Selection of Korean heat tolerant rice lines in West Java irrigated lowland agro-ecosystem

U Susanto¹,² and W R Rohaeni¹

¹Indonesian Center for Rice Research (ICRR) of the Indonesian Agency for Agricultural Research and Development (IAARD), Street 9th, Sukamandi, Subang, West Java, Indonesia
²corresponding Author, email: untungsus2011@gmail.com

Abstract. One condition in global climate change era is increasing of world temperature which is approaching critical point of rice plant adaptation. Thus, heat tolerant rice variety is needed. Indonesian Centre for Rice Research (ICRR) and RDA (Rural Development Administration) of Korea through ASEAN-Korean Economic Cooperatives collaborates to breed heat tolerant rice variety. In this regard, 150 BC1F5 recombinant inbred lines (RIL) along with 5 checks was tested following Augmented Design of five blocks. Transplanting was conducted at 21 days after sowing on 25 cm x 25 cm planting space in 2 m x 5 m square plots. The results showed that SR34132(41)-1-1-1 (13.00 t/ha) and SR34132(11)-1-1-1 (11.65 t/ha) had higher yield than the best check Inpari 42 Agritan GSR (8.23 t/ha). The first line had big grain size (27.72 g) and medium productive tiller (15 tillers), while the second had more productive tiller (23 tillers) even though had low filled grain/panicle, seed set, and grain size (21.60 g). There were 69 lines having comparable yield with Inpari 42 Agritan GSR. Combining high yield with heat tolerance traits is feasible for Indonesian agro ecosystem condition. Further testing to confirm the tolerance of the lines to heat stress is needed.

1. Introduction
Global temperature has increased by 0.74 ± 0.18 °C during the last century [1]. Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate. It was imply on the mean temperature in most land and ocean regions (high confidence), hot extremes in most inhabited regions, heavy precipitation in several regions, and the probability of drought and precipitation deficits in some regions [2].

The period high temperature during plant growing season is expected to rise in the majority of rice areas in the world [3]. Increasing of temperature is reported affecting rice plant physiology. The increase of the minimum night temperature by 1°C would be reduced the rice yield by 10% [4]. It is agreed by other research which reported that increasing of night temperature by 1 °C and 2 °C decreased parameters for yield such as number of panicles, weight of seed per plant, harvest index (HI), the number of productive tillers, flowering time, harvesting time, nitrogen content in the leaves, and the percentage of open stomata [5]. On the other hand, it is reported that temperature increase of 0.5°C by 20125 reduced rice production in Java by 1.8 Mton and 1°C increase by 2050 will reduce 3.6 Mton [6]. High temperature affecting rice yield [7]. Rice growrs optimally at 20 °C to 35 °C [8]. The plant would be sensitive beyond the optimum temperature, and would be more sensitive during flowering.
Development of rice varieties for high temperature tolerance is very important in addressing climate change scenarios in rice growing areas where 90-95% of the population depends on rice. There is a need to breed rice varieties that can tolerate higher temperatures or can avoid exposure to high temperatures by having shorter growing seasons or flowering that occurs during cooler periods of the day [8]. Breeding rice plant adaptation to heat stress had been conducted by several international as well as national institutions. Some countries, such as South Korea, Philippines, Indonesia, Cambodia, Thailand, and Vietnam have initiated breeding for heat tolerance rice at 2010 [9]. The lines had been produced and exchanged among countries. This study aimed to test 150 BC1F5 of Gayabyeo/N22//Gayabyeo and Gayabyeo/Dular//Gayabyeo recombinant inbred lines (RIL) from South Korea under Indonesian agro ecosystem condition.

2. Material and method
Materials of the study is 150 BC1F5 of Gayabyeo/N22/Gayabyeo and Gayabyeo/Dular/Gayabyeo recombinant inbred lines (RIL). The materials were transplanted at 21 days after sowing at 25 cm x 25 cm planting space of 2 m x 5 m square plots. The field experiment was conducting according to Augmented Design of five blocks with five checks varieties, i.e. Inpari 42 Agritan GSR, Inpari 13, Inpari 32 HDB, Nipponbare, and Ciherang. The checks were chosen for various traits which has been available in Indonesia, i.e. Inpari 42 for high yield, Inpari 13 for short growth duration, Inpari 32 for high yield and bacterial blight resistance, Nipponbare representing available japonica rice, and Ciherang is the most popular variety. The experiment was conducted during wet season of 2015/2016 (December 2015 to March 2016) in ICRR Experimental Station in Sukamandi, West Java Indonesia. Peak of yearly temperature is happen during Oktober and March, nevertheless it was not reach the critical temperature of 35°C. The testing was was at least representing the potential of adaptability of the lines under optimum of Indonesian agro ecosystem condition.

Some agronomic traits, such as heading date, plant height, tiller number, yield (t/ha at 14% moisture content), and yield components (filled grain/panicle, unfilled grain/panicle, seed set (percentage of filled grain/panicle), and 1000 grain weight. Analysis of variance was conducted for check varieties over the blocks. Yield was adjusted according to Peterson (1994) [10].

3. Result and discussion
Sukamandi is one of the highest temperature in Indonesia along with Semarang, Surabaya, Kupang, Palu, Banjarmasin, Jakarta, Palangkaraya, Aceh, Pekanbaru, Jambi, Ujung Pandang, dan Kendari. Nevertheless, data of 2006 -2010 showing that there is no area having monthly average of daily maximum temperature above 35 °C [11]. Considering increasing of earth temperature, anticipative breeding heat tolerant rice is needed, with no reduction in other traits superiority.

Agronomic traits of the 150 lines was varied. The adjusted yield of the tested lines were ranged from 0 to 13.00 t/ha (Figure 1.a) with the average of 4.43 t/ha. SR34132(41)-1-1-1 (13.00 t/ha), SR34132(11)-1-1-1 (11.65 t/ha), SR34132(7)-1-1-1 (10.37 t/ha), and SR34131(4)-1-1-1 (9.82 t/ha) had the highest yield (Table 1). On the other hand, the best check Huanghuazhan, which released as Inpari 42 Agritan GSR in 2015 [12] had the average yield of 8.23 t/ha (Table 2). The first mentioned line had significantly higher yield compared to the best check. The first line had big grain size (27.72 g) and medium productive tiller (15 tillers), while the second had more productive tiller (23 tillers) even though had low filled grain/panicle, seed set, and grain size (21.60 g). The first line had big grain size (27.72 g) and medium productive tiller (15 tillers), while the second had more productive tiller (23 tillers) even though had low filled grain/panicle, seed set, and grain size (21.60 g). The first line had big grain size (27.72 g) and medium productive tiller (15 tillers), while the second had more productive tiller (23 tillers) even though had low filled grain/panicle, seed set, and grain size (21.60 g). The 20 lines bearing the highest yield is shown in Table 1. There were 69 lines had comparable yield with the best check. It indicated that some lines were adaptable for tropical condition of irrigated agro ecosystem in Indonesia.
Some lines had very early heading date. It may due to photoperiod sensitivity of the lines [13]. The 10 highest yield lines had heading date within 74 and 86 days after sowing. It means that the selected lines grew normally under Indonesian (tropical) condition and adaptable for Indonesian condition. Thus, further yield testing is prospective to be conducted. Plant height of the 150 lines was ranged from 79.20 cm to 165.30 cm. The productive tiller number ranged from 10 tillers to 30 tillers and filled grain/panicle from 22 grains to 160 grains. Seed set was ranged from 31.06% to 94.18%. The frequency distribution of the yield and agronomic characters is shown in Figure 1. Those value of the best lines are comparable with the check varieties. It indicated that the selected lines are adaptable to Indonesian agro ecosystem condition and competable with those check varieties.

Table 1. Yield of 20 best RILs heat tolerant populations originated from South Korea under Augmented Design, Sukamandi, WS, 2015/2016

| Designation   | Block | Yld Adj | Hdg  | PH  | TN   | FG   | UFG | SS  | 1000GW |
|---------------|-------|---------|------|-----|------|------|-----|-----|--------|
| SR34132(41)-1-1-1 | 5     | 13.00   | 74   | 119.7C | 15 | 91.97 | 25.61 | 0.78 | 27.72 |
| SR34132(11)-1-1-1 | 4     | 11.65   | 84   | 100.2C | 23 | 68.34 | 73.03 | 0.48 | 21.60 |
| SR34132(7)-1-1-1 | 4     | 10.37   | 76   | 79.2C  | 18 | 67.86 | 27.30 | 0.71 | 23.27 |
| SR34131(4)-1-1-1 | 1     | 9.82    | 74   | 91.5C  | 17 | 159.66 | 129.30 | 0.55 | 21.10 |
| SR34131(15)-1-1-1 | 1     | 9.10    | 80   | 107.4C | 15 | 103.65 | 89.19 | 0.54 | 22.33 |
| SR34131(85)-1-1-1 | 3     | 8.85    | 76   | 103.5C | 20 | 111.75 | 37.48 | 0.75 | 24.56 |
| SR34132(35)-1-1-1 | 5     | 8.53    | 74   | 102.9C | 24 | 140.29 | 13.73 | 0.91 | 24.73 |
| SR34131(81)-1-1-1 | 3     | 8.50    | 74   | 102.8C | 22 | 108.44 | 63.44 | 0.63 | 22.23 |
| SR34131(28)-1-1-1 | 1     | 8.32    | 76   | 97.6C  | 18 | 95.34   | 72.54 | 0.57 | 22.03 |
| SR34131(82)-1-1-1 | 3     | 8.21    | 74   | 100.7C | 19 | 127.48 | 43.61 | 0.75 | 19.07 |
| SR34131(89)-1-1-1 | 3     | 8.08    | 80   | 106.1C | 20 | 86.11   | 65.70 | 0.57 | 27.50 |
| SR34131(17)-1-1-1 | 1     | 8.04    | 76   | 98.9C  | 14 | 123.34 | 62.77 | 0.66 | 23.62 |
| SR34131(77)-1-1-1 | 3     | 7.96    | 80   | 116.7C | 21 | 87.10   | 77.90 | 0.53 | 23.19 |
| SR34131(110)-1-1-1 | 4     | 7.91    | 80   | 90.3C  | 20 | 82.72   | 31.71 | 0.72 | 29.24 |
| SR34131(73)-1-1-1 | 3     | 7.89    | 74   | 111.3C | 20 | 106.85 | 43.08 | 0.71 | 23.45 |
| SR34131(95)-1-1-1 | 3     | 7.52    | 74   | 94.7C  | 21 | 83.06   | 43.10 | 0.66 | 20.14 |
| SR34131(62)-1-1-1 | 2     | 7.49    | 76   | 94.5C  | 25 | 68.11   | 41.19 | 0.62 | 20.47 |
| SR34132(44)-1-1-1 | 5     | 7.46    | 80   | 111.0C | 22 | 91.03   | 51.02 | 0.64 | 29.27 |
| SR34132(4)-1-1-1 | 4     | 7.40    | 80   | 94.6C  | 21 | 70.63   | 59.70 | 0.54 | 24.97 |
| SR34131(3)-1-1-1 | 1     | 7.34    | 80   | 111.7C | 16 | 120.32 | 53.57 | 0.69 | 19.33 |

Remark: Hdg = Heading date (days after sowing), PH=Plant height (cm), TN = Tiller number/plant, FG = Number of filled grain/panicle, UFG= Number of un filled grain/panicle, SS = Seed Set, proportion of filled grain/panicle (%), 1000GW = 1000 grain weight (g). Adj. Yld = adjusted Yield (t/ha) based on augmented design in 5 blocks using 5 check varieties (t/ha). SR34131 = cross of Gayabyeo/N22//Gayabyeo, SR34132 = cross of Gayabyeo/Dular//Gayabyeo.
Figure 1. Frequency distribution of the adjusted yield and other agronomic traits of 150 RIL of heat tolerant rice originated from South Korea, Planted in Sukamandi, WS 2015/2016.
Table 2. Yield (t/ha) of checks over five block, for testing heat tolerant RIL from South Korea, Sukamandi, WS 2015/2016

| No | Genotype  | Hdg  | PH   | TN    | FG   | UFG  | SS    | 1000GW | Yld  |
|----|-----------|------|------|-------|------|------|-------|--------|------|
| 1  | Inpari 42 | 80.80| 107.86| 18.92 | 121.64| 69.87| 0.63  | 22.15  | 8.23 |
| 2  | Inpari 13 | 73.00| 114.72| 19.62 | 76.98 | 59.22| 0.56  | 25.76  | 8.19 |
| 3  | Inpari 32 | 72.00| 110.94| 19.82 | 85.21 | 33.65| 0.73  | 27.79  | 7.58 |
| 4  | Nipponbare| 58.79| 64.97 | 29.40 | 11.70 | 22.92| 0.38  | 21.97  | 2.00 |
| 5  | Ciherang  | 81.60| 120.62| 19.84 | 78.90 | 53.10| 0.60  | 26.27  | 7.90 |

5%LSD 4.27 4.76 2.95 24.72 17.36 0.13 1.70 2.01
CV (%) 4.30 3.40 10.40 23.60 26.40 16.00 5.10 21.70
P Gen 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00

Remark: Hdg = Heading date (days after sowing), PH = Plant height (cm), TN = Tiller number/plant, FG = Number of filled grain/panicle, UFG = Number of un filled grain/panicle, SS = Seed Set, proportion of filled grain/panicle (%), 1000GW = 1000 grain weight (g), Adj. Yld = adjusted Yield (t/ha)

 Indonesian tropical condition may cause coincident of high temperature during reproductive stage. This coincident could induce floret sterility and reduce grain yield. Rice plant is most sensitive to increasing temperature during flowering which can lead to a decline in yields [14]. Heat stress during grain filling period causes the combined reduction on grain yield and quality. The severe yield losses in South, Southeast and East Asia were caused by spikelet sterility due to high temperature. In the tropical regions, the mean daily temperature during March to April may reach up to 40°C [15].

The selected lines in this experiment are derived from heat tolerant parents, Nipponbare. Therefore, there is a big chance to find high yielding as well as heat tolerant genetic materials from the selected lines. Nevertheless, screening for tolerance to heat tolerance had not been conducted in Indonesia. Sharing data with the origin country may help to identify which lines having good tolerance to heat stress. Combination of high yield under Indonesian condition and heat stress characteristic would make the lines more prospective to be further testing.

The other aspect that should be considered is the quality of the rice and its resistance to pest and diseases. Javanese people in which mostly the Indonesian people stay have high preference to low amylose rice. Translucence and white color correlated with the people preference [16]. Resistance to at least one biotype of BPH (brown plant hopper) and one pathotype of bacterial blight is necessary to be released in Indonesia [17].

4. Conclusions
Climate change had happened and one of the main change is increasing of temperature. In term of yield, it is identified Korean RILs which are adaptable to Indonesian irrigated lowland agro-ecosystem condition. SR34132(41)-1-1-1 (13.00 t/ha) had the highest yield, higher than the best check inpari 42 Agritan GSR (8.32 t/ha) while the other 69 lines had comparable yield with the check. The lines are derived from heat tolerant parents, Dular and N22. Therefore, there is a big chance to find high yielding as well as heat tolerant variety from the selected lines. These genotypes are suspected to be withstand and giving high yield under global climate change condition.

References
[1] IPCC 2007 Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change ed S Solomon, D Qin, M Manning, Z chen, M Marquis, K B Averyt, M Igor and H L miller (Cambridge, UK: Cambridge University Press)
[2] IPCC 2018 Global Warming of 1.5°C: An IPCC Special Report on the impacts of global
warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty ed V Masson-Delmotte, P Zhai, H-O Pörtner, D Roberts, J Skea, P R Shukla, A Pirani, W Moufouma-Okia, C Péan, R Pidcock, S Connors, J B R Matthews, Y Chen, X Zhou, M I Gomis, E Lonnoy, T Maycock, M Tignor, and T Waterfield (Geneva: World Meteorological Organization) p 32

[3] IPCC 2012 Managing the risks of extreme events and disasters to advance climate change adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change ed C B Field, V Barros, T F Stocker, D Qin, D J Dokken, K L Ebi, M D Mastrandrea, K J Mach, G K Plattner, S K Allen, M Tignor, and P M Midgley (Cambridge, UK and New York, USA: Cambridge University Press)

[4] Peng S, Huang J, Sheehy J E, Laza R C, Visperas R M, Zhong X, Centeno G S, Khush G S and Cassman K G 2004 Rice yields decline with higher night temperature from global warming PNAS 101 9971-9975

[5] Putra D F, Tyasmoreo S Y, Wicaksono K P and Vincie L 2015 Simulation of increasing night temperature on vegetative and generative of paddy (Oryza sativa L.) Journal of Degraded and Mining Landsmanagement 3 469 – 475

[6] Boer R, Buono A, Sumaryanto, Surmaini E, Estiningtyas W, Rataq M A, Perdinan, Pramudia A, Rakhman A, Kartikasari K and Fitriani 2008 Laporan Akhir: Pengembangan Sistem Prediksi Perubahan Iklim untuk Ketahanan Pangan Balai Besar Litbang Sumberdaya Pertanian (Jakarta: Badan Litbang Pertanian)

[7] Manigbas N L and Sebastian L S 2007 Breeding Rice for High Temperature Tolerance in the Philippines The International Workshop on Cool Rice for Warmer World (March 26-30, 2007 Wuhan, Hubei, China)

[8] Redona E D, Laza M A and Manigbas N L 2007 Breeding Rice for Adaptation and Tolerance to High Temperatures the International Workshop on Cool rice for Warmer World (March 26-30, 2007 Wuhan, Hubei, China)

[9] Manigbas N L, Lambio L S F, Madrid L B and Cardenas C C 2013 Irrigated lowland rice adaptation to changing climate: heat tolerance breeding in the Philippines and other ASEAN region Proceeding International Seminar Technology innovation for increasing rice production and conserving environment under global climate change Book 2 ed Kusbiantoro B, Nugraha U S, Wardana I P, Abdulrachman S, Susanto U, Rumanti I A, Nuryanto B, Pratiwi G R, Susanti Z, Usyati N, Mejaya MJ (Jakarta: Indonesian Ceter for Rice Research, Indonesian Agency for Agricultural Research and Development) pp 671 – 681

[10] Petersen R G 1994 Agricultural Field Experiment Design & Analysis (New York: Marcel Dekker Inc)

[11] Susanto U 2012 Breeding of heat tolerant rice in Indonesia. Guidebook Bilateral Seminar Toward climate change adaptation strategy management of hydrology and agriculture system (Surakarta: Faculty of Agriculture of Sebelas Maret University Indonesia and Faculty of Applied Biological Sciences Gifu University Japan)

[12] Sasmita P, Satoto, Rahmini, Agustiani N W, Handoko D D, Suprihanto, Guswara A and Suharna 2019 Deskripsi Varietas Unggul Padi (Jakarta: Badan Penelitian dan Pengembangan Pertanian) p 107

[13] Dogara A M, Tahir S M, Shehu I, Abbah M, Shitu U and Ladidi Z I 2014 Mechanism of photoperiod in regulation of rice flowering International Journal of Technical Research and Applications 2 56-58

[14] Matsui T and Omasa K 2002 Rice (Oryza sativa L.) Cultivars Tolerant to High Temperature at Flowering: Anther Characteristics Annals of Botany 89 683-687

[15] Matthews R B, Kropff M J, Bachelet D, van Laar H H 1994 The impact of global climate change on rice production in Asia: A simulation study. Report No. ERL-COR-821. (US: US Environmental Protection Agency, Environmental Research Laboratory, Corvallis)
Acknowledgement

This research is part of the collaborative project of Breeding Heat Tolerance Rice supported by ASEAN-Korean Economic Cooperation, Korea -Rural Development Administration (RDA), and Indonesian Agency for Agricultural Research and Development (IAARD) through Indonesian Center for Rice Research (ICRR). Untung Susanto contribute mainly for the experimental design, data analysis, and preparing the manuscript.