
6
5
4
3
2
1
0
M1
M2
M3
M4
S1
S2
S3
S4
S5
S6
S7
ADTRH 1
CORH 2


b. R line
Number
16
14
12
10
8
6
4
2
0
M1
M2
M3
M4
S1
S2
S3
S4
S5
S6
S7
ADTRH 1
CORH 2

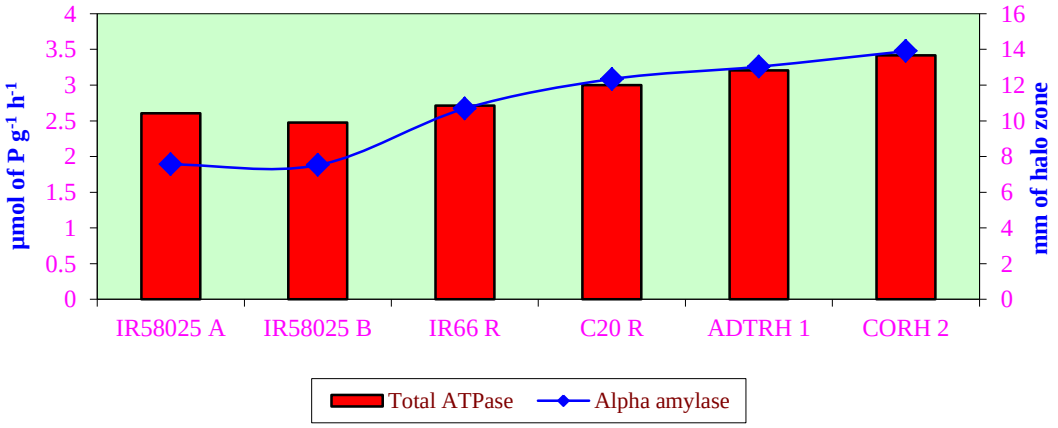
a. Imbibition rate



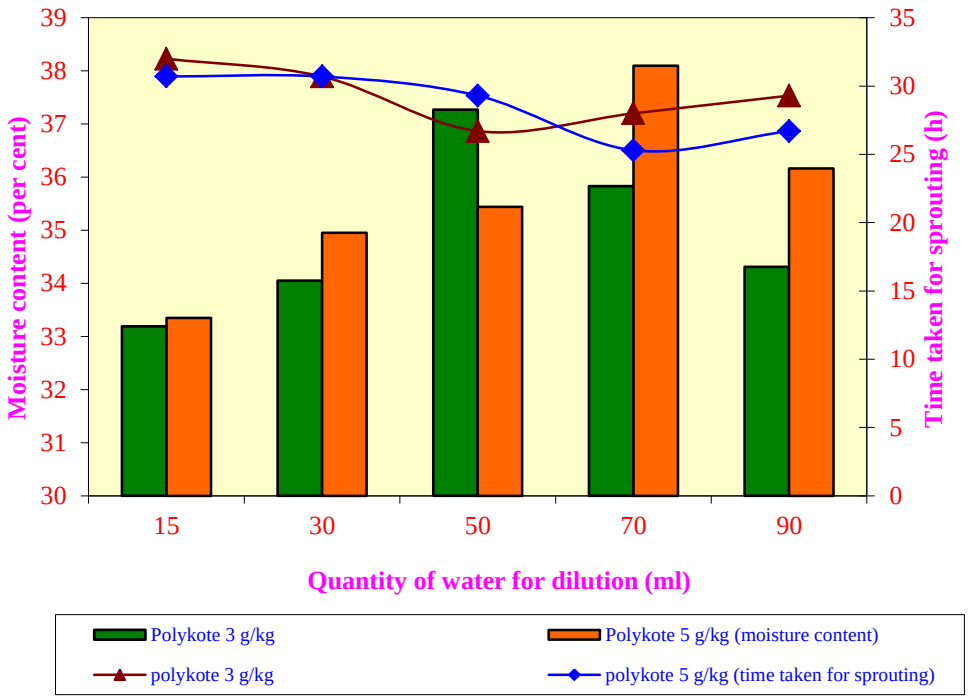
b. Dehydrogenase and peroxidase activity



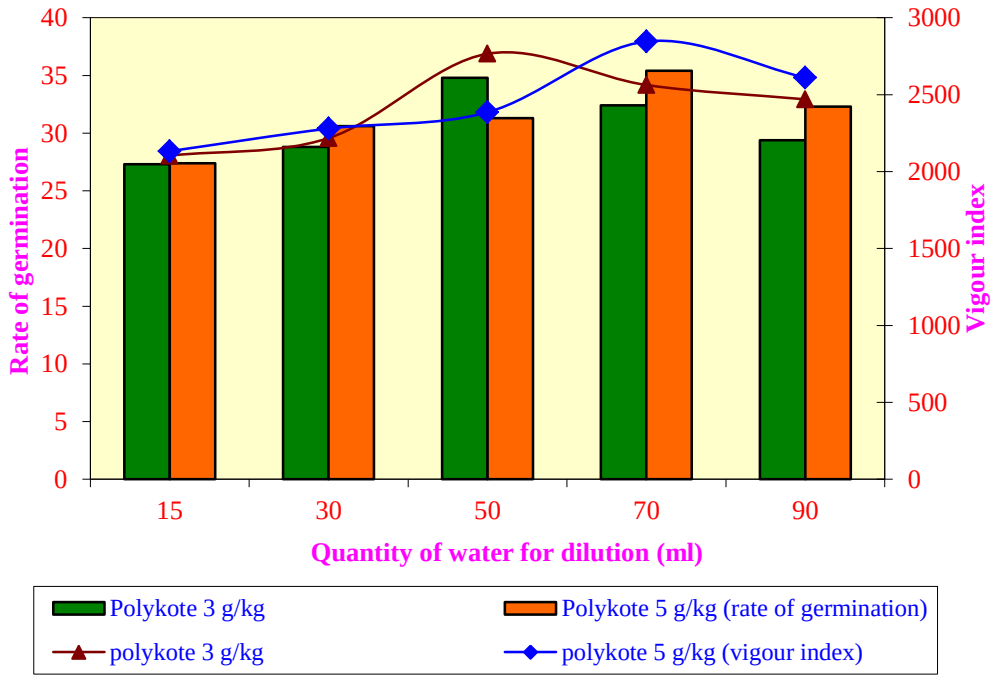
c. Total ATPase and alpha amylase activity



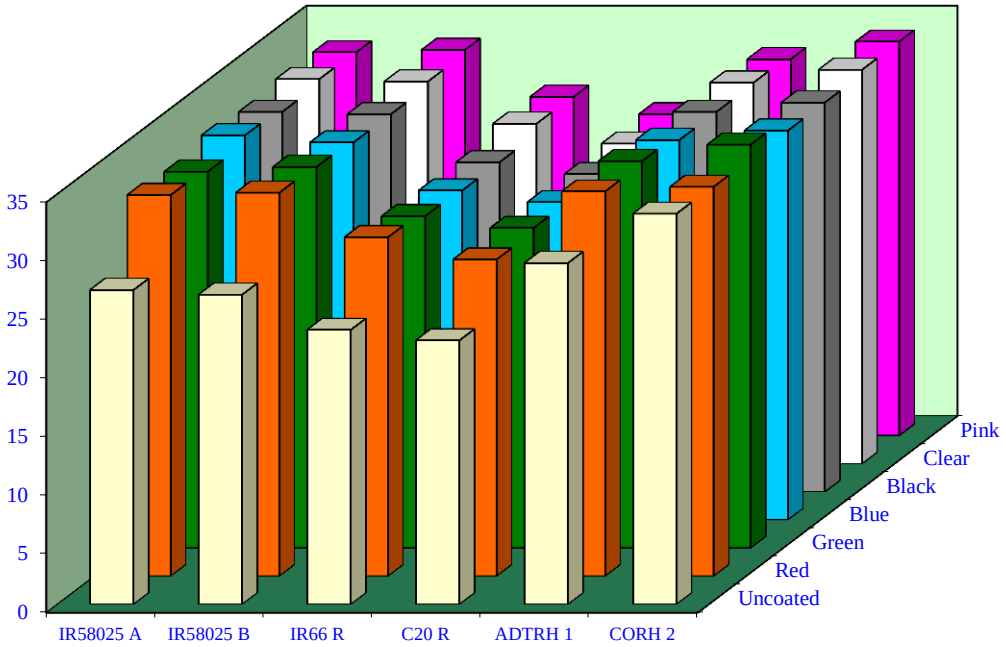
a. Imbibition rate and time taken for sprouting



b. Rate of germination and vigour index



a. Rate of germination



b. Vigour index