Yield of green super rice (GSR) lines under legowo and squared planting system

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Abstract. Green Super Rice (GSR) is rice genotypes designed to have high yield which is stable under low input conditions. Legowo was reported to give higher yield compared to The square planting system. This research aimed to study The yield of 10 GSR lines along with four check i.e. Situ Bagendit, Cihervang, Inpari 8, and Inpari 13 under legowo 2: 1 (20 cm x 10 cm x 40 cm) and square (20 cm x 20 cm) planting system. The experiment was conducted in ICRR experimental station in Sukamandi during DS 2012 following split-plot design of two replications with The spacing system as the main plot and genotype as a subplot. Transplanting was conducted at 21 days after sowing into 3 m x 7 m plots of 1 – 3 seedlings/hill. The results showed that the interaction between genotypes and spacing systems was identified only for plant height. There were differences among genotypes on plant height, tiller number, unfilled grain/panicle, 1000 grain weight and yield. The spacing systems affected The tiller number and yield. Huanghuazhan (8.81 t/ha) had highest yield, higher than The best check Cihervang (7.81 t/ha). FFZ1, IR 83140-B-11-B, IR 83142-B-19-B, WTR 1 dan Zhongzu 14 considered to be adapted for legowo planting system. Keywords: Green Super Rice, Planting System, legowo

1. Introduction
Green Super Rice (GSR) is rice genotypes designed to have high yield which is stable under low input condition and relatively environmental friendly, since it is tolerant to biotic and abiotic stresses, as well as efficient in utilizing fertilizers so that it needs a lower rate of organic fertilizers [1,2]. Development of GSR varieties had been conducted by improving mega varieties utilized genes of various superior traits from various donors from various countries across the world through special strategy by utilizing most advanced technologies [3]. The GSR variety development is conducted based on A comprehensive study of The interaction of genes (gene network) in expressing a trait [4].

GSR varieties either inbred or hybrid was firstly initiated in IRRI (International Rice Research Institute) and China. The lines had been produced and tested in various rice-producing countries in Asia and Africa supported by Bill and Melinda Gates Foundation (BMGF), The government of the People Republic of China, and the collaborator countries. Two GSR lines had been selected, tested, and finally released a new variety in Indonesia, i.e Huanghuazhan and Zhongzu 14. Both are released as Inpari 42 Agritan GSR and Inpari 43 Agritan GSR with yield potential of 10.58 t/ha and 9.02 t/ha, respectively [5]. It is suspected that the varieties could increase production in optimum irrigated lowland as well as sub-optimum lowland areas.
Beside variety, agronomy had a key role in increasing rice production in Indonesia. Integrated crop management (ICM) or called PTT (Pengelolaan Tanaman Terpadu) is a concept of utilizing resources to optimize rice yield in a specific farmer field [6]. One component of the PTT is legowo planting system. Legowo system means the planting of some rows of rice plant with one row vacant. The plants in the vacant rows were transferred to fill up the rows beside the vacant row. The logowo system had been initiated at The 1980s and further improves with various row numbers [7]. The technique is further improved by incorporating quality seed of new improved variety, soil bio-decomposer, organic manure as seed treatment and balanced fertilizers, integrated crop protection, and mechanization. Legowo of 2:1 is reported to give the highest yield [8] and used in further recommendation [9].

Legowo was reported to give higher yield compared to the square planting system. It is due to The increasing population numbers by filling up the border rows (rows beside the vacant row [7]. Squared planting system of 20 cm x 20 cm or 25 cm x 25 cm gives population density of 200,000 to 250,000 plants/ha. On the other hand, legowo 2:1 system makes the population density of 333,250 plants/ha, legowo 4:1 makes the population become 300,000 plants/ha, and legowo 6:1 makes 285,000 plants/ha [10]. This research aimed to study the yield of 10 GSR lines along with four check varieties, i.e. Ciherang, Inpari 8, Inpari 13, and Situ Bagendit under legowo 2:1 (20 cm x 10 cm x 40 cm) and square (20 cm x 20 cm) planting system.

2. Methodology
The experiment was conducted in ICRR experimental station in Sukamandi during DS 2012. Ten selected GSR lines, i.e. Zhongzu 14, Huanghuazhan, IR83140-B-11-B, FFZ 1, KCD 1, SACG 4, ZX 117, IR83142-B-19-B, Zhonghua 1 dan Weed Tolerant Rice 1 Along with four check varieties, i.e. Ciherang, Inpari 8, Inpari 13 dan Situ Bagendit was tested in this study. The experiment was conducted following split-plot design of two replications with The spacing system as The main plot and genotype as a subplot. There was two planting system, i.e. square of 20 cm x 20 cm and Legowo 2:1 (30 cm x 10 cm x 40 cm). Transplanting was conducted at 21 days after sowing into 3 m x 7 m plots of 1–3 seedlings/hill. Fertilizers were applied optimally according to local recommendations. Plant was protected Intensively according to integrated crop protection principles.

Observation was executed into agronomic traits as follows.
1. Plant height (cm) = distance from The soil surface into the tip of main panicle of 5 plants randomly chosen in each plot
2. Tiller number = productive tiller at matured stage of 5 plant randomly chosen in each plot
3. Filled grain/panicle = average number of filled grains/panicle of whole panicles of three randomly selected plants
4. Un-filled grain/panicle = average number of un-filled grains/panicle of whole panicles of three randomly selected plants
5. Seed Set (%) = average percentage of filled grain from the total grains in the whole panicle of three randomly selected plants
6. 1000 grain weight (g) = weight of 1000 grains at 14% moisture content
7. Yield (t/ha) = yield was converted into t/ha at 14% moisture content based on population density of the plot.

Variance and difference mean based of Least Significant Different at α=5% was analyzed using Cropstat Ver 7.2 [11].

3. Results and Discussion
The results showed that the interaction between genotypes and spacing systems was identified only for plant height. It indicated that the planting system (square and legowo) at a specific genotype could increase plant height. There were differences among genotypes on plant height, tiller number, unfilled grain/panicle, 1000 grain weight and yield. On the other hand, the spacing systems affected the tiller number and yield (Table 1).
Table 1. F value of genotype, planting season and interaction of genotype x planting system of seven agronomic traits of 14 genotypes under squared and legowo planting system, Sukamandi, DS 2012

| No. | Trait               | Genotype   | Planting System | Genotype x Planting System |
|-----|---------------------|------------|-----------------|---------------------------|
| 1   | Plant height (cm)   | 18.85**    | 0.32 ns         | 3.33*                     |
| 2   | Tiller number/plant | 2.69*      | 26.22**         | 1.51 ns                   |
| 3   | Number of filled grain/panicle | 1.19 ns | 0.90 ns | 0.81 ns |
| 4   | Number of un-filled grain/panicle | 4.20** | 0.07 ns | 0.86 ns |
| 5   | Seed set (%)        | 2.45 ns    | 0.12 ns         | 0.76 ns                   |
| 6   | 1000 grain weight (g) | 58.21**    | 0.62 ns         | 0.57 ns                   |
| 7   | Yield (t/ha)        | 3.77*      | 82.71**         | 0.35 ns                   |

Remarks: ns = not significant at α level of 5%, * = significantly different at α level of 5% of split-plot analysis, ** = significantly different at α level of 1% of split-plot analysis

For plant height, among the check, Ciherang is the highest plant (104.65 cm). SAGC 4 (113.35 cm), Weed Tolerant Rice 1 (110.75 cm) and ZX 117 (109 cm) are however higher than Ciherang. On the other hand, Huanghuazhan (95.65 cm), IR 83142-B-19-B (100.3 cm), Zhonghua 1 (95.45 cm) and Zhongzu 14 (95.40 cm) were shorter than Ciherang. For tiller number, Ciherang, Inpari 8 and Situ Bagendit had 21 tillers, SAGC 4 (14 tillers), Weed Tolerant Rice 1 (15 tillers) and ZX 117 (15 tillers), fewer than Ciherang. For un-filled grain/panicle, Inpari 13 (11 grains) was the least among the tested genotypes. However, FFZ 1 (26 grains), SAGC 4 (25 grains), Zhonghua 1 (34 grains) and Zhongzu 14 (27 grains) had the highest. For the seed set, Inpari 13 (91.32 %) had the highest among the tested genotypes. All the GSR lines had comparable seed set with Inpari 13, except Zhonghua 1 (80.91%) and Zhongzu 14 (82.16%). For 1000 grain weight, Situ Bagendit (27.13 g) had the highest among the checks, but it is lower than ZX 117 (30.69 g). FFZ 1 (23.53 g), Huanghuazhan (23.85 g), Zhonghua 1 (23.45 g) and Zhongzu 14 (23.20 g) had lower than Situ Bagendit. Mostly the lines had erect plant type. It means that the tested lines had been selected for acceptable agronomic performance in Indonesia and having high yielding ability under Indonesia agro ecosystem condition (Table 2).

There is no significant interaction between genotype and planting system on yield. Therefore the genotypes tended to have the same pattern in both planting systems. Based on yield average over square and legowo planting system, Huanghuazhan (8.81 t/ha) had the highest yield, higher than the best check Ciherang (7.81 t/ha). The yield of all the tested genotypes was increased at legowo spacing system. The increase was varied among genotypes ranging from 17.52% (SAGC 4) to 45.03% (FFZ 1). Ciherang increased 41.1 % and Inpari 13 26.75 %. Weed Tolerant Rice 1 (9.63 t/ha), FFZ 1 (9.63 t/ha), Huanghuazhan (9.61 t/ha), Zhongzu 14 (9.58 t/ha), KCD 1 (9.52 t/ha), and SAGC 4 (9.19 t/ha) had the highest yield, comparable with Ciherang (9.14 t/ha) are the highest bearing yield lines under legowo planting system and the lines also had relatively higher yield compared to Ciherang under square planting system (Table 3). It indicated that the lines are adaptable for either the square and legowo planting systems. Planting under legowo planting system most probably giving more Advantages to farmers. This result may not change significantly under rainy and dry season, especially under irrigated lowland condition. Rice has various yield gap between wet and dry season, and in some cases there is no yield gap between the seasons [12].
The concept of GSR is to have high yield and stable under sub-optimal conditions [1]. It could be seen that mostly GSR lines had relatively higher yield compared to Ciherang under a lower yield environment (square planting system) and it tended to have also higher yield compared to Ciherang under a higher yielding environment (legowo planting season). Legowo 2:1 (two dense rows followed by one row vacant) was reported to had highest yield among the other type of legowo (3:1, 4:1, 5:1, 6:1, and 7:1) [8]. This research was comparing legowo 2:1 with square spacing also showed that legowo 2:1 gave higher yield compared to mostly practiced by farmers square spacing technique.

Yield of the five highest yield average GSR lines is shown in Figure 1. These results indicated that selected lines had the predicted characteristics of GSR, especially high yielding ability and stable under various environmental condition. The selected best GSR lines had higher yield compared to the best check and the most popular variety in Indonesia. It indicated that GSR concept and materials is hopefully applicable for the Indonesian agro-ecosystem condition.

Table 2. Performance of 14 rice genotypes under squared and legowo planting system, Sukamandi, DS 2014

| No | Genotype                  | PH  | TN  | FG  | UG  | SS  | B1000 | Plant Type |
|----|---------------------------|-----|-----|-----|-----|-----|-------|------------|
| 1  | Ciherglass                | 104.65 | 21 | 111 | 13  | 89.99 | 26.89 | Errect     |
| 2  | FFZ 1                     | 100.7 | 19 | 138 | 26  | 84.2  | 23.53 | Errect     |
| 3  | Huanghuazhan              | 95.65 | 16 | 140 | 13  | 90.75 | 23.85 | Errect     |
| 4  | Inpari 13                 | 101.8 | 19 | 109 | 11  | 91.32 | 26.45 | Errect     |
| 5  | Inpari 8                  | 103.65 | 21 | 114 | 23  | 83.21 | 24.2  | Errect     |
| 6  | IR 83140-B-11-B           | 106.3 | 19 | 131 | 12  | 91.66 | 27.23 | Semi Errect|
| 7  | IR 83142-B-19-B           | 100.3 | 22 | 103 | 7   | 93.29 | 26.78 | Errect     |
| 8  | KCD 1                     | 107.25 | 16 | 119 | 21  | 83.8  | 26.58 | Errect     |
| 9  | SACG 4                    | 113.35 | +  | 14  | -  | 152   | 25  | 86.09 | 27.38 | Errect     |
| 10 | Situ Bagendit             | 97.6  | -  | 21  | 113 | 89.35 | 27.13 | Errect     |
| 11 | Weed Tolerant Rice 1      | 110.75 | +  | 15  | -  | 146   | 18  | 89.09 | 27  | Errect     |
| 12 | ZHONGHUA 1                | 95.45 | -  | 16  | 145 | 34    | +  | 80.91 | 23.45 | Errect     |
| 13 | Zhongzu 14                | 95.4  | -  | 20  | 123 | 27    | +  | 82.16 | 23.2  | Errect     |
| 14 | ZX 117                    | 109   | +  | 15  | -  | 111   | 12  | 92.03 | 30.69 | Errect     |
|    | LSD 5%                    | 4.13  | 5   | 44.4 | 11.7 | 8.1  | 0.85  |            |
|    | CV                        | 1.7   | 13.5 | 17.5 | 60  | 8.1  | 3.4   |            |

Remarks: + = number at the same column is significantly higher than Ciherglass at a level of 5%, - = number at the same column is significantly lower than Ciherglass at a level of 5%, no sign= number at the same column is not different from Ciherglass at a level of 5%, PH = plant height (cm), TN = tiller number/plant, FG = number of filled grain/panicle, UG = number of un-filled grains/panicle, SS = seed set (%), 1000GW = 1000 grain weight (g).

Based on average over genotypes, legowo (9.01 t/ha) system had a 27.76 % higher yield compared to the square system (7.05 t/ha) (Table 3). It is higher than the previous report that legowo increases around 10-15% from square system [13]. The high yield in legowo system may due to The increasing population number per square area compared to The square planting system. Borderline with A dense population increase the population density [14]. On the other hand, the vacant row caused more sunlight to penetrate into the rice canopy that maximizes the photosynthesis capacity. These border plants had higher yield thus increase the quantity and quality of the harvested grains. It is because the plants in the borders catch more sunlight. This phenomenon is called a border effect [15]. The other advantage of legowo system is easier for plant controlling and establishment. The space in every 2, 4, 6, or 8 rows makes easier the mobility of farmers in taking care of the plants [16].

The concept of GSR is to have high yield and stable under sub-optimal conditions [1]. It could be seen that mostly GSR lines had relatively higher yield compared to Ciherang under a lower yield environment (square planting system) and it tended to have also higher yield compared to Ciherang under a higher yielding environment (legowo planting season). Legowo 2:1 (two dense rows followed by one row vacant) was reported to had highest yield among the other type of legowo (3:1, 4:1, 5:1, 6:1, and 7:1) [8]. This research was comparing legowo 2:1 with square spacing also showed that legowo 2:1 gave higher yield compared to mostly practiced by farmers square spacing technique.
Table 3. Yield of 14 rice genotypes under squared and legowo planting system, Sukamandi, DS 2014

| No | Genotype            | Squared | Legowo | Average | Difference (%) | Difference (ton) |
|----|---------------------|---------|--------|---------|----------------|-----------------|
| 1  | Ciherang            | 6.48    | 9.14   | 7.81    | 41.05          | 2.66            |
| 2  | FFZ 1               | 6.64    | 9.63   | 8.14    | 45.03          | 2.99            |
| 3  | Huanghuazhan        | 8.01    | 9.61   | 8.81*   | 19.98          | 1.6             |
| 4  | Inpari 13           | 6.84    | 8.67   | 7.76    | 26.75          | 1.83            |
| 5  | Inpari 8            | 5.71    | 7.65   | 6.68    | 33.98          | 1.94            |
| 6  | IR 83140-B-11-B     | 6.91    | 8.67   | 7.79    | 25.47          | 1.76            |
| 7  | IR 83142-B-19-B     | 6.64    | 8.85   | 7.75    | 33.28          | 2.21            |
| 8  | KCD 1               | 7.73    | 9.32   | 8.53    | 20.57          | 1.59            |
| 9  | SACG 4              | 7.82    | 9.19   | 8.51    | 17.52          | 1.37            |
| 10 | Situ Bagendit       | 6.29    | 8.51   | 7.4     | 35.29          | 2.22            |
| 11 | Weed Tolerant Rice 1| 7.36    | 9.63   | 8.5     | 30.84          | 2.27            |
| 12 | Zhonghua 1          | 7.2     | 8.84   | 8.02    | 22.78          | 1.64            |
| 13 | Zhongzu 14          | 7.61    | 9.58   | 8.6     | 25.89          | 1.97            |
| 14 | ZX 117              | 7.48    | 8.83   | 8.16    | 18.05          | 1.35            |

Rata-rata

LSD₃% GxE 1.73

CV (%) 10.00

Nevertheless, the yield achieved in this research is still around 10 t/ha. Yield potential of rice plant is predicted to be around 10 t/ha since the Green Revolution. It also indicated that new concept for high yield potential for rice is needed after refining some previous concept such as IRRI’s New Plant Type and China’s Super Hybrid Rice [17]. Incorporating of tolerance to biotic and abiotic stresses tolerance into the high yielding varieties may give more advantage. On the other hand, giving optimum condition to the plant may rise up the yield exploiting the potential maximally.

Figure 1. Trend of yield increase of five highest yielding GSR lines due to legowo planting system
4. Conclusions
There is interaction between genotype and planting system only on plant height. The spacing systems affected the tiller number and yield. The tested genotypes had variation on plant height, tiller number per plant, number of un-filled grain/panicle, 1000 grain weight, and yield. Huanghuazhan (8.81 t/ha) had a higher yield compared to the best check Ciherang (7.81 t/ha). GSR lines are considered to be adapted for the square and legowo planting system and planting under legowo planting system is more benefitting. Further studies on different seasons and agro-ecosystem may needed. Overall, the GSR concept and materials are suspected to be working for The Indonesian agro-ecosystem condition.

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