Conference Paper

# Towards Developing Salinity Tolerant Rice Adaptable for Coastal Regions in Indonesia

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## Abstract

Lowland rice areas along the coastal regions are a major contributor for rice production in Indonesia. Sustainability of rice production in those areas is challenged by the increase of soil salinity as the result of sea water inundation. The problem is exacerbated by the increase of sea water level as the impact of global climate change. High concentration of salt ion in the soil could significantly reduce rice growth and yield. Development of salinity tolerant rice varieties is therefore important to maintain sustainability of rice production in the coastal regions. Breeding programs to improve salinity tolerance of Indonesian rice has been established in Indonesian Centre for Rice Research. Through intensive salt tolerant screening program genetic variations in salinity tolerance have been identified within rice germplasm allowing the improvement of salinity tolerant of existing rice varieties. Different genetic resources have been used for salinity tolerant improvement including landraces, improved varieties and introduction lines. A number of promising salt tolerant rice breeding lines have been developed and showed adaptability to salt affected areas in the lowland coastal areas. Two new salt tolerant rice varieties have been released recently which are adaptable to salt affected areas. This paper will describe the progress in the breeding programs to develop salt tolerant rice for lowland rice areas in the coastal regions. Strategy to accelerate the improvement of the salinity tolerant of Indonesian rice varieties in the future will be also discussed.

**Keywords:** rice, breeding, salinity tolerance, coastal regions.

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## 1. Introduction

Soil salinity is a major abiotic constraint in rice production, threatening sustainability of the staple food for almost half the world's population. The salinity problem in rice cultivation is mainly happen in coastal region as the result of sea water intrusion into the rice field [1–3]. About 48 million ha of potential agricultural areas in South and South East Asia remained uncultivated due to saline soils [4]. In Indonesia, about 13.2 million ha of potential rice production areas in tidal swampland are affected by salinity [4, 5].

In addition, about 30,000 ha of rice farming areas in the Aceh province of Indonesia have been affected by salinity because of the sea water inundation during the tsunami in 2004 [6]. The area of saline soils is predicted to be increasing as the impact of global climate changes [7].

Rice responses to salinity stress varies during the rice developmental stage with the electrical conductivity threshold of 3 dS/m [7, 8]. The seedling and reproductive stages are considered as the most sensitive period to salt stress, while rice is more tolerant during the germination and vegetative stages [8]. Salt stress caused both osmotic and ionic stresses on rice plant which result in the plant growth reduction and premature leaf senescence [9, 10]. Plant adaptation to salt stress involving complex mechanisms and generally categorized into three main mechanisms including osmotic tolerance, ion exclusion and ion tissue tolerance [9, 10].

The adoption of salt tolerant rice is crucial to maintain sustainability of national rice production. Breeding program to develop salinity tolerant rice varieties has been established in Indonesian Centre for Rice Research (ICRR) in collaboration with other research institutes. The program mainly used conventional breeding approach by utilizing diverse rice germplasm. This paper will review progress in the development of salt tolerant rice varieties in Indonesia and discuss future breeding strategies to accelerate the improvement.

## 2. Variation of salinity tolerance among Indonesian germplasm

Intensive studies have been conducted worldwide to identify salt tolerant rice germplasm which can be utilized for genetic improvement [1, 11–13]. Among rice germplasm, two landraces, Nona Bokra and Pokkali, were widely used for breeding salinity tolerant rice varieties [14]. A number of quantitative trait loci (QTL's) responsible for salinity tolerance in these two varieties have been also identified [2, 14, 15].

Several studies have been also performed to screen Indonesian landraces for salinity tolerant traits. Screening mainly targeted salinity tolerance in vegetative stage. Among hundreds Indonesian landraces, only few which were tolerant to salinity such as Siputih, Lahatan Jambu, Sirendah, Ketan Nangka, Raden Ayu, Cingri, and Celebes Maros (Table 1). Their salinity tolerances in reproductive stage are not clarified yet due to difficulty in screening procedures.

Variation in salinity tolerance among Indonesian improved rice varieties have been also observed and apparently with different sodium transport mechanisms [19]. Rice cultivars such as Fatmawati and Dendang were suggested predominantly use $Na^{+}$ exclusion mechanism in adapting to saline condition, indicated by low sodium concentration in their shoot when exposed to high salt concentration [19]. In contrast,

Table 1: Indonesian landraces having tolerant response to salinity stress at the level of 12 dS/m during vegetative stage.

| Varieties | Accession number | References |
|---|---|---|
| Siputih | 1567 | Wening and Susanto [16] |
| Lahatan Jambu | 1626 | Wening and Susanto [16] |
| Sirendah | 6168 | Wening and Susanto [16] |
| Ketan Nangka | 2224 | BBPadi [17] |
| Raden Ayu | 2216 | BBPadi [17] |
| Cingri | 1123 | BBPadi [18] |
| Celebes Maros | 1135 | BBPadi [18] |

IR64 was suggested mainly used tissue tolerance mechanism in respond to salt stress. The IR64 variety showed lower leaf senescence even though the salt concentration in their shoot was higher than other varieties such as Fatmawati and Dendang [19].

## 3. Progress in the breeding program to develop salt tolerant rice varieties in Indonesia

Breeding program for salinity tolerant improvement in Indonesia initially directed to develop improved variety for swampy areas where salinity is one of the major soil problems in such areas. Two improved rice varieties, Dendang and Lambur, were released in 1999 and 2001, respectively, which are moderately tolerant to salinity and adapted to tidal swamp areas (Table 2). These varieties had comparable grain yield and were also tolerant to iron toxicity which is frequently happen in tidal swamp areas. While Dendang was categorized as medium maturity rice variety (about 125 d after sowing), Lambur was an early maturity rice variety (Table 2).

In recent years, greater concern was given to lowland rice in coastal areas such as in northern coastal area of Java Island (Pantura region) which are more vulnerable to salinity caused by the inundation of sea water. The region is the main producers of rice in Indonesia, and therefore soil salinity in these areas becoming serious problem for the stability of national rice production. Therefore, breeding program was then focused targeting rice ecosystem in irrigated and rainfed lowland coastal areas. Through national rice consortium, three salinity tolerant rice varieties were released in 2014 (Table 2). The three varieties were more tolerant to salinity stress at vegetative stage with Electrical Conductivity (EC) of 12dS/m compared to Dendang and Lambur (Table 2). The varieties had higher grain yield and earlier maturity compared to previous salt tolerant rice varieties (Table 2). Continuous breeding program is on-going to improve existing salt tolerant rice varieties using more diverse donor parents.

Development of improved rice varieties for lowland rice in coastal areas in Indonesia is mainly done through conventional breeding programs (Figure 1). Desirable traits

Table 2: Improved varieties for saline areas in Indonesia.

| Varieties | Year released | Maturity (DAS) | Yield average | Yield potential | Desirable characters |
|---|---|---|---|---|---|
| Dendang | 1999 | 123-127 | 4.0 | 5.0 | Moderately tolerant to salinity and Fe toxicity, moderately tolerant to brown plant hopper and blast disease |
| Lambur | 2001 | 113-117 | 4.0 | 5.0 | Moderately tolerant to salinity, tolerant to Fe toxicity. |
| Inpari 34 Salin Agritan | 2014 | 102 | 5.1 | 8.1 | Tolerant to salinity, tolerant to blast disease |
| Inpari 35 Salin Agritan | 2014 | 106 | 5.3 | 8.3 | Tolerant to salinity, tolerant to blast disease |
| Inpari Unsoed 79 Agritan | 2014 | 105 | 4.9 | 8.2 | Tolerant to salinity, tolerant to blast disease |

from different parents were combined through hybridization and the progenies were selected using combination of modified bulk method and pedigree method. Selected lines from pedigree nursery were then evaluated in a series of yield trials including observational yield trial, preliminary yield trial and advanced yield trial. During these processes, selected salt tolerant rice lines were also screened for other important traits such as pest and disease resistance and grain quality (Figure 1). Promising breeding lines were then evaluated in 16 locations of irrigated lowland rice coastal areas as the requirement for varietal released. Several salt tolerant rice breeding lines which were developed by Indonesian Centre for Rice Research and introduced from other countries have been evaluated in saline areas and showed promising results (Table 3).

To complement the formal breeding programs, participatory approach was also used in selecting promising rice lines for saline areas. This approach has been used to increase the adoption of rice varieties by farmers and has been widely used in the breeding program for unfavorable environments [20]. In this approach, farmers in target saline areas were involved to select advance breeding lines based on their preference. The approach was usedto evaluate promising lines of salt tolerant rice varieties in Indramayu during wet season 201-2015 (Table 3). A total of 23 farmers and five breeders were involved in the preference analysis in the saline area of Indramayu [21]. Farmers and breeders selected their preferred varieties based on the morphological and agronomical performance at mature stage before harvest. A number of salt tolerant rice lines received positive preference score indicating the acceptance of the breeding lines by farmers.

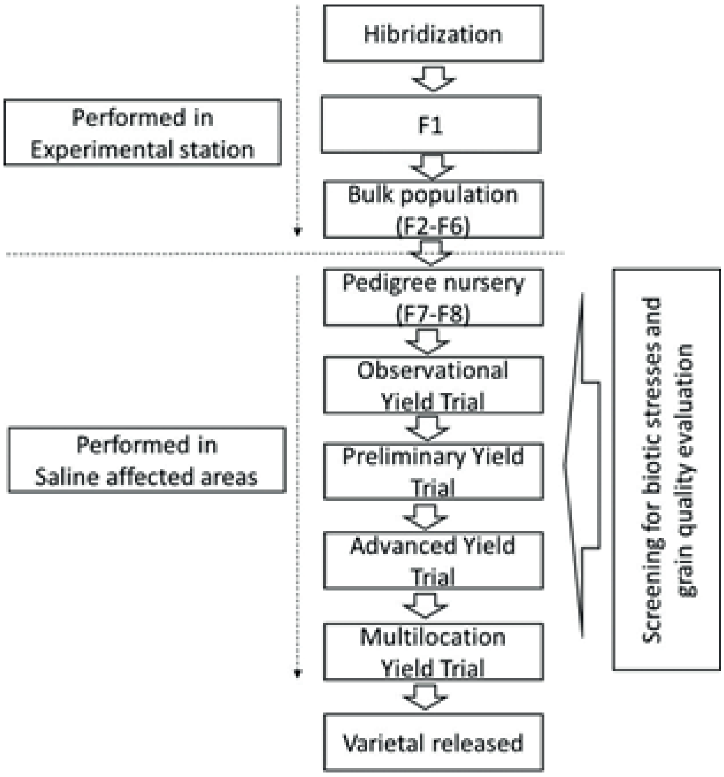


**Figure** 1: Breeding scheme for the development of salinity tolerant rice varieties in Indonesia using combination of modified bulk population and pedigree methods.

## 4. Future strategies to develop salt tolerant rice varieties adapted to coastal region in Indonesia

The complexity of mechanism underlying salinity tolerance in rice has made the progress in the development of salt tolerant rice varieties remained slow [2, 23]. In addition, the lack of screening procedures which are able to target different tolerant traits have also prevent the progress [1]. However, the advance in physiological and molecular studies on salinity tolerance mechanism in recent years have enable the dissection of complex mechanism of salt tolerance traits. The remaining challenges is how to bring and apply those knowledge in practical breeding. In particular, the conventional breeding programs which mainly adopted in Indonesian breeding programs need to be improved utilizing molecular breeding approaches to increase the precision and efficiency. In addition, the use of new technologies in phenotyping should be more emphasized to increase the reproducibility and accuracy in the screening of salinity tolerance traits. The use of non-destructive image based phenotyping method has shown promising in screening different salt tolerant traits in rice [19]. Even though the technology is still expensive at this time, the cost is expected to be rapidly decreasing as the imaging technologies get cheaper and phenotyping method improved to be more cost efficient. More importantly, image based phenotyping allowed the

Table 3: Yield and preference score of selected salinity tolerant rice breeding lines in yield trial in Indramayu district, Wet Season 2014-2015 (Data compiled from Nafisah *et al*. [22] and Hairmansis and Nafisah [21]).

| Line | Yield (t/ha) | Preference score | |
|---|---|---|---|
| | | Farmers | Breeder |
| BP 14082-2b-2-5-TRT-36-5-SKI-1*B | 7.27 | -0.022 | 0.000 |
| BP 14092-1b-2-1-TRT-20-2-SKI-1 | 5.86 | -0.011 | 0.100 |
| BP 14082-2b-2-5-TRT-35-4-SKI-1*B | 6.87 | -0.098 | -0.050 |
| BP 14082-2b-2-3-TRT-23-3-SKI-1*B | 5.10 | 0.000 | 0.050 |
| BP 14098-3b-1-4-TRT-1-1-2 | 7.03 | 0.022 | 0.050 |
| IR 83142-B-57-B-SAL-IND-2 | 7.07 | -0.033 | -0.150 |
| HHZ12-SKI-1-2-0Kr-JK-0 | 7.03 | 0.033 | 0.150 |
| HHZ 5-DT20-DT3-Y2 | 6.29 | 0.022 | -0.050 |
| WTR1-JK-0 | 6.95 | 0.043 | -0.050 |
| HHZ8-SAL6-SAL3-Y2 | 7.03 | 0.130 | 0.100 |
| RC8-SAL-IND-*1B | 8.24 | -0.011 | 0.000 |
| FL 478 | 8.60 | 0.011 | -0.100 |
| Inpari 35 Salin Agritan | 6.20 | -0.054 | -0.050 |
| Cilamaya Muncul | 5.03 | -0.033 | 0.000 |

dissection of different salinity tolerance traits [14] which will enable pyramiding of different tolerant mechanisms to increase salinity tolerant of rice.

Furthermore, rice lands in coastal regions are not only facing salinity problem but also other abiotic stresses such as submergence during rainy season and drought during dry season. Therefore, development of multi stress tolerant rice varieties is crucial in the future breeding program. Development of breeding population to combine several abiotic stress tolerant traits has been already initiated and the selections of those populations are ongoing.

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