Stability of High-Yielding Rice Cultivars Released for Commercial Cultivation to Disease Resistance and Yield

Abstract

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Abstract

The world human population according to the United Nations prediction is expected to reach 9.4 billion by 2050. A substantial increase in yield and in crop stress resistance is therefore required, along with better use of water and fertilizer, to ensure food security and environmental protection in future decades. The twin elements of climate variability and climate change have direct effects on both food production and food security. Globally atmospheric CO_2 has increased, with accompanying changes in pest and pathogen incidence and to farming practices. Many pathogens and pests exhibit considerable capacity for generating, recombining, and selecting fit combinations of variants in key pathogenicity, fitness, and aggressiveness traits that there is little doubt that any new opportunities resulting from climate change will be exploited by them. The potential risks from epidemics of leaf blast and sheath blight have been suggested from data on rice grown under elevated CO_2 concentration. Therefore it is imperative to watch for the stability of reaction of rice varieties to pathogens and prevent yield losses.

Rice research network has made significant contributions to rice improvement in all the rice growing countries. The All-India Co-ordinated Rice Improvement Project (AICRIP) evaluate ecosystem-oriented yield nurseries in replicated trials in rainfed upland, rainfed lowland, semi-deep and deep water and irrigated rice areas. With the multi- environment tests (METs) of AICRIP, a number of varieties were released with similar yield potential but with varied maturity duration (early, medium, and late), grain size, appearance, scent and quality, and possessing resistance to one or more pathogens

and insect pests that cause damage. The annual production oriented surveys of AICRIP have shown a wide prevalence of diseases on at least some varieties under cultivation in different districts and states of India to cause yield losses. These production losses could add up to 500,000 tonnes of rice valued at Rs 2911 millions in one district.

The importance of re-evaluation of varieties under commercial cultivation was realized in all crops, more importantly in food grain crops as reports are continuously made on the level of yield losses from different cropped field, districts, states or countries. Epidemic outbreaks focus on the importance of continued vigil on pathogen and crop varieties. Seldom shift from a minor to a major status of a pathogen may occur. Plants have developed a set of mechanisms to face the challenge of foreign pathogens through a long history of co-evolution. The continuous changes in host plants, pathogens, production technology and environment are reasons for periodical re-evaluation of variety performances and adaptation. Analyses of old varieties help understand the yield potential and stability of varieties.

Typical techniques of screening for resistance in germplasm of most crop plants involve field ratings for the presence of lesions and other damage caused by pathogen. A disadvantage of this method is dependence on favorable environmental conditions or controlled facilities in a greenhouse for the pathogen development before rating can be taken. Variation in virulence of pathogen populations also will likely influence these tests, producing differences in observed cultivar susceptibility between locations. To bypass these inherent difficulties in conducting field tests, a detached leaf method is used for assessing variety resistance in several plant species. This makes it potentially better method of screening for disease resistance, as it is cost effective, space saving and a faster method of conducting screening tests on large sample size. In the present investigations, detached leaves of 80 commercially released rice varieties inoculated with *P. oryza* spore drops produced very clear lesions. Irrespective of the ecosystem for which a variety was released for commercial cultivation, overall means showed 17 to 30 lesions/54 spore drops placed on detached leaves. All these leaf lesions were fully developed that later coalesced in detached leaves of all the varieties tested. Lesions developed in all detached leaves tested irrespective of whether a variety was known as resistant, moderately resistant or susceptible. The elevated peroxidase and polyphenol oxidase enzymes activities reported by many researchers may be the critical factor in making detached leaf susceptible to the *P.oryzae*. The present investigation clearly demonstrated that irrespective of the source of resistance incorporated in varieties, all the 80 varieties tested showed typical blast lesion development in detached leaf assay. Therefore, detached leaf test for screening rice or mapping blast resistance genes as advocated have no practical value as this test with varieties shows only one reaction of susceptibility to *P. oryzae*.

One hundred and twenty varieties including two checks in three replications in two repeat tests were systematically studied for their reaction in greenhouse and fields to four major pathogens *viz., Pyricularia oryzae, R. solani, Xanthomonas oryzae* pv *oryzae*, and rice tungro virus. In the present study, the susceptible checks *viz.,* HR12 for *P.oryzae*, and TN1 for *R. solani, X. oryzae* pv. *oryzae* and tungro virus, were killed by the respective pathogens (score = 9) in all the repeat tests. This indicated that disease pressure on varieties was high in these tests and the reactions scored are valid and useful for analysis. Overall a few changes in reactions of varieties earlier known to be resistant or moderately resistant were also recorded: 13 varieties changed from resistance to susceptible (5 to *P. oryzae,* 6 to *X. oryzae* pv *oryzae*, and 2 to rice tungro virus); and 45 varieties from moderate resistance to susceptible (11 to *P. oryzae,* 14 to *R. solani*, 17 to *X. oryzae* pv *oryzae*, and 3 to rice tungro virus). However, 24 of these varieties recorded a marginal increase in scores bordering moderate resistance and susceptibility (6 to *P. oryzae,* 9 to *R. solani*, 8 to *X. oryzae* pv *oryzae*, and 1 to rice tungro virus). This evidently leads to a conclusion that the reactions of most varieties categorized in METs and declared as resistant, moderately resistant or susceptible have more or less remained very stable despite passage of several years and decades after their release. With the exception of a few varieties, most of them showed borderline reaction change from moderate resistance to susceptibility. It was of interest to note that a few varieties have actually improved on the resistance performance in the present tests in comparison with the claim made at their release. This is illustrated by the changed reaction of varieties recorded in the present tests from susceptibility to resistance (8 to *P. oryzae* and 4 varieties to rice tungro virus), or from susceptibility to moderate resistance (19 to *P. oryzae,* 11 to *R. solani*, 9 to *X. oryzae* pv *oryzae*, and 42 varieties to rice tungro virus). The reason for such changes could be due to elimination of susceptible plants in apparently mixed population of breeding lines released as varieties.

Generally for such changes in resistance or moderate resistance to susceptible reaction of varieties, or susceptible to resistance or moderate resistance, the most common explanations given are the changed virulence of pathogen, environmental conditions or the disease escape in the tests. The minor changes recorded might also be due to the monir deficiencies in the scoring system using the decimal scale which is apparently in a pronounced quantitative scale when classifying varieties as moderate resistant and susceptible. The low levels of changes recorded in the present investigations, however, lead to conclude on the very stable resistance imparted and claimed in these varieties at the time of release. The METs performed at 5 to 53 locations in 16 states of India for a minimum period of three years in screening nurseries ensure that the genotypes are many times exposed to various virulence populations and environmental conditions that are present at different locations in different years before they are selected on consistent performance and qualified for release as commercial varieties. The durability identified in the present tests further proves the strength of METs of AICRIP.

The mean grain yields actually observed and recorded in the three kharif seasons data on the 100 varieties were also derived for each ecosystem kharif (first set of means) and rabi (second set). Using the published models of Muralidharan et al (1996, 2002), the mean grain yields for the base year were predicted (third set of means) as the expected grain yields for each ecosystem. As these models predicted yields only for the kharif season yields, the differences between the kharif and rabi seasons on estimated mean yields in the present investigations were used to adjust model derived yields by adding these differences (fourth set of means) to rabi seasons data (second set of means) for a comparison.

While the overall model derived mean yield was 3.24 t/ha, the mean grain yields actually harvested in the present study from 100 varieties released was 3.50 t/ha in kharif, and 4.0 t/ha in rabi seasons. In general tillers and tillers with panicles were higher in kharif crop than that of rabi crop of all the varieties studied. Grain weight was more in rabi (94 to 124 g/10 hills) except deep water rice (83 g/10 hills), compared to kharif (89 to 108 g/10 hill). In rabi seasons, panicle weight was slightly higher in the varieties, but the straw weight was lower.

Positive Pearson correlation coefficient were estimated for mean grain yields of varieties released for different ecosystems in kharif (r = 0.578 non-significant) and rabi (r = 0.779 highly significant at P= *0,01*) seasons. Comparison of paired means *t-test* showed significant differences in the mean yields. Such differences were essentially due to differences in mean grain yields obtained in varieties released for rainfed uplands, deep water and semideep water ecosystems that were higher in kharif seasons by 0.58, 0.93 and 1.9 t/ha, respectively, and in rabi seasons by 0.75, 1.92 and 1.97 t/ha, respectively, than those of model derived yields. The apparent cause was that the mean grain yields of 100 varieties were estimated only under irrigated conditions at DRR farm, Rajendranagar, Hyderabad in the present investigations in all seasons. It also proved that rice varieties released for rainfed uplands, semideep and deep water ecosystems possessed the potential of higher yields in favorable (irrigated) ecosystem.

Granting that a few varieties showed differences in yields, it is interesting to note that only 13 varieties (9 for rainfed upland, and 2 each for semideep and deep water ecosystems) had shown higher mean yield difference between actual yields estimated in the present tests and predicted yields. Even granting for the deviation to high yields in 13 commercially released varieties than what was predicted with models of Muralidharan et al (1996, 2002), it is very much evident that 87% of the 100 released varieties tested showed a very stable yield performance as shown earlier in a few varieties.

The potential of plant diversity to increase or stabilize productivity is of great interest in crop systems. In the present study, DNA fingerprinting of 100 released rice varieties with five ISSR primers produced interpretable and variable banding patterns. Yet, none of the primers was able to uniquely discriminate between the 90 varieties studied. Dendrograms generated with the five primers showed more or less similar placement of varieties into respective clusters and subdivisions with some exceptions. There was no exclusive ecosystem grouping of varieties although they were released as suitable for nine specific rice ecosystems. Similarly there was no exclusive grouping based on maturity duration of varieties. These results confirmed the diversity in released rice varieties.

Rice ecosystems are characterized by elevation, rainfall pattern, depth of flooding and drainage, and by the adaptation of rice to these agroecological factors. Genotypes are evaluated every year in METs. AICRIPs aim was to study the performance of breeding lines developed for various ecosystems and to identify stable genotypes with wide adaptability. They differ in the genetic expression of maturity period and photosensitivity. The genetic makeup of some varieties discussed in the present study includes female progenitors, with *Cina* (IR 36, IR 50, IR 8, Swarnadhan, and Savitri); and *Mayang Ebos* cytoplasm (Mahsuri). Including Jaya, Rasi, IR 8, IR 36, IR 50 and Savitri, most semidwarf improved rice cultivars developed worldwide, derive their dwarfing gene from the Chinese dwarf *DGWG*. The present study demonstrated beyond doubt that varieties released for commercial cultivation, barring a few exceptions, remain stable for the reaction to *P. oryzae, R. solani*, *X. oryzae* pv *oryzae*, and rice tungro virus and produce stable grain yields. The diversity in these genotypes has successfully prevented vulnerability and yield instability in rice production in India.

Quantitative resistance affects quantitative components of pathogenicity (e.g., rate of infection, latent period, rate of sporulation), which are dependent on the host, the pathogen and the interaction between host and pathogen. Quantitative resistance is therefore, frequently cited to be more durable than qualitative resistance. The erosion of quantitative resistance at one site over time has not been demonstrated. Diverse mechanisms have been proposed to explain quantitative resistance different corresponding adaptation process becomes a necessity for the pathogen with only a few leading to the emergence of generalist pathogen populations. The need to look for diversified quantitative resistance factors that combine complementary modes of action on the pathogen, resulting in trade-offs between quantitative components of pathogenicity, and to optimize the management of cultivar distribution in space and time to limit the possibilities of step-by-step evolution in pathogen populations. Genetic diversity as observed in landraces of rice and its wild relatives enables the plants to evolve and differentiate into various cultivars adapted to different environments.

The present study demonstrated for the first time beyond doubt that varieties released for commercial cultivation, barring a few exceptions, are stable or durable for the reaction to *P. oryzae, R. solani*, *X. oryzae* pv *oryzae*, and rice tungro virus and produce stable grain yields. A high level of durable resistance to these four pathogens might have been achieved by the cumulative effects of multiple QTLs, including the residual effects of "defeated" major resistance genes. It is therefore apparent that breeder across different cetres in the country have pooled diverse resistance genes in the varieties nominated to AICRIP for an evaluation and METs successfully aided in the selection of those possessing quantitative resistance genes resulting in the stability or durability of reaction to pathogens even decades after their selection and release for commercial cultivation. The diversity in these durably resistant varieties has successfully prevented vulnerability and yield instability in rice production in India.