Morpho-agronomic traits and balance of sink and source of rice planted on upland rainfed

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Abstract. Rice morpho-agronomic traits determine the yield at different planting seasons due to the characters that are closely related to genetic characteristics and environmental factors. This study aims to observe morpho-agronomic traits of three varieties, namely Situ Patenggang (as the check variety that can be planted in rice fields and upland rainfed), Sipulo and Sanbei (both as the test varieties). The varieties planted in upland rainfed in order to observe the morpho-agronomic traits occur, as the rice planted in rainfed might be able to be planted elsewhere, due to its water stress tolerance. The result showed that the check variety have morpho-agronomic traits that show a balanced sink and source, while the two test varieties, Sipulo and Sanbei have a larger but imbalance source and sink capacity. The imbalance of source and sink was caused by the large amount of the last panicles that appeared from tertiary or quaternary tiller, in which increased the percentage of unfilled grains that later caused a low percentage of filled grain. However, the potential yield remains high compared to the check variety. Therefore, from the observation, it is clear that the morpho-agronomic traits of rice can be determinants in determining rice yield.

1. Introduction

Rice productivity in tropical regions is affected by water shortage. Drought is a major barrier to rice productivity [1]. Therefore, it is necessary to adjust rice cultivation in the dry season so that productivity can be maintained, as rice is a plant that is very sensitive to water limitations in the reproductive phase [2]. Moreover, water shortages are the main barrier that continues to increase with climate change. Upland rice often experiences water limitations. Severe drought for upland rice was at 0.06 MPa. In this sense, drought tolerant varieties planted because they were able to produce high yield under water deficit conditions [3]-[6]. Prolonged drought during the reproductive phase causes reduced translocation of carbohydrate to the reproductive organs thereby increasing empty grains [7]. In terms of varieties, Situ Patenggang is a variety that can adapt well to upland soils by using organic matter in the soil. Situ Patenggang is tolerant to drought, as with a 10% PEG, the tolerance ratio is at 93.83% and at 20% PEG, the tolerance ratio is at 77.78%, meanwhile, drought tolerance index at different irrigation periods is at
81.23%, with a tolerance index value of 85.80 on the PEG test and 81.23 in the pot test, making it suitable for upland rice [8]. Further, Situ Patenggang tolerance to drought can be seen from the total root length, number of panicles, and weight of 1000 grains [9]. Moreover, according to Tarigan et al. [10] Towuti, Situ Patenggang, Kalimutu and Gajah Mungkur are drought tolerant.

Rice yields that experience drought stress were affected by chromosome number 12 in each variety [11]. In this sense, drought tolerance can be increased by delaying stress in plants such as the induction of cytokines [12]. Plants that experience drought also naturally increase cytokinin to overcome aging due to drought. Meanwhile, in the occurrence of decreasing soil water, water stress affects the sink and source of rice, because leaves as sources that are gripped by water shortages will reduce their ability to produce photosynthates [13]. Furthermore, upland rice response to drought is also depending on varieties selected for planting. For instance, there are varieties that delay flowering or accelerate flowering after experiencing drought stress [14]. In this sense, increased drought also causes a decrease in plant height, number of tillers, biomass dry weight, leaf area, number of grains per hill, weight of 1000 grains and dried roots [15].

In the world, at the moment, there are 27 million hectares of upland rice experiencing drought [15]. Drought tolerance degree of upland rice is based on the average ratio of leaf length to total every leaf length from leaf number 3 from above, the value is 0 to 1 [15]. The higher the drought tolerance degree, the more drought resistant the rice. However, upland rice that is produced by small farmers, often results in yield of grain and experience drought [16]. For this cause, to increase yields, it is necessary to select high-yielding varieties, which means variety with a large sink, as sink is known as where the plant stores the assimilates. In this sense, selection of varieties with large sinks can be done through observing the number of panicles and grains to produce high-yield rice, as a new plant type (NPT) rice [17].

Morpho-agronomic traits were the result of photosynthetic accumulation, balanced sink and source in plants. The balanced sink and source was influenced by genetic and environmental factors. In the tropical environment, it was influenced by two main seasons, namely the dry season and wet season. In which, rice productivity was usually higher in the dry season than the rainy season, as in the dry season it was often limited by lack of water. However, if the lack of water can be overcome, the balanced sink and source was no longer affected by the water deficit. Further, it was necessary to keep the plant's assimilation phase unaffected by too high temperatures and humidity, as it can cause an increase in the sterility of the pollen. This can result in the increase of empty grains in rice. Moreover, planting in the dry season decreases the number of tillers and panicles per hill [18]. If it occurs in the vegetative phase, dry weight biomass decreased [19], [20]. In the case of vegetative phase, drought might decrease root growth, root length, root coverage, root volume and root dry weight [21], [22].

In term of growth rate, even though there is a reduced growth rate due to a decrease in soil water content in a short time, it did not cause a reduction in the weight of dry biomass [22] and did not cause a decrease in yield [6],[23]. However, a reduction in soil moisture content in a long time and severe, it decreased the number of tillers [24], [25]. Meanwhile, limited root growth in the vegetative phase will reduce the formation of deep roots and root branches, thereby affecting the ability of root penetration to deeper soil layers [26]. Furthermore, prolonged drought will limit the diameter of the roots, especially in drought tolerant varieties which are formed to be smaller and denser to take water in deeper layers to avoid drought [27].

In terms of grain weight, drought occurs when grain filling will reduce the weight of the grain [28]. Therefore, it is necessary to study the effect of the environment on rice plants even more so in denser soils, as the root development unfolds because of the low percentage of water pores [29], as if drought occurs during the grain filling phase, empty grain will increase [30]. Drought also causes a decrease of up to 76.34% of shoot length in sensitive varieties and 58.68% in drought tolerant varieties [19]. Drought also decreases root length to 36.57% in sensitive varieties and 11.84% in tolerant varieties [19]. Therefore, varieties with long, dense, large diameter rooting shows characters of drought tolerant varieties [21]. In this sense, plants have various mechanisms of adjusting to drought in various growth phases [31]. Therefore, it is important to understand these varieties’ response mechanisms to drought in order to give a proper treatment resulting in higher yield.
Therefore, the purpose of this study was to observe the productivity of varieties through different morphologies, balanced sink and source in an upland rainfed, so that various agronomic treatments can be carried out to increase the productivity of rice based on its morpho-agronomic changes.

2. Materials and methods

2.1 Materials and grow conditions
The study was conducted in November 2016 until April 2017 at BPP Jantho, Aceh Besar Indonesia. Three varieties, namely Situ Patenggang, Sipulo and Sanbei. In this case, Situ Patenggang was the check variety as it is a tolerant drought variety [9,10], while Sipulo and Sanbei were the test varieties, in which those varieties are commonly grown by farmers in Simeulue (Sanbei) and Pulo Aceh (Sipulo), Aceh Besar Indonesia. The seeds washed with tap water for 30 minutes, soaked for 24 hours, incubated for 48 hours and sown in nursery trays with a mixture of soil and compost 3:1. Seeds transplanted 12 days after sowing. The seeds planted in plot measuring 2.5 x 2.0 m that were given rice straw compost 20 tons per hectare at the time of soil land preparation, fertilized with NPK 900 kg per hectare, urea 150 kg per hectare given at planting, 30 and 60 day after planted (DAP) each 1/3 dosage, KCl 100kg per hectare given at planting, and single super phosphate (SP 36) 150 kg per hectare given at planting. Planted spacing was 25 X 20 cm. The planting carried out in plots consisting of the three varieties with nine replications arranged in a non-factorial randomized block design. During the days, the weather was sunny and irradiating for 12 hours every day on rainfed uplands at BPP Jantho city, with minimum/maximum temperature 20.0/34.6°C, relative humidity 72/93%, and solid soil. Observation of plant height done at 10 weeks after planted, while other observations taken after harvested, according IRRI [32] and IRRI [33].

2.2 Sampling and measurement
Observation of plant height done at 10 weeks after planting, while other observations were taken after harvested [32],[33].

2.3 Data analysis
Statistical analysis of variance (ANOVA) using Microsoft excel window 10. The differences between varieties were determined by least significant difference (LSD) P<0.05 to determine statistically significant differences.

3. Results

3.1 Changes of morpho-agronomic characters of the varieties planted in wet season
There were varied morpho-agronomic traits of the three rice varieties planted on upland rainfed as shown in table 1. Plant height of Sipulo was much longer than Sanbei and Situ Patenggang so that in terms of photosynthate use, Sipulo takes longer for the growth of vegetative parts. In Term of number of tiller, Sipulo had more tillers than Situ Patenggang, but the number was smaller than Sanbei. In this sense, higher productive tillers produced more panicles, in which panicles were a component of rice yield. In terms of the age of flowering, Situ Patenggang was the fastest, Sanbei's flowering age was longer than Situ Patenggang, while Sipulo's was the longest among three. This caused more photosynthates to be stored in the vegetative and reproductive organs due to the length of the assimilation in the vegetative and reproductive phases.

In terms of harvesting time, the fastest was Situ Patenggang, followed by Sanbei and Sipulo. In this sense, the age of the harvest affects the distribution of assimilation partition into the grains, as it was also used to keep the leaves alive and photosynthetic. Therefore, it needs a balanced sink and source. In term of the panicle length, it was not significantly different between the varieties, however, in term of the number of different filled grains, the highest was in Sipulo, followed by Sanbei and Situ Patenggang.
Table 1. Changes of the morpho-agronomic characters of the varieties planted in wet season.

| Parameter                          | Varieties          | LSD 0.05 |
|------------------------------------|--------------------|----------|
|                                    | Situ Patenggang   | Sipulo   | Sanbei   |
| Plant height (cm)                  | 118.1b             | 135.39c  | 115.39a  |
| Number of productive tillers (tiller) | 11.98a            | 17.08b   | 20.02c   |
| Flowering age (days)               | 82.34a             | 105.71c  | 91.22b   |
| Harvest age (days)                 | 112a               | 129.11c  | 123.33b  |
| Length of panicles (cm)            | 21.07a             | 21.63b   | 21.31a   |
| Number of grains per panicle (grains) | 114.78a          | 143.78b  | 141.89b  |
| Weight of filled grains per hill (g) | 27.76a            | 36.11b   | 35.78b   |
| Weight of 1000 grains (g)          | 25.94c             | 24.43b   | 21.94a   |
| Percentage of filled grains (%)    | 82.17b             | 63.49a   | 64.34a   |
| Yield potential (tha⁻¹)            | 5.55a              | 7.22b    | 7.16b    |

Common letters (a, b, c) are notations of significance difference between varieties. Data followed by the common letters within the same row indicates no significant difference, while data followed by different common letters (a,b,c) within the same row indicate significant difference at α < 0.05 (LSD test).

This is because there were more number of panicles found in Sipulo and Sanbei, therefore, there are more grains in Asipulo and Sanbei, which indicates bigger sinks than Situ Patenggang. In terms of grains weight, the weight of filled grains were much heavier in Sipulo and Sanbei than Situ Patenggang. However, the weight of 1000 grains between varieties was not significantly different. This is because the genetic influence of varieties also affects the balance of photosynthate partitions between yield components and vegetative organs, in this sense, the weight of 1000 grains was reduced in varieties with a lot of tiller (Sanbei and Sipulo) as they have to distribute photosynthates to the grains and also for other sink, like roots and old leaves.

The highest filled grains percentage was in Situ Patenggang, while Sipulo and Sanbei were lower. This is because Sipulo and Sanbei have a large number of tillers, which limits the photosynthates to be allocated to the grain. These morpho-agronomic traits showed Sipulo and Sanbei have bigger sources and sinks than Situ Patenggang. In terms of potential yields, all three varieties were not significantly different, with the lowest yield potential found on Situ Patenggang. Based on the morphological and agronomic components, it can be seen that Situ Patenggang, Sipulo and Sanbei can survive growing on rainfed upland. However, planting time needs to be adjusted to the condition of rainfall or ground water content, this is specially related to panicle initiation and grain filling in order to get the suitable soil moisture in early and late growing season.

3.2 Pearson correlation among parameter

The morpho-agronomic relationship with sink and source showed in the correlation between parameters in Table 2.

There is a close relationship between morpho-agronomic traits. Plant height was closely related to the age of flowering (r = 0.87), harvest age (r = 0.67), and panicle display (r = 0.84). Meanwhile, the number of productive tillers was closely related to the age of flowering (r = 0.51), harvest age (r = 0.76), panicle length (r = 0.56), number of panicle grain (r = 0.91), weight of clumped rice (r = 0.95), the weight of 1000 grain (r = -0.95), the percentage of filled grain (r = -0.91), and yield potential (r = 0.95). In terms of age of flowering, it was closely related to age of harvest (r = 0.91), panicle length (r = 0.99), number of panicle grain (r = 0.82), weight of clumped grain (r = 0.73), percentage of filled grain (r = -0.81), and potential yield (r = 0.73).

In terms of harvest age, it was closely related to panicle length (r = 0.96), number of panicle grain (r = 0.96), weight of grains per hill (r = 0.91), weight of 1000 grains (r = -0.53), filled grains percentage (r = -0.96), and potential yield (r = 0.91). While for panicle length, it is closely related to the number of panicle
grain \((r= 0.85)\), weight of grains per hill \((r= 0.77)\), percentage of filled grain \((r= -0.84)\), and yield potential \((r= 0.77)\).

### Table 2. Pearson correlation among parameters.

| Parameter                        | X1   | X2   | X3   | X4   | X5   | X6   | X7   | X8   | X9   | X10  |
|----------------------------------|------|------|------|------|------|------|------|------|------|------|
| Plant height (cm)                | 1    | 0.029| 0.872| 0.672| 0.844| 0.441| 0.310| 0.265| -0.425| 0.311|
| Number of productive tillers     | 1    | 0.514| 0.760| 0.561| 0.910| 0.959| -0.956| -0.917| 0.959  |
| Flowering age (days)             | 1    | 0.948| 0.998| 0.824| 0.736| -0.240| -0.813| 0.736  |
| Harvest age (days)               | 1    | 0.964| 0.961| 0.913| -0.536| -0.956| 0.913  |
| Length of panicles (cm)          | 1    | 0.854| 0.772| -0.294| -0.844| 0.772  |
| Number of grains per panicle (g) | 1    | 0.990| -0.748| -1.000| 0.990  |
| Weight of filled grains per hill | 1    |      | -0.834| -0.992| 1.000  |
| Weight of 1000 grains (g)        | 1    | 0.760|      | -0.834  |
| Percentage of filled grains (%)  |      |      |      |        | 1      | -0.992  |
| Yield potential (tha\(^{-1}\))   |      |      |      |        |        |        | 1    |

X1 (Plant Height), X2 (Number of productive Tillers), X3 (Flowering age), X4 (Harvest age), X5 (Length of panicles), X6 (Number of grains per panicle), X7 (Weight of filled grains per hill), X8 (Weight of 1000 grains), X9 (Percentage of filled grains), X10 (Yield potential). Correlations above 0.5 indicate a close relationship, while correlations below 0.5 indicate not closely related. 

(-) indicates the relationship is inversely proportional
(+ ) indicates the relationship is proportional
*Significantly different
**Very significantly different

The number of grains per panicle was closely related to the weight of grains per hill \((r= 0.99)\), the weight of 1000 grains \((r= -0.74)\), the percentage of filled grains \((r= -1.00)\), and yield potential \((r= 0.99)\). While for the weight of grain per hill, it is closely related to the weight of 1000 grains \((r= 0.83)\), the percentage of filled grain \((r=0.99)\), and the potential yield \((r= 1.00)\). Further, the weight of 1000 grains is closely related to the percentage of filled grains \((r= 0.76)\), and yield potential \((r= 0.83)\). Moreover, the percentage of filled grain is closely related to the yield potential \((r= -0.99)\). In this case, there was a close correlation between the yield components, which showed influence between the yield components, age of harvest and age of flowering. In which age of harvest and age of flowering determine the accumulation of dry matter, which affects the sink and source of plant.

### 4. Results and discussion

Morpho-agronomic changes of three rice varieties planted on rainfed upland showed significant differences. These differences lead to large differences in sinks and source of Situ Patenggang, Sipulo and Sanbei. The amount of sink can be observed through panicle length, number of panicles, number of grain per panicle, and weight of 1000 grain. However, those morpho-agronomic traits were also determined by the ability of the plant source, in which this includes the number of tillers, number of leaves, and plant height. This is in line with the results of the research of Vanita and Mohandass [34] and Warraich et al. [35]. In term of the size of the source, among the test varieties, Sipulo and Sanbei were bigger than Situ Patenggang. In which, the size of sink can be seen from its yiled components, while the size of source can be seen from the plants' height and the number of tillers.
In term of plant height, the tallest height was in Sipulo, followed by Situ Patenggang and Sanbei. While for the number of tillers, the highest was at Sanbei, followed by Sipulo and Situ Patenggang. This highest number of tillers indicates that Sanbei has the biggest amount of source, followed by Sipulo and Situ Patenggang. In this sense, the number of tillers shows the number of leaves that produced photosynthates or source. When viewed from the panicles length, Sipulo has the longest panicle length followed by Sanbei, meanwhile the shortest was at Situ Patenggang. When viewed from the number of filled grains, Sipulo and Sanbei have the highest number of filled grains, which means sink of Sipulo and Sanbei were greater than Situ Patenggang. This is in line with the results of the study by Davatgar et al., [25]. In this sense, varieties with large sinks are always followed by large sources as well. When viewed from both the sink and source size, Sipulo and Sanbei have the amount of sink and source larger than Situ Patenggang. However, the new typical plants that are now being developed often have a balance sink and source, in which it has a lot of panicles of short size so that the size of its sink matches with the source [17].

From the Pearson correlation, it shows that the balanced of sink and source can be seen from age of flowering that was closely related to age of harvest (r = 0.94), panicle length (r = 0.99), number of panicle grain (r = 0.82), weight of filled grains per hill (r = 0.73), percentage of filled grains (r = -0.81), and potential yield (r = 0.73). The age of flowering affects the age of harvest, as the longer the flowering age the more delayed the harvest, and the longer the panicle the heavier grains per hill. The lower percentage of empty grains therefore, the potential of yield was achieved. This is in line with Gago et al. [14]. In which, the higher the percentage of filled grains, the higher the yield. This also indicates that the long flowering period is related to the accumulation of photosynthate in the reproductive phase. In which, it was the result of photosynthate mobility in the yield component from the reproductive phase which affects the percentage of filled grain. The longer harvest age, therefore, the lower of the filled grains, this is because there are more photosynthates used to maintain vegetative organs such as old leaves and roots, while sinks have to be maintained. This is in line with Tarigan et al., [9].

Furthermore, harvest age was closely related to panicles length (r = 0.96), number of grains per panicle (r = 0.96), weight of grains per hill (r = 0.91), weight of 1000 grains (r = -0.53), percentage of filled grains (r = -0.96), and potential yield (r = 0.91). This shows that the longer harvest age, the more amount of grain formed in the reproductive phase. The heavier grains which were mobilization of photosynthate from the reproductive phase were stored in the vegetative tissue, also photosynthate in the ripening phase were filled to grains. However, the reduction in weight of 1000 grains was due to too much photosynthate being used to maintain the vegetative organs due to the long harvest life, which was related to the decrease in the percentage of filled grain. This is due to the large number of sinks used to maintain the organs, although usually the greater yield potential is also due to panicle length and grain volume. It is in line with Sabetfar et al. [24].

In terms of Panicles lengths, it was closely related to the number of grains per panicle (r = 0.85), weight of filled grain per hill (r = 0.77), percentage of filled grain (r = -0.84), and yield potential (r = 0.77). The longer the panicles, the greater number of grain per panicle, the heavier grains per hill, the higher percentage of filled grain and the higher yield. It was due to the long panicles and the more grains could compensate for the increase in the percentage of empty grains or decrease in filled grains. This is in line with the results of the study by Manurung et al., [13] and Paleg et al., [12].

The number of filled grains was closely related to the weight of grains per hill (r = 0.99), the weight of 1000 grains (r = -0.74), the percentage of filled grains (r = -1.00), and yield potential (r = 0.99). The number of filled grains, the length of panicle determines the weight of the filled grains per hill and the yield potential. The greater number of grains per panicle, requires greater photosynthate to be filled into grains. This affects the increase in empty grains and decreases in weight of 1000 grains. Because they must be divided into a lot more grains, causing the percentage of filled grains to decrease. This is in line with the results of the study by Davatgar et al., [25].

Regarding to the weight of filled grains, it was closely related to the weight of 1000 grains (r = 0.83), the percentage of filled grains (r = -0.99), and the potential yield (r = 1.00). This shows that the heavier grains per hill, the higher potential yield, but the decreased weight of 1000 grains. It means that the
grains were getting smaller and the percentage of filled grains were decreasing. This is due to the large number of grains which must be offset by photosynthates allocated to the grain both from photosynthate that were stored at the vegetative and reproductive phases and from the ripening phase. The weight of 1000 grains were closely related to the percentage of filled grains ($r = 0.76$), yield potential ($r = 0.83$).

The heavier weight of 1000 grains showed the greater grains, the more photosynthate allocation to the grains so that the percentage of filled grains increased. On the other hand, decreased yield was due to the 1000 grains weight that produced from the lower number of filled grains. The less panicles such as in Situ Patenggang, therefore, often there was a higher yield. This is because the number of panicles influenced the balance between sink and source, therefore having a balance sink and source, the yield increase. This was not the case for Sipulo and Sanbei, as they have a large, but imbalance sink and source in their yields components, however, their yields remain not different, it is even slightly greater than Situ Patenggang’s. However, in this sense, the percentage of filled grains was closely related to the potential yield ($r = -0.99$).

Furthermore, still in the same relation, the higher the percentage of unfilled grains, the lower yield. This is due to the high percentage of unfilled grains usually in varieties with greater number of panicles. Thereby to maintain the yield potential, hence the variety needed to have a balance between yield components such as panicles number, panicles length, number of grains per panicle. Because all yield components affect the percentage of filled grains and weight of 1000 grains. Therefore, varieties cultivated at upland rice fields must have a balance between sink and source, to maintain productivity. This is in line with the results of the study by Tarigan et al. [9]; Manurung et al. [13]; and Gago et al. [14]. Therefore, to increase the test varieties’ results, effort taken by adjusting the input that can increase the ability of the source to supply the sink. This can take the form of managing fertilizers, organic matter and other inputs that can increase source capacity.

5. Conclusion
Rice varieties that can adapt to upland cultivation, have the nature of balanced sink and source, which seen from the morpho-agronomic traits in the form of high yields with a balanced sink and source. In varieties, having many tillers affects the source and the yield component affects sink size. If the varieties are grown in a water shortage environment such as in upland rice fields, efforts should be made in increasing and maintaining soil moisture, through the adjustment of the growing season, the use of organic matter, and fertilization that can increase water content in plants. In the wet season, with full sun exposure, the potential results achieved. In which the amount of sink and source were not limited by the lack of water, but by the genetic traits and the capacity of the source and sink of each variety. Furthermore, in the dry season, it is necessary to adjust culture technically according to the growing phase of rice and source of water available.

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