EFFECT OF DIFFERENT CHEMICALS AND PLANTING RATIO ON SEED YIELD AND QUALITY OF HYBRID RICE

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Dedicated to my

Beloved parents

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CERTIFICATE – I

This is to certify that the thesis entitled "**EFFECT OF DIFFERENT CHEMICALS AND PLANTING RATIO ON SEED YIELD AND QUALITY OF HYBRID RICE**" submitted in partial fulfilment of the requirements for the award of the Degree of **MASTER OF SCIENCE (AGRICULTURE)** in the discipline of **Seed Science and Technology,** is a faithful record of *bona fide* research work carried out by Miss Kakali Chakravarty under my guidance and supervision.

This research work is original and no part of this thesis has been submitted for any other degree or diploma. The assistance received during the course of investigation has been duly acknowledged by her.

(P. Sahoo)

CERTIFICATE – II

This is to certify that the thesis entitled **"EFFECT OF DIFFERENT CHEMICALS AND PLANTING RATIO ON SEED YIELD AND QUALITY OF HYBRID RICE"** submitted by **Miss. KAKALI CHAKRAVARTY** to the Orissa University of Agriculture and Technology, Bhubaneswar, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** in the discipline of **SEED SCIENCE AND TECHNOLOGY** has been approved by the Student's Advisory Committee after an oral examination on the same in collaboration with the External Examiner.

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Bhubaneswar
Dated 28 · 3 , 2005.

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ABSTRACT

A study was conducted on seed production of rice hybrid KRH-2 using the male parental line KMR-3R and the female parental line IR 58025A under Bhubaneswar agroclimatic condition during *kharif* 2003. The parental lines were planted in the ratio of 2:6 and 2:8./ The female parental line received spray application of GA_3 50g/ha, 75g/ha. 100g/ha and 125g/ha and boric acid at the concentration of 1%. The chemical solutions were sprayed at 5% heading stage.

Results of the study revealed that the plant height increased from 3.8 cm to 10.6 cm at different doses of GA_3 application. Boric acid also increased the plant height by 4.3 cm.

The number of effective tillers also increased under the influence of the chemicals. However, no change was observed for days to 50% flowering and period of flowering. The spray application of the two chemicals also increased the style length, stigma length, panicle length, spikelet opening angle, spikelet opening period and percentage of seed setting.

The number of developed seeds per panicle increased from 24.05 in the control to the extent of 29.45 with the application of 125 g GA_3/ha. However, seed weight did not show any change due to application of chemicals.

The effect of spray application of chemicals was clearly manifested in seed yield per hill as well as computed seed yield per hectare.

In the control, per hill seed yield values were 5.25g and 5.03 g under 2:6 and 2:8 planting ratio, respectively. Spray application of chemicals increased seed yield significantly. The computed seed yield in the control was 1387 kg/ha with spray application of 50 g GA_3/ha, 75 g GA_3/ha, 100 GA_3 g/ha, 125 GA_3 g/ha and boric acid (1%), the seed yield were 1606 kg, 1733kg, 1821kg, 1831kg and 1431 kg per hectare respectively.

The observation data on seed quality attributes revealed that seeds produced through application of GA_3 possessed high germinability vigour and storability. However, spray application of boric acid produced relatively low vigour seeds.

CONTENTS

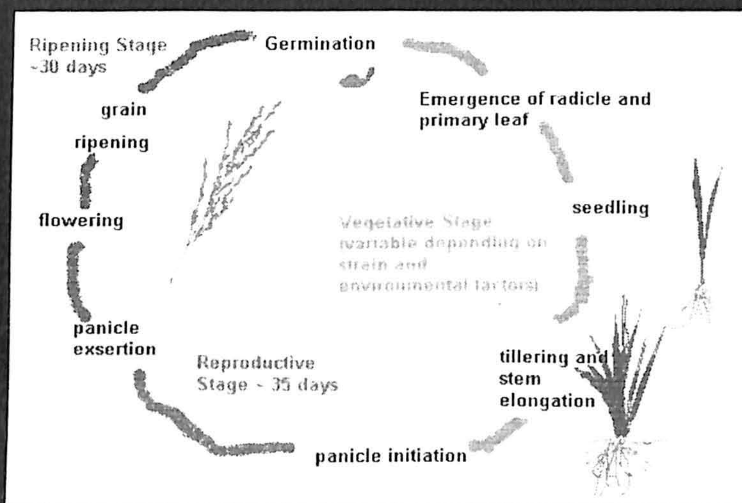
LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

kg	-	Kilogram
g	-	Gram
mg	-	Milligram
m	-	Metre
cm	-	Centimeter
mm	-	Millimeter
l	-	Litre
t/ha	-	Tonnes per hectare
kg/ha	-	Kilogram per hectare
^oC	-	Degree centigrade
^{o}	-	Degree
%	-	Percentage
@	-	At the rate of
DAS	-	Days after sowing
SEm(±)	-	Standard error mean
C.D.	-	Critical difference
Fig.	-	Figure
GA_3	-	Gibberellic acid
NAA	-	Napthalene acetic acid
MH	-	Maleic hydrazide
2,4-D	-	2,4-Dichloro phenoxy acetic acid
IAA	-	Indole acetic acid
CCC	-	Cycocel

CHAPTER -I



INTRODUCTION

INTRODUCTION

Rice is the primary food source for more than half the world's population. It is grown in all the continents of the world except Antarctica with total production of 608.5 million tonnes. In Asia, more than two billion people obtain 60 to 70 per cent of their calorie intake from rice and rice-based products (Mishra *et al.*, 2005). Among the global rice producing countries, Indonesia has the highest production (531 million tones) followed by China (186.7 million tonnes). Other major rice producing countries are India (124.4 million tonnes), Bangladesh (37.9 million tonnes), Vietnam (35.5 million tones), Thailand (25.2 million tones), Philippines (14.2 million tonnes) and Japan 11.4 million tonnes) (FAOSTAT, 2004).

In India, rice is the staple food crop for two third of population. It contributes 44 % of the total food grain production in our country (Mishra *et al.*, 2005). The area under rice is about 42.5 million hectare, which is the highest in the world. However, in terms of production it occupies third position at the global level. Comparison of productivity between rice producing countries clearly reason out the differences in area-production relationship across the world. Among the global rice producing countries Japan has the highest rice yield approaching 6.9 tonnes per hectare followed by South Korea (6.4 tonnes per hectare), China produces 6.3 tonnes per hectare as an average yield. However, the productivity level of India is as low far as 2.9 tonnes for hectare. No doubt, the country has achieved three-fold increase in production of rice since 1965, but the productivity showed marginal increase and the value failed to reach 3.0 tonnes per hectare. The low productivity is mainly due to diverse ecosystems under which rice is grown encompassing irrigated and rainfed area involving drought prone uplands, shallow semi-deep and deep water situations, high altitude and wide array of problem soils like saline, alkaline, acid and toxic. With such a low productivity level, it is difficult to meet the demand for food for the increasing population of our country. At present, the country has achieved self-sufficiency due to cultivation of plant type based high yielding varieties. To sustain the same level of self-sufficiency, the country will have to increase yield by 3 million tonnes every year. This is a challenging task, as area under rice cannot be expanded. Plateauing of yields in areas of assured irrigation and our failure to make any significant improvement in yield levels of dwarf varieties during the last two and half decades makes the task ahead much more difficult. Maximising yield in low productivity areas and exploring ways to raise the genetic yield ceiling in areas where average form yields are approaching potential yield are considered to be national strategies for achieving production goals. Among various approaches for raising the yield ceiling further, exploitation of hybrid vigour is widely acknowledged as having the most potential (Siddiq *et al.*, 1994).

The Chinese scientists are the pioneers in this regard. They have successfully demonstrated the feasibility of exploiting hybrid vigour in self-pollinated crops and came out with the world's first commercially viable hybrid rice in 1976. Subsequently, a number of hybrids were released for general cultivation. The hybrid rice varieties on an average have yield advantage of 15-20 per cent over the best-inbred varieties. The cytoplasmic-nuclear male sterility-fertility restorer system based on 3 lines hybrids occupy 58 per cent of the rice area in China and adds annually about 20 million tonnes to the national production. This has enabled China to reduce its rice area from 35.2 million hectares in 1978 to 32.5 million hectares in 1988 and increased production from 140 million tonnes to 173 million tonnes during the same period (Virmani *et al.*, 1993). Presently China produces about 187 million tonnes of rice per year through increases in area under hybrid rice. The other countries, which adopted to hybrid rice technology are Japan, Indonesia, Philippines and Vietnam.

In India, under a coordinated research network jointly sponsored by the ICAR and UNDP involving 12 research centres, impressive progress has been made in the evaluation of hybrids. Intensive research efforts of the network have led to the identification and release of seven region specific hybrids. In 1994, two hybrids namely APHR-1 and APHR-2 from ANGRAU, Hyderabad, MGR-1 from TNAU, Coimbatore, KRH-1 from UAS, Bangalore were released for commercial cultivation. Three more hybrids namely, CNRH-3 from Chinsurah, West Bengal, DRRH-1 from DRR, Hyderabad and KRH-2 from UAS, Bangalore were released during 1995. Besides these, some hybrids were marketed by private seed companies for commercial cultivation. Subsequently some more hybrids were developed by ICAR institutes and State Agricultural Universities. Presently, 17 rice hybrids have been made available for cultivation. The commercial cultivation of hybrid rice has increased the productivity and production. In spite of high productivity level, the area remained stagnant at about two lakh hectares. This is primarily due to unavailability of required quantity of hybrid rice seeds for the farmers and the high cost of the seed material. Hence, the major important constraint for hybrid rice cultivation lies with the seed factor. The success of hybrid rice cultivation in India depends on the success of seed production. So far, the country could achieve a seed yield of 1.5 – 2.0 tonnes per hectare (Subramanian, 2001). It is necessary to enhance seed yield level to more than 2.0 tonnes per hectare in order to economise the seed cost as well as make available more quantity of seeds for public distribution. The reasons for low productivity of hybrid seeds in rice are non-synchronization of flowering of A and R parental lines, incomplete panicle exsertion and poor seed setting. In order to overcome the above bottlenecks, planting ratio of male and female parental lines has been manipulated and some chemicals have been used as spray application (Viraktamath and Ramesha, 2000). However, adoption of such practices to increase hybrid seed production needs standardization under different agro-climatic condition.

With a view to enhance seed production of rice hybrid KRH-2 under Bhubaneswar agro-climatic condition the present investigation has been planned with the following objectives.

1. To study the efficacy of different concentration of GA_3 and boric acid on panicle exsertion and duration of anthesis.

2. To find out proper planting ratio of male and female parental lines for higher seed yield.

3. To assess proper concentration of GA_3 and boric acid for higher quantity of seed production.

4. To evaluate quality of hybrid seeds produced in untreated and treated plants.

CHAPTER -II
REVIEW OF LITERATURE

REVIEW OF LITERATURE

Hybrid rice technology has helped enhancement of rice production in several countries in this world. In India, so far 17 rice hybrids have been released for cultivation (Mishra *et al.,* 2005). But the major constraint of expansion of area under hybrid rice is the availability of sufficient quantity of seeds at affordable price. Hence, efficient and economic seed production package is one of the basic pre-requisite for success of hybrid rice technology (Ramesha and Viraktamatha, 2000).

Hybrid seed production using the Cytoplasmic-Genetic Male sterility system involves three lines viz. CMS or A line, maintainer or B-line and restorer or R-line. The three steps involved in the system are

(i) Multiplication of CMS line (A x B)

(ii) Multiplication of B and R lines

(iii) Production of hybrid seeds (A x R)

Multiplication of CMS lines and hybrid rice seed production are important activities, which decide the success of hybrid rice technology. The maintainer and restorer line can be routinely multiplied as conventional varieties, of course, with special care to ensure genetic and physical purity. On the other hand, hybrid rice seed production requires specialized techniques, which need to be thoroughly understood. (Viraktamatha and Ramesh, 2000). However, there are few CMS lines available for hybrid seed production with specific combining ability with the restorer. The alternate approach is to explore the environmental sensitive genetic male sterility (Jauhar Ali, 1996).

The environmental sensitive male sterile lines are of two types viz.

(i) PGMS (Photoperiod sensitive Genetic Male Sterile) line which responds to photoperiod or duration of day length in respect of pollen fertility and sterility behaviour.

(ii) TGMS (Thermo Sensitive Genetic Male Sterile) line which respond to the day temperature in terms of its pollen fertility and sterility behaviour.

In PGMS and TGMS systems, seeds of the Male sterile (MS) line can be multiplied by selfing and hybrid seed production involves only one crop, growing the MS line with the pollen parent in the isolation plot (Subramanian, 2001).

Hybrid seed production in two line breeding is less cumbersome as compared to three line breeding. TGMS lines are multiplied where staple temperature prevails during its sensitive stage for nearly 30 days. TGMS lines and non TGMS lines of good combining ability are planted in proper ratio and supplementary pollination techniques are adopted.

To site another work on it, TGMS line PL 12 (H89-1) becomes male sterile under higher temperature above 30°C and becomes fertile below 26°C (Maruyame *et al.*, 1991).

The PGMS lines show fertility alterations under different photoperiods within a certain temperature range. The PGMS lines usually show pollen sterility under long day conditions but revert to fertility under short day condition (Lu *et al.*, 1994).

Hence, the PGMS lines should be grown under short day condition. Then the seeds produced are grown under long day condition with non-PGMS lines of good combining ability at proper planting ratio to produce hybrid seeds.

The TGMS system is considered to be more useful than the PGMS lines in tropical areas where day length differences are small but temperature differences between low and high altitude exists (Virmani, 1992).

The problems in hybrid seed production are associated with

(i) suitable climatic condition,

(ii) synchronisation of flowering,

(iii) panicle exsertion,

(iv) duration of opening of flower and stigma receptivity, and

(v) compatibility of seed and pollen parent

Climatic condition has profound influence on seed yield. A detailed information on the weather data of a given locality is necessary for fixing the seeding date. Seeding of parental lines should be planned in such a way that the flowering coincides with the most favourable climatic condition (Viraktamath and Ramesha, 2000). Daily mean temperature between 24-30^{0}C helps in good seed setting. Seed yield is adversely affected if the temperature is below 20^{0}C and above 35^{0}C. Higher temperature causes pollen sterility while lower temperature hinders the process of fertilization (Lu *et al.*, 1994).

Some experimental results have shown the seed yield to be little higher during *Rabi* season as compared to yields obtained during *Kharif* season (DRR, 1992). However, seed setting was drastically reduced in IR 58025A during seed production of KRH-2 in *Rabi*/Summer season under Orissa condition (Sahoo, unpublished). Moderately high relative humidity is also essential for hybrid seed production. The relative humidity within a range of 70-80% prevents desiccation of stigma and favours opening of spikelets for longer period. Moderately high RH favours higher percentage of seed setting and there by seed yield.

During the period of flowering, there should not be continuous rain, which may cause poor seed setting due to washing of pollen. Sufficient sunshine with wind velocity of 2-3 m sec. favours higher seed yield (Ponnuswamy, 2001).

In hybrid rice seed production, the seed parent and pollen parent are planted in a certain row ratio at certain spacing. The row ratio and spacing of pollen parent and seed parent have distinct effect on the hybrid seed yield. Transplanting of one male sterile line accompanied by one pollinator line results in maximum seed setting in the male sterile plant, but does not give a high yield because the total number of male sterile plant is not large enough. If there are few pollinator lines, the seed set percent may be so low as to affect yield. Among the tested row ratio of 1:5,1:8, 1:12, 2:10, 2:12 and 2:18, higher seed yields were obtained in row ratio of 2:12 and 2:18 (Peijin, 1994).

It has also been reported that the row ratio 2:5 gave highest seed yield among the planting ratio studied (2:3 to 2:8) (Suprihatno, 1986). A row ratio of 6:1 gave higher seed yield in another study (Prabagaran and Ponnuswamy, 1986).

In another study, the planting ratio 2:10 gave highest seed yield in CMS line (Yadav *et al.*, 2002). Results of some other extensive study conducted at Karnal (India) to assess the effect of 12 row ratio combinations revealed that the row ratio 2:6 gave highest yield followed by 2:7 and 2:8 (NSP, 1994). However, a number of factors influence the quantity of seed yield using a specific row ratio (Ponnuswamy, 2001). The factors associated with the characters of parental lines viz. (i) plant height of pollen parent (ii) growth and vigour of the pollen parent (iii) size of panicle and amount of residual pollen (iv) duration and angle of floret opening in CMS lines and (v) stigma exsertion of CMS line. However, the row ratio of 2:8 has been recommended for highest seed yield, involving IR 58025A CMS line (Sharma, *et al.*, 2003). The row ratio may vary from region to region depending on weather, management practices and parental line (Viraktamath and Ramesha, 2000).

Synchronization of flowering is a major problem for hybrid seed production in rice. Since, it is not always possible to select parental lines of same maturity duration for the development of hybrids, it is necessary to find out ways to achieve synchrony of flowering in parental lines differing in maturity duration, when there is a wide gap between them. However, the method is found ineffective in getting synchrony since the parental lines are found to respond differently with change of season and location (Yogeesha *et al.*, 2004).

Synchronized anthesis between the parental lines is as important as the synchronization in flowering between them. Some parental lines have different anthesis time which affects the extent of seed set.

Anthesis of CMS lines is sometimes delayed compared with pollen parents. If the difference in anthesis time between a CMS and or R line is more than 1 hour, seed set is decreased substantially. Stigmas of some genotype remain outside the lemma and palea after spikelet closure. They are receptive and accept pollen grains even the next day. The exserted stigma is, therefore, useful for higher seed yield (Virmani and Athwal, 1973).

To obtain higher seed set, it is necessary that A and R lines should be in full bloom at the same time of the day during flowering period. This ensures that maximum amount of pollen is available when maximum number of stigma are receptive for cross-pollination. Minor differences in anthesis time of parental lines can be corrected by dew driving to hasten the anthesis or by water spray to delay anthesis time (Ramesha and Viraktamath, 2000).

There is general recommendation to adjust the seedling time of parental lines with prior knowledge of flowering duration of both the parents in order to get synchrony in flowering. (Vidyachandra *et al.*, 1997). However, sometimes synchronisation may not be attained due to weather fluctuations and changes in management practices. Therefore, it is essential to predict the heading dates of parental lines. So that corrective measures can be taken up at the appropriate period. The prediction of heading dates is possible by detecting panicle initiation stage. This can be done by observing panicle initials after making a longitudinal slit from the base to top of the tiller. (Ramesha and Viraktamath, 2000). When non-synchronisation of flowering is expected, there may be need to hasten or delay the flowering process in any of the parents. A number of management practices have been recommended in literature for alternation of flowering duration and bring about synchronisation in flowering.

The heading date of a variety can be adjusted according to seedling age at transplanting. Flowering of CMS, maintainer and restorer lines is affected by age of the seedlings irrespective of growth duration. Normal seedling age at transplanting is 21 days. Experiments conducted at IRRI showed that the flowering was 2.3 to 2.8 days earlier on average when 16 days old seedlings were transplanted. On the other hand, flowering was delayed by 1.8 to 2.2 days and 4.4 to 4.8 days, when seedlings were transplanted after 26 and 31 days, respectively (Peijin, 1994).

In order to bring about synchronisation of flowering of seed and pollen parents, a number of studies have been conducted by rice research workers. The chemicals tried were urea, 2,4-D, boric acid, KNO_3, TIBA, IAA, CCC, Ethrel, MH and P_2O_5. The chemicals were sprayed at the panicle initiation stage of CMS and restorer lines at IRRI. The chemicals delayed or enhanced flowering in all the lines significantly as compared to the control. Urea and 2,4-D delayed flowering in all the lines by 1 day on average while boric acid, KNO_3, IAA, CCC, Ethrel, GA_3 enhanced flowering by 1.8-2.8 days (IRRI, 1990 and IRRI, 1991). Phosphate solution (1%) can also enhance the flowering in both CMS and pollen parent (Peijin, 1994).

Among the chemicals studied in hybrid seed production in rice, GA_3 application was found to be most effective (Yuan, 1985).

Virmani *et al.*, 1991, Virmani, 1994, Suprihatno, 1994, Bong *et al.*, 1994, Prabagaran and Ponnuswamy, 1991; Morzhong and Zaman, 1999; Kalavathi *et al.*, 2000. GA_3 application changed the physiology of rice plants in a favourable direction, such that the seed yield in CMS lines was enhanced to a considerable extent. GA_3 at different concentrations increased plant height of CMS lines (Bong *et al.*, 1994; Prabagaran and Ponnuswamy, 1997, Jagadeeswari *et al.*, 1998; Morzhong and Zaman, 1999; Jarugula *et al.*, 2002).

Increases in plant height reduced the height difference between seed parent and pollen parent and facilitated easy pollen transfer to the stigma. Spray application of GA_3 also increased number of productive tiller per plant (Prabagaran and Ponnuswamy, 1997; Jagadiswari *et al.*, 1998; Tiwari, Ahmed *et al.*, 2004). Since number of productive tillers has direct contribution towards seed yield, the increase in yield is expressed through this character .The increase in panicle length to the extent of 40-50% was also observed in GA_3 treated plants (Ahmed *et al.*, 2004).

Incomplete panicle exsertion is a draw back with CMS lines. Due to incomplete panicle exsertion 10-15 % spikelets are enclosed in the flag leaf and not available for out-crossing (Ramesha and Viraktamath, 2000). Gibberellic acid has been found to be an efficient and effective growth regulator, which stimulates the cell elongation. Spray application of GA_3 at different concentrations enhanced panicle exsertion in CMS lines (Yuan, 1985 and 1994; Kalavati *et al.* 2000, Tiwari, 2002). Besides the positive effect on panicle exsertion, GA_3 application also increases duration of floret opening (Yuan, 1985; Virmani *et al.*, 1991) increases stigma exsertion and receptivity (Yuan, 1985; Yuan, 1994; Morzhong and Zaman, 1999).

GA_3 application increases percentage of seed set in CMS lines. The results of an experiment conducted in IRRI; during wet season of 1991, revealed that the CMS line IR 58025A showed 3206% seed set due to application of GA_3 @ 45g/ha against the control value of 24%.

In another study, it was observed that the out-crossing rate increased to 27 % through spray application of GA_3 (60 ppm) when the control value was 17% (Bong *et al.*, 1994). Such increase in seed setting was also observed in other studies (Jagadeesawari, *et al.*, 1998; Morzhong and Zaman, 1999). There was linear increase in percentage of seed setting with the increase of doses of GA_3 (Kalavathi *et al.*, 2000). GA_3 at 90 g/ha resulted in maximum seed set as compared to other doses (Jarugula *et al.*, 2002).

GA_3 application increased seed yield in CMS lines in almost all studies those reviewed. However, it has been reported that, GA_3 application reduced germination and vigour of hybrid seeds produced in CMS line IR 58025A (Jagadeeswari *et al.*, 1998). It has been suggested that the dosage of GA_3 should be selected meticulously.

The time of application of GA_3 has been reported to be important. GA_3 has to be sprayed at the most appropriate stage of the crop growth for its maximum effect. In hybrid rice seed production plots, 5-10% panicle emergence stage is most appropriate for the first spraying (40%). The remaining 60% has to be sprayed on the next day. Morning (8-10 AM) and evening (4-6 PM) are ideal for taking up spraying (Ramesha and Viraktamath, 2000).

Some scientists working on hybrid rice have advocated some substitute for GA_3 (Prasad *et al.*, 1988). They used urea (2%), boric acid (0.5%, 1.0%, and 1.5%) and KNO_3 (2%) and reported comparable yield increase with application of boric acid and urea.

Bong *et al.*, 1994 also advocated application of urea (2%) to be a substitute for GA_3 but did not suggest the positive effect of boric acid. Besides, some biochemical products such as Tiaohualin were found to be more effective than GA_3 (Yuan, 1994).

Spray application of NAA @ 200g/ha also resulted in increase in panicle exsertion, seed set and seed yield compared with GA_3 application. (Despande *et al.*, 2004).

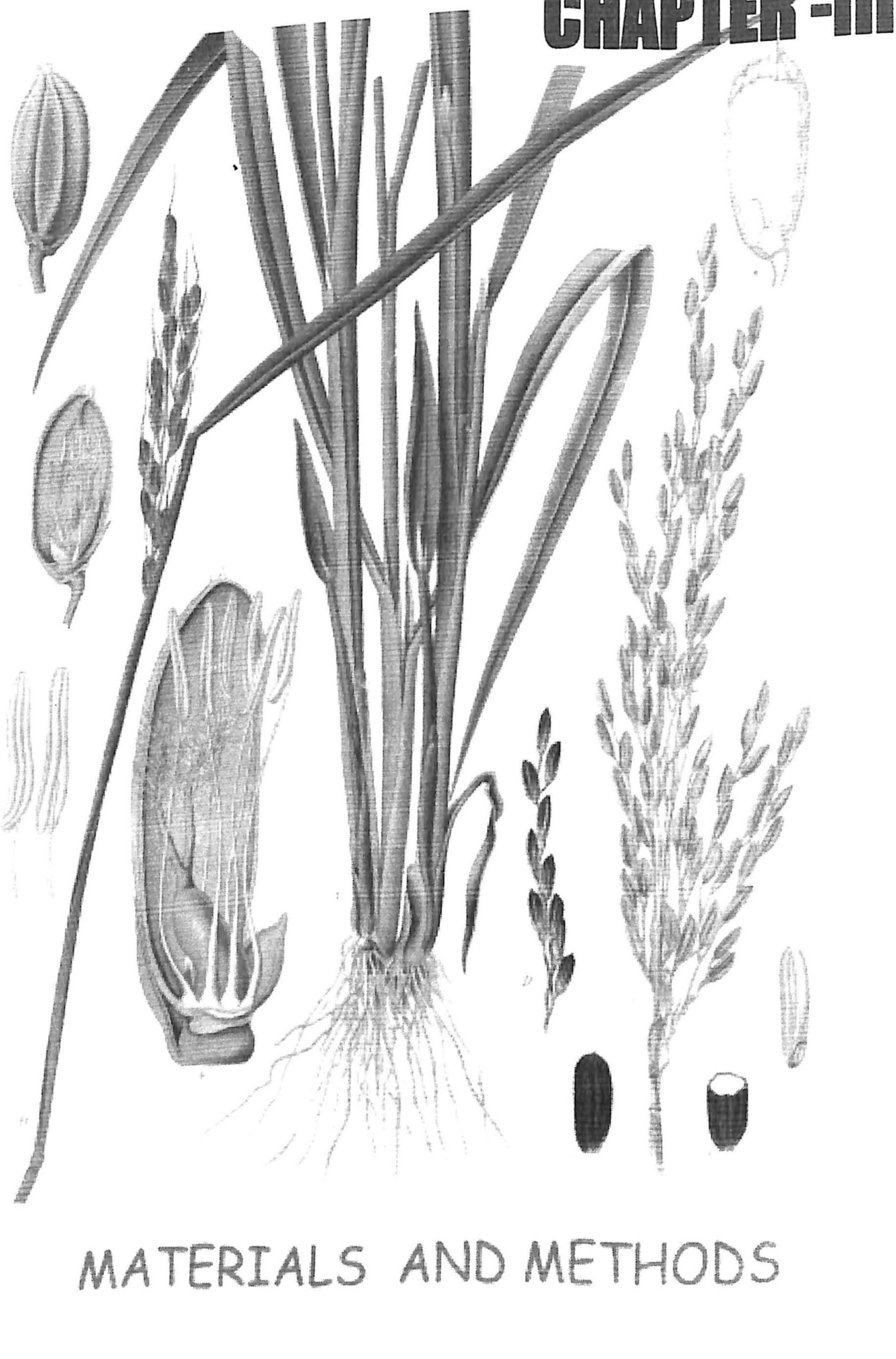
In another study NAA, urea (1%), $ZnSO_4$ (0.1%), boric acid (0.1%) and KH_2PO_4 (0.2%), when used with GA_3 increase in plant height (9-15 cm), seed set (5-10%) panicle exsertion (10-70%) and seed yield (20-70%) were observed (Tiwari and Mishra, 2004).

Rice is basically a self pollinated crop and hence there is a need to go for supplementary pollination in order to enhance the extent of out-crossing. Supplementary pollination is a technique of shaking of the pollen parent so that pollen is shed and effectively dispersed over the A line plants.

Supplementary pollination can be done either by rope pulling or by shaking the pollen parent with the help of two bamboo sticks. Timing and frequency of supplementary pollination is very important. The first supplementary pollination should be done at peak anthesis time i.e. when 30-40% of the spikelets are opened. This process is repeated 3-4 times during the day at an interval of 30 minutes. Supplementary pollination has to be done for 7-10 days during the flowering period. (Ramesha and Viraktamath, 2000).

Results of other work in the line revealed that supplementary pollination started at the peak time of anther dehiscence, increased seed yield by 30% (Peijin *et al.*, 1994).

CHAPTER -III



MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigation was planned to study the effect of spray application of some chemicals on seed production of rice hybrid KRH-2. In the investigation, KMR-3R and IR 58025A were used as the male and female parental lines, respectively. During the course of investigation from June 2003 to December 2003, the quality and quantity of hybrid seeds were studied in field and laboratory experiments.

3.1 Experimental site

The field experiment was conducted in the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar situated at 20°15' N latitude and 85°52' E longitude. The experimental plot was chosen in the medium land with good drainage facility.

3.2 Soil

The textural class of the experimental plot was sandy loam

3.3 Cropping history of the plot

The experimental plot remained fallow during the previous *Rabi* season. Hence, here was less possibility of appearance of volunteer rice plants.

3.4 Season

The seed crops were raised during *Kharif*, 2003. The climatic condition was suitable for hybrid seed production as conceived from meteorological data furnished in Fig.1.

3.5 Experimental details

The experiment was laid out in Factorial Randomised Block design with three replications.

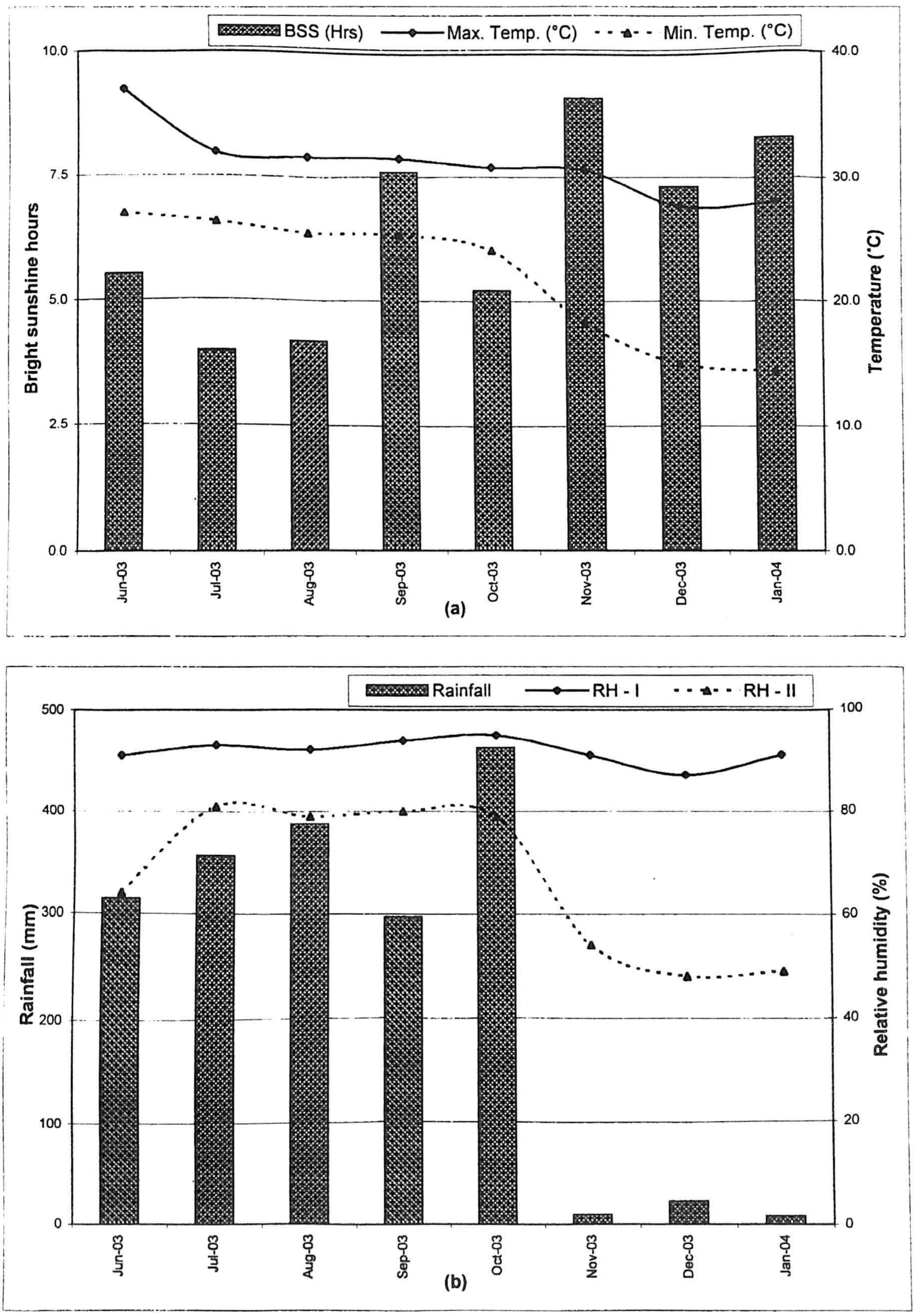


Fig. 1. Mean monthly maximum and minimum temperature, bright sunshine hours, RH-I (morning), RH-II (afternoon) and rainfall during the experiment

a) Parental lines

i) Male parental line KMR-3R

ii) Female parental line IR 58025A

b) Planting ratio: Two planting ratio were adopted during the experiment

i) 2:6:: Male parental line: Female parental line

ii) 2:8:: Male parental line : Female parental line.

c) Chemical spray application

i) Control

ii) GA 50 g/ha

iii) GA 75 g/ha

iv) GA 100 g/ha

v) GA 125 g/ha

vi) Boric acid 1 % solution

d) Plot size

The experiment was conducted in a plot of size 22 x 25 sq.m. area. Drainage channels are left in two sides of the main plot. The main plot was divided into three sub-plots each comprising of a single replication.

e) Raising of seed crops

i) Raising of seedling in nursery bed

Seedlings of male and female parental lines were raised in separate nursery beds. The seeds of male parental line were sown on three dates at 4 days interval. The seeds of the female parental line were sown after 10 days of first sowing of the male parental line. Such staggered sowing was made in order to synchronies the flowering of male and female lines because the female parental line flowered six days earlier than the male parental line.

f) **Preparation of main plot**

The main plot was ploughed two weeks before transplanting. FYM was mixed properly in the soil. One day before transplanting the land was ploughed, puddled and labelled properly. The basal doses of fertilizers were applied during field preparation. In order to drain out excess water, drainage channels were prepared and then the plot was laid out according to the experimental plan (Fig.2).

g) **Fertilizer application**

Fertilizer were applied @ 100 kg N, 50 kg P_2O_5 and 50 kg K_2O along with 10 cartloads of FYM per hectare. One third of nitrogen, whole of the phosphate and potash and FYM were applied at the time of land preparation for transplanting. The remaining nitrogen was applied in two equal splits, one during maximum tillering stage and the second at the time of heading.

h) **Transplanting of seedlings**

Seedlings of male and female lines were transplanted in three-meter rows in east to west direction. Seedlings of male line sown on three different dates were mixed in equal proportion after uprooting in 2:6 (male: female) and 2:8 (male: female) ratio in different treatments as per the plan. In one replication, each subplot has either 12 or 16 female parental line rows and 4 male parental line rows including the border parental line rows. During transplanting a spacing of 20 cm, 20 cm and 15 cm were maintained between the rows of male parental line, between the rows of male parental line and first female parental line and between the rows of female parental lines, respectively. Further, a spacing of 15 cm was maintained between the hills and two seedlings were planted per hill.

i) **Weeding and plant protection measures**

Care was taken to make the experimental crops weed free. Hence, frequent hand weeding was done as and when required. Prophylactic plant protection measures were taken to protect the crop from various pest attacks.

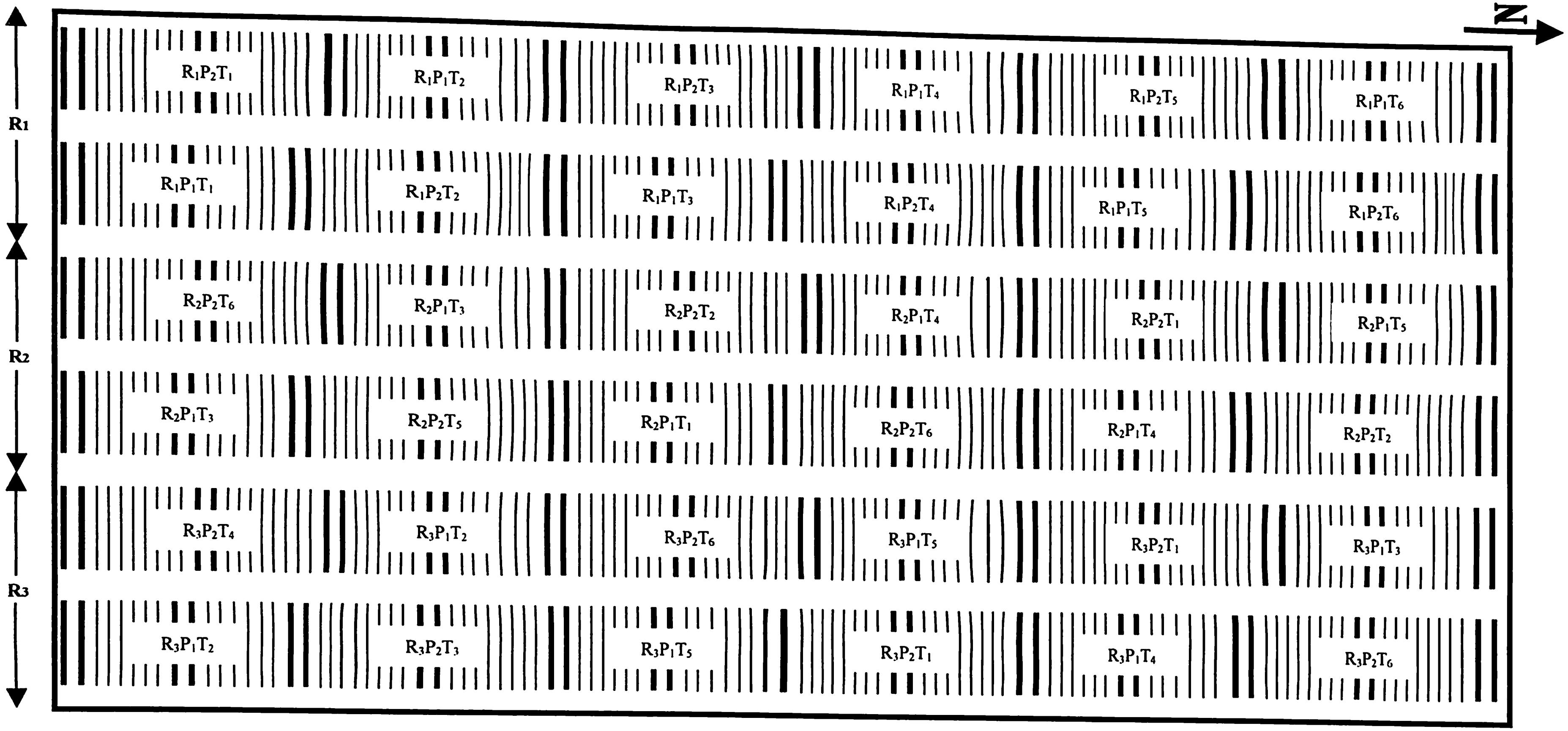


Fig. 2. Layout plan of the experiment

j) **Water management**

Uniform standing water of 2-3 cm was maintained in the experimental plot until about 10-12 days before harvest.

k) **Preparation of chemical solution and application**

GA_3 solution was prepared by dissolving GA_3 in 70 % ethanol @ 5 ml ethanol/gm of GA_3. The GA_3 solution was sprayed in two consecutive days at 5 % heading stage. On the first day 40 % of GA_3 was sprayed by knapsack @ 25 l/ha in the morning hours (8-10 AM) and the rest 60 % GA_3 was sprayed on the following day by Knapsack sprayer @ 25 l/ha in the morning hours. Boric acid was sprayed at a concentration of 1 % @ 25 l/ha once at 5 % heading stage in the morning hours.

l) **Supplementary pollination**

In order to increase the extent of pollination rope pulling was done twice at peak anthesis time (9.30 AM to 10.30 AM).

m) **Selection of sample plants for observation**

For different pre-harvest and post harvest observations two sample hills were selected from each female parental line row under each treatment. The sample hills were tagged for clean demarcation.

n) **Observation of different parameters**

i) **Days to 50 % flowering:** Flowering in 50 % hills was observed in each treatment and the flowering duration was expressed as days after sowing (DAS).

ii) **Flowering period:** Visual observation was taken to estimate the flowering period of all the spikelets present in the panicle. The flowering duration of the seed crops under different treatments was recorded separately and was expressed in days.

iii) **Panicle exsertion:** The extent of panicle exsertion was observed in sample hills by measuring total length of each panicle and the portion of panicle came out from flag leaf and the panicle exsertion percentage was calculated. The average values were recorded for each treatment.

iv) **Spikelet opening duration:** Spikelet opening duration was observed by eye estimation in each treatment and was expressed in minutes

v) **Style and stigma length:** Twenty spikelets were sampled from the panicles borne by primary tillers and were kept on moist blotters in a petridish. In the laboratory, the length of style and stigma of individual spikelet was measured by the help of a stereoscopic microscope and micrometer. The average length of style and stigma was computed and was expressed in millimetre. The measurement of style and stigma of spikelets was taken separately for each treatment.

vi) **Spikelet opening angle:** Twenty spikelets born by primary tillers were used to observe the parameter. Spikelet opening angle was measured by gently pressing the spikelet on a piece of paper and drawing lines extended from the tip of lemma and palea. In the laboratory, the lines were converged and resulting angle was measured by the help of protractor and was expressed in degree. The values of twenty observations were averaged to express the parameter. The measurement of spikelet opening angle was taken separately for each treatment.

vii) **Plant height:** The height of the main shoot of sample hill was measured from base to the top of the panicle and was expressed in centimetre. The average value of height was computed.

viii) **Total tiller number:** The total number of tiller in each sample hill was counted and the average value was computed.

ix) **Number of effective tillers:** The number of effective tillers in each hill was counted and the average value was computed.

x) **Panicle length:** The length of all the effective panicles in the sample hills was measured from neck node to tip and was expressed in centimetre. The average value was computed for presentation.

xi) **Number of spikelet per panicle:** Total number of spikelets in effective panicles in sample hills was counted and the average value was computed.

xii) **Number of seeds per panicle:** Total number of seeds formed in each panicle in sample hills was counted and the average value was computed.

xiii) **1000-seed weight:** After harvest of the seed crops and completion of post harvest operations, 1000 seeds were counted from each replication under each treatment. The weight of 1000 seeds was taken by an electronic balance and was expressed in gram.

xiv) **1000-kernel weight:** After recording seed weight, all the seeds were dehusked and 1000-kernel weight was determined by the help of electronic balance and was expressed in gram.

xv) **Yield per plant:** The sample plants were threshed separately and subjected to post harvest operations. Then the seed yield per plant was recorded by a balance and average seed yield per plant was computed and was expressed in gram.

xvi) **Seed yield per hectare:** After harvest of seed crops and completion of post harvest operations the total seed yield in each replication under each treatment was determined. From the observation data, seed yield per hectare was computed and was expressed in kilogram.

xvii) **Germination percentage:** Germination test for seeds harvested from crops receiving different treatments was conducted by adopting standard BP method (ISTA, 1985). Both first and final counts were recorded on specified dates.

xviii) **Shoot and root length of seedlings:** On the day of final count of germination test the measurement of length of shoot and root of individual seedlings was taken. The average length of shoot and root was computed and was expressed in centimetre.

xix) **Shoot and root dry weight:** On the day of final count of germination test the shoot and root of individual normal seedling were separated and dried in the oven at 85^0C for 24 hours followed by drying at 100^0C for 24 hours. Then the fully dried shoot and fully dried root were weighed by an electronic balance and the weight was expressed in milligram.

xx) **Vigour index:** Seed vigour index was computed by utilizing germination and seedling length data generated from germination test. The vigour index was calculated by adopting the following formula (Abdul Baki and Anderson, 1973).

Vigour index = Germination (%) x Seedling length (cm)

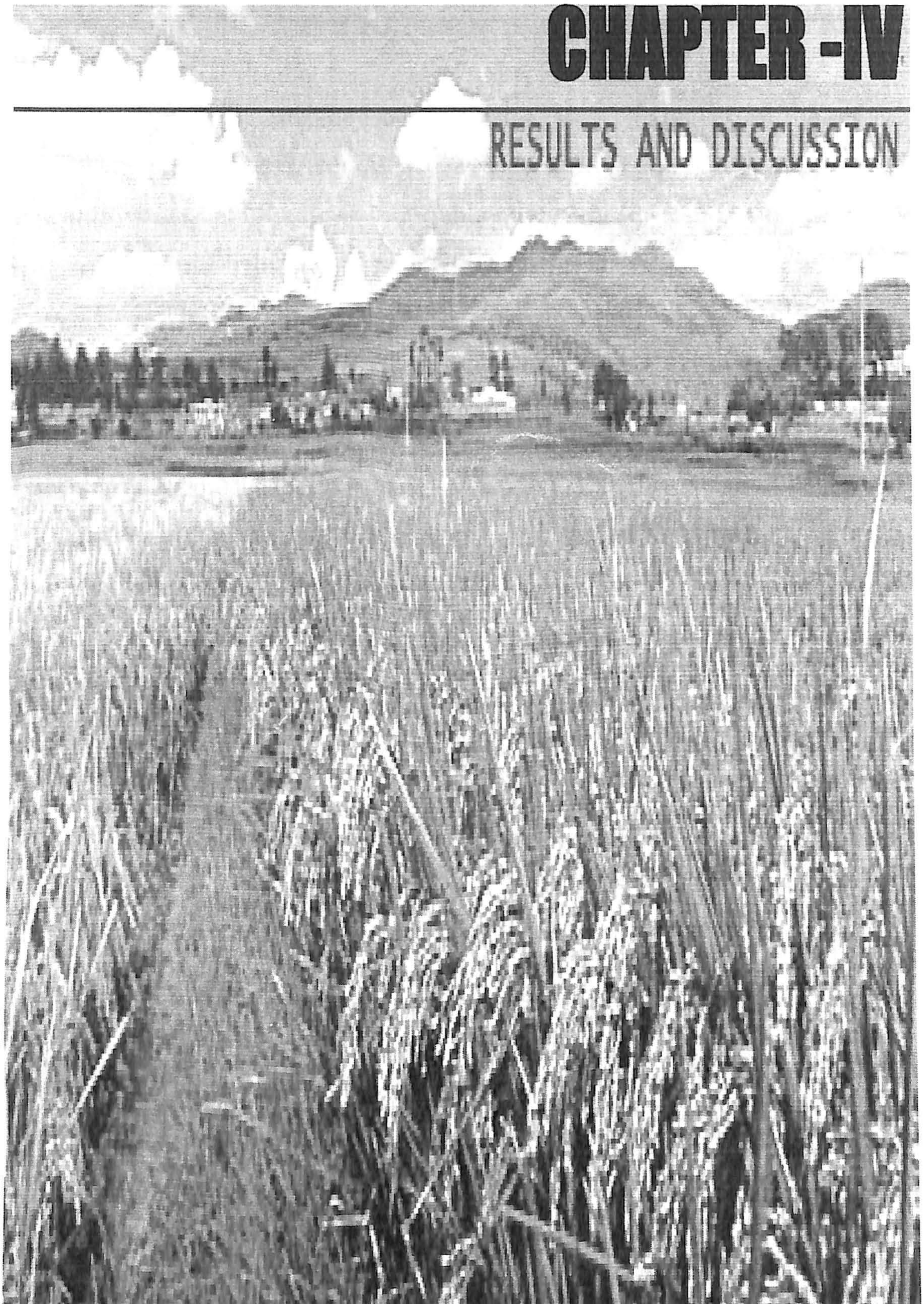
xxi) **Field emergence:** Seeds produced under each treatment were sown in a well prepared plot in 4 x 5 metre lines with a spacing of 5 cm from plant to plant and 10 cm from row to row. After 15 days, the seedling emergence was recorded and was expressed as percentage of seeds sown in the field.

xxii) **Accelerated ageing treatment:** Seeds produced under different treatments were exposed to accelerated ageing for 7 days at 40^0C temperature and 95 % RH. After completion of accelerated aging treatment, germination test of aged seeds were conducted as per ISTA rules (ISTA, 1985) seed vigour was also assessed by determining vigour index of seeds receiving accelerated aging treatment.

xxiii) **Statistical treatment:** The observation data recorded for different parameter were subjected to statistical treatments by adopting the procedures laid out by Panse and Sukhatme (1978).

CHAPTER -IV

RESULTS AND DISCUSSION



RESULTS AND DISCUSSION

Standardization of seed production technology in hybrid rice in different agro-climatic conditions is necessary to make available sufficient quantity of seeds for expansion of area under hybrid rice. The major problems associated with hybrid seed production in rice have been discussed by some workers in the field. In order to take tackle the problems, some line of research have been suggested besides certain recommendation.

The present investigation has been planned to study and standardize the seed production technology of rice hybrid KRH-2 by using IR 58025A and KMR-3R as the female and male parental lines, respectively with spray application of GA_3 and boric acid under Bhubaneswar agro-climatic condition. The results obtained from the field and laboratory experiments have been discussed under different heads.

4.1 Plant height

The growth character, plant height, though genetically controlled is often influenced by the prevalent environmental condition. This character receives important consideration during hybrid seed production.

In the present study, the average plant height of the male parental line, KMR-3, was observed to be 99.0 cm (Table 1) and that of female parental line 66.7 cm (Table 2, Fig. 3). The plant height increased progressively with the increase of concentration of GA_3. Maximum increase in plant height to the extent of 10.6 cm was observed with spray application of 125 g GA_3/ha. Such an increase in plant height might have been mediated through the effect of GA_3 on cell elongation. The present findings confirmed the findings of previous workers (Bong *et al.,* 1994; Prabagaran and Ponnuswamy, 1997; Jagadeeswari *et al.*, 1998; Morzhong and Zaman, 1999, Jarugula *et al.*, 2002).

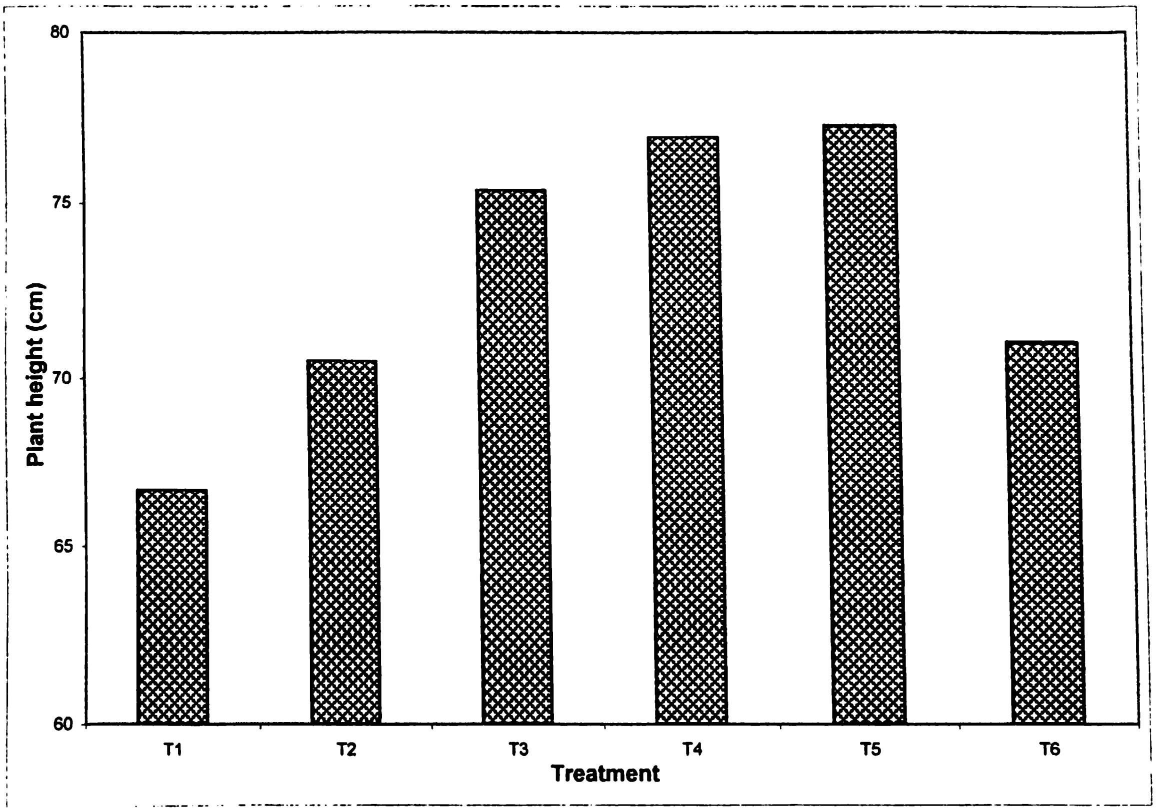


Fig. 3. Effect of different concentrations of GA3 and Boric acid on plant height of female line (IR 58025A) during hybrid seed production in rice

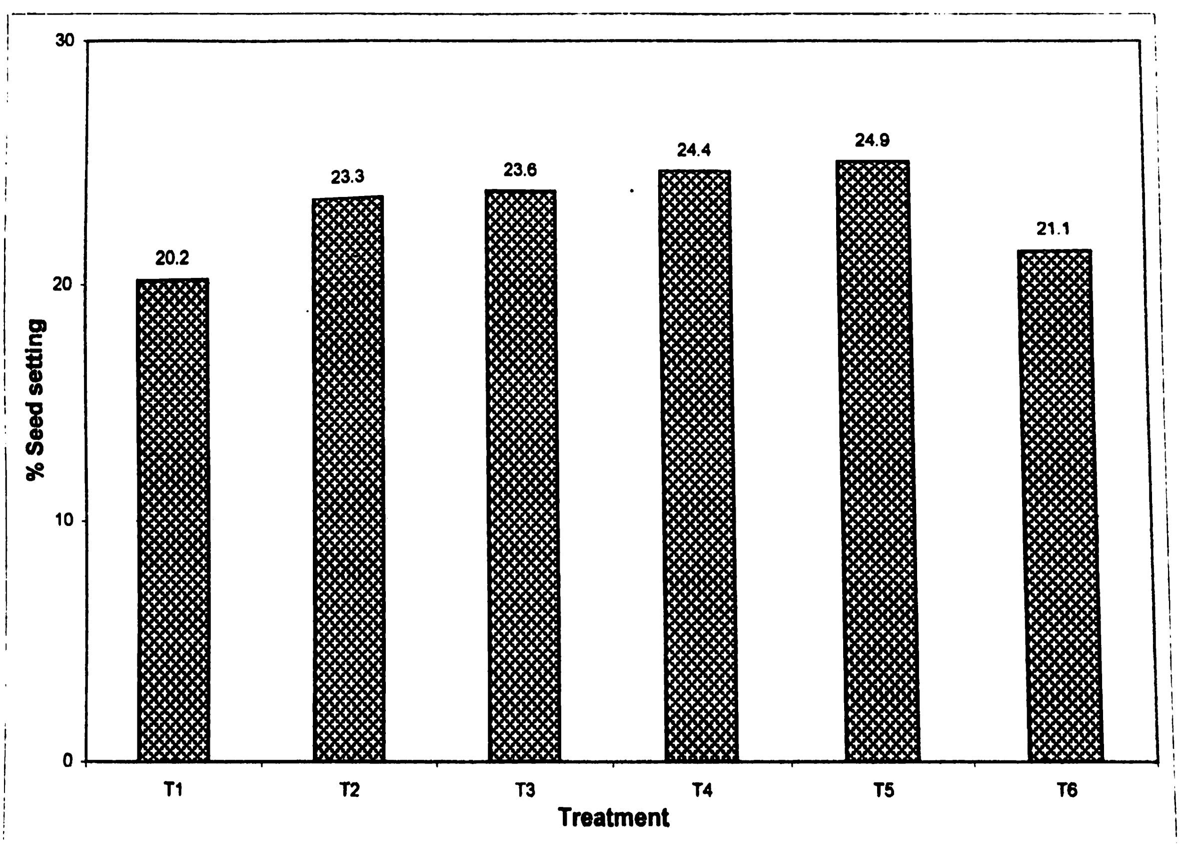


Fig. 4. Effect of different concentrations of GA3 and Boric acid on % seed setting in female line (IR 58025A) during hybrid seed production in rice

Table 1. Some characters of male parental line KMR-3R expressed during *Kharif* season

Sl. No.	Character	Value
1.	Average plant height (cm)	99
2.	Average number of tillers / hill	11
3.	Average number of effective tillers	9.5
4.	Days to 50% flowering	77
5.	Flowering period (days)	5 – 6
6.	Average panicle length (cm)	26
7.	Average number of spikelets per panicle	145
8.	Spikelet opening duration (minute)	130

Table 2. Effect of spray application of different doses of GA_3 and boric acid on plant height (cm) of rice female parental line IR 58025A and difference of height (cm) with male parent (mean of three replications)

a) Plant height (cm) | b) Difference in plant height (cm) with male parent

Treatment	a) Planting ratio			b) Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	66.4	66.9	**66.7**	32.4	33.1	**32.8**
GA_3 50 g/ha	70.2	70.8	**70.5**	28.6	29.0	**28.8**
GA_3 75 g/ha	75.6	75.2	**75.4**	23.7	23.2	**23.5**
GA_3 100 g/ha	76.8	77.1	**77.0**	22.5	21.4	**22.0**
GA_3 125 g/ha	77.3	77.3	**77.3**	22.0	22.2	**22.1**
Boric acid 1%	72.2	69.8	**71.0**	26.2	29.1	**27.7**
Mean	**73.1**	**72.9**		**25.9**	**26.3**	
	P	**T**	**P x T**	**P**	**T**	**P x T**
S.Em.(±)	**0.51**	**0.88**	**1.24**	**0.34**	**0.58**	**0.82**
C.D.$_{(0.05)}$	**NS**	**1.82**	**NS**	**NS**	**1.20**	**1.70**

P – Planting ratio
T – Treatment

Boric acid also increased the plant height but to a less extent (4.3 cm). The increase in plant height due to spray application of chemicals especially GA_3 reduced the difference in plant height of male and female parental lines (Table 2b) which facilitated better transfer of pollen to the spikelet borne by the female parent, which eventually resulted in better seed set (Table 9). Planting ratio did not produce any significant effect on plant height.

4.2 Number of tillers

The average number of tillers, per hill in treated and untreated plants under different planting ratio varied from 14.8 to 15.6 (Table 3a). However, the spray application of chemicals and the planting ratio did not produce any significant effect in the female parental line.

The number of effective tillers, per hill in female parental line varied within the range of 9.4 to 10.6 in treated and untreated plants under different planting ratios (Table 3b). There was no significant difference in the number of effective tillers between the two planting ratios. However, spray application of chemicals showed significant increase in the number of effective tillers especially for GA_3 treatment and the values ranged from 9.70 to 10.55. The increase in number of effective tillers possibly resulted due to increase in exsertion of panicle (Table 5b). The observation in the present study confirmed the findings of previous workers in line (Kalavathi, 2000; Tiwari, 2002).

4.3 Days to flowering

The female parent took 71-72 days to come to 50% flowering (Table 4a). The spray application of chemicals and planting ratio did not produce any significant effect.

Table 3. Effect of spray application of different doses of GA_3 and boric acid on total number of tillers per hill and number of effective tillers per hill in rice female parental line IR 58025A (mean of three replications)

Treatment	a) Total number of tillers: Planting ratio			b) Number of effective tillers: Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	15.2	14.8	**15.00**	9.4	9.8	**9.60**
GA_3 50 g/ha	15.2	14.5	**14.90**	9.8	10.2	**10.00**
GA_3 75 g/ha	14.8	15.3	**15.05**	10.3	10.4	**10.35**
GA_3 100 g/ha	14.6	15.3	**14.95**	10.6	10.5	**10.55**
GA_3 125 g/ha	15.0	15.6	**15.30**	10.5	10.5	**10.50**
Boric acid 1%	14.9	14.8	**14.85**	9.7	9.7	**9.70**
Mean	**14.95**	**15.05**		**10.05**	**10.18**	
	P	T	P x T	P	T	P x T
S.Em.(±)	0.19	0.33	0.47	0.12	0.20	0.28
C.D.$_{(0.05)}$	NS	NS	NS	NS	0.42	NS

P – Planting ratio
T – Treatment

Table 4. Effect of spray application of different doses of GA_3 and boric acid on days to 50% flowering (DAS) and period of flowering (days) in rice female parental line IR 58025A (mean of three replications)

Treatment	a) Days to 50% flowering: Planting ratio			b) Period of flowering: Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	72.0	72.0	**72.0**	8.0	8.0	**8.0**
GA_3 50 g/ha	71.0	71.0	**71.0**	7.0	8.0	**7.5**
GA_3 75 g/ha	71.0	72.0	**71.5**	8.0	8.0	**8.0**
GA_3 100 g/ha	72.0	72.0	**72.0**	7.0	7.0	**7.0**
GA_3 125 g/ha	71.0	71.0	**71.0**	8.0	8.0	**8.0**
Boric acid 1%	72.0	71.0	**71.5**	8.0	7.0	**7.5**
Mean	**71.5**	**71.5**		**7.66**	**7.66**	
	P	T	P x T	P	T	P x T
S.Em.(±)	**0.2**	**0.3**	**0.4**	**0.3**	**0.4**	**0.6**
$C.D._{(0.05)}$	NS	NS	NS	NS	NS	NS

P – Planting ratio
T – Treatment

4.4 Period of flowering:

The period of anthesis in the female parent was observed to be 7-8 days both in treated and untreated plants (Table 4b). Neither planting ratio nor spray application of chemicals could produce any significant effect.

4.5 Panicle length

In the control the mean panicle length was observed to be 22.82 cm and planting ratio did not produce any significant effect (Table 5a). There was progressive increase in panicle length with the increase in dosage of GA_3. The increase was maximum (5.30 cm) when 125 g GA_3/ha was sprayed.

Boric acid (1% also increased the panicle length but to a lesser extent. The difference in panicle length due to chemical treatment was found to be statistically significant. Such increase in panicle length under the influence of chemicals might have been possible through cell elongation (Yuan, 1994). The present findings confirmed the findings of other workers in the field (Ahmed *et al.*, 2004).

The increase in panicle length would help in out-crossing due to wide spacing of spikelets.

4.6 Panicle exsertion

In the control the average panicle exertion values were 72.36% and 73.00% under 2:6 and 2:8 planting ratio, respectively. However, planting ratio did not produce any significant effect (Table 5b). With the spray application of GA_3 and boric acid, panicle exsertion percentage increased in all the treated plants. In GA_3 treated plants the increment ranged from about 6.5% to 13.0% while in boric acid treated plant the same was about 1%. Such increase in panicle exsertion

Table 5. Effect of spray application of different doses of GA_3 and boric acid on panicle length (cm) and panicle exsertion (%) in rice female parental line IR 58025A (mean of three replications)

	a) Panicle length			b) Panicle exsertion		
Treatment	**Planting ratio**			**Planting ratio**		
	2:6	**2:8**	**Mean**	**2:6**	**2:8**	**Mean**
Control	22.92	22.72	**22.82**	72.36	73.00	**72.68**
GA_3 50 g/ha	24.63	24.84	**24.74**	80.02	78.28	**79.15**
GA_3 75 g/ha	26.85	26.65	**26.75**	81.56	81.83	**81.70**
GA_3 100 g/ha	27.86	27.73	**27.80**	84.44	85.62	**85.03**
GA_3 125 g/ha	28.23	28.00	**28.12**	85.27	85.76	**85.52**
Boric acid 1%	23.75	23.64	**23.70**	73.58	73.46	**73.52**
Mean	**25.71**	**25.60**		**79.54**	**79.66**	
	P	**T**	**P x T**	**P**	**T**	**P x T**
S.Em.(±)	**0.188**	**0.325**	**0.459**	**0.355**	**0.614**	**0.869**
C.D.$_{(0.05)}$	**NS**	**0.674**	**NS**	**NS**	**1.274**	**NS**

P – Planting ratio
T – Treatment

percentage was also observed by other workers (Yuan, 1985; Prabagaran and Ponnuswamy, 1997; Kalavathi *et al.*, 2000, Tiwari, 2002). Increase in panicle exsertion has been considered as a desirable physiological event which facilitates out-crossing (Ramesha and Viraktamath,2000).

4.7 Style length and stigma length:

Higher stigma exsertion and large stigmatic area and its receptivity play a major role for better seed set in CMS line. The longer the pistil length the greater would be the stigma exsertion. Percent spikelet with exerted stigma has been significantly correlated with seed set percent. (Rudraradhya and Panchaksharaiah, 1997).

In the present study, the observed stigma length was 1.15 mm in the control. There was no difference in stigma length under different planting ratio. However, the stigma length increased in all the plants receiving spray application of chemicals. The values ranged between 1.17 mm and 1.19 mm (Table 6a). The style length also responded positively to chemical application (Table 6b). Maximum style length was observed (1.32 mm) in the plants sprayed with 125g/ha. The control value was however 1.20 mm. The increased stigma exsertion was also reported by some workers in line (Yuan, 1994; Morzhong and Zaman, 1999). As indicated in literature, changes in style and stigma characteristics in CMS line brought about by spray application of GA_3 and boric acid facilitated out-crossing.

4.8 Spikelet opening angle

Spikelet opening angle is important for out crossing and seed set. In the present experiment, the angle of glume opening was measured during the period

Table 6. Effect of spray application of different doses of GA_3 and boric acid on stigma length (mm) and style length (mm) in rice female parental line IR 58025A (mean of three replications)

Treatment	a) Stigma length – Planting ratio			b) Style length – Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	1.14	1.15	**1.15**	1.20	1.20	**1.20**
GA_3 50 g/ha	1.16	1.17	**1.17**	1.24	1.25	**1.25**
GA_3 75 g/ha	1.18	1.19	**1.19**	1.31	1.30	**1.31**
GA_3 100 g/ha	1.18	1.19	**1.19**	1.31	1.31	**1.31**
GA_3 125 g/ha	1.18	1.18	**1.18**	1.32	1.32	**1.32**
Boric acid 1%	1.17	1.18	**1.18**	1.28	1.27	**1.28**
Mean	**1.17**	**1.18**		**1.28**	**1.28**	
	P	T	P x T	P	T	P x T
S.Em.(±)	0.005	0.009	0.013	0.008	0.014	0.020
$C.D._{(0.05)}$	NS	0.018	NS	NS	0.029	NS

P – Planting ratio
T – Treatment

of anthesis. In the control, the spikelet opening was about 20° (Table 7a). Spray application of chemicals (GA_3 and boric acid) increased the spikelet opening angle. The increase in dose of GA_3 from 50g/ha to 125g/ha resulted in spikelet opening angle from 21.84^0 to 28.25^0. However, spray application of boric acid (1%) increased the angle by 1.0^0 only. The opening angle of higher magnitude possibly brought about by maintenance of higher turgidity of lodicules effected through the action of the sprayed chemicals. The wider opening of the spikelet must have increased the chances of pollen transfer to the stigmatic surface, for fertilization. The effect of GA_3 on spikelet opening angle was observed in a previous study. (Sharma *et al.,* 2003). The planting ratio did not produce any effect on spikelet opening angle.

4.9 Spikelet opening duration:

Spikelet opening period controls the extent of seed set to a considerable extent. The observations recorded in the present investigation revealed that the average spikelet opening investigation revealed that the average spikelet opening duration was 118 minutes (Table 7b). Planting of male and female parental lines in the ratio of 2:6 showed significantly higher value (132 min) than observed in 2:8 ratio (129 min). Spray application of GA_3 and boric acid increased the period of opening of spikelets. Although spray application of boric acid kept the spikelet opened for 8 minutes more than the control, the highest dose of GA_3 (125 g/ha) could keep the spikelet opened for 20 minutes more than control. Such observations were also reported by previous workers (Yuan, 1985; Virmani *et al.*, 1991). The longer period of opening of spikelets in the female parent must have increased the chances of receiving pollen from the male parent and eventually the seed set.

Table 7. Effect of spray application of different doses of GA_3 and boric acid on spikelet opening angle (^{0}) and spikelet opening duration (min) in rice female parental line IR 58025A (mean of three replications)

Treatment	a) Sipkelet opening angle: Planting ratio 2:6	2:8	Mean	b) Spikelet opening duration: Planting ratio 2:6	2:8	Mean
Control	20.24	19.82	**20.03**	120	116	**118**
GA_3 50 g/ha	21.94	21.73	**21.84**	132	128	**130**
GA_3 75 g/ha	23.52	23.66	**23.59**	134	132	**133**
GA_3 100 g/ha	24.62	24.04	**24.33**	136	137	**137**
GA_3 125 g/ha	26.52	25.98	**26.25**	138	137	**138**
Boric acid 1%	21.22	20.82	**21.02**	129	122	**126**
Mean	**23.01**	**22.68**		**132**	**129**	
	P	**T**	**P x T**	**P**	**T**	**P x T**
S.Em.(±)	**0.251**	**0.434**	**0.614**	**1.0**	**1.7**	**2.4**
$C.D._{(0.05)}$	**NS**	**0.900**	**NS**	**2.0**	**3.5**	**NS**

P – Planting ratio
T – Treatment

4.10 Number of spikelets per panicle and number of developed seeds

In the present study, the number of spikelets per panicle did not show any significant variations due either to spray application of chemicals or planting ratio. The number of developed seeds per panicle showed significant variations. The average number of spikelets per panicle ranged from 116.2 to 120.6. In the control, the average number of developed seeds in the panicle was 24.6 under 2:6 planting ratio and 23.98 under 2:8 planting ratio (Table 8b). The reasons of less number of developed seeds in the panicle of female parental line planted in 2:8 ratio may be assigned to less chance of distant rows of female line to get adequate pollen for out crossing. Spray application of chemicals increased the number of developed seeds per panicle. With application of 50g of GA_3/ha the mean number of developed seeds per panicle was 27.4 (Table 8b). There was progressive increase in number of developed seeds with increase in the dose of GA_3. At 125 g GA_3/ha the number of developed seeds per panicle increased to 29.45 (Table 8b). However, there was marginal increase in developed seeds due to application of boric acid.

The reasons for such increase in developed seed number may be attributed to better seed setting under the influence of spray application of chemical (Fig. 4). The present finding confirmed the findings of other workers in the field (Jagadeeswari *et al.*, 1998; Kalavathi *et al.*, 2000)

4.11 1000 seed weight and 1000 kernel weight:

Both seed weight and kernel weight reflects the extent of seed developed occurred during seed production.

Table 8. Effect of spray application of different doses of GA_3 and boric acid on number of spikelets per panicle and number of developed seeds per panicle in rice female parental line IR 58025A (mean of three replications)

a) Number of spikelets per panicle **b) Number of developed seeds per panicle**

Treatment	Planting ratio			Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	120.2	118.3	**119.25**	24.6	23.5	**24.05**
GA_3 50 g/ha	117.2	117.5	**117.35**	28.8	26.0	**27.40**
GA_3 75 g/ha	118.3	120.6	**119.45**	29.2	27.1	**28.15**
GA_3 100 g/ha	120.2	118.2	**119.20**	30.1	28.2	**29.15**
GA_3 125 g/ha	116.2	120.6	**118.40**	30.1	28.8	**29.45**
Boric acid 1%	119.5	117.2	**118.35**	25.7	24.2	**24.95**
Mean	**118.60**	**118.73**		**28.08**	**26.30**	
	P	T	P x T	P	T	P x T
S.Em.(±)	0.6	1.0	1.4	0.08	0.15	0.21
C.D.$_{(0.05)}$	NS	NS	NS	0.18	0.30	0.43

P – Planting ratio
T – Treatment

In the present study the mean 1000-seed weight in the control was 21.84 gram and the mean 1000 kernel weight was 17.46 g (Tables 9a, 9b). The planting ratio and spray application of chemicals did not produce any significant effect on seed weight and kernel weight. The present findings confirmed the reports of previous workers. (Jagadeeswari *et al.*, 1998).

4.12 Seed yield per hill and seed yield per hectare:

Seed yield is of prime importance in any study pertaining to seed production.

In the present study, the mean seed yield per hill in the control was 5.25 g under 2:6 planting ratio and 5.03 g under 2:8 planting ratio (Table 10a, Fig. 5). The reason for lower yield per hill under 2:8 planting ratio than 2:6 planting ratio may be assigned to less chance of distant rows of female line to get adequate pollen for out crossing. Higher seed yield per plant due to higher ratio of male:female has been reported in previous studies (Peijin, 1994). However, the seed yield per hectare was significantly higher under 2:8 planting ratio. (1408 kg) than that under 2:6 ratio (1366kg). This was possible due to higher population of female parental line per hectare.

Spray application of chemicals increased seed yield per plant as well as per hectare. In the control the mean seed yield was 1387 kg per hectare (Table 10b, Fig. 6). With spray application of GA_3 50g/ha, 75g/ha, 100g/ha and 125g/ha, the seed yield values per hectare were 1606 kg, 1733 kg, 1821 kg and 1831 kg, respectively (Table 10b). Spray application of boric acid (1%) resulted in marginal increase in seed yield (1431 kg/ha). Such increase in seed yield was brought about by increase in number of productive tillers and higher percentage of developed seeds in the panicle. A good number of research reports have indicated increase in seed yield due to spray application of GA_3 and boric acid (Jagadeeswari *et al.*, 1998; Morzhong and Zaman, 1999; Kalavathi *et al.*, 2000; Jarugula *et al.*, 2002; Sharma, *et al.*, 2003).

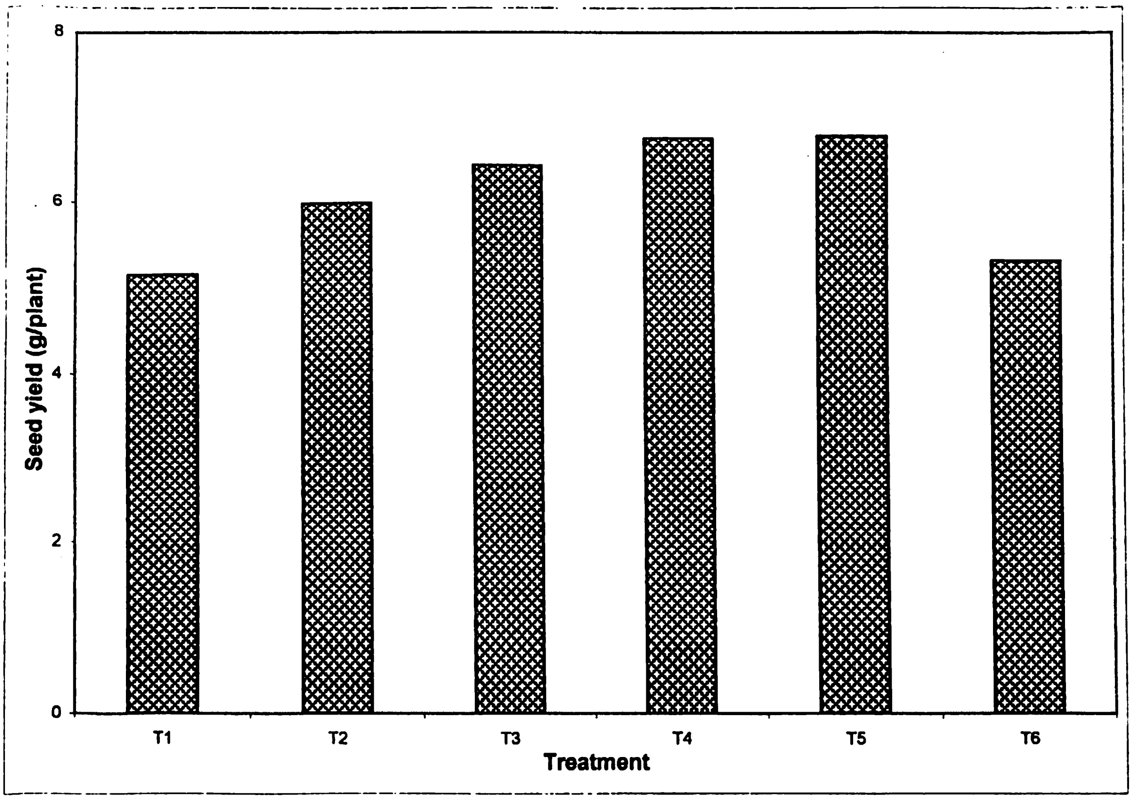


Fig. 5. Effect of different concentrations of GA3 and Boric acid on seed yield per hill in rice hybrid KRH-2

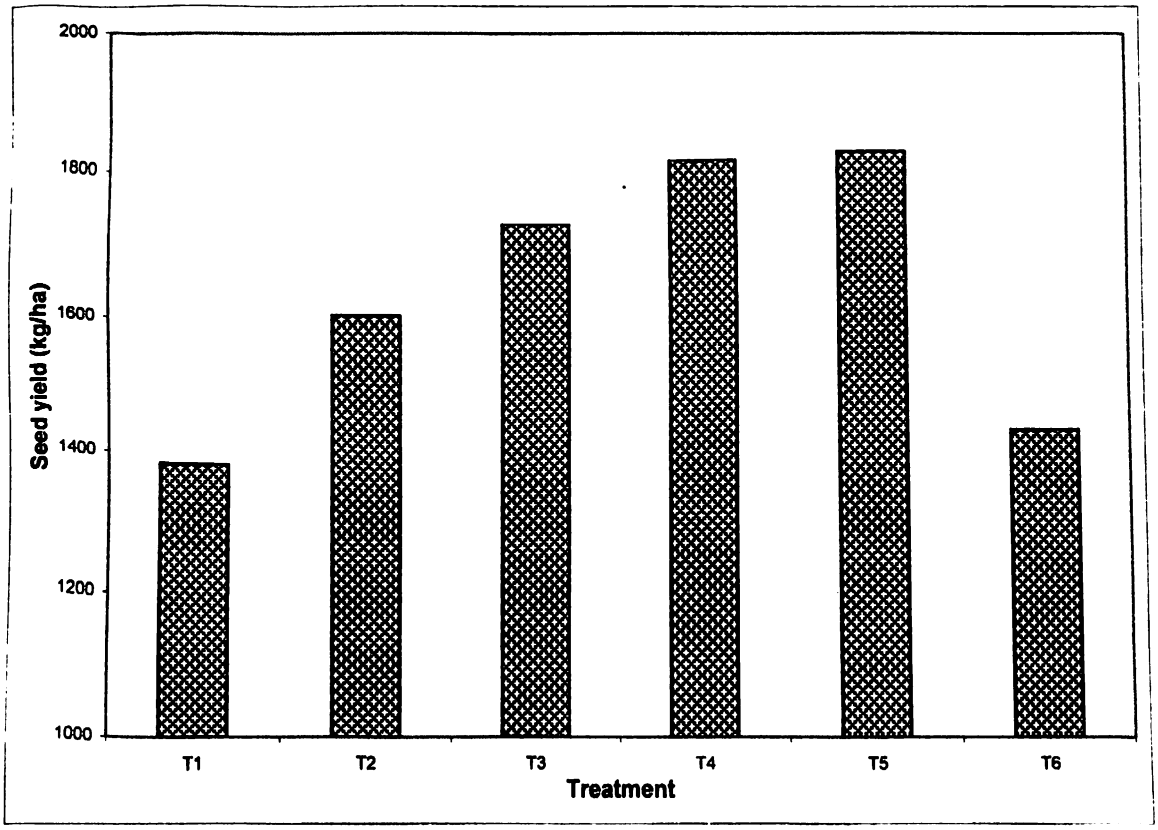


Fig. 6. Effect of different concentrations of GA3 and Boric acid on seed yield per hectare in rice hybrid KRH-2

Table 9. Effect of spray application of different doses of GA_3 and boric acid on 1000-seed weight (g) and 1000-kernel weight (g) obtained from rice female parental line IR 58025A (mean of three replications)

Treatment	a) 1000-seed weight: Planting ratio			b) 1000-kernel weight: Planting ratio		
	2:6	**2:8**	**Mean**	**2:6**	**2:8**	**Mean**
Control	21.79	21.88	**21.83**	17.28	17.65	**17.46**
GA_3 50 g/ha	21.82	21.76	**21.79**	17.46	17.33	**17.40**
GA_3 75 g/ha	22.02	21.82	**21.92**	17.51	17.32	**17.41**
GA_3 100 g/ha	21.73	22.12	**21.92**	17.27	17.54	**17.41**
GA_3 125 g/ha	22.01	21.82	**21.91**	17.43	17.38	**17.41**
Boric acid 1%	21.83	21.92	**21.87**	17.72	17.37	**17.55**
Mean	**21.87**	**21.89**		**17.44**	**17.43**	
	P	**T**	**P x T**	**P**	**T**	**P x T**
S.Em.(±)	**0.122**	**0.212**	**0.300**	**0.063**	**0.109**	**0.154**
$C.D._{(0.05)}$	**NS**	**NS**	**NS**	**NS**	**NS**	**0.320**

P – Planting ratio
T – Treatment

Table 10. Effect of spray application of different doses of GA_3 and boric acid on yield per hill (g) and yield per hectare (kg) obtained from rice female parental line IR 58025A (mean of three replications)

Treatment	a) Yield per hill: Planting ratio			b) Yield per hectare: Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	5.25	5.03	**5.14**	1366	1408	**1387**
GA_3 50 g/ha	6.15	5.76	**5.96**	1599	1613	**1606**
GA_3 75 g/ha	6.61	6.24	**6.43**	1719	1747	**1733**
GA_3 100 g/ha	6.96	6.54	**6.75**	1811	1830	**1821**
GA_3 125 g/ha	6.98	6.59	**6.79**	1814	1847	**1831**
Boric acid 1%	5.44	5.16	**5.30**	1416	1445	**1431**
Mean	**6.23**	**5.89**		**1621**	**1648**	
	P	T	P x T	P	T	P x T
S.Em.(±)	**0.074**	**0.128**	**0.182**	**6.8**	**11.9**	**16.8**
$C.D._{(0.05)}$	**0.154**	**0.265**	NS	**14.2**	**24.6**	NS

P – Planting ratio
T – Treatment

4.13 Evaluation of sowing quality of seeds

In order to assess the sowing quality of seeds of rice hybrid KRH-2 produced through different treatments, germination test was conducted and early seedling growth was studied. Results of the germination test revealed that all the seed lots produced with or without treatment possessed high germination potentiality. The germination values ranged between 92% and 94% (Table 11b). The spray application of either GA_3 or boric acid to the seed crop did not alter the germinability of seeds. However, the first count values, which indirectly indicated the vigour level of seed lots, showed little depression of vigour of seeds produces through application of boric acid (1%). The mean first count of values of seeds produced through application of boric acid was 77%, while all other seed lots possessed values ranging from 82% to 84% (Table 11a, Fig. 7).

Early seedling growth was studied by measuring length and dry weight of both shoot and root of all the normal seedlings obtained on the days of final count of germination test. Average shoot length of germinated seeds produced without treatment was 14.2 cm (Table 12a). The seeds harvested from plants receiving GA_3 treatment produced marginally longer shoot (14.3 to 14.6 cm). Such seeds also produced slightly longer roots (Table 12b).

Average dry weight of shoot measured after germination of different seed lots varied from 4.9 mg to 5.3 mg (Table 13a). The treatment effect was not significant. Similarly average dry weight of roots of germinated seeds, produced through different treatments ranged between 1.1 mg to 1.3 mg. (Table 13b).

Seed vigour index values of seeds produced with and without treatment did not reveal any remarkable difference. The mean values ranged from 2383 to 2473 (Table 14a, Fig. 8). However, relatively low vigour seeds were produced due to spray application of boric acid as revealed from experimental data.

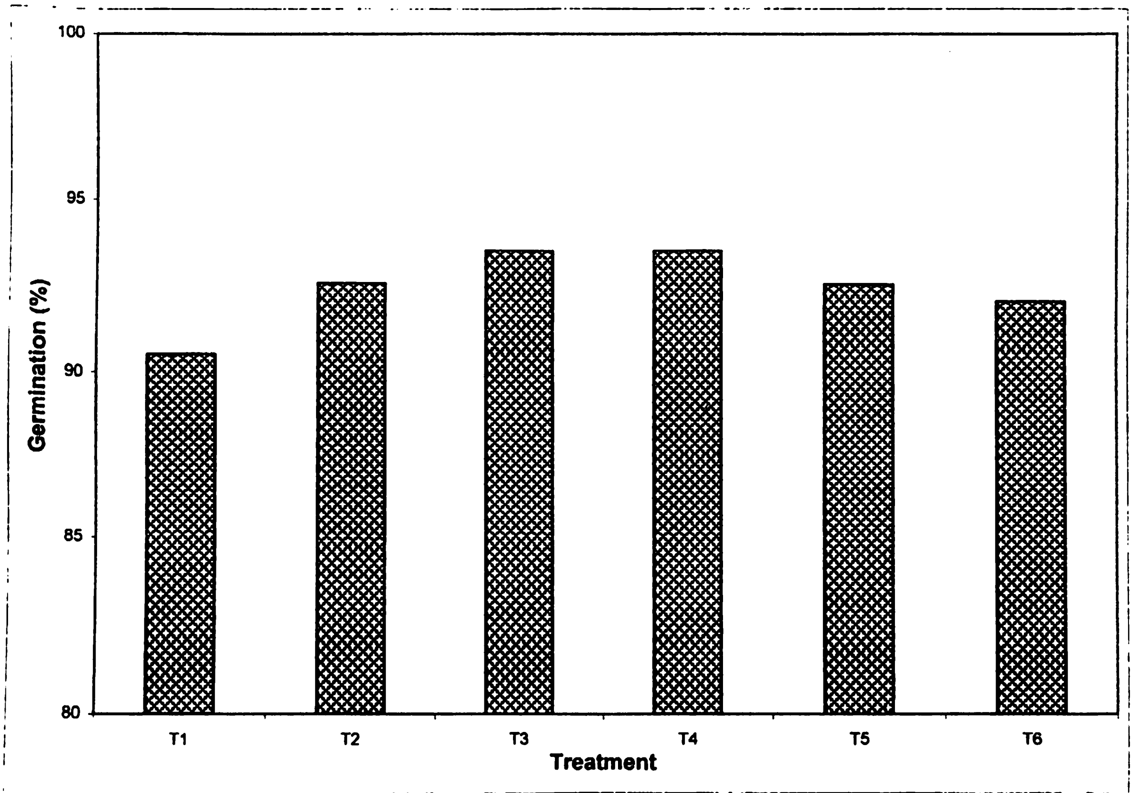


Fig. 7. Germination (%) of seeds of rice hybrid KRH-2 produced through application of different doses of GA_3 and Boric acid

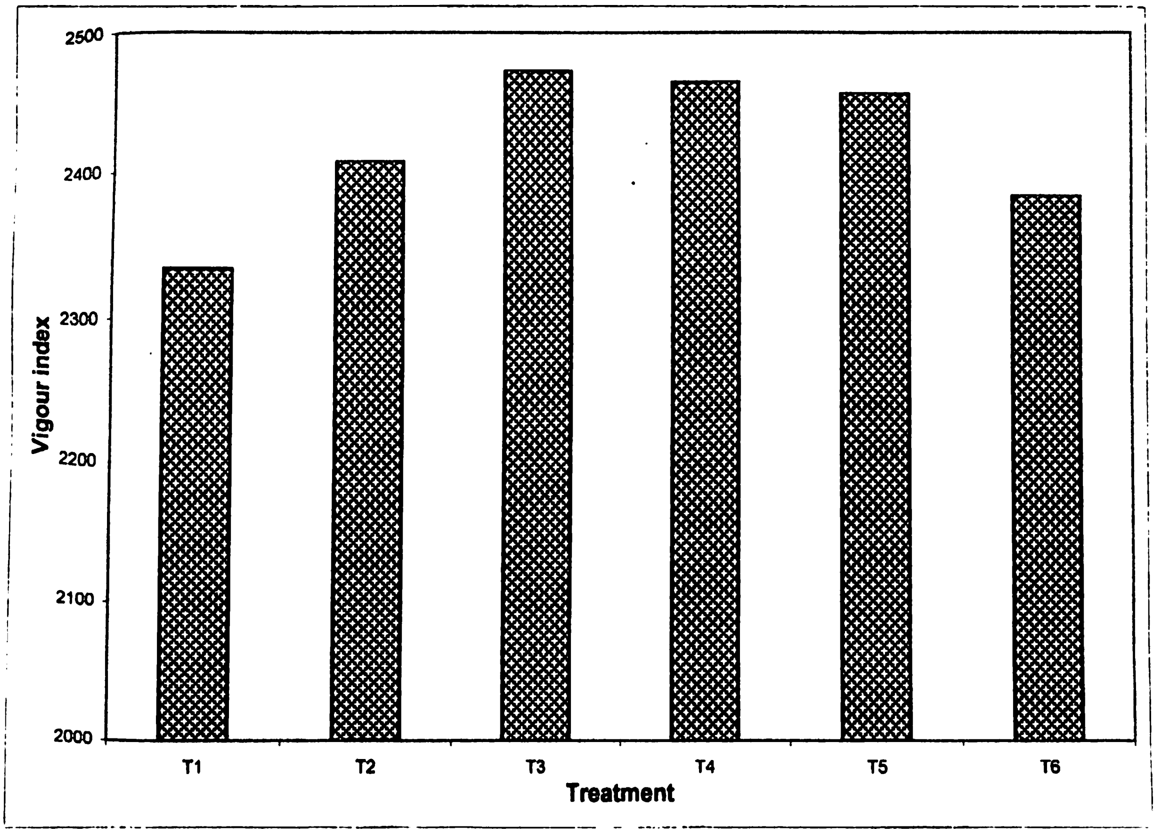


Fig. 8. Vigour index of seeds of rice hybrid KRH-2 produced through application of different doses of GA_3 and Boric acid

Table 11. First count and final count germination values (%) of hybrid rice seeds (KRH 2) produced through spray application of different doses of GA_3 and boric acid in female parental line IR 58025A (mean of three replications)

Treatment	a) First count: Planting ratio			b) Final count: Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	84.0	82.0	**83.00**	93.0	93.0	**93.00**
GA_3 50 g/ha	83.0	80.0	**81.50**	92.0	93.0	**92.50**
GA_3 75 g/ha	81.0	83.0	**82.00**	94.0	93.0	**93.50**
GA_3 100 g/ha	83.0	83.0	**83.00**	93.0	94.0	**93.50**
GA_3 125 g/ha	82.0	85.0	**83.50**	92.0	93.0	**92.50**
Boric acid 1%	76.0	78.0	**77.00**	92.0	92.0	**92.00**
Mean	**81.50**	**81.83**		**92.66**	**93.00**	
	P	**T**	**P x T**	**P**	**T**	**P x T**
S.Em.(±)	**0.7**	**1.3**	**1.8**	**0.5**	**0.9**	**1.2**
C.D.$_{(0.05)}$	**NS**	**2.6**	**NS**	**NS**	**1.8**	**NS**

P – Planting ratio
T – Treatment

Table 12. **Shoot length (cm) and root length (cm) of germinated hybrid rice seeds (KRH 2) produced through spray application of different doses of GA_3 and boric acid in female parental line IR 58025A (mean of three replications)**

Treatment	a) Shoot length – Planting ratio			b) Root length – Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	14.2	13.9	**14.05**	11.8	11.9	**11.85**
GA_3 50 g/ha	14.2	14.3	**14.25**	11.7	11.9	**11.80**
GA_3 75 g/ha	14.4	14.4	**14.40**	12.0	12.1	**12.05**
GA_3 100 g/ha	14.3	14.4	**14.35**	12.1	11.9	**12.00**
GA_3 125 g/ha	14.5	14.6	**14.55**	11.9	12.1	**12.00**
Boric acid 1%	14.1	14.0	**14.05**	11.8	11.9	**11.85**
Mean	**14.28**	**14.26**		**11.88**	**11.96**	
	P	**T**	**P x T**	**P**	**T**	**P x T**
S.Em.(±)	**0.08**	**0.14**	**0.20**	**0.09**	**0.10**	**0.23**
C.D.$_{(0.05)}$	**NS**	**0.30**	**NS**	**NS**	**NS**	**NS**

P – Planting ratio
T – Treatment

Table 13. **Shoot dry weight (mg) and root dry weight (mg) of germinated hybrid rice seeds (KRH 2) produced through spray application of different doses of GA_3 and boric acid in female parental line IR 58025A (mean of three replications)**

Treatment	a) Shoot dry weight: Planting ratio			b) Root dry weight: Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	5.1	4.9	**5.00**	1.1	1.2	**1.15**
GA_3 50 g/ha	4.9	4.9	**4.90**	1.2	1.3	**1.25**
GA_3 75 g/ha	5.1	5.2	**5.15**	1.2	1.2	**1.20**
GA_3 100 g/ha	5.3	5.0	**5.20**	1.2	1.3	**1.25**
GA_3 125 g/ha	5.2	5.3	**5.25**	1.3	1.2	**1.25**
Boric acid 1%	5.0	5.0	**5.00**	1.1	1.2	**1.15**
Mean	**5.10**	**5.05**		**1.18**	**1.23**	
	P	T	P x T	P	T	P x T
S.Em.(±)	0.06	0.10	0.15	0.02	0.04	0.06
$C.D._{(0.05)}$	NS	0.22	NS	NS	0.09	NS

P – Planting ratio
T – Treatment

Table 14. Vigour index and field emergence (%) of hybrid rice seeds (KRH 2) produced through spray application of different doses of GA_3 and boric acid in female parental line IR 58025A (mean of three replications)

Treatment	a) Vigour index: Planting ratio			b) Field emergence: Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	2422	2447	**2435**	90.0	90.0	**90.0**
GA_3 50 g/ha	2383	2436	**2410**	90.0	90.0	**90.0**
GA_3 75 g/ha	2482	2464	**2473**	91.0	91.0	**91.0**
GA_3 100 g/ha	2456	2475	**2465**	90.0	91.0	**90.5**
GA_3 125 g/ha	2429	2483	**2456**	90.0	90.0	**90.0**
Boric acid 1%	2383	2383	**2383**	89.0	88.0	**88.5**
Mean	**2426**	**2448**		**90.0**	**90.0**	
	P	T	P x T	P	T	P x T
S.Em.(±)	14.5	25.1	35.4	0.7	1.2	1.6
$C.D._{(0.05)}$	NS	52	NS	NS	2.4	NS

P – Planting ratio
T – Treatment

It is noteworthy that, all the seed lots produced with and without treatment exhibited field emergence values around 90% (Table 14b). Hence, the seeds produced through GA_3 treatment preserved the germinability and vigour, while the vigour index of seeds produced through boric acid treatment was slightly lower. On the contrary, Jagadeeswari *et al.* (1998) reported that the seeds produced through GA_3 treatment showed much lower vigour as compared to seeds produced without application of growth hormone. The present finding did not confirm the report of the above workers.

4.14 Evaluation of storability of seeds

The storability of all the seed lot produced with and without treatment was studied by exposing the seeds to accelerated ageing. It has been suggested that accelerated ageing caused by exposing the seeds to an unfavourable hot and moist atmosphere is representative of natural ageing (Heydecker, 1972).

Results of the germination test of seed lots receiving accelerated ageing treatment revealed that all the seed lots behave almost in a similar fashion except the seeds produced through application of boric acid. The values of all other seed lots ranged between 65% and 67%, while that produced through boric acid treatment showed 56% germinability (Table 15a, Fig. 9). The seed vigour index values also showed similar trend (Table 15b, Fig 10). Hence, the hybrid seeds produced through GA_3 treatment possessed similar storability as observed in seeds produced without treatment. Seed produced though boric acid treatment was observed to be relatively poor storer.

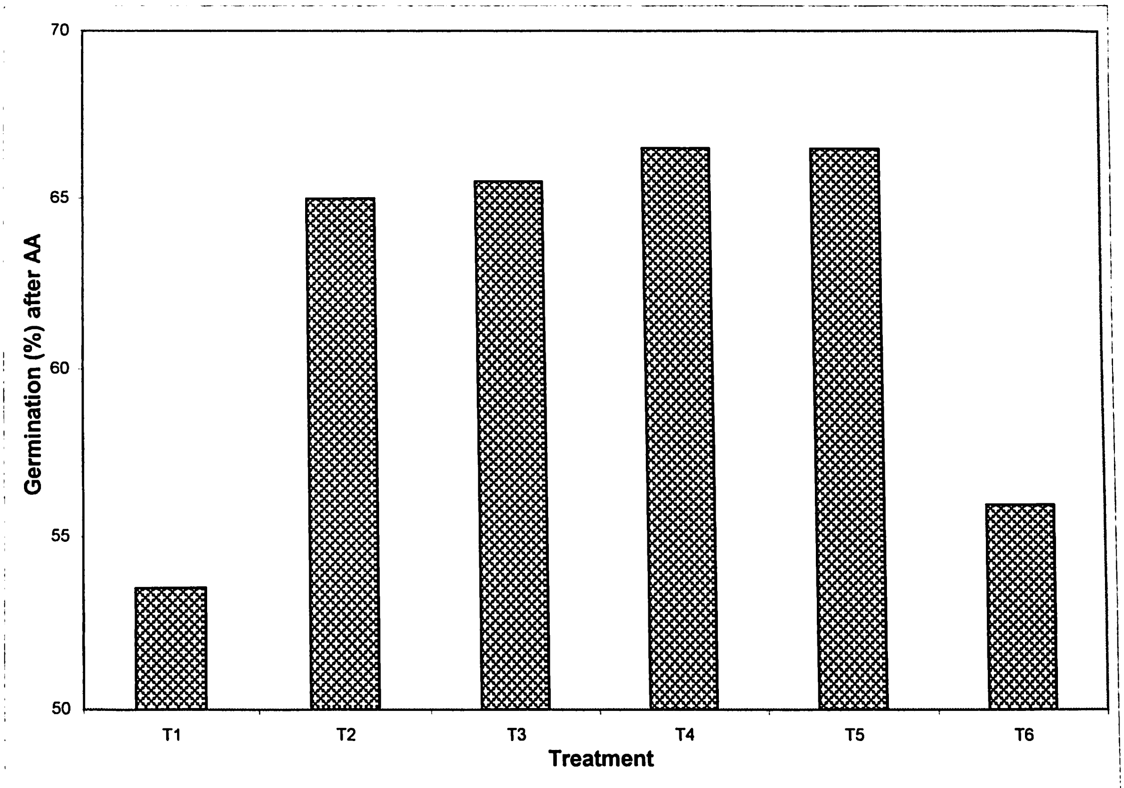


Fig. 9. Germination (%) after accelerated ageing of seeds of rice hybrid KRH-2 produced through application of different doses of GA_3 and Boric acid

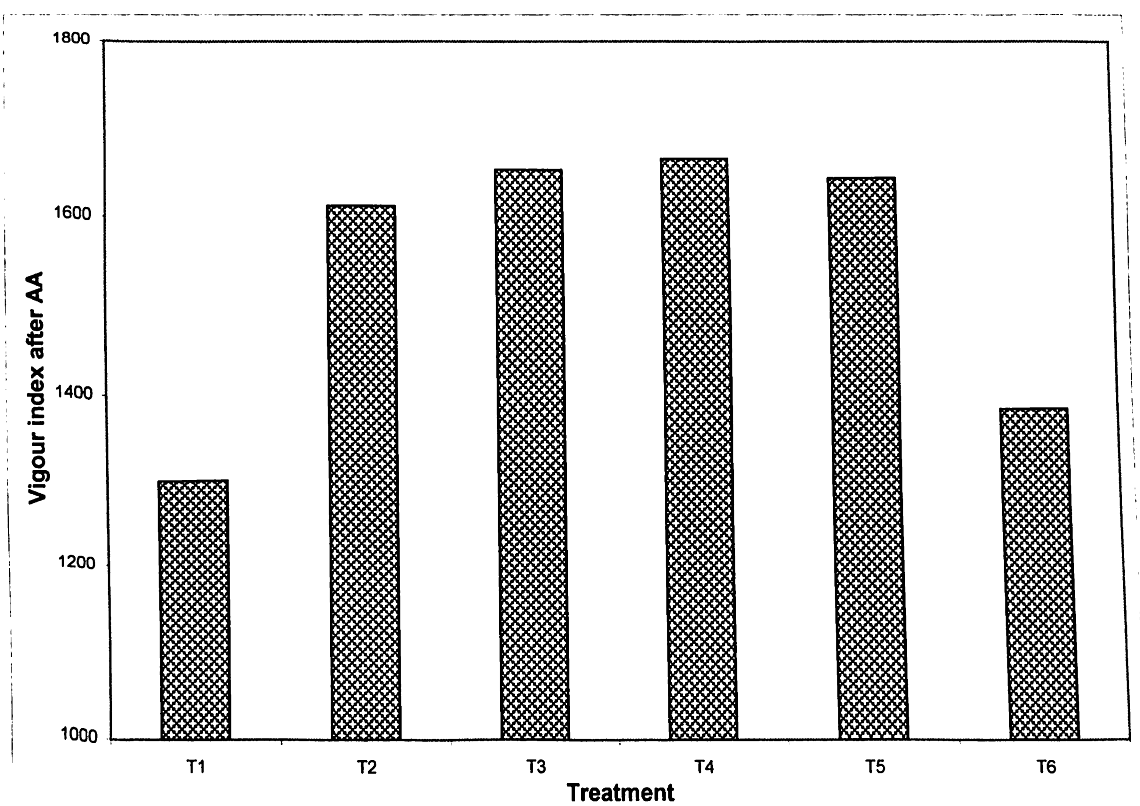


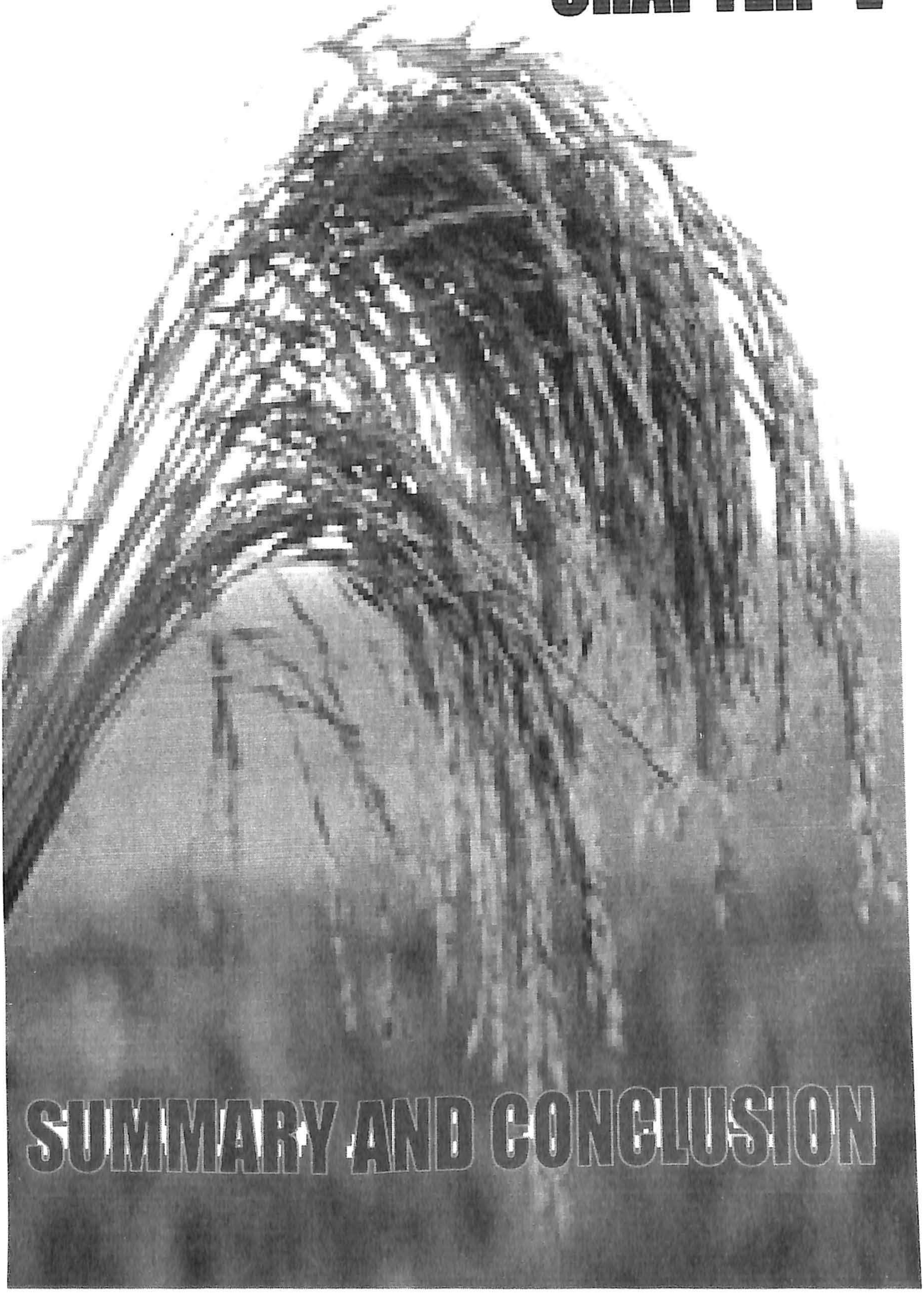
Fig. 10. Vigour index after accelerated ageing of seeds of rice hybrid KRH-2 produced through application of different doses of GA_3 and Boric acid

Table 15. Germination (%) and vigour index after accelerated ageing of hybrid rice seeds (KRH 2) produced through spray application of different doses of GA_3 and boric acid in female parental line IR 58025A (mean of three replications)

Treatment	a) Germination after AA: Planting ratio			b) Vigour index after AA: Planting ratio		
	2:6	2:8	Mean	2:6	2:8	Mean
Control	65.0	67.0	**66.00**	1627	1631	**1629**
GA_3 50 g/ha	64.0	66.0	**65.00**	1594	1630	**1612**
GA_3 75 g/ha	64.0	67.0	**65.50**	1619	1688	**1654**
GA_3 100 g/ha	68.0	65.0	**66.50**	1706	1625	**1666**
GA_3 125 g/ha	66.0	67.0	**66.50**	1604	1681	**1643**
Boric acid 1%	55.0	57.0	**56.00**	1358	1385	**1372**
Mean	**63.66**	**64.83**		**1585**	**1607**	
	P	**T**	**P x T**	**P**	**T**	**P x T**
S.Em.(±)	**0.7**	**1.2**	**1.7**	**12.5**	**21.6**	**30.6**
$C.D._{(0.05)}$	**NS**	**2.5**	**NS**	**25.9**	**44.8**	**63.4**

P – Planting ratio
T – Treatment

CHAPTER -V



SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

An investigation was conducted on seed production of rice hybrid KRH-2 in the Central Research Station, Orissa University of Agriculture and Technology, Bhubaneswar during *Kharif* 2003. The male parental line and the female parental line were KMR-3R and IR 58025A, respectively and they were planted in the ratio of 2:6 and 2:8. The female parental line received spray application of GA_3 @ of 50g/ha, 75g/ha, 100g/ha and 125g/ha and boric acid at the concentration of 1%. During the course of investigation, the effects of spray application chemicals on growth behaviour, and seed yield in female parental line were studied.

Plant height of female parental line increased progressively with the increase of dose of GA_3. Maximum increase in plant height (10.6 cm) was observed with application of 125g GA_3/ha. Boric acid (1%) also increased plant height but to a lesser extent (4.3cm).

The total number of tillers per hill varied from 14.8 to 15.6. There was no significant variation in total number of tillers due to spray application of chemicals and planting ratio. However, the number of effective tillers increased due to spray application of chemicals and the mean value ranged between 9.70 to 10.55.

The female parental line took 71-72 days after sowing to come to 50% flowering with or without treatment. The flowering period was observed to be 7-8 days.

The mean panicle length was 22.82 cm in the control. Spray application of GA_3 increased panicle length and maximum increase in panicle length was observed at a dose of 125g/ha.

In the control, the average panicle exsertion values were 72.36% and 73.00% under 2:6 and 2:8 planting ratio, respectively. Spray application of GA_3 and boric acid increased the panicle exertion values, which ranged between 73.52% to 85.52%.

The observed stigma and style length in the control were 1.15 mm and 1.20 mm, respectively. Spray application of GA_3 increased stigma and style length. Maximum length of style (1.32 mm) was recorded due to spray application of GA_3 @125 g/ha.

In the control, the spikelet opening angle was about 20.0^0. However, spray application of chemicals increased the value of the angle by 1^0 to 6.25^0.

Spikelet opening period was 118 minutes in the control spray application of chemicals increased the period by 9 minutes to 20 minutes. The minimum increase was observed under boric acid treatment.

The mean number of spikelets per panicle varied within a short range of 117.35 to 119.45. The planting ratio and spray application of chemicals did not produce any effect. The number of developed seeds per panicle increased due to application of GA_3 and boric acid. Maximum number of developed seeds (29.45) was observed due to spray application of 125 g GA_3/ha.

In the control, the mean seed weight and the mean kernel weight were 21.84g and 17.46g respectively. Spray application of chemicals did not produce any significant effect.

In the present study, the mean seed yield per hill in the control were 5.25 g and 5.03 g, under 2:6 and 2:8 planting ratio, respectively. Spray application of chemicals increased seed yield significantly. The computed seed yield in the control was 1387 kg/ha. With spray application of 50g GA_3/ha, 75 g GA_3/ha, 100g GA_3/ha, 125g GA_3/ha and boric cid (1%), the seed yield were 1606 kg, 1733 kg, 1821 kg and 1831 kg per hectare, respectively.

The germination values of seeds of rice hybrid KRH-2 produced with or without chemical application ranged between 92% to 94%. The mean seed vigour index values ranged from 2383 to 2473.

Examination of germination, early seeding growth and vigour index data revealed that seed quality was not altered due to application of GA_3. However, seeds produced through application of boric acid possessed relatively lower vigour.

Accelerated ageing treatment indicated the storability of seeds of rice hybrid KRH-2. Seeds produced through GA_3 application possessed better storability than those produced through application of boric acid.

The necessity of standardization of seed production technology in hybrid rice under coastal agro-climatic condition has been felt to make available sufficient quantity of seeds for expansion of area under hybrid rice. The research data generated from the present investigation would help to increase seed yield of hybrid rice per hectare. The results of the study revealed that application of GA_3 from 50 g/ha to 125 g/ha to female parental line IR 58025A could increase seed yield of rice hybrid KRH-2. The yield advantage per hectare due to spray application of GA_3 @ 50 g/ha, 75 g/ha, 100 g/ha and 125 g/ha were 219 kg, 346 kg, 434 kg, 444 kg, respectively. Hence, such a seed production technology can successfully be used to get higher seed yield of hybrid rice. The seeds produced through application of GA_3 also preserved the sowing quality as well as storability. Boric acid application was found to be less efficient.

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