Dissecting yield affecting traits of GSR lines under Indonesian agro-ecosystem, an initial study

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Abstract. Green Super Rice (GSR) is a concept of developing rice varieties which are having high yield under optimum and stable under sub-optimum condition combined with environmental friendly characters such as resistant to pest and diseases, efficient in using fertilizers, tolerant to abiotic stresses such as drought and salinity, thus it needless chemical agricultural inputs. It would hopefully match with the need to increase yield by considering environmental sustainability. The research had been initiated in IRRI and China and supported by BMGF (Bill and Melinda Gates Foundation) and the government of the People Republic of China, the materials had been imported to Indonesia. This study aimed to test 30 GSR lines under the Indonesian agroecosystem condition. The trial was conducted in ICRR experimental station in Sukamandi, during WS 2012/2013 following a randomized complete block design of three replications. The results showed that 28 lines had comparable yield with the best check Inpari 18 (11.09 t/ha). The highest yielded lines are Huanghuazhan (13.66 t/ha), D4098 (12.91 t/ha), IR83142-B-61-B (12.38 t/ha), Weed Tolerant Rice 1 (12.38 t/ha), and HHZ17-DT6-SAL3-DT1 (12.33 t/ha). Correlation analysis showed that the Filled grain (0.53) and seed set (0.40) is the most affecting traits to yield.

1. Introduction
There are some challenges to secure global rice production, i.e. increasingly pests and diseases occurrence with indiscriminate pesticide applications, high pressure for yield increase and overuse of fertilizers, drought and water shortage, and extensive cultivation in marginal lands. Green super rice is formulated to answer the challenges. It is designed to have resistance to multiple insects and diseases, high nutrient efficiency, and abiotic especially drought resistance. Increasing yield potential is one of the major goals. Quality is also considered, due to people’s preference and requirement dynamics. Thus, the variety should gradually reduce the application of pesticides, fertilizers, and water while still achieving continuous yield increase and quality improvement. This attributes in rice plant would reduce the consumption of pesticides, chemical fertilizers, and water [1]. Some efforts had been taken to develop the designed genotypes, such as screening of germplasm collections, mapping and identifying QTLs, screening of mutant libraries, microarray analysis of genes differentially regulated, and functional test of targeted genes [2].
Green Super Rice Project had been launched in IRRI (International Rice Research Institute) the Philippines at 2008 to develop GSR varieties as concepted above. The research of GSR had been initiated in IRRI and China and supported by BMGF (Bill and Melinda Gates Foundation) and the government of the People Republic of China. The developed materials are ready for adaptation study in various countries in Asia and Africa [3]. Some of the materials had been continuously tested in Indonesia for various agroecosystem and traits, such as for various dosage of fertilizers application [4], rainfed lowland condition [5], salinity [6], quality aspects [7], and so on resulting some prospective lines. This study is aimed to test 30 GSR lines under the Indonesian agroecosystem condition, especially irrigated lowland.

2. Material and Method
The materials which are tested in this study are 30 GSR lines alongwith 4 check varieties, i.e. Ciherrang, Inpari 10, Inpari 13, and Inpari 18. The trial was conducted in irrigated lowland field of ICRR experimental station in Sukamandi, during WS 2012/2013. The experiment was managed following randomized complete block design of three replications. The materials were transplanted at 21 days after sowing with planting space of 25 cm x 25 cm, 1 – 3 seedlings/hill in a plot of 2 m x 5 m square.

The observation was conducted for heading date, plant height, productive tiller number/plant, yield component based on random of three sampling hills including a number of filled and un-filled grain/panicle and 1000 grains weight. Thw yield was converted into t/ha of 14% moisture content. Flag leaf and two top leaves below flag leaf was measured for length, width, thickness, and degree of angle. Variance for the observes traits was analyzed using CropStat Ver 7.2. Pearson correlation among the observed traits was analyzed using Minitab Ver. 14.

3. Results and Discussion
The results showed that 28 lines had comparable yield with the best check Inpari 18 (11.09 t/ha). The highest yielding lines are Huanghuazhan (13.66 t/ha), D4098 (12.91 t/ha), IR83142-B-61-B (12.38 t/ha), Weede Tolerant Rice 1 (12.38 t/ha), HHz17-DT6-SAL3-DT1 (12.33 t/ha), SACG4 (12.11 t/ha), and TME80518 (12.05 t/ha). Ciherrang, the most popular variety, had yield of 11.02 t/ha, comparable with Inpari 18. Huanghuazhan is identified as having a high yielding ability and it had been further tested and release as a new variety, named Inpari 42 Agritan GSR [8]. The yield achieved by Huanghuazhan had surpassed the yield potential of IR5 and IR8 (around 10 t/ha) [9]. These results indicated that GSR lines are mostly adaptable to Indonesian lowland agro-ecosystem condition. This trial was conducted during wet season. There is a variation of yield gap between wet and dry season, but in some cases there is no yield gap between both seasons [10]. A further test to further study genetic x environment interaction is prospective to be conducted to select the best lines for various conditions.

The GSR lines had relatively good and preferable agronomic traits. It has relatively comparable agronomic traits with the check varieties. Ciherrang is the most popular rice variety starting in West Java [11] and then in Indonesia [12]. GSR lines had relatively high yield. It tends to have more grains/panicle with comparable tiller number with Ciherrang (17 tillers), shorter plant stature compared to Ciherrang (126.47 cm), earlier to mature compared to Ciherrang (heading date 80 days after sowing), but smaller 1000 grain weight compared to Ciherrang (26.63 g) (Table 1, Figure 1). D4098 (31.83 g) had higher 1000 grain weight, while the other highest yield lines had comparable 1000 grain weight with Ciherrang such as D4098 (31.83 g 1000 grain weight with the yield of 12.91 t/ha, IR83142-B-61-B (27.03 g, 12.38 t/ha), WEED TOLERANT RICE 1 (25.73 g, 12.38 t/ha), HHz17-DT6-SAL3-DT1 (24.27 g, 12.33 t/ha), SACG4 (26.77 g, 12.11 t/ha), and TME80518 (22.27 g, 12.05 t/ha). Huanghuazhan (13.66 t/ha), the highest yielding line, had 1000 grain weight of 23.77 g. It indicated that further increasing of yield could be achieved by increasing grain size of the highest recent variety such as Huanghuazhan. Grain size is a major which determing rice yield. Genes or WTLs controlling grain size had been identified and could be utilized for this breeding purpose [13].
| Genotype         | Yld  | Hdg  | PH   | TN   | FG   | UFG  | TG  | SS  | 1000GW |
|------------------|------|------|------|------|------|------|-----|-----|--------|
| Inpari18         |      |      |      |      |      |      |     |     |        |
| Ciherang         | 9.49 | 83.65| 111.47| 21.07| 83.65| 13.09| 96.74| 86.78| 25.47  |
| IR83142-B-57-B   | 10.20| 87.17| 125.47| 16.03| 87.17| 29.34| 116.51| 75.44| 26.67  |
| IR83142-B-60-B   | 12.38| 96.64| 123.87| 17.68| 96.64| 14.93| 111.57| 86.59| 27.03  |
| IR84678-25-5-B   | 10.82| 114.59| 126.40| 16.57| 114.59| 57.11| 171.70| 68.01| 24.83  |
| Luoyi46          | 8.32 | 96.20| 150.13| 16.42| 96.20| 28.45| 124.65| 76.89| 26.83  |
| P35              | 10.49| 81.57| 126.07| 16.35| 81.57| 36.71| 118.28| 68.51| 27.67  |
| PSBRC68          | 8.69 | 83.65| 148.27| 15.52| 83.65| 42.44| 126.08| 66.32| 30.27  |
| RC8              | 11.29| 129.99| 131.00| 15.13| 129.99| 17.10| 147.09| 88.30| 24.00  |
| SACG4            | 12.11| 124.49| 131.60| 14.47| 124.49| 53.51| 178.01| 69.67| 26.77  |
| SAGC-05          | 12.02| 95.31| 130.47| 17.12| 95.31| 35.85| 131.16| 72.82| 25.97  |
| TME80518         | 12.05| 135.24| 121.33| 16.13| 135.24| 28.01| 163.25| 82.98| 22.27  |
| Wuxian7777       | 7.66 | 88.74| 126.20| 13.65| 88.74| 40.95| 129.70| 70.07| 25.70  |
| WTR1             | 12.38| 125.12| 126.40| 16.85| 125.12| 27.45| 152.57| 82.31| 25.73  |
| Yunjing23        | 8.98 | 106.86| 124.27| 15.53| 106.86| 34.84| 141.69| 75.33| 26.07  |
| ZGY1             | 8.78 | 110.56| 125.67| 14.27| 110.56| 55.95| 166.51| 70.36| 25.50  |
| Zhonghua1        | 10.88| 112.39| 117.40| 17.40| 112.39| 52.59| 164.98| 68.27| 23.77  |
| Ciherang         | 11.02| 87.74| 126.47| 16.67| 87.74| 17.82| 105.57| 83.07| 26.63  |
| Inpari10         | 7.08 | 66.88| 119.73| 19.30| 66.88| 18.74| 85.62| 78.23| 28.20  |
| Inpari13         | 11.06| 106.93| 124.40| 18.27| 106.93| 34.56| 141.49| 76.05| 24.97  |
| Inpari18         | 11.09| 95.08| 115.53| 14.27| 95.08| 20.94| 116.02| 82.11| 29.00  |
| 5%LSD            | 4.14 | 27.83| 5.63 | 2.82 | 27.83 | 21.95 | 45.36 | 9.39 | 2.21   |
| CV (%)           | 24.20| 17.20| 2.70 | 10.30| 17.20 | 44.00| 21.60 | 7.40 | 5.20   |

Remark: Yld = plant yield (t/ha) at 14% moisture content, Hdg = Heading date (days after sowing), PH = Plant height (cm), TN = Tiller number/plant, FG = Number of filled grain/panicle, UFG = Number of unfilled grain/panicle, SS = Seed Set, proportion of filled grain/panicle (%), 1000GW = 1000 grain weight (g)
Remark: $\star$ = position of Ciherang among the tested genotypes

**Figure 1.** Histogram of frequency distribution of some agronomic traits of GSR lines, Sukamandi WS 2012/2013

Correlation analysis showed that the Filled grain (0.53) and seed set (0.40) is the most correlated traits to yield. It agreed with the previous report that yield was significantly correlated with its components, i.e.: number of productive tillers per plant, number of grains per panicle and flag leaf area [14]. Nevertheless, this study could not find any correlation between a number of productive tiller and leaf characteristics with yield. The yield potential is hypothetically could be increased by increasing photosynthetic capacity of flag leaf [15]. These results indicated that increasing the number of filled grain/panicle and seed sets would hopefully increase the yield. Nevertheless, compensation among characters may be caused the yield increase is difficult to be achieved. Study of SPIKE/GPS which a controlling number of spikele per panicle confirmed that increasing of spikelet number canceled by decrease of panicle number [16]. Efforts to dissect and break the compensation among the traits are strongly needed. Physiological understanding inside the plant is also a necessity.
Table 2. Correlation among yield and agronomic traits of 30 GSR lines alongwith four check varieties, Sukamandi WS 2012/2013

| Trait | YLD | PH | TN | Hdg | FG | UG | TG | SS | 1000GW | FLL | LL2 | LL3 | FLW | LW2 | LW3 | FLT | LT2 | LT3 | FLA | LA2 |
|-------|-----|----|----|-----|----|----|----|----|-------|-----|------|------|------|-----|-----|-----|-----|-----|-----|-----|
| PH    | -0.215 | 0.221 |     |     |     |     |     |     |       |     |      |      |      |     |     |     |     |     |     |     |
| TN    | 0.216 | -0.544 | 0.22 |     |     |     |     |     |       |     |      |      |      |     |     |     |     |     |     |     |
| Hdg   | 0.003 | 0.523 | -0.049 | 0.986 | 0.001 | 0.783 |     |     |       |     |      |      |      |     |     |     |     |     |     |     |
| FG    | 0.528 | 0.034 | -0.303 | -0.088 | 0.001 | 0.847 | 0.082 | 0.62 |       |     |      |      |      |     |     |     |     |     |     |     |
| UG    | -0.284 | 0.469 | -0.541 | 0.485 | 0.039 |     |     |     |       |     |      |      |      |     |     |     |     |     |     |     |
| TG    | 0.272 | 0.333 | -0.539 | 0.299 | 0.672 | 0.705 | 0.12 | 0.054 | 0.001 | 0.005 | 0.001 | 0.004 | 0.829 |     |     |     |     |     |     |     |
| SS    | 0.4   | -0.481 | 0.449 | -0.515 | 0.231 | -0.946 | 0.5   |     |       |     |      |      |      |     |     |     |     |     |     |     |
| 1000GW | -0.181 | 0.513 | -0.274 | 0.252 | -0.39 | 0.116 | -0.187 | -0.239 | 0.305 | 0.002 | 0.116 | 0.023 | 0.513 | 0.289 | 0.173 |     |     |     |     |
| FLL   | 0.025 | 0.404 | -0.036 | 0.367 | 0.283 | 0.304 | 0.386 | -0.231 | -0.105 | 0.887 | 0.018 | 0.841 | 0.033 | 0.105 | 0.081 | 0.024 | 0.189 | 0.555 |     |
| LL2   | 0.077 | 0.357 | 0.084 | 0.406 | 0.242 | 0.194 | 0.289 | -0.145 | -0.218 | 0.983 | 0.663 | 0.039 | 0.657 | 0.017 | 0.168 | 0.098 | 0.412 | 0.215 | 0.0     |     |
| LL3   | -0.019 | 0.557 | -0.045 | 0.694 | 0.483 | 0.348 | 0.297 | -0.342 | -0.012 | 0.686 | 0.039 | 0.001 | 0.802 | 0.002 | 0.189 | 0.002 | 0.003 | 0.001 | 0.003 |     |
| FLW   | -0.136 | 0.525 | -0.117 | 0.626 | 0.029 | 0.489 | 0.358 | -0.483 | -0.053 | 0.72 | 0.828 | 0.933 | 0.443 | 0.001 | 0.508 | 0.008 | 0.033 | 0.038 | 0.004 | 0.767 | 0.0     |     |
| LW2   | -0.19 | 0.626 | -0.22 | 0.631 | 0.01 | 0.532 | 0.38 | -0.534 | 0.07 | 0.709 | 0.79 | 0.922 | 0.98 | 0.281 | 0.0 | 0.211 | 0.0 | 0.955 | 0.001 | 0.026 | 0.001 | 0.695 | 0.0     |     |
| LW3   | -0.258 | 0.649 | -0.24 | 0.589 | -0.07 | 0.531 | 0.332 | -0.56 | 0.127 | 0.631 | 0.726 | 0.889 | 0.049 | 0.981 | 0.141 | 0.0 | 0.172 | 0.0 | 0.692 | 0.001 | 0.055 | 0.001 | 0.475 | 0.0     |     |
| FLA   | -0.04 | 0.501 | -0.197 | 0.685 | 0.175 | 0.563 | 0.5 | -0.514 | -0.005 | 0.758 | 0.775 | 0.866 | 0.891 | 0.888 | 0.835 | 0.822 | 0.003 | 0.263 | 0.0 | 0.323 | 0.001 | 0.003 | 0.002 | 0.976 | 0.0     |     |
| LT2   | -0.052 | 0.471 | -0.188 | 0.757 | 0.119 | 0.556 | 0.46 | -0.521 | -0.02 | 0.62 | 0.7 | 0.888 | 0.879 | 0.868 | 0.827 | 0.952 | 0.769 | 0.005 | 0.287 | 0.0 | 0.504 | 0.001 | 0.003 | 0.002 | 0.976 | 0.0     |     |
| LT3   | -0.105 | 0.541 | -0.23 | 0.803 | 0.003 | 0.595 | 0.416 | -0.592 | 0.001 | 0.504 | 0.6 | 0.886 | 0.849 | 0.893 | 0.868 | 0.889 | 0.963 | 0.556 | 0.001 | 0.190 | 0.0 | 0.985 | 0.001 | 0.014 | 0.002 | 0.976 | 0.0     |     |
| FLA   | -0.221 | 0.087 | 0.143 | -0.156 | 0.003 | -0.087 | -0.047 | 0.03 | -0.259 | 0.331 | 0.45 | 0.332 | 0.371 | 0.364 | 0.415 | 0.148 | 0.087 | 0.073 |     |     |     |     |     |     |     |     |
| LA2   | -0.165 | -0.021 | 0.205 | -0.257 | 0.117 | -0.14 | -0.025 | 0.149 | -0.343 | 0.511 | 0.557 | 0.259 | 0.305 | 0.29 | 0.297 | 0.146 | 0.016 | -0.059 | 0.858 |     |     |     |     |     |     |     |     |
| LA3   | -0.122 | -0.07 | 0.183 | -0.352 | 0.111 | -0.166 | -0.041 | 0.187 | -0.339 | 0.529 | 0.524 | 0.15 | 0.216 | 0.201 | 0.199 | 0.069 | -0.076 | -0.162 | 0.752 | 0.954 |     |     |     |     |     |     |     |     |

Legend: Yld = plant yield (t/ha) at 14% moisture content, Hdg = Heading date (days after sowing), PH = Plant height (cm), TN = Tiller number/plant, FG = Number of filled grain/panicle, UFG = Number of unfilled grain/panicle, SS = Seed Set, FLL = Flag leaf angle, LL2 = length of second leaf, LL3 = length of third leaf, FLW = flag leaf width, LW2 = width of second leaf, LW3 = width of third leaf, FLT = flag leaf thickness, LT2 = thickness of second leaf, LT3 = thickness of third leaf, FLA = flag leaf angle, LA2 = angle of second leaf, LA3 = angle of third leaf. Number in the first row = Pearson correlation value, Number in the second row = P-value of the correlation.
4. Conclusions

Selected Green Super Rice materials had comparable yield with the best check Inpari 18 and the most popular variety Ciherang. Some of the highest yielding lines are Huanghuazhan (13.66 t/ha), D4098 (12.91 t/ha), IR83142-B-61-B (12.38 t/ha), Weed Tolerant Rice 1 (12.38 t/ha), HHZ17-DT6-SAL3-DT1 (12.33 t/ha), SACG4 (12.11 t/ha), and TME80518 (12.05 t/ha). The lines had preferable agronomic performance such as plant height, tiller number, and growth duration. The lines had more grains/panicle, nevertheless some showed less 1000 grain weight compared to Ciherang. Leaf observation, nevertheless, could not identify any correlation with yield. Filled grain (0.53) and seed set (0.40) instead is the most correlated traits to yield.

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