

Ideal Hybrid Rice Seed Production Package: An Overview

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ABSTRACT

Rice is the staple food providing about 35-59% of the total calorie intake of people in South and Southeast Asia. The demand for rice would be 800 million t by 2020. This means that we have to produce about 350 million t more rice by 2020 than what we are producing today to feed the ever increasing population. By 2030 the world must produce 60% more rice than it produced in 1995 to meet demands created by increasing populations and rising incomes. This production increase must be achieved on less land, with less labour, less water, and less pesticides, and must be sustainable. Experience in China, India, and Vietnam have established that hybrid rice offers an economically viable option to increase varietal yields beyond the level of semi dwarf rice varieties. Several other countries are currently exploring the prospects of hybrid rice. Availability of adequately trained human resources is an essential prerequisite for developing an effective national hybrid rice breeding program. More than 50% of the total rice area in China is planted to hybrid rice, and many countries outside China are developing and exploiting hybrid rice technology. Hybrid technology which has made wonder's in rice production in China, is expected to give similar dividends in India in case the adequate quantity of quality seed of hybrid rice is made available at reasonable price to the farmers. This will be possible when ambitious programme on seed production is launched involving farmers and public and private sectors in a mission mode manner. The technology of Hybrid Seed Production in rice is quite different from that of maize, sorghum and pearl millet. Rice being self-pollinated, the cytoplasmic male sterility (CMS) is used in Hybrid seed production. In order to make the farmers, seed production organization and scientists aware of seed production of hybrid rice, this paper on Hybrid Rice Seed Production Package has been written based on the experiences at Farmers' Field as well as at Research Farm.

Key words: Hybrid Rice; Seed Production Package; CMS Lines; Restorer Lines;

By 2030 the world must produce 60% more rice than it produced in 1995 to meet demands created by increasing populations and rising incomes. This production increase must be achieved on less land, with less labour, less water, and less pesticides, and must be sustainable. Experience in China, India, and Vietnam have established that hybrid rice offers an economically viable option to increase varietal yields beyond the level of semi dwarf rice varieties. Several other countries such as Bangladesh, Brazil, Colombia, Egypt, Democratic People's Republic of Korea, Japan, Malaysia, Myanmar, Pakistan, Philippines, Republic of Korea, Sri Lanka, Thailand and USA are currently exploring the prospects of hybrid rice. Availability of adequately trained human resources is an essential prerequisite for developing an effective national hybrid rice breeding program. Hybrid rice is the commercial rice

crop grown from F1 seeds of a cross between two genetically dissimilar parents. Hybrid rice breeding uses several concepts, skills, and procedures which are strikingly different from those used for inbreds rice breeding. These must be learned by plant breeders before initiating a comprehensive hybrid rice breeding program. Heterosis breeding, which exploits the phenomenon of hybrid vigor, has proven to be a practical method of crop improvement, especially for increasing yield potential in many crops. This phenomenon has been exploited primarily in several cross and often cross-pollinated crops such as maize, pearl millet, onion, sorghum, cotton, etc. but its application is also being extended to several self-pollinated crops including rice. In the past, adoption of hybrid technology in rice was considered impractical because of the strict self-pollinating nature of the crop and skepticism about the

practical feasibility nature of the crop and skepticism about the practical feasibility of producing hybrid seed on a commercial scale. Fortunately, rice breeders have overcome these hurdles by developing a usable system of cytoplasmic-genetic male sterility and packages for efficient and economic seed production. The success of hybrid rice technology primarily depends on genetic purity, timely availability and the affordability of hybrid seed costs to the farmers. The production of pure hybrid seed at affordable price in rice a self-pollinated crop, is a highly skill oriented activity. A good hybrid may not reach a large number of farmers, unless it is feasible to commercially produce the seed on large scale economically. In this paper an Ideal Seed Production aspects particularly in Northern India has been discussed. More than 50% of the total rice area in China is planted to hybrid rice, and many countries outside China are developing and exploiting hybrid rice technology.

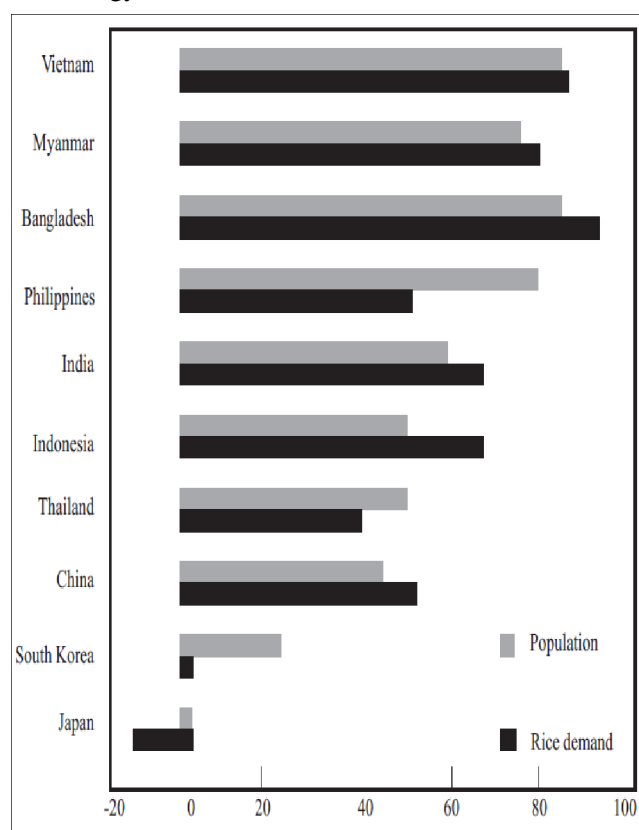


Fig. 1 Projection of population growth and demand for rice, 1990-2025.

METHODOLOGY

In this paper an Ideal Seed Production aspects particularly in Northern India conditions based on the information of agriculture research farm as well as at

farmers' field have been discussed.

RESULTS AND DISCUSSION

To make the India self sufficient in rice, it is needed to improve the productivity to a greater extent. The task is quite challenging and the options available are very limited. Among the various possible genetic approaches to achieve this target, hybrid rice technology is the most feasible and readily adaptable one. Efforts to develop and use this technology in India, though initiated in 1970's, have been systematized and intensified since December 1989, with launching of a mission oriented project. Within a short span of seven years, half a dozen hybrids each from public and private sectors are made available for commercial cultivation. Some more promising hybrids with better grain quality, resistance to some of the major pests and diseases and higher magnitude of heterosis are in final stages of evaluation. Hybrid seed production technology has been developed and demonstrated on large scale and an average seed yield of 1.0 -1.5 t/ha is being obtained on large scale.

Hybrid rice is the commercial rice crop grown from F1 seeds of a cross between two genetically dissimilar parents. Good rice hybrids have the potential of yielding 15-20% more than the best inbred variety grown under similar conditions. To exploit the benefits of hybrid rice, farmers have to buy fresh seeds every cropping season. Hybrid rice has helped China to increase rice production nearly by 200 million tons from 1976-1991. Hybrid rice has yield advantage of more than 30% over conventional varieties. The area under hybrid rice is 65% of total rice area in China and the contribution in total production of hybrid rice was over 75% of the total rice output. Although research on the commercial utilization of heterosis in rice has made tremendous gain during the last 20 years, it is from a strategic point of view, that the high yield potential of hybrid rice has not been fully tapped yet, in India.

Conventional Hybrid Rice Seed Production : The successful development and use of hybrid rice technology in china during 1970's led the way for development and release of rice hybrid varieties elsewhere. India has made good progress in this regard and about 45 hybrids have been released by national programme and it is expected that these hybrid varieties of rice shall make an impact on rice productivity of country.

Methods of Hybrid-seed production: Hybrid-rice can be produced in the following ways

Three-line System: The hybrid seed production involves multiplication of cytoplasmic-genetic male sterile line (A line), maintainer line (B line) and a restorer line (R line); and production of F1 hybrid seed ($A \times R$)

Two-line system: The hybrid seed production involves the use of photo-period sensitive genetic male sterile systems (PSMS). Any no development of male sterile or restorer lines is required, and extensive varietal resources are available. Chemical emasculators such as male gametocide 1 (MF1) and male gametocide 2 (MG 2) were developed in China and have been successfully used in hybrid rice production. In chemical emasculation, physiological male sterility is artificially created by spraying the rice plant with chemicals to induce stamen sterility without harming the pistil. In hybrid seed production, two varieties are planted in alternate strips, and one is chemically sterilized and pollinated by the other.

Three-line System of Hybrid Seed Production: In the years to come location-specific specialized seed production technology for the released/commercial hybrids would have to be developed for obtaining maximum seed yields and ensuring good seed quality. Good crop management is necessary for raising a hybrid-rice seed production crop. Hybrid-rice production technology described below may be used as a guideline.

Choice of areas and Growing Season for Seed Production: The areas of seed production should be chosen so as to provide the best possible conditions at flowering and the pollen shedding period. The most suitable conditions are 24-28 °C day light average temperature, the relative humidity 70-80 per cent, the temperature difference between day and night 8-10 °C and good sunshine. An average day temperature of more than 30°C or less than 23°C, continuous rains, or strong wind are generally harmful to flowering, pollination and cross-fertilization. As a rule, in high temperature with low humidity or in low temperature with high humidity some glumes will not open. This lowers the seed yields. The growing of hybrid seed crop should be so adjusted that flowering takes place after the end of high temperature period, but before the start of low temperature period.

Selection of Seed Fields: The selection of prime field plots is necessary. The seed fields should be free of volunteer plants, well levelled, should have fertile soil with good physical and chemical characteristics, and well drained.

Isolation: The hybrid paddy fields should be isolated from the other paddy fields, including commercial hybrid of same variety; and same hybrid not conforming to varietal purity requirements for certification at least by 200 meters for foundation seed class (A, B & R line production) and by 100 meters for hybrid seed production ($A \times R$ Production)

Brief Cultural Practices for Nursery: Raising of vigorous seedlings is an important factor for obtaining high seed yields. The root system of vigorous seedlings are flourishing, leaf sheaths have high carbon content and all this contributes to produce green growth and tillering at the lower nodes so that more panicles and a high seed setting rate per panicle. It has been observed that tillering at the lower nodes gives more and bigger panicles which helps to achieve the goal of 100 kernels per ear. Prepare the seedling bed with basal manure. Seed at 150 kg/ha for the female parent and 110-115 kg/ha for the male parent. At present the appropriate methods for raising seedlings are either to sow under plastic film the field or in a green house.

Sowing Time: The proper sowing time is dictated by the number of days required from sowing time to panicle formation. The sowing should be so adjusted that the crop comes to panicle stage soon after the end of high temperature period.

Transplanting: Seedlings with healthy tillers are the basis for increased panicle size. For hybrid seed production, the seedlings of both parents should be standardized. Seedlings of the male parent for short duration varieties should be 20-30 days old with 5.5-7 leaves and 2-3 tillers and for long duration varieties 30-35 days old with 5.5-7 leaves and 2-3 tillers

Planting Ratio: The ratio of female and male lines is generally kept at 2:10-12; and the row spacing 10×10 cm for male parent and 20×15 cm for female parent. One seedlings are planted per hill.

Row direction: Both parents should receive good aeration and equal amounts of sunlight. Row direction should be nearly perpendicular to prevailing winds at flowering to ensure more cross-pollination.

Fertilization: Adequate fertilization is necessary. In general a seed field with moderate fertility should be treated with 200 kg N, 50kg P and 150kg K per ha; 90 per cent applied as a basal dose and 10 per cent after panicle differentiation.

Water Management: Good water management is very important for regulating water, fertilizer, air and

temperature of soil. Give shallow irrigation at the transplanting and tillering stages. In soils where water permeability is poor the field must not be allowed to remain under water for too long so that root growth could be encouraged. During the middle stages the water should be drained off properly. Shallow water must be maintained again during the booting stage. During heading, if the air temperature is above 35° C, water should be applied during the day and drained-off at night so as to decrease soil temperature. Other cultural practices are the same as described for conventional (open pollinated) varieties.

Synchronization of Flowering: Synchronizing the flowering of both parents is the key to increased yields. Technical measures such as staggering seeding dates of the male and female parents, sowing the male parents three times to extend the time pollen is available, and predicting and adjusting flowering dates may be adopted. Actual practices would have to be standardized for each hybrid and the locations selected for the hybrid seed production.

- (i) Staggered sowing of male parents: Seeding date is usually determined by leaf age, effective accumulated temperature (EAT), and growth duration. In general, the period from initial to full heading of a CMS line is 4-6 days longer than for a restorer line. The first sowing of the male parent establishes the dates for second and third sowing. The second sowing is done when the leaf emergence on the first sowing is 1:1; the third sowing when the leaf emergence is 2:1. The second sowing is the main parent. The planting ratio for sowing at different dates is 1:2:1.
- (ii) By fertilizer application. Beginning about 30 days before heading, 3 or 4 random samples of the main culm of both parents are taken every 3 days. Young panicle development is compared under magnification. During the first three stages of panicle differentiation, treat the earlier developing parent with quick releasing N fertilizer; and spray the later developing parent with potassium dihydrogen phosphate. This adjusts development differences of 4-5 days.
- (iii) By water management; during later stages of panicle differentiation, draining water from the field will delay male parent panicle development, higher standing water will speed panicle development.

Methods of Improving Seed Setting :

- (i) *Supplementary Pollination (Rope pulling)*. On calm days during anthesis, supplementary

pollination can be carried out. Panicles of the restorer lines are shaken by pulling along nylon rope (5 mm diameter) back and forth every 30 minutes until no pollen remains on the restorer line. This method is often used on even topography and regularly shaped plots. In hilly, uneven topography with small, irregular plots, a bamboo pole may be used.

- (ii) *Leaf clipping*: Leaves taller than the panicles are the main obstacles to cross pollination. Clipping leaves 1-2 days before initial heading increases the probability of pollination and out crossing rate. The blade of flag leaf is cut back ½ to 1/3 from the top.
- (iii) *GA3 Spray*. Spraying seed parent with 75 gm GA3/ha 60 ppm or more 2 or 3 times increases panicle exertion and helps increased seed setting.
- (iv) *Roguing*: The seed field should be free of rogues. Remove off-type plants in both the parents first before the onset of flowering stage and then soon after emergence of the panicle. Rogue out the plants of maintainer line, if any and the semi-sterile plants in the seed parent as often as necessary.
- (v) *Harvesting of seed crop*: Harvest male rows first to avoid chances of mechanical admixture. Seed yield 5-15 Quintals/ha.

Table: 1 Seed production package of Hybrid Rice

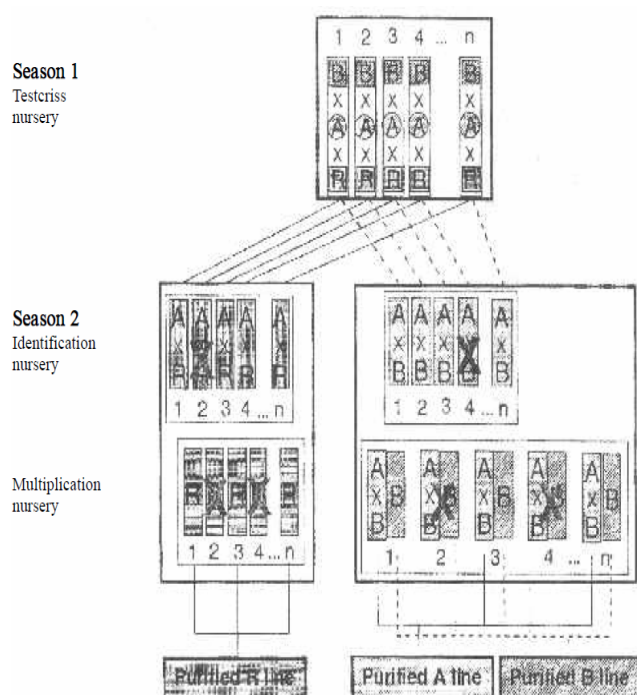
Activity	Particulars
Seed rate	See parent 15 kg/ha, Pollen parent 4kg/ha
Nursery	Sparse seeding to ensure multi-tillered (M-5) seedlings in 25 days.
Row ratio	2B : 6A, for CMS multiplication, 2R : 8A, for hybrid seed production.
Number seedlings /hill	Two seedlings/hill for seed parent, Three seedlings/hill for pollen parent.
Spacing	B/R to B/R 30 cm B/R to A 30 cm A to A 15 cm
GA 3 application	45 g/ha at 5.0% heading in two split doses on consecutive days.
Supplementary pollination	Twice a day at peak anthesis during flowering phase.
Rouging	During vegetative phase based on morphological characters and twice during and after flowering based on floral characters etc.
Seed yield	1.5-2.0 tons per ha

The availability of a genetically pure and good quality seed is a primary prerequisite for exploiting the full potential of hybrids. Lack of purity in parental lines and improper isolation conditions in seed production are the major causes of poor hybrid seed quality. Chinese scientists have reported that with every 1% decrease in purity of the hybrid seed, the eventual yield loss in the F1 hybrids would be about 100 kg/ha. The parental lines get contaminated or deteriorate during the process of handling by foundation seed growers. Therefore, it is most necessary to produce pure nucleus and breeder seed of parental lines under the strict supervision of plant breeders. Following procedure has been standardized;

Procedure for A, B, and R lines

Nucleus and breeder seed of A, B, and R lines can be produced simultaneously by following the method described below.

- Select about 50-100 typical and completely male sterile single plants of the selected CMS line (Fig. 2).



- Make 50-100 crosses of the selected CMS plants with corresponding single plants of the maintainer and restorer lines of the promising hybrids.
- Sow and plant few seeds of A x B crosses and all the seeds of A x R crosses in an identification nursery to select the best pairs that produce typical, uniform, and stable progeny.
- Plant balance seeds of A x B crosses and their

corresponding B line progeny in an isolated multiplication block, 21 days after the planting of A x B crosses in an identification nursery.

- Based on the observations made in A x B crosses grown in the first planting, mark those which lack uniformity in growth and flowering and spotted B lines are removed from the A x B multiplication block before flowering. The remaining A x B pairs are allowed to get cross-pollinated to produce the nucleus seed of the A line.
- Among the pairs of A x R crosses, identify those which exhibit poor restoration and lack of uniformity.
- Plant all the maintainer and restorer progenies of respective A x B crosses and A x R crosses in isolated plots for multiplication. Such lines whose F1 progenies failed to meet the set standards based on the observations made in the identification nursery are discarded and the remaining lines are bulked to form the nucleus seed of 'B' and 'R' lines.
- The nucleus seed of 'A' and 'B' lines are used for producing breeder seed of the A line. Plant the A and B lines in strictly isolated plots (preferably 100 m away from other rice varieties) to produce the breeder seed of A line.
- Plant the nucleus seed of B and R lines in isolated plots as per certification standards for producing the breeder seed of respective B and R lines.

Nucleus Seed

The nucleus seed produced under the direct supervision of the plant breeder has high genetic purity and is used for producing breeder seed on a large scale. The breeder seed will be distributed for producing foundation seed of parental lines, which in turn will be used for producing the hybrid seed.

Seed Production and Isolation

- Twenty five-day-old seedlings of A and R lines are planted in alternate rows of five plants each at a spacing of 20 x 20 cm (**Fig. 3**).
- Frames of 1 x 1 x 1 m are prepared either with iron or aluminium angles.
- Cubicles of 1 x 1 x 1 m are stitched with muslin cloth with a flap at the top.
- The metal frame is placed around a 1 m² area where A and R plants are planted just before flowering.
- T frame is covered with a muslin cloth bag to prevent cross pollination.

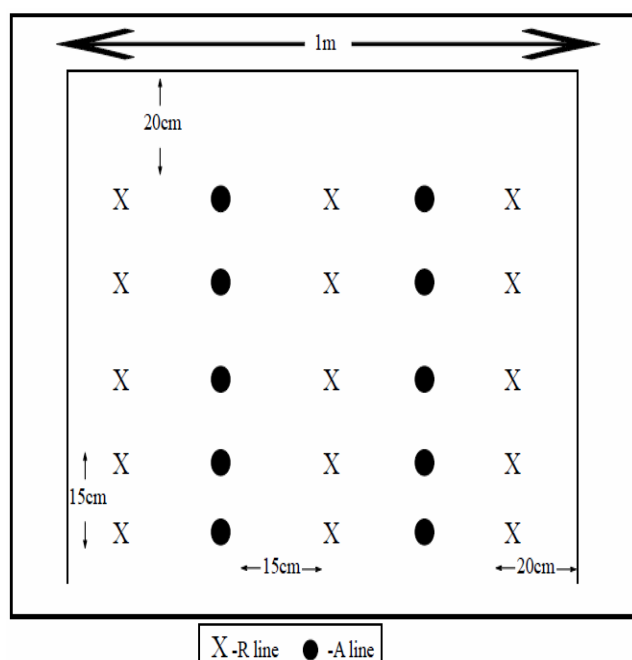


Fig. 3: Position of a (?) and R (x) line plants in a chimney.

- During the flowering period, the pollen plants are shaken to increase seed setting on A line. This can be facilitated by opening the flap.
- Restorer plants are harvested first and threshed separately. 'A' line plants are harvested and threshed later, to avoid possible mixing.

Modified Chimney Isolation Procedure

The chimney isolation method of seed production has been modified to overcome the problem of synchronization and to simplify the supplementary pollination. The basic layout is the same as that of the chimney method except the following differences:

- All the 'R' lines are sown on the same day, while the 'A' lines staggered 5-6 times with an interval of 6-7 days.
- Twenty five-day-old seedlings of 'R' lines are planted in a 1 m² area at a spacing of 15 × 15 cm in alternate rows, leaving a space for an 'A' line in between (Fig. 4).
- At the boot leaf stage of 'R' lines, 2 m high barriers are erected to cover the three sides of a 1 m plot, leaving a gap of 20 cm from the ground. The open side is covered by the barrier of the opposite plot. The space between the opposite plots is convenient for cultural operations, including supplementary pollination.
- Just before the panicle emergence of R lines, the

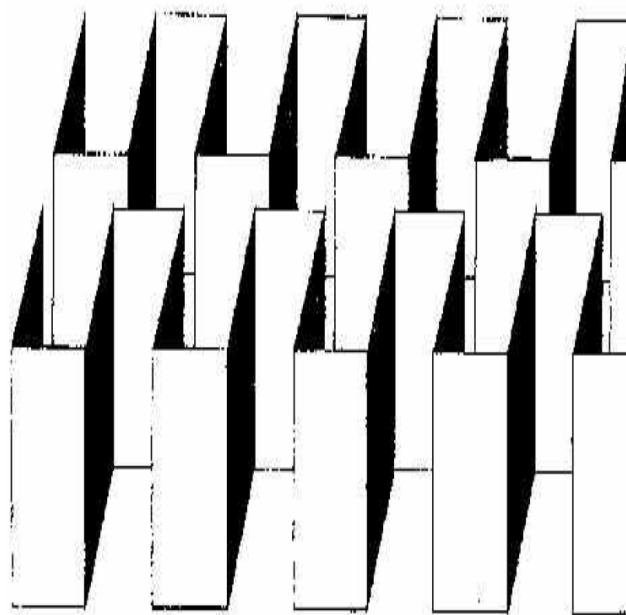


Fig. 4 Layout of a modified chimney method.

- plants of CMS lines which are in similar stage as that of the R line are removed in the morning hours and planted in the vacant spaces between the 'R' lines.
- Supplementary pollination is done by using sticks 3-4 times/day at peak anthesis during the flowering period of 7-10 days.
- About 30-35 g of hybrid seed can be obtained from each plot measuring 1 m²

Isolation Free Method

An isolation free method developed at the international Rice Research Institute has been found to be more practical and popular in tropical countries. This method is most ideal for producing small quantities of hybrid seed required for trials.

- Selected 'R' lines are grown side by side in 5 × 3 m plots. In each R line plot, four rows of 'R' line plants are planted as border rows at 20 × 20 cm spacing to provide isolation from adjoining plots. Four vacant spaces 40 cm in width are left in the middle of the plots which are interspersed by single rows of R line plants. About 68 CMS plants can be planted in these vacant spaces at the time of flowering (Fig. 5).
- Male sterile lines of experimental hybrids are staggered five times at 8-10-day intervals to ensure a continuous supply of CMS plants in the flowering stage to synchronize the flowering of R lines in different seed production plots.

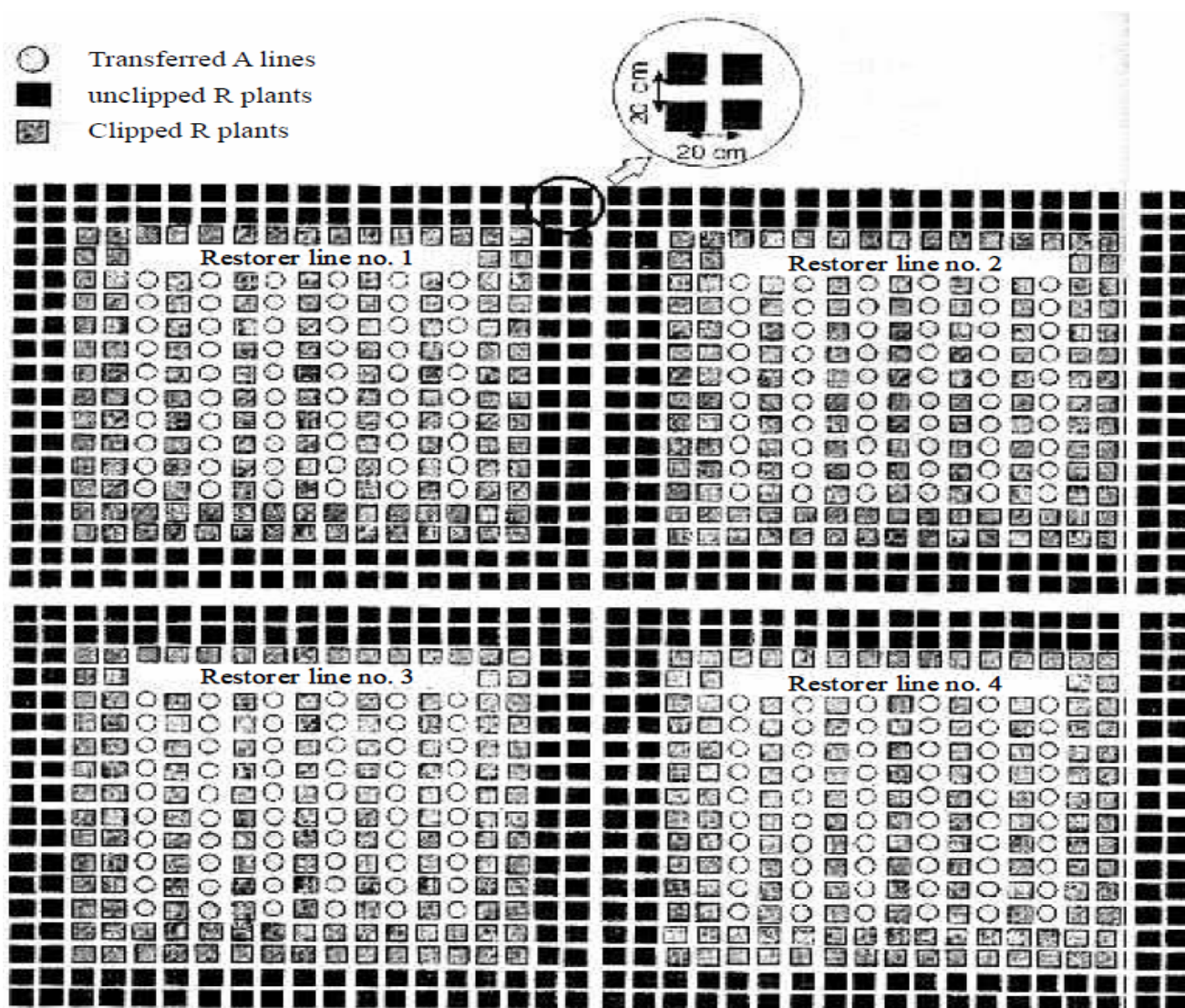


Fig. 5 Layout for isolation free system for producing seeds of experimental hybrids.

- When primary tillers of A and R lines are in the boot leaf stage, their flag leaves are clipped except for the two outermost border rows of R lines which act as a barrier for pollen from adjoining plots.
- Three to five days after leaf clipping, the A lines are uprooted (preferably in the morning, i.e., 6-8 a.m.), and are planted in the vacant spaces of plots.
- To enhance out crossing, supplementary pollination is advocated at the peak anthesis period. Care should be taken to shake only those R lines which are flanking the A lines
- R line plants are harvested first and threshed separately followed by A line plants bearing the hybrid seeds.
- By adopting this method, 3-5 g of hybrid seed can be obtained from each CMS plant. A plot with 15-40 CMS plants can yield 50-200 g hybrid seed which will be enough to conduct OYT for two seasons (20 g per season) and replicated preliminary yield trials also for two seasons (100 g per season).
- R line plants are harvested first and threshed separately followed by A line plants bearing the hybrid seeds.
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