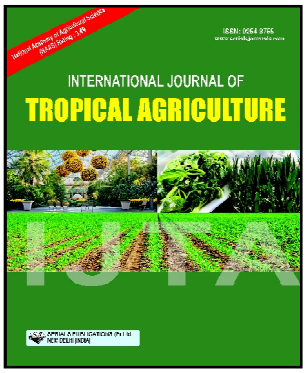

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Saline and flood tolerant long duration organic rice variety (*Oryza sativa* L.), 'Ezhome -4'

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Abstract: Salinity and flood are combined menace at sea coastal tracts. Breeding for salt stress tolerance is a more promising, energy efficient, economic and socially acceptable approach compared to any other development approach. In the current scenario, varieties having traits amenable for organic farming (organic varieties) are the missing link in the organic production chain. Here we report about development and commercial release of a non lodging organic rice variety, 'Ezhome -4' which is tolerant to salinity and suited to sea coastal ecosystem as well as non saline flooded tract. The variety was developed by adopting the combined strategy of conventional breeding linked with novel strategies of organic plant breeding and participatory plant breeding and growing the entire filial generations and all yield trials in the target area of farmers.

Key words: rice, abiotic stress, salinity and flood tolerance, Kaipad, naturally organic tract

INTRODUCTION

Human exploitation of earth's resources is leading to new problems day by day and hence newer methods are devised to overcome the same. Breeding for abiotic stress, utilizing even non arable land, to feed the ever increasing population is one of the steps. Inland and coastal salinity is a major stress leading to yield loss. It is estimated that half of the world's farms have been damaged by salt (Pearse, F.1987). Breeding for salt tolerance is a more promising, energy efficient, economic and socially acceptable approach than major engineering processes and soil amelioration, which had gone beyond the reach of marginal farmers. In spite of a

significant amount of research on the effect of salinity on plants, there has been little success in putting salt resistant plants in farmers' field (Flowers & Yeo, 1995). Similarly flood is another menace both at saline sea coastal as well as at non saline inland wetlands. As the global climate changes makes difference in the microclimate environment, the adaptation and mitigation strategy should be for development of location specific varieties. To attain this, the breeder should utilize locally adapted genetic resources in breeding programmes.

The focus of the present era is upon organic farming for health as well as environment protection. As organic farming management and environments are fundamentally different from conventional, organic farmers need specific varieties that are adapted to their lower input farming system and can perform higher yield stability than conventional varieties (Lammerts van Bueren *et al*., 2003). Many breeding programs took yield potential as the primary target. With the increased living standard, the improvement in cooking, eating, and appearance quality of the rice grain has become a priority. For further optimization of organic product quality and yield stability, new varieties are required that are adapted to organic farming systems (Lammerts van Bueren *et al*., 2003). In the current scenario, varieties having traits amenable for organic farming (organic varieties) are the missing link in the organic production chain. In the short and middle long run, organic market segment can utilize the best available varieties among the existing conventionally bred varieties which can also be propagated organically. But in the long term, breeders can influence further improvement of organic seed production by integrating organic traits in varieties (Lammerts van Bueren *et al*., 2003). At this context, development of rice varieties responding well to organic cultural management with good cooking and nutritive qualities and having resistance to important pests and diseases is imperative to meet increasing requirements, in both quantity and quality, and should be in harmony with the environment thus ensuring a proper level of sustainability.

Coastal wetlands of North Kerala are popularly known as *Kaipad* . Rice farming is carried out in a peculiar way in this tract purely in a natural way relying on the monsoon and the sea tides. Development of saline tolerant high yielding varieties for *Kaipad* ecosystem with favourable grain and cooking qualities was the demand of the farmers for long. Hence a challenging breeding project for development of saline tolerant high yielding non lodging variety was begun in 2001 for the first time utilizing a local land race of *Kaipad* in breeding programme. As a result of sustained research efforts an array of promising breeding lines were developed and out of them four saline tolerant non lodging organic varieties were released commercially christened as 'Ezhome -1' , 'Ezhome -2' , 'Ezhome -3' and 'Ezhome -4' . Here we report the details of development of the one in the series , 'Ezhome -4' - a long duration saline tolerant organic rice variety suitable to the saline coastal flooded wetlands of Kerala as well as for non saline flooded tracts.

MATERIALS AND METHODS

Orkayama, the land race of Kaipad tract of North Kerala, the newly identified genetic resource for salinity tolerance, biotic stress tolerance, excellent cooking and nutritive qualities and not exploited so far in breeding programmes (Vanaja and Mammootty, 2010) was utilized as donor parent for salinity tolerance. A combined strategy of pedigree breeding, organic plant breeding (Bueren, 2003) and farmer participatory breeding approach (Morris and Bellon, 2004) was followed during the variety development programme, conducting the entire experiment directly at the target area of saline sea coastal problem area to harvest the genetic potential under field condition. 'Orkayama' land race was hybridized with high yielding saline susceptible variety, 'Jaya, 'which is under cultivation at the

proximity of *Kaipad* field, in 2001. All the filial generations as per pedigree breeding, and yield trials were raised as on-farm trials in the *Kaipad* fields under the test name culture JO 532-1, ensuring the participation of farmers in the selection process of promising progenies from the segregating filial generations itself as per strategies of participatory plant breeding unlike in the conventional breeding programme where farmer participation is done at farm trial stage only. The F_2 filial generation was raised in the field adjacent to the saline problem area having intruded slight salinity (2dS m^{-1}), and adopted organic rice farming practices. Single plant pedigree selection was followed in F_2 generation. All the F_2 progenies survived in the slight saline condition were carried forward to F_3 generation in the problem area of *Kaipad,* the target site. From F_3 generation onwards, all advanced filial generations were evaluated directly in the target area having medium salinity. Fourteen high yielding stabilized rice cultures were obtained from thousands of F_2 progenies developed from various cross combinations among saline susceptible high yielding varieties and saline tolerant traditional land races. These promising progenies were evaluated in replicated yield trials in saline *Kaipad* fields along with local lodging check (Kuthiru) and non-lodging *Pokkali* check (Vytilla 6). *Pokkali* tract in Kerala is similar to *Kaipad* tract but differ in soil structure and rice genotypes cultivated. The design of yield trials was RBD with three replications. Salinity level varied between 4 to 8 dS m^{-1}during the cropping season. Culture JO 532-1 was also tested at 16 locations of different states of India through the National Saline Alkaline Screening Nursery (NSASN) of the All India Coordinated Rice Improvement Programme. Trials were also conducted at flood prone areas of North Kerala. Pests and disease scoring was done under natural saline field condition of *Kaipad* and also under artificial infection in non-saline wet land condition of Regional Agricultural Research Station, Pattambi, Kerala, India. Standard evaluation system for rice (IRRI, 1988) was used for describing the cultures.

The efficiency of breeding for salt tolerance was perceived to be low because of the evident genetic complexity of the trait, large genotype x environment interactions, and the problem of controlling relevant environmental variables during field based selection (Flowers and Yeo, 1995). Hence, in order to improve the suitability of the varieties produced to specific local farming situations, the new approach of farmer participatory varietal selection (Bennet and Khush, 2003) was integrated to develop high yielding varieties suited for *Kaipad* rice field. Participatory Plant Breeding (PPB) is the latest strategy in the area of plant breeding to integrate end user based participatory approach (Morris and Bellon, 2004). It is based on a set of methods that involve close farmer –researcher collaboration to bring about plant genetic improvement within a crop. It is expected to produce more benefits than the traditional global breeding model in situations where a highly centralized approach is inappropriate. Participatory plant breeding methods designed to incorporate the perspective of farmers usually by inviting farmers to participate in selection within the unfinished segregating material with high degree of genetic variability. Realizing the fact that modern varieties developed for favorable production conditions have not always diffused readily into marginal environments, the procedures like selection of parents and segregating progenies were done in the target area of farmers. Further, participation of farmers is imperative when crops are grown in agriculturally difficult and environmentally challenging situations. By involving farmers in the genetic improvement process, plant breeding programmes will be able to produce better varieties that will be adopted more widely and generate greater benefits on aggregate. PPB provides a means of assessing so-called 'subjective traits'. In food crops these include taste, aroma, appearance, texture, and other characteristics that

determine the suitability of a particular variety for culinary use. These traits are difficult to measure quantitatively because they are a function of human perceptions.

RESULTS AND DISCUSSION

Research efforts adopting new frontiers of crop improvement resulted in development of an array of high yielding saline tolerant rice cultures, having distinct traits, for the first time to the unique sea coastal saline organic rice tracts of north Kerala , *Kaipad* (Vanaja *et al* 2009). There after these diverse rice cultures were tested in various trials in saline *Kaipad* ecosystem, saline screening trials of AICRP and also in non saline flooded wetlands of North Kerala. The details of performance of Culture JO 532-1 which was released in the name 'Ezhome-4' for commercial cultivation in Kerala state of India are summarized below.

Grain yield

Pedigree of selected saline tolerant *Kaipad* rice cultures and their grain yield in PYT, CYT, and farm trials in saline *Kaipad* fields of farmers are given in table 1. Preliminary Evaluation trial was conducted separately for both non-lodging and lodging genotypes. Comparative evaluation trial was conducted for good performing non-lodging and lodging genotypes together. 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 on par yield performance and significantly higher yield than that of *Kaipad* and *Pokkali* local checks. These cultures have wide genetic base because, one of the parents is a local cultivar having abiotic and biotic stress resistance. These cultures have more grain and straw yield, and higher harvest index than that of local land races. These hybrid derivatives are tolerant to all kinds of pests and diseases at *Kaipad* field condition. Screening in ordinary wetland condition they were invariably found to be resistant and moderately resistant to many pests and diseases. Besides their proven yield potential, pest and disease resistance and other preferable traits to saline and flooded areas, they possess desirable grain qualities as per the farmers need, like absence of awn and non-shattering unlike local land races, better taste and more acceptable appearance of cooked rice, appealing to both consumers and millers. The cooking qualities of all the cultures are above or on par with traditional land race 'Kuthiru' whose cooking qualities are much appreciated by farmers. Out of these cultures, four were released in 2010 for commercial cultivation in saline prone *Kaipad* tracts christened as 'Ezhome -1' (Culture JK 70) (Vanaja *et al*., 2015) and 'Ezhome - 2' (Culture JO 345)(Vanaja *et al* 2017). One culture, MK 22 released in 2013 as 'Ezhome -3'(Vanaja *et al* 2015).

Varietal diversity with broad genetic base is required in *Kaipad* saline tracts because the tract is highly heterogeneous with respect to salinity for which varieties of different resistance mechanism are essential. Varietal difference in stress resistance is mainly due to difference in regulatory pathway which in turn is under the control of stress induced signal transduction. Hence varietal diversity in an abiotic stress prone area is a must. Heterogeneous breeding populations have to be developed in situations where agriculture is risk prone, complex and require low input like *Kaipad* tract. Varietal diversity is also required to fight against break down of pest and disease resistance. Further, to outweigh the negative impact of micro-climate change and to help mitigate risk in agriculture sector, crop varietal diversity to a particular micro climate is imperative. Carbon dioxide locking capacity of varieties may vary(Flowers and Yeo,1995). Out of the remaining good performing three cultures, culture JO 532-1 was commercially released in 2015 to impart varietal diversity to the unique ecosystem of *Kaipad*.

Table 1
Saline tolerant *Kaipad* rice cultures in PYTs and CYTs in farmer's field

Sl. No.	*Genotypes*	*Parentage*	*Pooled PYT Grain yield (t / ha)*	*Pooled CYT Grain yield (t / ha)*
1	**Non-lodging genotypes** MK 22 (Ezhome-3)	Mahsuri x Kuthiru*	6.61 [a]	5.69 [a]
2	MK 146	- do-	2.26	-
3	MK 162	- do-	1.08	-
4	JK 23	Jaya x Kuthiru	0.99	-
5	OK 43	*Orkayama x Kuthiru	5.73 [a a]	-
6	JK 67	Jaya x Kuthiru	1.11	-
7	JO 560-2-1	Jaya x Orkayama	1.08	-
8	JK 74	Jaya x Kuthiru	6.08 [a a]	-
9	JO 583	Jaya x Orkayama	7.30 [a]	4.70 [a]
10	JK 76	Jaya x Kuthiru	4.88	-
11	JK 70 (Ezhome-1)	- do-	7.54 [a]	6.0 [a]
12	JO 532-1	Jaya x Orkayama	6.89 [a]	6.23 [a]
13	JO 556	- do-	1.33	-
14	JO 345 (Ezhome-2)	- do-	7.20 [a]	5.86 [a]
15	Vytilla 6	Non-lodging *Pokkali* check	1.91	2.58
	C D (1%)		0.93	-
16	**Lodging genotypes** JK 46	Jaya x Kuthiru	3.20	-
17	JK 59	- do-	4.71 [a a]	4.9 [a]
18	KO 5	Kuthiru x Orkayama	1.35	-
19	JK 15	Jaya x Kuthiru	7.33 [a]	4.0
20	KO 43	Kuthiru x Orkayama	1.68	-
21	JO 32-2	Jaya x Orkayama	1.03	-
22	OK 45	Orkayama x Kuthiru	3.23	-
23	MK 61-1	Mahsuri x Kuthiru	4.70 [a a]	-
24	JO 91	Jaya x Orkayama	3.08	-
25	OK 38	Orkayama x Kuthiru	4.97 [a a]	-
26	JK 58-1	Jaya x Kuthiru	1.05	-
27	JK 58-2	- do-	1.30	-
28	Vytilla -1	lodging *Pokkali* check	2.01	-
29	Kuthiru	Lodging local check of Kaipad	2.10	2.10
	C D (1%)		0.72	2.05

contd. table

* Land races of *Kaipad* ecosystem

[a] -In a column, means followed by the same alphabet do not differ significantly from each other

PYT: Preliminary Yield Trial

CYT: Comparative Yield Trial

The mean grain and straw yield of 'Ezhome -4'(Culture JO 532-1) in farm trials in *Kaipad* tracts during *Kharif* seasons are given in table 2. Culture JO 532-1 showed 168% more yield than the local check 'Orkayama'.

The yield performance of 'Ezhome -4'in National Saline Alkaline Screening trials of AICRP is given in table 3. In alkaline normal soils in inland saline soils, compared to coastal check(CST 7-1), 'Ezhome -4' showed higher yield performance.

Another added advantage of ' Ezhome -4' is that, it performs well in non -saline flooded wetland tract with an average grain yield of 3.2 t/ha under organic management (table 4). In flooded / submerged condition of non-saline wetland tracts if flood comes immediately after sprouting it decays first and later regenerate when flood subsides.

Cooking qualities

As quality is more important in organic agriculture, the cooking qualities of the variety was evaluated in

Table 2
Mean grain yield and straw yield of culture JO 532-1 in Multi location/farm trials during Kharif seasons

Name of culture/variety	*Mean Grain yield (t/ha)*				*Mean Straw yield (t/ha)*				
	2011[*]	*2012*[**]	*2013*[***]	*Pooled Mean*	*2011*[*]	*2012*[**]	*2013*[***]		*Pooled Mean*
JO 532-1	4.5	5.7	5.1	5.1	9.4	12.2	9.9	10.5	
Orkayama (local check & male parent)	2.0	2.0	1.8		1.9	5.9	6.0	5.4	5.8

[*] Pooled over 4 locations [b] [**]Pooled over 5 locations [***] Pooled over 56 locations

Table 3
Mean grain yield of culture JO 532-1 (Ezhome -4) in National Saline Alkaline Screening trials of AICRP

		Mean yield under different situations (Kg/ha)				
Name of culture/ National check	*IET No*	*Alkaline* [a]	*Alkaline Normal* [b]	*Coastal Saline* [c]	*Coastal Saline normal* [d]	*Inland saline* [e]
Culture JO 532-1	22608	2384	3754	3118	1857	1726
National 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)

Table 4
Performance of Culture JO 532-1 in farm trials in non-saline flooded tract during *Kharif* seasons under organic management

Name of culture/variety	*Mean Grain yield (t/ha)*	
	2013 (Broad casted)	*2014 (Transplanted)*
Culture JO 532-1	2.5	3.8
Ezhome -1	2.0	3.5

detail. Sensory evaluation for cooking qualities showed that ' Ezhome -4' possess better taste and more acceptable appearance of cooked rice appealing to both consumers and millers. Milling and head rice recovery percentages are more than local check 'Kuthiru' and 'Orkayama' as well as previously released 'Ezhome' varieties(table 5). Cooking traits of ' Ezhome -4' are given in table 6. Most of the

cooking qualities are on par with traditional land race 'Kuthiru'. The cooking qualities of the traditional land race 'Kuthiru' is very much appreciated by the *Kaipad* farmers long before. Cooked rice of ' Ezhome -4' is delicious and non-sticky like 'Kuthiru'. Cooked rice is swollen and tender unlike the split and hard nature of that of 'Kuthiru'. Kernel is white in colour.

Table 5
Quality evaluation at commercial level

Name of culture/cultivar	*For parboiled rice*	
	Milling % in commercial mill	*Head rice recovery %*
JO 532-1	80.0	75.0
Kuthiru	69.7	68.9
Ezhome -1	69.0	62.0
Ezhome -2	68.0	63.0
Ezhome -3	63.7	62.6

Table 6
Cooking and nutritive qualities of ' Ezhome -4' compared to local check 'Kuthiru'

Item	*Ezhome -4 (Cul. JO 532-1)*	*Kuthiru (Kaipad check)*
Cooking qualities		
Volume expansion	2.8	3.5
Kernel elongation ratio	1.4	1.52
Water uptake	1.7	1.69
Alkali spreading value	4.3	4.0
Amylose content	23.5	25.0

Taste, texture, aroma and appearance of cooked rice as per sensory evaluation Delicious with acceptable and appealing appearance, and non-sticky Delicious with acceptable and appealing appearance and non-sticky

Pest and disease resistance

There is no incidence of pests and diseases in saline *Kaipad* ecosystem, may be due to high potassium content of soil and salinity induced biotic stress tolerance. Further, when screened at wet land condition of RARS Pattambi (Table 7 & 8), it is revealed that 'Ezhome -4'is resistant to pests - gall midge and leaf folder and moderately resistant to case worm and whorl maggot. Resistant to the diseases- sheath blight and bacterial leaf blight. Besides the proven yield potential, pest and disease tolerance and other preferable characteristics of 'Ezhome -4'to saline and non-saline flooded areas, it possess desirable grain qualities like awn-less, fair shattering and medium bold grains unlike awned, shattering and bold grains of traditional landraces, but white rice.

Salient characteristics of 'Ezhome-4'

It is a long duration variety (130-135days) having high grain and straw yield with high harvest index, and tolerant to low to medium salinity(4-6dS m^{-1}) as well as suitable for non saline flooded tract. Further, unlike

Table 7
Reaction of Culture JO 532-1 to important pests when Screened at the wetland condition* of RARS, Pattambi during 2006 & 2007

Culture/ Variety	*Gall midge (% SS)*		*Leaf folder (% DL)*		*Whorl maggot (% DL)*		*Case worm (% DL)*	
	30 DAT	*50 DAT*	*30 DAT*	*50 DAT*	*30 DAT*	*50 DAT*	*30 DAT*	*50 DAT*
JO 532-1	0(R)	7.8(R)	1.6(R)	5.0(R)	13.7(M R)	1.6(R)	25.8(M R)	0(R)
Kuthiru (local check)	0 (R)	4.55 (R)	1.85 (R)	6.31 (R)	22.22 (M R)	3.88 (R)	11.11 (M R)	0 (R)

< 10% infection = resistant., 10 -30% infection = moderately resistant., >30% infection = susceptible

* In *Kaipad* ecosystem there is no problem of pests

Table 8
Reaction of 'Ezhome-4'to important diseases when screened at non-saline wet land condition of RARS, Pattambi

Culture/ Cultivar	*Score (0-9 SES scale)*			
	Sheath blight	*Brown spot*	*BLB*	*Blast*
JO 532-1	1(R)	6(MS)	1(R)	5(MS)
Kuthiru (local check)	1(R)	4(MS)	1(R)	3 (M R)

Score 1 = resistant., Score 2 & 3 = moderately resistant., (20% infection = score 5; 10% infection = score 3)

* In *Kaipad* ecosystem there is no problem of diseases

Ezhome- 4 4 in large scale cultivation in farmer's field of saline flooded tract

'Kuthiru', the popular local cultivar of the ecosystem, it has intermediate plant stature (110cm) with strong and sturdy culm with wide angle orientation, and hence tolerant to lodging. Panicle is compact with 176 grains panicle^{-1}. Healthy flag leaf and stay green index during reproductive stage shows its photosynthetic ability and efficient source sink relationship. As it is an organic variety developed for a naturally organic tract adopting the concepts and strategies of organic plant breeding, when we do cultivation in non-saline *Kaipad* tract, the management should be of organic mode and if farmers want to apply fertilizers the recommendation may be of local cultivars.

CONCLUSION

One of the major reasons farmers moving away from *Kaipad* tidal farming ecosystem is unfavorable characteristics of locally available cultivars. A challenging breeding programme involving traditional land race of target area resulted in, for the first of its kind adopting novel strategies like organic plant breeding an farmer participatory evaluation from the filial generation itself and conducting entire experiment stages in target area, four high yielding saline tolerant rice varieties were commercially released in Kerala state. 'Ezhome -4' is the last one of this series. It is a white rice with favourable grain, cooking and nutritional qualities. It is equally suitable for non-saline flooded tract during *Kharif* season. The non-lodging nature of the variety helps in easy harvest both manually and using machine. As the entire development stages of the variety were conducted in farmer's field adopting Participatory Plant Breeding, the emerging strategy in the area of plant breeding to integrate end user based participatory approach which involves close farmer-researcher collaboration to bring about plant genetic improvement within a crop, the farmers are very much convinced about the yield potential and suitability of this variety to *Kaipad* saline flooded conditions as well as in non saline flooded tracts. Farmer participation ensured revival of rice cultivation in *Kaipad* without much extension efforts and helped in easy and early adoption of the variety. As there are increasing demands for organic rice across the world market, development of this type of rice variety, suited to organic production system, is the need of the hour. Further as it is a white rice it will have demand in

international market also .Development and commercial release of high yielding 'Ezhome-4' rice variety of *Kaipad* helped in transforming this vast less productive saline prone naturally organic tracts into an arable and highly productive farming land which will lead to enhancement of nutritional and livelihood security, in addition to food security of small and marginal farmers of rural Kerala.

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