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Review article

Genetics of salt tolerance in rice

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Experimental procedures *viz.*, line x tester analysis, diallel analysis and stability analysis have been utilized in rice breeding programs to study combining ability, heterosis, gene action and stress tolerance capacity of various genotypes based on yield related traits. The results have helped in development of good varieties and hybrids. Excessive work is available in the particular area of research as many plant breeders in Asia work towards improving the yield of rice. A review on gene action studies in rice has been attempted with emphasis on the research progress made in India.

Key Words: Rice, gene action, additive, non additive

Rice is synonymous to food in Asia, a life giving cereal, highly respected and considered auspicious by many in the world. It is also well known for its easy digestibility, taste and nutritive value. Rice is preferred differentially based on grain quality and the nature of processing (Deepa Sankar, 2015). Widespread salinity is a major factor in world agriculture that limits crop productivity. Rice is an important crop and experimental evidence suggests that most rice varieties exhibit salt sensitivity and varietal differences tend to manifest only at moderate salt concentration, that is 50mM NaCl (Yeo and Flowers, 1984).

Nature of yield related traits under salt stress

The *in situ* performance of a variety and its reduction in grain yield at defined stress levels can be followed in screening and evaluating rice breeding materials and varieties. A high percentage of spikelet sterility relates to a low level of salt tolerance in rice. Low Na^+/K^+ ratio of ion uptake is positively correlated with a high level of salt tolerance and can be taken into consideration as a desired characteristic while screening rice lines (Mishra *et al.*, 1997). Early studies reported that salt injury in rice was caused by both osmotic imbalance and an accumulation of the chloride ion (Akbar, 1975). Besides osmotic imbalance and ion toxicity, nutritional imbalance causes salt injury in rice. The symptoms of salt injury were observed to be stunted growth, rolling and withering of leaves, occurrence of white blotches, browning and drying of older leaves (Tagawa and Ishizaka, 1963; Akbar, 1975; Akbar, 1986).

Rice has been found to be tolerant during germination, vegetative growth and maturity but very sensitive at early seedling growth (2-3 leaf stage), pollination and fertilization stages (Pearson *et al.*, 1966; Akbar and Ponnamperuma, 1982). Krishnamurthy *et al.* (1971) observed that tillering was not influenced by salinity. Karim and Haque (1986) reported that plant height, root length, number of tillers per plant, straw yield and dry weight of root was affected by salinity during vegetative stage. Yield reduction at maximum tillering stage due to salinity was observed by Ahmed *et al.* (1989). Decreasing grain yield with increase in salinity was reported by Powar and Mehta (1997).

Table 1. Nature of yield attributing genes

Character	Gene action	Author and year
Days to 50 per cent flowering	Additive	Lakshmi Narayanan (2000)
	Non additive	Rogbell and Subbaraman (1997); Ghara *et al.* (2012)
	Both additive and non additive	Narayanan and Rangasamy (1991)
Plant Height	Additive	Akbar *et al.* (1985); Mosina (1986); Rogbell (1995); Lakshmi Narayanan (2000); Babu (2002)
	Non additive	Thirumeni *et al.* (2003); Malini *et al.* (2006); Ghara *et al.* (2012)
	Both additive and non additive	Narayanan and Rangasamy (1991); Rahimi *et al.* (2010)
Productive tillers per plant	Additive	Bhattacharya (1978); Babu (2002)
	Non additive	Rogbell (1995)
	Both additive and non additive	Narayanan and Rangasamy (1991)
Panicle length	Additive	Thirumeni *et al.* (2000) ; Lakshmi Narayanan (2000)
	Non additive	Thirumeni *et al.* (2003); Malini *et al.* (2006); Ghara *et al.* (2012)
	Both additive and non additive	Narayanan and Rangasamy (1991); Rahimi *et al.* (2010)
Grains per panicle	Additive	Thirumeni *et al.* (2000); Malini *et al.* (2006)
	Non additive	Rogbell and Subbaraman (1997); Ghara et al. (2012)
		Narayanan and Rangasamy (1991)
	Both additive and non additive	Rahimi *et al.* (2010)
Spikelet fertility	Additive	Bhattacharya (1978)
	Non additive	Akbar and Yabuno (1974); Babu (2002)
		Thirumeni *et al.* (2003); Ghara *et al.* (2012)
100 grain weight	Additive	Ba Tao *et al.* (1992)
	Non additive	Lakshmi Narayanan (2000)
	Both additive and non additive	Narayanan and Rangasamy (1991)
Single plant yield	Additive	Akbar *et al.* (1985); Narayanan and Rangasamy (1991); Choung *et al.* (1991)
	Non additive	Rogbell and Subbaraman (1997)
	Both additive and non additive	Yoshida *et al.* (1976); Mishra (1995)
Na^+ : K^+ ratio	Additive	Babu (2002)
	Non additive	Thirumeni (1998)
	Both additive and non additive	Gregario and Senadhira (1993); Mishra (1995); Mishra *et al.* (1996); Mishra *et al.* (2003)
Salinity tolerance	Additive	Jones (1986); Mishra *et al.* (2003)
	Non additive	Moeljopawiro and Ikehashi (1981); Lavrichenko (1985)
	Both additive and non additive	Akbar *et al.* (1985) ; Mosina (1986) ; Gregario and Senadhira (1993) ; Mishra *et al.* (1996)

For transplanted rice, initial survival is crucial in determining later performance. Seedlings that survive at this stage are expected to produce grain although spike sterility cannot be ruled out (Ansari *et al.*, 2003). Seedling survival after planting could, to some extent, be compensated for by using old seedlings (Ansari *et al*., 1994), but initial seedling survival also reflects upon the performance of a particular line in terms of yield. In a study performed by Ansari *et al.* (2003) cultivars Ganga White, Nona Bokra, IR 6 and Shua-92 had better seedling survival, whereas IR 28 and Basmati had the lowest seedling survival. These cultivars had a more or less similar ranking in straw or grain weight.

Gene action studies

Gene action refers to the behavior or mode of expression of genes in a genetic population. Success in breeding for quantitative traits depends upon the gene action involved for the traits concerned. Baker (1978) pointed out that the relative importance of general and specific combining ability variances could be used for predictability of gene action. Nature of gene action of various yield related traits is useful to the plant breeders in formulating the breeding procedure for obtaining maximum genetic advance in yield and yield components. Works on rice regarding nature of gene action are presented in Table 1.

Gene action studies involving two line hybrids

Rice hybrids have already contributed towards food security in China. India has also made remarkable progress towards development and use of hybrid rice technology. But the excessive dependence on a single source of cytoplasmic male sterility (CMS) *via* WA and the cumbersome process of seed production and parental line development warrant the development of alternate approaches to exploit hybrid vigour in rice. Two line breeding is one such possibility that emerged following the chance discovery of a photoperiod-sensitive genic male sterile plant called Nongken 58 by Prof. Shi Ming Song of China (Shi and Deng, 1986) which was found to be sterile under longer photoperiods (>14 hr) and fertile under shorter photoperiods (<13 hr) subsequently. Temperature sensitive genic male sterility (TGMS) lines were identified by Chinese and Japanese scientists. They are sterile under high temperature (>32^{0}c) but under low temperature (< 24^{0}c) they are fertile (Tan *et al*., 1990; Maruyama *et al*., 1990).

World will have to produce 60% more rice by 2030 than what it produced in 1995. Theoretically rice has great yield potential to be tapped and there are many ways to raise rice yield. Among them it seems at present that the most effective and economic way available is to develop hybrid varieties based on successful experience in China. Following the success of three–line hybrid rice in 1970's, two-line hybrid rice was successfully commercialized in 1995 with a yield advantage of 5–10 % higher than that of existing three–line hybrid rice (Yuan Longping, 2004). Hence it becomes really important to analyze genetic studies made on two line rice hybrids as well.

Chen *et al*. (1997) studied combining ability of agronomic traits in two line inter-subspecific hybrid rice. They reported that yield per plant appeared to be mainly controlled by non-additive effects while plant height and heading date were mainly conditioned by additive gene effects.

A combining ability study was made to assess the nature of gene action for seven quantitative traits using three TGMS lines (Lines) and six non TGMS lines (Testers) in a L x T mating design (Rangaswamy *et al.*, 1998). TS-15 showed significant positive *gca* effects for number of filled grains per panicle and spikelet fertility. TS-16 was a good general combiner for plant height, productive tillers per plant and panicle length. TS-18 recorded significant *gca* effect for number of filled grains per panicle, spikelet fertility and grain yield per plant. Among the testers, ADT 36 and IR-37399 recorded significant positive *gca* effects for grain yield per plant. Seven hybrids *viz.*, TS-15 x ASD-18, TS-15 x IR-55722, TS-15 x IR-59601, TS-16 x ASD-18, TS-16 x ADT-36, TS-18 x ADT-36, and TS-16 x IR-68902B exhibited significant positive *sca* effects for grain yield.

Sampoornam and Thiyagarajan (1998) studied combining ability for grain yield and related traits in two line hybrids and found that TS 18 was the good general combiner for many traits.

Aananthi (2000) studied combining ability of TGMS lines and reported the predominance of additive gene action for the traits productive tillers per plant, panicle length, plant height, 100 grain weight and single plant yield. Among the TGMS lines TS 29 and TS 6 were reported as good combiners.

A study was undertaken by Bini Philip (2001) using 21 TGMS based rice hybrids obtained by crossing three TGMS lines with seven testers to evaluate gene action in a line x tester design. Predominance of non additive gene action was observed for most of the traits except for single plant yield, chlorophyll content and plant height. Harvest index showed both GCA and SCA variance in equal magnitude.

Radhidevi *et al*. (2002) performed combining ability analysis using two CMS, two TGMS lines, 12 testers and 48 hybrids in Line x Tester fashion. The greater role of non additive gene action was observed for most of the characters except days to 50 per cent flowering and panicle length which offers much scope for the exploitation of hybrid vigour through heterosis breeding.

Kalaiyarasi *et al.* (2002) reported the preponderance of non additive gene action in terms of yield components from a study based on two line inter-subspecific rice hybrids.

Patil *et al*. (2003) studied combining ability by making 84 cross combinations from seven TGMS lines and 12 non-TGMS testers. The magnitude of specific combining ability variance was greater than the general combining ability for all the traits except days to 50 per cent flowering. Combining ability revealed the predominance of non additive gene action for productive tillers per plant, panicle length, grains per panicle and grain yield per plant and offered more scope for exploitation of hybrid vigour through heterosis breeding.

Gnanasekaran (2003) performed genetic analysis involving TGMS based rice hybrids. He reported that the traits days to 50 per cent flowering, plant height, number of productive tillers per plant, panicle exsertion, 100 grain weight and kernel L/B ratio were governed by additive gene action while panicle length, number of grains per panicle, spikelet fertility, harvest index, single plant yield, kernel elongation and amylase content were controlled by non additive gene action.

Deepa Sankar *et al.* (2008) have reported that the traits days to 50 per cent flowering, productive tillers per plant, panicle exsertion, panicle length, panicle weight, filled grains per panicle, spikelet fertility, 100 grain weight, $Na^+ : K^+$ ratio, harvest index and grain yield per plant are controlled by dominance gene action and plant height was controlled by additive gene action. The study was undertaken to get genetic information on salt tolerance in a set of rice genotypes comprising of five TGMS lines, eight salt tolerant testers and 40 hybrids obtained by crossing in line x tester design.

Conclusion

Conventional breeding approaches *viz.*, recombination and heterosis breeding are the real problem solvers which have brought in food security. Gene action studies reveal good combiners for specific breeding purposes. Though tissue culture, molecular and biotechnological methods employed aid in improving yield, quality and tolerance to stresses the main backbone of plant breeding has always been the conventional techniques employed. Efforts of breeders in creating such wonderful genotypes have led to the perpetuation of the human race.

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