Performance of improved upland rice cultivars under farmer’s field condition in Banten province, Indonesia

A Saryoko*, S Kusumawati, and A Pohan
Assessment Institute for Agricultural Technology (AIAT) Banten, Indonesian Agency for Agricultural Research and Development (IAARD), Jl. Ciptayasa km.01 Ciruas Serang Banten Indonesia

*Corresponding author: andysaryoko@yahoo.com

Abstract. The use of improved upland rice (Oryza spp.) cultivars would be an alternative approach for improving rice production in Indonesia. The objectives of study were to identify cultivars with high yield potential and to determine its related traits. Five improved upland rice cultivars, namely Inpago 8, Inpago 9, Inpago 10, Inpago 11 and Inpago 12, released in 2011 to 2017 were observed under farmer’s field condition in Lebak district, Banten Province, Indonesia from September 2018 to January 2019. Grain yield, yield components, and biomass production and partitioning were measured at maturity stage. Grain yield of five cultivars showed higher performance than regional average yield performance. Grain yield performance was closely correlated with panicle number per m². The Inpago 9 and Inpago 12 were greater in grain yield due to greater number of panicle as compared to other cultivars. Superior performance of Inpago 9 and Inpago 12 were also due to greater biomass production and better harvest index (HI). On the other side, smaller value of panicle number per m² and HI of Inpago 11 resulted in lower performance in grain yield. In conclusion, panicle number, biomass production, and partitioning were some good traits in selecting adaptive cultivars. In addition, cultivars Inpago 9 and Inpago 12 are considerable to be chosen by the farmers in Lebak district, Banten Province to improve upland rice production.

1. Introduction
Rice is the most important food crop after wheat and maize. Rice production system can be classified into two types, lowland and upland rice system [1][2]. In lowland rice, field is usually flooded for whole or part of growing season [1]. In upland rice system, rice is grown in rainfed fields that prepared and seeded under dry condition [3], and in some cases supplemented with irrigation water [1].

Rice is number one of staple food crops, being eaten by almost population in Indonesia. Rice is mostly produced from lowland rice system, contributed to more than 95% of total rice production in Indonesia. Nowadays, rice production is being faced by the reduction of lowland area due to land-use change from agricultural use to non-agricultural use. On the other side, dryland area is highly potential to be explored in terms of rice production improvement [4].

Banten Province is one of the rice producers in Java Island, Indonesia, produced for more than 2 billion rice per year, contribute for more than 1.6 million tons of rice in 2018, contributed to near 3 % of national rice production [5]. Upland rice production in Banten Province is relatively low, ranged from 2 to 3 tons per hectare and vary between area [6]. The dryland area in Banten, besides, has a large
potential to be used for improving upland rice production, combining with high-yielding upland rice cultivars and improvement in agricultural practices.

In the last decade, Indonesian Rice Research Centre – IAARD, has been released new high-yielding upland rice cultivars that can produce more than seven tons rice per ha with the average of four to five tons per ha [7]. The use of high-yielding upland rice cultivars is expected to improve rice production in upland rice system and enhance its contribution to total rice production. The aim of study was to identify cultivars with high yield potential and to determine its related traits

2. Material and Methods

2.1. Cultivars and agronomical practices

The field experiment was conducted from September 2018 to January 2019 under farmer’s field condition in Lebak district, Banten Province, Indonesia (Lat. 6.8°S, Long. 106.2°E). On 20 September 2018 seeds of five improved upland rice cultivars, namely Inpago 8, Inpago 9, Inpago 10, Inpago 11 and Inpago 12, released in 2011 to 2017, were directly seeded. Three to five seed per hole were arranged with a double row with a spacing of 25 cm between rows, 12.5 cm between plant within rows, and 50 between two rows. The cultivars were arranged into a plot with 4 m wide and 13 long for each cultivar, resulting in 6 double rows for each. The soil was fertilized with 11.5 g m$^{-2}$, 5.4 g m$^{-2}$ and 4.5 g m$^{-2}$ of N, P$_2$O$_5$ and K$_2$O, respectively. The N fertilizer in the form of urea was applied three times at 10, 25 and 35 days after sowing (DAS) as much as 50, 25 and 25% respectively. The P$_2$O$_5$ and K$_2$O in the form of SP36 and KCl, respectively, were applied at 10 DAS. Regional recommended management programs were employed for irrigation, weed and pest control to optimize growth condition.

2.2. Agronomical traits, plant growth, and yield components

Plant height was measured weekly from 4 weeks after planting (WAP) to 11 WAP. Two plants per plot were collected at 6, 8 and 11 WAP and oven-dried at 80°C for 48 hours to measure the above-ground biomass (TDW). Total leaf area was measured at 6, 8 and 11 WAP using the similar plant samples. Fresh leaf sample was taken and specific leaf area was measured using digital image technique. The leaf further oven-dried at 80°C for 48 hours and leaf dry weight was recorded. Total leaf area was calculated from specific leaf weight and total leaf dry weight.

Canopy size and development were measured using a digital imaging technique [8] [9][10][11] using ImageJ (National Institute Health, USA) with some modifications, and expressed as a percentage of soil coverage by the rice canopy. For this purpose, plots were maintained as weed-free as possible during the growth stage.

At maturity stage, four plants per cultivar were harvested, and yield and yield components were observed. Panicle number per plant was counted, and panicle length and seed number per panicle were observed from 5 panicles per plant. Seed number was counted and weighted, and 1000 seed weight (1000SW) and seed moisture content was measured. Grain yield per plant was calculated as a multiplication of grain number, 1000SW, panicle number per plant at 14% moisture content. The remaining plant organs (leaves and straws) were dried at 80°C for 48 h. Harvest index (HI) was calculated as a ratio of dry grain yield (Y) and total biomass at maturity (TDW), as follows:

$$HI = \frac{Y}{TDW}$$

(1)

2.3. Cultivars preference

Cultivar preference in terms of plant performance and grain quality was evaluated by collecting data using structured questioner. In total 47 respondents, consisted of farmers, rice consumers, rice traders were involved. For the plant performance, respondents were provided a 110 days old standing crop of each cultivar, and asked to give a score of preference for each trait i.e. plant structure, plant height, panicle number, panicle length, days to maturity, grain number per panicle, and resistance to pest and disease. For grain quality, respondents were provided grain rice, husked-grain rice and steamed rice to be evaluated in terms of grain shape, size and color, and of steam rice eating quality (aroma, color, and stickiness).
2.4. Data Analysis

Variability among cultivars on plant performances, growth and yield components were analyzed using an analysis of mean. As for cultivars preference data, descriptive statistic was applied.

3. Results and Discussion

3.1. Plant growth and development

The growth in plant height is shown in figure 1. The plant height for all cultivars at 4 WAP was relatively similar. The variation in plant height occurred starting from 7 WAP and later. Cultivar Inpago 11 consistently showed taller in plant height as compared to other cultivars. The characteristics of most upland rice cultivars in Indonesia is indicated with height of plant (> 120 cm), especially when it compared to lowland cultivars (around 100 cm) [7]. The cultivar Inpago 8 was consistently the shortest as compared to other cultivars. The TDW of five tested cultivars were increased significantly from 6 WAP to 8WAP (figure 2). The TDW was also significantly increased from 8 WAP to 11 WAP, but not for Inpago 9. The characteristics of Inpago 9 was earlier in maturity (109 days) especially as compared to Inpago 10 (115 days) [7]. The cultivar Inpago 11 was the highest in TDW, and TDW was correlated with plant height ($R^2 = 0.56$).

![Figure 1](image1.png)  
Figure 1. Growth of plant height of five upland rice cultivars from 4 to 11 week after planting.

![Figure 2](image2.png)  
Figure 2. Growth of total dry weight (TDW) of five upland rice cultivars from 6 to 11 week after planting.
The variation in growth of total leaf area from 6 WAP to 11 WAP was various among cultivars (figure 3). At the 6 and 8 WAP, cultivar Inpago 8 was the smallest in total leaf area, but tend to be moderate at 11 WAP. The growth of total leaf area of Inpago 11 from 8 WAP to 11 WAP was the highest resulted in greater total leaf area as compared to other cultivars.

Figure 3. Growth of total leaf area of five upland rice cultivars from 6 to 11 week after planting.

For the canopy growth, in terms of canopy coverage, were measured from 3 WAP to 7 WAP (figure 4). Canopy coverage expressed the ability of plant to intercept light for photosynthetic activities [12][8]. Larger variation in canopy coverage occurred at 4 WAP. Canopy coverage of tested cultivars reached a fully covered at 7 WAP.

Figure 4. Growth of canopy coverage of five upland rice cultivars from 3 to 7 week after planting.

3.2. Yield and yield components
Grain yield and biomass accumulation performance of five tested cultivars were varied (table 1). Grain yield was ranged from 510 – 821 g m$^{-2}$, and the TDW ranged from 1,362 – 1,894 g m$^{-2}$. Inpago 9 and Inpago 12 were the greatest in grain yield with the yield of 821 g m$^{-2}$ and 771 g m$^{-2}$, respectively. The biomass accumulation in terms of TDW of Inpago 8 was the highest followed by Inpago 9 with the TDW of 1,894 and 1,874 g m$^{-2}$, respectively. In addition, the HI, ratio dried grain yield and TDW, of Inpago 9 was the highest (0.517) followed by Inpago 12 (0.514).

The yield components that commonly used to explain yield performance were also varied. Panicle number was ranged from 8.0 – 16.6 per plant. The Inpago 12 were the greatest in panicle number, followed Inpago 9 with the panicle number around 16 per plant. The greater number of filled seed number was found in Inpago 11 and Inpago 12 with the filled seed number per panicle of 129.6 and 123.8, respectively. Bigger seed size was identified in Inpago 8 (31.0 g 1000seed$^{-1}$) followed by Inpago
9 (30.2 g 1000seed⁻¹). Total filled seed number per panicle length of Inpago 12 was the highest with the seed number per panicle length of 5.5 seed cm⁻¹.

**Table 1.** Yield and yield components of five upland rice cultivars

| Cultivar | Yield (g/m²) | TDWa | HIb | Panicle Number (per plant) | Panicle Length (cm) | Filled Seed Number (per panicle) | Sterile Seed Number (per panicle) | 1000SWc (g 1000seed⁻¹) |
|----------|--------------|------|-----|----------------------------|---------------------|----------------------------------|----------------------------------|------------------------|
| Inpago 8 | 693          | 1,894| 0.512 | 12.5                        | 26.8                | 94.2                             | 68.1                             | 31.0                   |
| Inpago 9 | 821          | 1,874| 0.517 | 16.0                        | 23.0                | 103.7                            | 29.6                             | 30.2                   |
| Inpago 10| 623          | 1,796| 0.511 | 13.3                        | 26.5                | 103.7                            | 44.3                             | 25.4                   |
| Inpago 11| 510          | 1,362| 0.509 | 8.0                         | 27.4                | 129.6                            | 23.6                             | 27.0                   |
| Inpago 12| 771          | 1,711| 0.514 | 16.5                        | 22.4                | 123.8                            | 35.0                             | 25.9                   |

a TDW = total dry weight  
b HI = harvest index  
c 1000SW = 1000 seed weight

A positive correlation was found between grain yield and panicle number per plant (figure 5) with R² 0.88. There are three groups of cultivar based on yield and panicle number performance. The first group consist of Inpago 9 and Inpago 12 with greater yield and panicle number. The second group consist of Inpago 8 and Inpago 10 with moderate yield and panicle number. The last group is Inpago 11 with inferior yield and panicle number.

Grain yield of five cultivars (ranged from 510 – 821 g m⁻²) showed higher performance than regional average yield performance (2 to 3 tons per ha ≈ 200 to 300 g m⁻²). Grain yield performance was closely correlated with panicle number per m². The Inpago 9 and Inpago 12 were greater in grain yield due to greater number of panicle as compared to other cultivars. Superior performance of Inpago 9 and Inpago 12 were also due to greater biomass production and better harvest index (HI). On the other side, smaller value of panicle number per m² and HI of Inpago 11 resulted in lower performance in grain yield.

**Figure 5.** Correlation between panicle number per plant with yield potential of 5 upland rice cultivars.
3.3. Cultivar preference

Cultivar preference was evaluated from two aspects, plant performance in the field, and grain quality. The main purpose of cultivars preference evaluation is to know the acceptability of cultivars by the users (rice growers, rice consumers, and rice traders) in accompanied by yield performance. Figure 6 and 7, respectively, show the cultivar performance in the aspect of plant performance in the field and grain quality for respective 5 upland rice cultivars.

![Cultivar preference in plant performance in the field of five upland rice cultivars](image)

![Cultivar preference in grain quality of five upland rice cultivars](image)

Figure 6. Cultivars preference in plant performance in the field of five upland rice cultivars

Figure 7. Cultivars preference in grain quality of five upland rice cultivars

For the field plant performance, cultivars preference is moderately distributed for each cultivars, ranged from 17 % to 26 %. The Inpago 11 was the most preferable cultivars due to plant vigor (plant height), panicle length and seed number that superior as compared to other cultivars (Table 1). For the other aspect, however, Inpago 8 was the most preferable cultivars (figure 7) in terms of grain quality. The Inpago 8 was preferable due to its good eating quality (stickiness), grain shape and colour and seed size. The rice consumers tend to choose cultivars with large size with long grain shape.

4. Conclusion

Grain yield of upland rice cultivars, Inpago 8, Inpago 9, Inpago 10, Inpago 11 and Inpago 12 showed higher performance than regional average yield performance. Grain yield performance was closely correlated with panicle number per m². The Inpago 9 and Inpago 12 were superior in grain yield due to greater biomass production and better harvest index (HI). Panicle number, biomass production and partitioning are some good traits for select adaptive cultivars. The Inpago 9 and Inpago 12 are considerably to be chosen by the farmers in Lebak district, Banten Province to improve upland rice production.

5. References

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