A high yielding organic rice variety suited for coastal saline and non-saline fields: 'Ezhome-2'

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Abstract

The Kaipad system of rice cultivation of Kerala, India, on land tracts fringed by mangroves, is an integrated organic farming system in which rice cultivation and aquaculture come together in coastal brackish water marshes which are rich in organic matter. The ecosystem is typically saline. Poor yielding traditional cultivars are cultivated in various Kaipad fields of Kerala. These traditional cultivars have some undesirable characteristics, however they are tolerant to salinity and have good cooking and nutritional qualities The development of high yielding, non-lodging rice varieties for the Kaipad ecosystem and with favourable qualities is a long standing desire of the local farmers. Here we report the development of a high yielding rice variety called 'Ezhome-2' suited for the Kaipad ecosystem. It has the favourable traits demanded by farmers and consumers. This variety is the outcome of adopting the combined strategy of organic plant breeding and participatory plant breeding, and growing the entire filial generations and early trials in the target area where farmers are cropping (which is unlike typical conventional breeding programmes). In addition to the saline Kaipad ecosystem, this variety is also suited for non–saline wetlands, unlike the land races of Kaipad. It is a medium duration variety with red kernel colour, a trait much preferred by the people of Kerala state in India, and has favourable cooking and nutritional qualities similar to the Kaipad land races.

Keywords: salinity tolerance, organic farming, organic plant breeding, participatory plant breeding, Kaipad, Pokkali, Kerala, India.

Introduction

India has reported more certified organic agriculture farmers than any other country (Paull & Hennig, 2016). Numerous other Indian farmers follow the traditional organic farming practices without being certified as organic, for reasons including their own poverty, the costs and requirements of certification, and the lack of access to price premiums. The importance of breeding varieties of crops suited to organic farming in India has been previously identified (e.g. Manjunatha et al., 2016).

Kaipad is the saline prone tidal farming rice production tracts of Kerala, India, as is the Pokkali tract of South Kerala. The Kaipad system of rice cultivation is an integrated

organic farming system in which rice cultivation and aquaculture are practised together in coastal brackish water marshes which are rich in organic matter.

Rice farming is carried out in a peculiar way in the Kaipad, purely in a natural way relying on the monsoon and the sea tides. Traditional cultivars tolerant of low and medium salinity are cultivated in various Kaipad fields of Kerala. Most of the Kaipad fields either lie fallow or produce low rice yields. The average rice yield of these local cultivars is about 2000 Kg ha^{-1}, making commercial rice cultivation in this region unprofitable. The absence of high yielding rice varieties suited to this rain-fed shallow lowland is a major reason holding back the cultivation of the Kaipad fields.

The traditional cultivars used are resistant to all pests and diseases in the natural field conditions of the Kaipad, and the cooked rice is very delicious and also nutritionally rich. However, the traditional cultivars of the Kaipad are susceptible to lodging, because of poor culm strength and excessive culm length. Further, complete lodging makes harvesting a tedious task, especially in the present scenario of the shortage of farm labourers. Also, the grain qualities of traditional cultivars are poor: awned grains, long bold, and heavy shattering of grains, and long panicles with low panicle numbers.

The development of saline tolerant high yielding varieties with favourable grain and cooking qualities for the Kaipad ecosystem has been the demand of local farmers for a long time. Breeding for salt tolerance is a more promising, energy efficient, and economically and socially acceptable approach than major engineering processes and/or soil amelioration, which are beyond the reach of marginal farmers (Flowers & Yeo,1995).

A breeding programme was undertaken to develop saline tolerant varieties retaining the characteristics favoured by locals, suited to the distinctive ecosystem, retaining the suitability for organic and low-input farming, and yet offering improved yield. Here we report the result of 12 years of a hybridization programme which successfully identified a saline tolerant high yielding rice variety suited for the Kaipad saline ecosystem, as well as for non-saline wetlands, and christened as ‘Ezhome-2’.

Materials and methods

The methodology adopted for variety development was pedigree breeding utilizing the land races of the ecosystem where the variety is intended to be used. The ecosystem is naturally organic and for sustainability, an organic plant breeding (Bueren, 2003) strategy was implemented. For easy and early adoption of any developed variety, a farmer participatory breeding approach (Morris & Bellon, 2004) was adopted during the variety development programme. It is based on a set of methods that involve close farmer-researcher collaboration to bring about plant genetic improvement within a crop. By involving farmers in the genetic improvement process, plant breeding programmes may be better able to produce varieties that will be taken up more widely and generate greater benefits in the aggregate (Bennet & Khush, 2003).

The efficiency of breeding for salt tolerance was perceived to be low because of the evident genetic complexity of the trait, large genotype by environment interactions, and the problem of controlling relevant environmental variables during field-based selection (Flowers & Yeo, 1995). For the present study, the entire experiment was conducted directly at the target area of saline sea coastal problem area to reveal the genetic potential under field conditions. Inter-varietal hybridization was carried out between high

yielding saline susceptible varieties, namely 'Jaya', 'Mahsuri' which are under cultivation in the proximity of Kaipad fields, and the popular saline tolerant traditional land races of Kaipad, such as 'Kuthiru' and 'Orkayama' which have multiple favourable traits including salinity tolerance, biotic stress tolerance, excellent cooking and nutritive qualities and which have not been exploited previously in breeding programmes (Vanaja & Mammootty, 2010).

All the filial generations as per pedigree breeding, and yield trials were raised as on-farm trials in the Kaipad fields. This facilitated the participation of farmers in the selecting of promising progeny from the segregating filial generations as per strategies of participatory plant breeding (unlike in the conventional breeding programme where farmer participation is done at the farm trial stage only).

The F2 filial generation (comprising 6,292 progeny) was raised in the field adjacent to the saline problem area having intruded with slight salinity (2dS m^{-1}) and using organic rice farming practices. Only 1,028 progeny survived in the slight salinity. Single plant pedigree selection was followed in the F2 generation. All the F2 progeny that survived in the slight saline condition were carried forward to the F3 generation in the subject area of the Kaipad.

From the F3 generation onwards, all advanced filial generations were evaluated directly in the target area having medium salinity. Fourteen high yielding stabilized rice cultures were evaluated in replicated yield trials in saline Kaipad fields along with local lodging check (Kuthiru) and non-lodging Pokkali check (Vytilla 6). The Pokkali tract in Kerala is similar to the Kaipad tract but differs in soil structure and in the rice genotypes cultivated. Further, different yield trials were also conducted in both the saline Pokkali tract and in non-saline wetlands.

The design of yield trials was random block design (RBD) with three replications. The promising cultures were also screened under National Saline Alkaline Screening trials of AICRP. Pests and disease scoring were done under natural saline field conditions of Kaipad and also under artificial infection in non-saline wet land condition of the Regional Agricultural Research Station, Pattambi, Kerala, India (Vanaja et al., 2015). The standard evaluation system for rice (IRRI, 1988) was used for describing the cultures.

Results and discussion

The hybridization programme started in the year 2002 and resulted in development of an array of high yielding saline tolerant rice cultures for the first time to the distinctive Kaipad ecosystem (Vanaja et al., 2009). Thereafter these diverse rice cultures were tested in various farm trials in the saline Kaipad ecosystem, saline Pokkali ecosystem, saline screening trials of AICRP, and also in the non saline wetlands of North Kerala. As a result the first high yielding variety 'Ezhome-1' (Culture JK70), a long duration red variety which is a cross between 'Jaya' and the Kaipad land race 'Kuthiru' was released. The details of the performance of Culture JO345, (a cross between 'Jaya' and the Kaipad land race 'Orkayama') was released under the name 'Ezhome-2' (Figure 1) for commercial cultivation in Kerala, state of India, are presented below.

Grain yield

A preliminary evaluation trial was conducted separately for both non-lodging and lodging

genotypes. A comparative evaluation trial was conducted for good performing non-lodging and lodging genotypes together (Table 1). In comparative yield trials, five non-lodging cultures, namely, JK 70, JO 345, MK 22, JO 532-1 and JO 583, and one lodging culture, JK 59, showed significantly higher and/or on par yield performance compared to Kaipad and Pokkali check varieties. These cultures have a broad genetic base because one of the parents is a local cultivar having abiotic and biotic stress resistance.

Table 1. Saline tolerant Kaipad rice cultures in comparative yield trials (CYTs) in farmer fields.

Sl.N0	Genotypes	Parentage	Pooled CYT Grain yield (t /ha)
1	MK 22	Mahsuri x Kuthiru*	5.7 [a]
2	JO 583	Jaya x Orkayama*	4.7 [a]
3	JK 70	Jaya x Kuthiru	6.0 [a]
4	JO 532-1	Jaya x Orkayama	6.2 [a]
5	JO 345 (Ezhome-2)	Jaya x Orkayama	5.9 [a]
6	JK 59	Jaya x Kuthiru	4.9 [a]
7	JK 15	Jaya x Kuthiru	4.0
8	Kuthiru	Kaipad local check-lodging	2.1
9	Vytilla 6	Non-lodging *Pokkali* check	2.6
	C D (1%)		2.1

* Land races of *Kaipad* ecosystem;
[a] Within a column, means followed by the same alphabet-character do not differ significantly from each other.

The mean grain and straw yield of 'Ezhome-2' (Culture JO 345) in farm trials in Kaipad tracts during Kharif seasons are given in Table 2. Culture JO 345 showed 69% greater yield than the local check 'Kuthiru' (Table 2).

Table 2. Mean grain yield (straw yield in parenthesis) of culture JO 345 in multi-location farm trials during Kharif seasons.

Name of culture/variety	Mean Grain yield (t/ha) (Mean Straw yield t/ha)				
	2008[a]	2009	2010 [a]	2011 [a]	Pooled Mean
Ezhome-2	3.20 (4.28)	3.45 (4.55)	3.35 (4.11)	3.40 (5.25)	3.35 (4.55)
Kuthiru (local check)	2.12 (3.92)	1.93 (3.93)	1.90 (3.73)	1.98 (3.85)	1.98 (3.86)

[a] Pooled over 5 locations.

The yield performance of 'Ezhome-2' in National Saline Alkaline Screening trials of AICRP is given in Table 3. In two situations (alkaline normal soils and in coastal saline normal soils), compared to coastal check (CST 7-1), 'Ezhome-2' showed higher yield performance (Table 3). This variety is also high yielding in saline Pokkali tracts of South Kerala with potential yields exceeding four tonnes/ha.

Table 3. Mean grain yield of 'Ezhome-2' in National Saline Alkaline Screening trials of AICRP.

Name of culture/ Variety	Mean yield under different situations (kg/ha)					
	IET No	Alkaline[a]	Alkaline Normal[b]	Coastal Saline[c]	Coastal Saline normal[d]	Inland saline[e]
Ezhome-2 (JO 345)	22607	2321	4332	3210	4512	1044
coastal check (CST 7-1)	--	2644	3538	3321	2466	1709

[a] Mean of 4 locations (Kanpur, Karnal, Karaikal, & Lucknow);
[b] Mean of 4 locations (Nawagam, Annamalainagar, Trichy, & Masodha);
[c] Mean of 3 locations (CRRI, Canning, & Machilipatnam);
[d] Mean of 3 locations (Chinsurah, Panvel, & Navasari);
[e] Mean of 2 locations (Karnal & Gangavati).

'Ezhome-2' is also regarded by the authors as suitable for non-saline wetland tracts, unlike traditional land races of Kaipad, with an anticipated average grain yield of five or more tonnes/ha under organic management and with the anticipated same duration as in Kaipad fields (120-125 days during Kharif and Rabi seasons) (Table 1). The gene recombination due to hybridization may have changed the genetics from stress induced yield enhancement to epigenetic yield enhancement.

Figure 1. Saline tolerant rice variety, Ezhome-2.

Cooking and nutritive qualities

Cooking quality analysis showed that 'Ezhome-2' possesses favourable taste and more acceptable appearance of cooked rice appealing to both consumers and millers. Cooking and nutritive traits of 'Ezhome-2' are given in Table 4. Most of the cooking qualities are on par with the traditional land race 'Kuthiru'. The cooking qualities of the traditional land race 'Kuthiru' is very much appreciated by the Kaipad farmers. Cooked rice of 'Ezhome-2' is reportedly delicious and non-sticky like 'Kuthiru'. Colour, texture, flavour, and appearance are reported as more acceptable and appealing than 'Kuthiru'. Cooked rice is swollen and tender unlike the split and hard nature of that of 'Kuthiru'. The nutrient quality analysis showed that 'Ezhome-2' possesses higher content of Ca, K and crude fibre than the traditional land race, 'Kuthiru', but Fe and Zn content are greater in the traditional land race (Table 4).

Table 4. Cooking and nutritive qualities of 'Ezhome-2'.

Item	Ezhome-2 (Cul. JO 345)	Kuthiru (*Kaipad* check)
Cooking qualities Volume expansion	3.3	3.5
Kernel elongation ratio	1.5	1.5
Water uptake	1.9	1.7
Alkali spreading value	4.3	4.0
Amylose content	29	25.0
Taste, texture, aroma and appearance of cooked rice as per sensory evaluation	Delicious and non-sticky like 'Kuthiru'. Color, texture, flavour, and appearance are more acceptable and appealing than 'Kuthiru'. Cooked rice is swollen and tender unlike the split and hard nature of 'Kuthiru'.	Delicious with acceptable and appealing appearance, and non-sticky. Cooked rice is hard and split.
Nutritive qualities Fe content (mg /kg)	87.6	121
Zn content (mg/kg)	16.5	21.1
Ca (mg/kg)	156	154
K (mg/kg)	9558	8359
Crude fibre (% by wt.)	11.3	10.7

Pest and disease resistance

There was no reported incidence of pests and diseases in the saline Kaipad ecosystem. This may be due to the high potassium content of the soil and salinity-induced biotic stress tolerance. It appears that 'Ezhome-2' is resistant to the pests, gall midge and leaf folder, and moderately resistant to whorl maggot, caseworm and blue beetle. Similarly, it appears that the variety is moderately resistant to sheath blight and bacterial leaf blight.

Salient characteristics of 'Ezhome-2'

'Ezhome-2' can be cultivated both in naturally organic saline Kaipad tracts as well as in non-saline wetlands. As it is an organic variety and has been developed adopting the concepts and strategies of organic plant breeding, when cultivation is in non-saline Kaipad tracts, the farming management should again be of organic mode. It is a medium duration variety (120-125 days) having high grain and straw yield with high harvest index, and tolerant to low to medium salinity (4-6dS m-1). Further, unlike 'Kuthiru', it has intermediate plant stature (120cm) with strong and sturdy upright culm tolerant to lodging. Panicles are compact with 215 grains/panicle. Healthy flag leaf and stay green index during reproductive stage demonstrates its photosynthetic ability and efficient grain filling ability.

Conclusion

One of the major reasons farmers move away from sea coastal Kaipad organic saline rice tracts is the unfavorable characteristics of locally available cultivars and low yields. 'Ezhome-2' exhibits favourable grain, cooking and nutritional qualities and appears to be equally high yielding in both Kaipad and non-saline wetlands. It gives 69% more yield in Kaipad than a local land race (Table 2).

The non-lodging nature of the variety helps in easy harvest both manually and using machines. The entire development stages of the variety were conducted in farmer fields adopting participatory plant breeding (PPB). This emerging strategy in the area of plant breeding to integrate an end-user based participatory approach involves close farmer-researcher collaboration to bring about plant genetic improvement within a crop. It is the experience of the authors that the farmers, having actively participated in the breeding, are much more convinced about the yield potential and suitability of a variety to Kaipad saline flooded conditions as well as for ordinary wetlands for Kharif and Rabi seasons.

Farmer participation ensures a revival of rice cultivation in Kaipad without much extension effort and has helped in an easy and early adoption of the variety. The development and commercial release of 'Ezhome-2' rice variety of the Kaipad can help in transforming these vast but less productive saline-prone, naturally organic tracts into arable and highly productive farming land. This can can lead to an enhancement of the nutritional and livelihood security, as well as the food security, of small and marginal farmers of rural Kerala. There may also be the potential to export organic red rice, as a premium speciality foodstuff, at some point in the future.

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