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Evaluation of Yield Traits between 15 Purple-Pericarp Rice Lines (*Oryza sativa* L.)

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Abstract Yield traits between 15 purple-pericarp rice lines (*Oryza sativa* L.) were evaluated. The examination was conducted between 24 October and 13 March 2016 in Chonburi province, Thailand. Treatments were 13 rice lines including BP2012-005, BP2012-010, BP2012-009, BP2012-258, BP2012-279, BP2012-350, BP2012-375, BP2012-412, BP2012-430, BP2012-445,BP2012-489,BP2014-001, BP2014-002, and compared to 2 commercial rice varieties, i.e. Riceberry and Khao Luempua. Transplanting method was used with 1 seedling per hill and 30 x 30 cm spacing. Results revealed that un-husked grains at 15 % moisture showed highly significant difference between treatments. BP2012-009 and BP2014-002 singnificantly produced maximum yield/Rai of 470.40 kg and 464.03 kg, respectively, and followed by BP2014-001, Riceberry, BP2012-010, BP2012-005 and BP2012-279 which the yield/Rai of 452, 448, 440, 438 and 432 kg, respectively. Whereas BP2012-412, BP2012-430, BP2012-445, and BP2012-489 yielded lower than Riceberry but higher than Khao Luempua as compared to the rice variety with the lowest yield/Rai of 134.40 kg. The current experiment indicated greater yield of 2 rice lines, BP2012-009 and BP2014-002, than Riceberry. BP2012-009 had only 110 days of harvesting date compared with 139 days of BP2014-002. Results also indicated that 4 rice lines including BP2014-001, BP2012-005, BP2012-010, and BP2012-279 showed non singnificantly differerce in yield compared to Riceberry, It suggested that these rice lines are promising for further selection and improvement as novel lines in the future.

Keywords: Evaluation, Yield traits, Purple-pericarp rice

Introduction

Rice with pericarp in various colors began to gain popular interest and increased consumption. The black- or dark-purple pericarp of rice came from the synthesis of pigment called anthocyanin that is rich in nutritional value and antioxidant properties. It helps to be lower cholesterol and against cancer (Mansuriwong *et al.*, 2005). The most common type of anthocyanin found in rice is cyanidin-3-glucoside that acts as antioxidant to prevent cancer (Stoner, 2009), metabolic disorder (Guo *et al.*, 2007),

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allergies, diabetes, heart disease, inflammatory bowel disease, as well as promotes vision health (Dilip and Tetsuya, 2007). Purple-pericarp rice has now become one among health foods for people in the current age. According to the report by Thipkanon *et al.* (2004), anthocyanin is a type of natural pigment ranged in colors from purple to dark blue. It posses antioxidant activities that helps slow down the deterioration of cells, reduce risk of heart disease, stimulate blood flow, and inhibits pathogenic *Escherichia coli* causing enteric diseases resulting in diarrhea and food poisoning.

Black purple color in many rice varieties are found in different organs of rice plant including leaf sheath, leaf blade, petal, husk, and pericarp (Kaladee and Jumjood, 2000; Hiratsuka *et.al*, 2001) The value and benefit of anthocyanin in purple rice grains previously described have drawn the research attention to those purple-pericarp rice lines with effective growth, high yield, and adaptability to different environment. The research aimed to select local Thai rice varieties that possed distinct properties and high yield suitable to local farming area and contained health promoting substances as well as medical properties such as GABA and anthocyanin.

Materials and Methods

The experiment was conducted at Chonburi province,Thailand, during 24 October 2015 to 13 March 2016, using a Randomized Complete Block Design (RCBD) with 2 repeated experiments. The 13 purple-pericarp rice lines were examined including BP2012-005, BP2012-010, BP2012-009, BP2012-258, BP2012-279, BP2012-350, BP2012-375, BP2012-412, BP2012-430, BP2012-445, BP2012-489, BP2014-001, and BP2014-002, and 2 commercial rice varieties, Ricerberry and Khao Luempoa served as the controls. The method was transplanting with one 30-day-old seedling per hill and 30 x 30 cm spacing. Agronomic characteristics were recorded following the method of Yoshida (1981) including plant height, tillering capacity, flowering date, number of panicle per hill, panicle length, panicle weight, number of filled grain per panicle, 100-seed weight, harvesting date, and rough grain yield per Rai. The data were statistical computed analysis of variance and treatment means were compared using Duncan's Multiple Rang Test (DMRT) at 95 % confidence level.

Results

Plant Height

Growth examination of plant height at harvesting date of 15 rice lines indicated highly statistically significant difference. BP2014-002 and

BP2014-001 showed maximum plant height of 132.44 and 122.7 cm, respectively but not different from BP2012-005, BP2012-010, BP2012-009, BP2012-258, BP2012-279, BP2012-350, BP2012-375, BP2012-412, BP2012-430, BP2012-430, BP2012-445, BP2012-489, and Riceberry, while Khao Luempoa produced minimum plant height of 83.78 cm (Table 1). BP2014-002 and BP2014-001 gave maximum plant height of respectively 132.44 and 122.7 cm. but did not differ to those lines in BP2012 and Riceberry, while Khao Luempoa gave minimum plant height of 83.78 cm. BP2012 and BP2014 are moderately tall and tolerant to logging, and hence suitable to harvest.

Tillering Capacity

Examination of tillering capacity of 15 purple pericarp rice lines demonstrated statistical difference. BP2012-005 and Riceberry showed highest tillering capacity of 5.05 tillers per hill, followed by BP2012-258 and BP2012-279 with 4.80 tillers per hill, while BP2014-001 produced the lowest number of 2.80 tillers per hill (Table 1). Current experimental results revealed that BP2012-005 and Riceberry had high capacity of tillering for 5.05 tillers per hill, while BP2014-001 produced the lowest numbers of 2.80 tillers per hill.

Flowering Date

Comparisons of flowering date among the rice lines indicated highly statistically significant differences, with BP2014-002 having longer flowering date, i.e. 90 days, than those other rice lines, followed by Riceberry, BP2014-001, and Khao Luempoa with flowering date of 82, 81.50, and 71 days, respectively. No statistical difference in flowering date was found for those lines in BP2012 with average flowering date of 58-62 days (Table 2).

Number of Panicle per Hill

Results on number of panicle per hill suggested statistical difference, with BP2014-002 producing the highest number of 13.50 panicles per hill, followed by Riceberry, and BP2014-001 with 12.50 and 12 panicles per hill, respectively. There was no statistical difference in number of panicle per hill among those lines in BP2012. Khao Luempoa appeared to give the lowest number of 5 panicles (Table 2).

Panicle Length

Comparisons of panicle length found reported highly statistically significant difference, with BP2014-002 produced the longest panicle of

28.84 cm, while Khao Luempoa produced the shortest panicle of 17.94 cm. Those lines in BP2012 did not differ statistically (Table 2).

Panicle Weight

Investigation of panicle weight indicated highly statistically significant difference, with BP2014-002 producing maximum panicle weight of 7 gm. which was greater than other rice lines, and Khoa Luempoa producing minimum panicle weight of 1.75 gm. (Table 3).

Number of Filled Grain per Panicle

Results suggested highly statistically significant difference in number of filled grain per panicle. BP2014-002, BP2014-001, and Riceberry gave the highest numbers of respectively 258.10, 249.10, and 245.90 filled grains per panicle. Statistical difference in number of filled grain per panicle was however not found among those lines in BP2012. Whereas the lowest number of 51.35 filled grain per panicle was obtained from Khao Luempoa (Table 4).

100-Seed Weight

Examination results of 100-seed weight demonstrated highly statistically significant differences. Maximum 100-seed weight of 3.52 gm. was obtained from Khao Luempoa, while minimum 100-seed weight of 2.12 gm. was obtained from Riceberry (Table 4)**.**

Harvesting Date

Highly statistically significant difference was found in harvesting date. BP2014-002 was reported with longest harvesting date of 139 days, followed by Riceberry, BP2014-001, and Khao Luempoa with harvesting date of 130.50, and 129 days, respectively. Statistical difference was not observed in harvesting date among those rice lines in BP2012 with harvesting date between 108 -111 days (Table 5).

Rough Grain Yield per Rai

Investigation of rough grain yield per Rai at 15 % moisture suggested highly statistically significant differences. BP2012-009 offered maximum yield of 470.40 kg/Rai and BP2014-002 offered 464.03 kg/Rai (Table 5), both lines producing greater yield than the 2 comparing varieties. Khao Luempoa was found to produce minimum yield, i.e. 134.40 kg/Rai.

Table 1. Plant height, harvesting date and number of tiller per hill of purple pericarp rice

Rice Lines	Plant Height (cm.)	Number of Tiller per Hill (Tiller/Hill)
BP2012-005	111.32 b	5.05 a
BP2012-010	109.38 b	4.50 ab
BP2012-009	141.68 b	4.50 ab
BP2012-258	107.23 b	4.80 a
BP2012-279	109.92 b	4.80 a
BP2012-350	106.43 b	4.30 ab
BP2012-375	107.62 b	4.55 ab
BP2012-412	106.26 b	4.55 ab
BP2012-430	107.62 b	4.20 ab
BP2012-445	105.28 b	4.20 ab
BP2012-489	101.52 b	4.15 ab
BP2014-001	123.70 a	2.80 b
BP2014-002	132.44 a	3.75 ab
Riceberry	102.76 b	5.05 a
Khao Luempoa	83.78 c	3.45 ab
Mean	108.46	4.30
F-test	**	*
C.V.(%)	4.95	17.79

* Statistical difference at 95% confidence level

** Highly statistically significant difference at 99% confidence level

In the same column, different letters signify statistical difference when comparisons were made with DMRT method.

Table 2. Flowering date and number of panicle per hill of purple pericarp rice

Rice Lines	Flowering Date (Days)	Number of Panicle per Hill (Panicle)
BP2012-005	59.50 d	10.50 bc
BP2012-010	61.00 d	9.00 bcd
BP2012-009	60.00 d	9.50 bcd
BP2012-258	59.50 d	9.50 bcd
BP2012-279	61.50 d	9.50 bcd
BP2012-350	61.50 d	9.50 bcd
BP2012-375	59.00 d	9.00 bcd
BP2012-412	60.50 d	7.50 cde
BP2012-430	60.00 d	7.50 cde
BP2012-445	62.00 d	9.00 bcd
BP2012-489	58.50 d	6.00 de
BP2014-001	81.50 b	12.00 ab
BP2014-002	90.00 a	13.50 a
Riceberry	82.00 b	12.50 ab
Khao Luempoa	71.50 c	5.00 e
Mean	65.87	9.3
F-test	**	*
C.V. (%)	4.83	16.97

* Statistical difference at 95% confidence level

** Highly statistically significant difference at 99% confidence level

In the same column, different letters signify statistical difference when comparisons were made with DMRT method.

Table 3. Panicle length and panicle weight of purple pericarp rice

Rice Lines	Panicle Length (cm.)	Panicle Weight (gm.)
BP2012-005	21.50 c	2.50 d
BP2012-010	19.91 c	2.00 de
BP2012-009	21.52 c	2.00 de
BP2012-258	20.59 c	2.00 de
BP2012-279	19.93 c	2.00 de
BP2012-350	20.25 c	2.00 de
BP2012-375	20.73 c	2.25 de
BP2012-412	20.92 c	2.00 de
BP2012-430	20.22 c	2.00 de
BP2012-445	20.19 c	2.25 de
BP2012-489	19.85 c	1.75 e
BP2014-1	27.21 b	6.00 b
BP2014-2	28.84 a	7.00 a
Riceberry	27.59 ab	5.00 c
Khao Luempoa	17.94 d	1.75 e
Mean	21.81	2.83
F-test	**	**
C.V. (%)	3.21	8.79

** Highly statistically significant difference at 99% confidence level
In the same column, different letters signify statistical difference when comparisons were made with DMRT method.

Table 4. Number of filled grain per panicle and 100-seed weight of purple pericarp rice

Rice Lines	Number of filled grain per panicle (Grain)	100-seed weight (gm.)
BP2012-005	82.95 b	2.34 g
BP2012-010	82.40 b	2.54 de
BP2012-009	88.65 b	2.48 de
BP2012-258	87.75 b	2.40 efg
BP2012-279	84.10 b	2.51 de
BP2012-350	85.40 b	2.64 c
BP2012-375	89.05 b	2.48 de
BP2012-412	88.75 b	2.55 de
BP2012-430	86.75 b	2.55 de
BP2012-445	85.80 b	2.37 fg
BP2012-489	80.05 b	2.52 de
BP2014-001	249.10 a	2.89 b
BP2014-002	258.10 a	2.78 bc
Riceberry	245.90 a	2.12 h
Khao Luempoa	51.35 c	3.52 a
Mean	116.40	2.58
F-test	**	**
C.V.(%)	9.10	21.58

** Highly statistically significant difference at 99% confidence level
In the same column, different letters signify statistical difference when comparisons were made with DMRT method.

Table 5. Harvesting date and rough grain yield per Rai of purple-pericarp rice

Rice Lines	Harvesting Date (Days)	Yield/Rai (kg/Rai)
BP2012-005	110.00 d	438.40 ab
BP2012-010	109.50 d	440.00 ab
BP2012-009	110.50 d	470.40 a
BP2012-258	110.00 d	387.20 bc
BP2012-279	109.00 d	432.00 ab
BP2012-350	111.00 d	384.00 bc
BP2012-375	108.00 d	328.00 cd
BP2012-412	110.00 d	280.00 de
BP2012-430	109.00 d	292.80 de
BP2012-445	108.00 d	304.00 d
BP2012-489	109.50 d	232.00 e
BP2014-001	129.00 b	452.00 ab
BP2014-002	139.00 a	464.03 a
Riceberry	130.50 b	448.00 ab
Khao Luempoa	119.00 c	134.40 f
Mean	114.80	391.63
F-test	**	**
C.V.(%)	2.72	2.78

** Highly statistically significant difference at 99% confidence level
In the same column, different letters signify statistical difference when comparisons were made with DMRT method.

Discussion

Growth examination of plant height at harvesting date of 15 rice lines indicated highly statistically significant difference. Plant height have a competitive advantage over weeds. Most of the farmers are likely to grow rice with moderate height as it is easy to harvest (Chang and Vergara, 1975). BP2014-002 and BP2014-001 gave maximum plant height of respectively 132.44 and 122.7 cm. but did not differ to those lines in BP2012 and Riceberry, while Khao Luempoa gave minimum plant height of 83.78 cm. Abifarin *et al.* (1972) noted that improvement and selection of rice varieties intended to obtain rice plant with moderate height, short and narrow leaf, logging tolerance, strong stem, moderate numbers of panicle, high numbers of filled grain per panicle, well adaptability to variable environmental conditions, early harvesting date, and high yield (Kawano *et al.*, 1972). Chang and De Datta, (1975) described that a good rice variety should be characterized by moderate height (120-140 cm), moderate leaf length and bending downward as they can adapt to growing conditions and compete with weeds. BP2012 and BP2014 are moderately heigh and tolerant to logging, and hence suitable to harvest.

Examination of tillering capacity of 15 purple pericarp rice lines demonstrated statistical difference. Tillering capacity provides an indicator of yield potential as new tillers are likely to produce more panicles and result in high yield but consideration is required on the percentage of producing panicles per plant. Lowland rice typically tillers better than highland rice. Lowland local rice varieties give approximately 5 – 20 tillers per hill. However, high or low numbers of tiller depend on the climate and

cultivation method. If these factors allow, tillering will be higher (Tutsongchan, 1987).

Comparisons of flowering date among the rice lines indicated highly statistically significant differences, with BP2014-002 having longer flowering date, i.e. 90 days, than those other rice lines, followed by Riceberry, BP2014-001, and Khao Luempoa with flowering date of 82, 81.50, and 71 days, respectively. No statistical difference in flowering date was found for those lines in BP2012 with average flowering date of 58 - 62 days Flowering date determine ripening date and harvesting date of rice varieties, that can be classified by harvesting date into 3 types, early variety, medium variety and late variety (Department of Rice Thailand, 2006).

The number of panicle per hill indicates yield capacity; high number of panicle per hill reflects high yield capacity. Generally, tillering is ranged between 5.88-10.06 tillers per hill (Tutsongchan, 1987). Based on our result, BP2014-002 demonstrated maximum capacity of 13.50 panicles per hill which was higher than both of the 2 comparing varieties. It is likely that rice varieties with high yield potential possess good yield components including number of tiller per hill and number of panicle per hill. (Department of Rice Thailand, 2006).

Comparisons of panicle length found reported highly statistically significant difference, with BP2014-002 produced the longest panicle of 28.84 cm, while Khao Luempoa produced the shortest panicle of 17.94 cm. Those lines in BP2012 did not differ statistically. Panicle length was indicated for rice yields. If the panicle length was very high, it likely that the number of seeds per panicle will increase. (Chang and De Datta, 1975).

Investigation of panicle weight indicated highly statistically significant difference, with BP2014-002 producing maximum panicle weight of 7 gm. which was greater than other rice lines, and Khoa Luempoa producing minimum panicle weight of 1.75 gm.. Panicle weight was index for rough grain yield per Rai. (Adams and Grafeus, 1971).

Results suggested highly statistically significant difference in number of filled grain per panicle. BP2014-002, BP2014-001, and Riceberry gave the highest numbers of respectively 258.10, 249.10, and 245.90 filled grains per panicle. Statistical difference in number of filled grain per panicle was however not found among those lines in BP2012. Whereas the lowest number of 51.35 filled grain per panicle was obtained from Khao Luempoa. Number of filled grain per panicle is another indicator of yield; high numbers of filled grain per panicle, high yield is more likely (Adams and Grafins, 1971).

Examination results of 100-seed weight demonstrated highly statistically significant differences. Maximum 100-seed weight of 3.52 gm. was obtained from Khao Luempoa, while minimum 100-seed weight of 2.12 gm. was obtained from Riceberry**.** One hundred-seed weight indicates grain size. According to the Department of Rice Thailand (2006), rice varieties

grown in Thailand produce 2 sizes of grain; large sized grain with 100-seed weight between 2.40 - 2.90 gm. and small sized grain with 100-seed weight between 2.10 - 2.39 gm. It can be seen in the current experiment that all of the rice lines being examined are of large size grain especially that of Khao Luempoa with highest 100-seed weight of 3.52 gm. However, Improvement of any particular yield components might lowering another component, for example, increased numbers of grain per tiller might result in decreased grain weight (Promsomboon, 2004).

Highly statistically significant difference was found in harvesting date. BP2014-002 was reported with longest harvesting date of 139 days, followed by Riceberry, BP2014-001, and Khao Luempoa with harvesting date of 130.50, and 129 days, respectively. Statistical difference was not observed in harvesting date among those rice lines in BP2012 with harvesting date between 108 -111 days. The Department of Rice Thailand had classified rice by harvesting date into 3 types: early variety, medium variety, and late variety. Harvesting date is counted from the date of seedling or broadcasting in the field to the date of harvesting. Harvesting date for early, medium, and late varieties are 90-100, 101-120, and 120 days or more, respectively. Based on the current results, rice varieties here can be classified into 2 types as medium variety including those rice lines in BP2012 and Khao Luempoa variety; and late variety including those rice lines in BP2014 and Riceberry variety (Department of RiceThailand, 2006).

Investigation of rough grain yield per Rai at 15 % moisture suggested highly statistically significant differences. BP2012-009 offered maximum yield of 470.40 kg/Rai and BP2014-002 offered 464.03 kg/Rai, both lines producing greater yield than the 2 comparing varieties. Khao Luempoa was found to produce minimum yield, i.e. 134.40 kg/Rai. This may be attributable to environmental influence on growth and yielding (Yoshida and Hara,1977). Therefore, selecting rice varieties that are tolerant to variable environmental conditions is an issue that should be taken into consideration. Our results found that rice lines in BP2012 and BP2014 are likely to demonstrate better adaptability than the 2 comparing varieties.

Conclusion

The results showed that rice varieties in this experiment can be classified by harvesting date into 2 types, i.e. medium variety of 101-120 days including rice lines in BP2012 and Khao Luempoa variety; and late variety of 120 days or more including rice lines in BP2014 and Riceberry variety. BP2012-009 and BP2014-002 produced highest yield/Rai of respectively 470.40 and 464.03 kg, followed by BP2014-001, Riceberry, BP2012-010, BP2012-005, and BP2012-279 with yield/Rai of 452, 448.00 440, 438, and 432 kg., respectively. Khao Luempoa produced minimum yield/Rai of 134.40 kg. BP2012-009 and BP2014-002 offered better

yield/Rai than the 2 comparing varieties, Riceberry and Khao Luempoa, with the first 2 lines having respectively 110 and 139 days of harvesting date. BP2014-001, BP2012-010, BP2012-005, and BP2012-279 did not differ statistically in yield form Riceberry. Two rice lines with greater yield than Riceberry and another 4 rice lines with no different yield from Riceberry were selected for further research and improvement.

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