Development of Heat Tolerant Breeding Lines and Varieties in Rice

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Rice cultivation is directly and significantly affected by climate change than other sectors of the economy. Agriculture is also a significant contributor to climate change and emission of nitrogenous oxide from rice field is one of the potent components causing global warming. Rice cultivation particularly in India is more affected by climate change and seasonal climate variability and its contribution is severe in yield reduction, crop failure and economic losses. The development of more sustainable, resilient agricultural systems could be achieved by identifying heat tolerant rice genotypes and development of new rice varieties for mitigating the yield losses under high temperature condition during summer and Kharif seasons. The chalky characteristic in rice grain is more prevalent with high temperatures that will bring quality and yield losses to rice growers. With a temperature rise of just 2 ºC is sufficient to trigger the trait, researchers have noted that a 4 ºC increase could ruin entire crop. The research focuses on identification of suitable rice genetic resources and development of heat tolerant rice varieties with high-quality grain and was carried out at Tamil Nadu Rice Research Institute, Aduthurai during 2007-08 and 2008-09. A total of 27 and 32 rice varieties from 7 countries, IRRI and WARDA were evaluated under International Rice Heat Tolerant Nursery (IRHTN, 2008 and 2009), the rice varieties *viz*., N22 and IDSA 77 were found to be high temperature tolerant. A total of 1669 F_4 breeding lines were screened for high temperature tolerance during June to September, 2009. A total of 154 breeding lines were advanced to F_5 generation and selection was carried out based on pollen sterility and spikelet sterility count (%), high-yielding potential with high grain quality above 35 ºC under field condition and 38 ºC under phytotron screening.

Key Words: Rice, Heat tolerance, Climate change, Chalky rice, Pollen sterility

Introduction

Rice is the staple food for 65% of the global population and forms the cheapest source of food, energy and protein. In India, rice is cultivated in 44 m ha by different methods under diverse environmental conditions. To meet the food demand of the growing population and to achieve food security in the country, the present production levels need to be increased by 2 million tonnes every year, which is possible through breeding rice varieties with sustainable production level against the effect of global warming. Atmospheric gases that absorb incoming energy and warm the lower atmosphere are known as greenhouse gases. About 75% of the natural greenhouse effect is due to water vapour. The next most significant greenhouse gas is carbon dioxide, followed by methane, nitrous oxide, ozone, synthetic halocarbons (such as chlorofluorocarbons and hydrofluorocarbons) and sulphur hexafluoride, all of which are influenced by human activities. Higher concentrations of greenhouse gases in the atmosphere will lead to increased trapping of infrared radiation. Scientists say the lower atmosphere is then likely to warm, changing the weather and climate.

The two greenhouse gases most linked to agricultural activity (other than CO_2 from stubble burning) are methane and nitrous oxide. The main sources of methane are cattle, rice growing and leakages in natural gas production. Nitrous oxide results from fertilizer use and other agricultural activities, such as land clearing and cultivation. With 1.1 to 6.4 ºC temperature increases in the next century rice areas of India and Pakistan may be endangered with temperature exceeding 40 ºC. Breeding rice for high temperature has received little attention however; there is ample evidence in other crops that it is possible to breed varieties (cotton, tomato, peanuts and cowpea). Due to high temperature during flowering, rice produces chalkiness. Rice that breaks or powders during milling due to a defect called chalk affects growers, millers and consumers. In domestic markets, chalk can devalue the grain by up to 25% and in international markets by up to 30% or more (Collis and Braidotti, 2009).

Materials and Methods

Heat Tolerance Screening in the Field

A total of 1669 F_4 breeding lines were received from International Rice Research Institute, Los Baños, Laguna,

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Philippines during June 2009 and those accessions were screened for high temperature tolerance under an irrigated lowland field at Tamil Nadu Rice Research Institute, Aduthurai. The genotypes were seeded and seedling establishment was done in dry beds and transplanting was done 21 days after seeding. Each accession was transplanted in a 2 m length row. Row spacing was 30 x 20 cm and one seedling per hill was used. Recommended agronomic practices were followed. Pesticides and bird nets were used to protect the plants against pests. All other crop management practices were at the optimum level. Observations were recorded on 50% heading, peak anthesis, pollen sterility (%), grain sterility (%), plant height, panicle number per plant, lodging (%), phenotypic acceptability and grain yield.

Fifty percent heading was determined when the panicles are exerted in approximately 50% of the plants in the plot. Peak anthesis was recorded at the time of flowering in three consecutive days. Observation was done from 6.00 AM to 1.00 PM. Pollen sterility/fertility was determined by taking 10 spikelets each from the main panicle of the all plants from each accession (total of 100 spikelets/accession). Spikelets were sampled from top, middle and bottom portion of the panicles. Taking one anther each from the 100 spikelets, anthers were mixed, crushed, and stained with I_2KI in a glass slide. The slides were mounted on a microscope at 10x magnification and the fertile and sterile pollen were counted at 3 microscope fields. The spikelet fertility/sterility data was obtained at harvest by counting the no. of filled and unfilled grains. The plant showing highest pollen fertility was tagged on the day of 50% flowering and its spikelet fertility per cent record was measured during harvest. A plant from each accession showing more than 90% pollen fertility and spikelet fertility was selected and advanced to F_5 generation for confirming the high temperature tolerance during flowering later. One or two or three plants from each accession were selected and advanced to F_5 generation.

A total of 27 entries were evaluated under the Third International Rice Heat Tolerance Nursery and a total of 32 entries were evaluated under the Fourth International Rice Heat Tolerance Nursery.

The plant height from 3 plants was recorded, number of panicle in 3 plants was recorded and lodging per cent was also noted during harvest. Phenotypic acceptability was measured (1=excellent, 3=good, 5=fair, 7=poor and 9=unacceptable). Grain yield was obtained from the bulk harvest of each row.

Results and Discussion

The genetic donors were evaluated in the Third and Fourth International Rice Heat Tolerance Nursery (2008 and 2009), the donors, *viz*., N22, Dular, IDSA 77, Giza 178 and Sadri were found to be high temperature tolerant during flowering (Table 1). The similar results were obtained earlier by Prasad *et al.* (2006). The time of day flowering (TDF) is the most important trait for rice high temperature tolerance, heat escape/avoidance, early flowering/short duration increase the pollen production, spikelet fertility and reduced the kernel damage.

A total of 105 families were advanced from F_4 generation to F_5 generation, those lines were showing early time of day flowering, less secondary branching in the panicle and higher pollen and spikelet fertility per cent. The higher pollen fertility and spikelet fertility was noticed despite exposure to >35 ºC during the flowering time 1564 F_4 breeding lines were rejected due to higher pollen sterility/spikelet sterility. Sterility is due to poor anther dehiscence, low pollen production, and low numbers of germinating pollen grains on the stigma. Similar results were observed by Yoshida (1981). High temperature causes high percentages of spikelet sterility in dry season crops in many tropical and subtropical countries. For example, if the temperature exceeds 35 ºC at anthesis and this state lasts for more than 1h, a high percentage of spikelet sterility occurs in a rice crops. Similar finding was noticed by Takeoka *et al*. (1991). The poor anther dehiscence was studied in the 1515 rejected lines. Anther dehiscence is due to rapid increase in pressure with swelling of pollen

Table 1. Genetic donors for high temperature tolerance (> 35 ºC)

Cultivar	Origin	Ecotype/subspecies	Time of day flowering	Fertilization (%)
N22	India	*O. indica*	9.00 – 10.00AM	96
Dular	India	*O. indica*	9.00 – 9.45 AM	97
IDSA 77	Ivory Coast	*O. glaberrima*	9.00 – 10.30 AM	94
Giza 178	Egypt	*O. glaberrima*	9.00 – 10.00 AM	90
Sadri	IRRI	Tropical japonica	9.15 – 10.30 AM	92

grains. High temperature inhibits swelling of pollen grains and reduces anther dehiscence. Similar results were obtained by Goto *et al*. (2001).

The floral abnormality in spikelets, *viz*., stamenless, more than one ovary, decrease in the number of stamens in the spikelet and extra glume was noticed in more than 1200 rejected F_4 breeding lines. Those floral abnormality as a cause of spikelet sterility has played significant role in rice yield reduction. Similar results were revealed by Takeoka *et al*. (1991), Wang and Zhu (2000), Sanchez and Khush (2000), Li Rongbai (2002) and Yamaguchi *et al*. (2004). The floral abnormality happened in the susceptible breeding lines caused severe yield reduction due to poor pollen production and sterility of the plant. The high temperature affected the floral biology of the rice plant that causes significant yield reduction. Breeding for high temperature tolerant genotypes and varieties in rice may be the solution for sustainable agriculture production in the tropical and sub-tropical regions of India in the future, where the rice production, productivity and cropping season will be significantly decreasing due to high temperature (38 to 40 ºC).

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