

# Genetic improvement of Aceh local rice variety Sikuneng to produce green super rice lines adaptive to abiotic stresses

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**Abstract.** The high genetic diversity of rice landraces of Aceh has great potential to contribute to the world's food security program in the future, especially in adapting to climate changes and environmental degradation. The objective of this research was to develop a new superior rice line adaptive to abiotic stress and maintains high productivity despite limited agricultural inputs. An Aceh's local variety, Sikuneng, was artificially crossed with an isogenic line IRBB27 and the F<sub>1</sub> plants were self-pollinated for two generations. The F<sub>3</sub> lines were cultivated in drought stress and high salinity conditions with the application of aerobic rice system and flash irrigation. It was discovered that the F<sub>3</sub> lines showed significantly improved plant height, number of panicles per plant, panicle length, grain weight per plant and grain yield potential per hectare. The plant height of the F<sub>3</sub> lines varied from 98 to 192 cm, whereas the plant height of Sikuneng was 172 cm. The number of panicles of F<sub>3</sub> lines ranged from 10.3 to 43.5, whereas Sikuneng had only 8.7 panicles. The panicle length of F<sub>3</sub> lines ranged from 23.9 to 47.3 cm and Sikuneng had only 28.1 cm of panicle length. The grain weight per plant of F<sub>3</sub> lines varied from 69.8 to 196.7 g, in contrast to the grain weight of Sikuneng which was 64.5 g. The weight of 1,000 grains of F<sub>3</sub> lines ranged from 21.0 to 34.9 g, whereas that of Sikuneng was 26.9 g. While the yield potential of Sikuneng was 7.6 t/ha, the yield potential of the F<sub>3</sub> lines varied from 7.2 to 13.9 t/ha. The highest yield potential was shown by Skn-68-1 line. Further evaluation and selection process need to be conducted in the next generations until the improved characters of the new lines are stable.

Keywords: Aceh, IRBB27, genetic improvement, green super rice, Sikuneng, abiotic stress.

## 1. Introduction

Among the impacts of climate change, drought is a serious threat, especially in lowland rain-fed areas where 75% of world rice supply is produced [1]. Extreme weather has led to increased frequency of abiotic stresses in plants, such as droughts, floods and heatwaves [2,3]. These extreme conditions are the major threats to food security, particularly in Asia, including Indonesia. More than 4 billion people live in Asia, where 90% of rice was produced and consumed as a staple food [4,5]. Therefore, the task of achieving and maintaining food security will be a big responsibility for Indonesia. The problem is further complicated by high population growth, environmental degradation, water limitation, and land degradation. Therefore, it is urgent to develop new rice varieties that are able to adapt to global climate change and can maintain high productivity under extreme environmental conditions despite water or fertilizer shortages [6,7]. A suitable solution is to develop Green Super Rice (GSR) through a plant breeding program by crossing adaptive local varieties to superior varieties. The GSR rice is



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developed through innovative introgression breeding strategies that utilize heterosis or codominance principles to improve rice varieties for sub-optimal or marginal land. GSR is a rice cultivar that can maintain high productivity despite less input (water, fertilizer and pesticide). Marcaida et al. [8] and Yorobe et al. [9] suggested that GSR cultivars in IRRI are able to overcome drought and soil fertility shortages or other extreme conditions.

Recently, a local superior variety in Aceh, Sikuneng, has been successfully crossed with the isogenic line IRBB27 obtained from IRRI. Sikuneng has a number of advantages including high yield potential and adaptive to extreme conditions, but it matures in 4.5 months and tall, which makes it susceptible to lodging. A previous study showed that local rice varieties from Aceh have several advantages, such as resistant to salinity and drought stresses [10], have higher yield potential and tolerant to high temperatures [10]. IRBB27 has high productivity, resistant to diseases, early maturing (3.5 months) and has the genes that make the architecture of the plant to be shorter with compact stems. Some of the F<sub>2</sub> generations derived from the cross between Sikuneng and IRBB27 showed improvement in several traits compared to the two parents, i.e. their yield potential is above 12 t/ha and mature at 100–110 days. The objective of this research was to produce a GSR rice line with high yield potential and able to adapt under low fertilizing and water-saving inputs, resistant to pest and diseases, and tolerant to drought stress and high temperature, by exploiting the heterosis aspect of crop breeding.

## 2. Materials and methods

This study was carried out in an experimental farm of Syiah Kuala University, Aceh, Indonesia from March to September 2017. The cultivated land for selection activities was a sub-optimal rice field in Darussalam, Banda Aceh, Indonesia. The genetic materials tested were 100 F<sub>2</sub> rice lines derived from a cross between a local superior rice variety, Sikuneng, and IRBB27 which was introduced from IRRI through Temasek Life Science, Singapore. F<sub>3</sub> seeds were harvested from the F<sub>2</sub> population in the Seed Science and Technology Laboratory, Syiah Kuala University. Fifty F<sub>3</sub> seeds from each F<sub>2</sub> lines were planted on the same location in 600 m<sup>2</sup> dry saline land situated 4 km from a beach at an altitude of 3 m above sea level. Seedlings were planted in dry, non-puddled and non-saturated soils which received intermittent irrigation which was supplied by aerobic system using saline water with a salinity level of about 8–12 mmhos/cm.

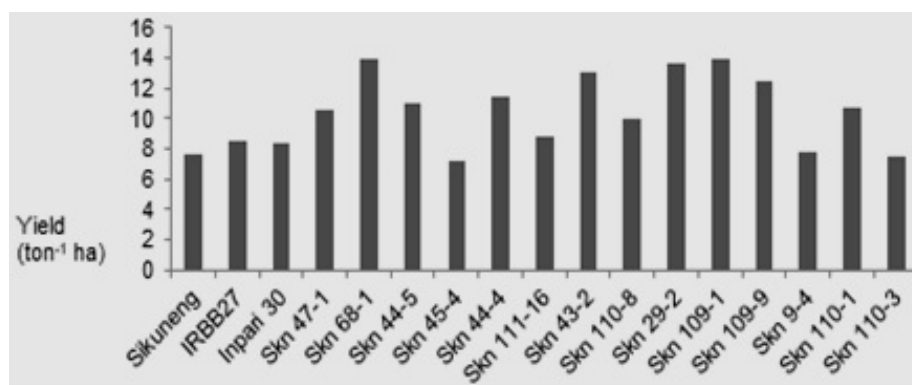
The pedigree selection method was carried out by recording genealogies of selected progeny from generation to generation. For each cross, one panicle was planted in two rows following a wide hill spacing system called 2:1 *Jajar Legowo*. Fifteen-day-old seedlings were transplanted with a spacing of 25 cm between rows and 25 cm between hills, with one plant per hill. Selection was conducted visually (qualitatively) based on desired criteria, especially for plant height, number of panicles, grain weight, panicle length and yield potential. Selection was done on the population as well as individuals to obtain plants with desired characters.

## 3. Results and discussion

The F<sub>3</sub> lines derived from a cross between Sikuneng and IRBB27 showed wide variation in the yield components, including the number of panicles, panicle length, grain weight per plant, weight per panicle or yield potential (Table 1). Generally, the F<sub>3</sub> rice lines produced higher number of panicles than the two parents (Figure 1). a similar phenomenon can also be found in the length of the panicle (Figure 2A). It was found that the panicle length of Skn 9-4 F<sub>3</sub> rice lines was significantly higher than that of their parents. The grain weight per plant was also significantly higher than that of the parents (Figure 2B). The number of panicles of Skn 44-5 F<sub>3</sub> rice lines was significantly increased compared to that of their parents. The same result was discovered on the yield of the F<sub>3</sub> rice lines. Yield potentials of F<sub>3</sub> rice lines were generally higher than that of both parents. These characters were the main selection criteria, aside from the semi dwarf phenotype. This indicates that the two parental lines contributed favorable alleles for yield component traits.

**Table 1.** Yield components of F<sub>3</sub> lines derived from a cross between Sikuneng and IRBB27.

Genotype	Panicle number	Length of panicle (g)	Grain weight per plant (g)	Grain weight per panicle (g)	Yield potential (t/ha)
Sikuneng	8.7	28.1	64.5	8.1	7.6
IRBB27	17.2	25.8	72.7	4.2	8.5
Inpari 30	20.4	27.2	74.1	3.7	8.3
Skn 47-1	24.9	32.3	149.4	6.2	10.6
Skn 68-1	27.5	36.8	196.7	8.3	13.9
Skn 44-5	39.2	35.4	162.3	4.2	11.0
Skn 45-4	17.7	26.2	69.8	4.1	7.2
Skn 44-4	29.4	31.1	109.9	3.8	11.4
Skn 111-16	22.5	23.9	84.4	3.8	8.8
Skn 43-2	43.5	30.7	181.7	4.2	13.0
Skn 110-8	35.4	33.8	171.9	4.9	10.0
Skn 29-2	22.8	31.5	193.4	8.9	13.7
Skn 109-1	24.2	36.2	142.6	5.9	10.1
Skn 109-9	26.5	38.1	156.5	6.0	12.4
Skn 9-4	10.3	47.3	73.6	7.3	7.7
Skn 110-1	21.6	28.6	102.8	4.9	10.7
Skn 110-3	18.2	26.7	71.7	4.0	7.5

**Figure 1.** Yield potential of the best selected F<sub>3</sub> lines derived from a cross between Sikuneng and IRBB27.

The F<sub>3</sub> lines Skn-68-1 and Skn-29-2 showed the highest grain weight per plant, i.e. 196.7 and 193.4 g, respectively (Table 1). However, selection needs to be continued in the next generations to fix the superior alleles in the selected progeny. The highest yield was found on Skn-68-1 and Skn-29-2, which reached 13.9 and 13.7 t/ha, respectively (Figure 1). This indicates that the F<sub>3</sub> lines from the cross between Sikuneng and IRBB27 have great potentials to produce GSR. Development of GSR is an important strategy to increase rice production in China compared to the existing varieties obtained through conventional rice breeding or hybrid rice [12]. After nearly a decade of cultivation, super rice

accounts for more than 60% of the total area planted with rice and has contributed about two billion dollars for China's national economy [13]. It was also discovered that the F<sub>3</sub> rice lines grew well in the aerobic system that was applied by cultivating the rice plants in dry, non-puddled and non-saturated soils with supplemental intermittent irrigation (Figure 3).



**Figure 2.** F<sub>3</sub> rice lines and their two parents (P1 Sikuneng and P2 IRBB27). (A) Panicle length of Skn 9-4 line was significantly longer than their parents. (B) Panicles number of Skn 44-5 line was significantly higher than their parents.



**Figure 3.** The F<sub>3</sub> rice line progenies of Sikuneng × IRBB27 grew well in dry, non-puddled and non-saturated soils with supplemental intermittent irrigation system.

Development of new rice varieties adapted to global climate change is highly needed in order to maintain high productivity under extreme environmental conditions despite fertilizer or water shortages [6,7]. A possible solution for this is by developing GSR through a plant breeding program using highly adaptive local varieties, which are crossed with newly available superior lines. Selection can then be performed to obtain GSR cultivars with high productivity and efficient in fertilizer and water input [14].

#### 4. Conclusions

The F<sub>3</sub> lines derived from a cross between Sikuneng and IRBB27 produced higher panicle number, panicle length and grain weight per panicle than those of both parents. F<sub>3</sub> lines Skn-68-1 and Skn-29-2 showed the highest grain weight per plant, i.e. 196.7 and 193.4 g, respectively.

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