VARIETAL DIFFERENCES OF FLAG LEAF CHARACTERS IN RELATION TO GROWTH AND YIELD OF UPLAND RICE GENOTYPES

Perbedaan Varietas Tentang Karakter Daun Bendera Hubungannya dengan Pertumbuhan dan Hasil Padi Gogo

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ABSTRAK

Penelitian sebelumnya telah mengungkapkan bahwa daun bendera padi gogo pada kondisi naungan berkorelasi positif dengan hasil. Namun hubungan antara daun bendera dan pertumbuhan serta hasil pada berbagai genotipe padi gogo pada kondisi tanpa naungan masih perlu diteliti lebih lanjut. Oleh karena itu, tujuan penelitian ini adalah untuk mengevaluasi perbedaan varietas dari karakter daun bendera berbagai genotipe padi gogo yang berhubungan dengan pertumbuhan dan hasil serta menghitung korelasi antara karakter daun bendera dan komponen pertumbuhan maupun hasil yang nantinya digunakan sebagai indikator seleksi hasil tinggi. Penelitian ini dilaksanakan di Sukoharjo, Tanggamus mulai awal Oktober 2002 sampai dengan akhir Maret 2003 dengan menggunakan 18 genotipe padi gogo. Hasil menunjukkan bahwa TB 165-TB-6 mempunyai luas daun bendera dan ukuran biji tertinggi, yaitu berturut-turut 53,1 cm^2 dan 34,3 g/1000 butir. Sebaliknya, genotipe Dodokan mempunyai luas daun kecil, yaitu 25,8 cm^2 dan menunjukkan ukuran biji yang kecil, yaitu 25,7 g/1000 butir. Kondisi ini secara tidak langsung menunjukkan bahwa luas daun bendera berkorelasi positif dengan ukuran biji, yaitu r= 0,31**. Luas daun bendera juga menunjukkan korelasi positif dengan bobot kering batang, yaitu r=0,23**. Hal ini berarti bahwa daun bendera mempunyai peran yang penting untuk mengalokasikan fotosintat ke bagian biji. Oleh karena itu, perbedaan varietas untuk daun bendera akan bermanfaat digunakan sebagai indikator seleksi ukuran biji pada padi gogo.

Keywords: Flag leaf, growth, upland rice, varietal difference, yield

INTRODUCTION

High-yielding rice variety is associated with large sink size due mainly to more panicle number and source strength as high photosynthetic rate during reproductive stage. In Indonesia, the strategy for high-yielding rice variety is frequently associated with short period of harvested type, tolerant to pest and disease, tolerant to drought condition, high panicle number, and heavy grain weight. The morphological trait of erect leaf is also considered as improved yield of rice genotype (Baker *et al.* 1990; Youding *et al.* 2005). Gilmour (1985) reported that dry matter accumulation at late tillering in rice positively correlated with grain yield. Laza *et al.* (2001) also studied in leaf character and concluded that the greater vegetative growth of F1 hybrid rice was associated with larger LAGR (leaf area growth rate) but not with tillering capacity. F1 hybrid rice does not produce more tillers than IR64 in the tropics because environmental factors, especially temperature and CO_2. Ziska *et al.* (1997) speculated about the combination of CO_2 and temperature effects in rice. They suggested that there would be quantitative and qualitative changes in rice supply if both CO_2 and air temperature continue to increase in warmer regions (more than 34°C) of growing rice. Moreover, deep root system would be concomitant with drought tolerance in rice (Suardi 2002) and in peanut (Setiawan 2002). Unfortunately, the morphological plant types, especially flag leaf characters, are rarely informed to be important for selecting high-yielding rice variety. Saitoh *et al.* (2002) reported that the larger, wider, longer, and more erect first and second leaves above panicle, the more dry matter would be produced. This was due probably to high light interception by leaves during ripening and led to the high photosynthetic rate. Additionally, Li *et al.* (2002) suggested that the ideotype that most breeder favor tended to be erect leaves and relatively small tiller angle, allowing a high leaf area index without causing mutual shading. Moreover, leaf shape and anatomy had already been used as indicators to identify the change of different growth phase in rice (Sylvester *et al*. 2001).

It seems that the promising technique to indicate high-yielding rice variety, particularly upland rice, is to study flag leaf characters in relation to yield and yield components. Flag leaf of rice is a last leaf that appears at reproductive stage, especially at the panicle appearance. The previous result showed that flag leaf width of upland rice highly positively correlated with yield (r=0.59**) under shading of 4-year-old rubber tree canopy (Kamal *et al*. 2004). Since the flag leaf has the main role on transferring photoassimilate as a source to reproductive parts of seeds as a sink, it can be utilized to select high yielding upland rice varieties based on flag leaf characters (length, width, and area). Based on this, Selvi *et al*. (2000) started to conduct the research and then concluded that flag leaf area associated with dry matter production, tiller, and stomatal conductance. They also reported that flag leaf area negatively associated with stomatal conductance. This is the fact that high flag leaf area would associate with high water use efficiency which might lead to the high yield. This also reproted in peanut by Setiawan (2002) that high water use efficiency could associate with low stomatal conductance resulted in high peanut yield. Additionally, Saitoh *et al*. (2002) revealed their result that the removal of flag leaf could decrease canopy photosynthesis, as 37 and 48% in rice genotypes of Nipponbare and Takanari, respectively. This implicitly means that flag leaf characters have the main role for photosynthetic activity, mainly in translocating source to sink parts, as grain. Kamal *et al*. (2004) had already studied flag leaf width of upland rice under shading condition of four-year rubber tree canopy in relation to yield. It seems that the association between flag leaf characters and yield components is still unclear yet. As a result, the information of flag leaf characters of upland rice in relation to yield components and yield is still quite rare. Consequently, the objectives of this study were to evaluate the varietal differences of flag leaf characters relating to the growth and yield of different upland rice genotypes and to determine the correlation between flag leaf characters and yield components to be used as selection indicator for high yielding upland rice variety. In this study, the flag leaf characters to be observed would be length, width, and area.

METHODS

This study was conducted in upland area of Kecamatan Sukoharjo, Kabupaten Tanggamus, Lampung from beginning of October 2002 to the end of March 2003. The soil condition showed the pH of 5.0, 0.18% N, 2.78 ppm P, and 0.15 ppm K. There were 18 upland rice genotypes in this study, as Jatiluhur, B 2966 F-N7-MR-2-PN-4, TB 177E-TB-30-B-2, TB 165-TB-6, B 9048C-TB-4-B-2, TB 154E-TB-1, S 3613F-PN-1-1, C22, B 8503E-TB-19-3-10, Kalimutu, Cirata, Limboto, Danau Tempe, Way Rarem, Bio 530A-5-14-2-8, TB 47H-MR-10, Dodokan, Bio 528B-TB-12-1-1. Jatiluhur, Kalimutu, Cirata, Limboto, Danau Tempe, and Way Rarem are the upland rice varieties frequently planted by local farmers. Moreover, Bio 530A-5-14-2-8 and Bio 528B-TB-12-1-1 are the potentially upland rice genotypes which are planning to be released the near future. The rest are the promising upland rice genotypes possible to be developed as the high yielding upland rice varieties. Because of this, we tried to select 18 different upland rice genotypes to be high yielding upland rice varieties based on flag leaf characters having correlation with growth and yield components.

The size of plot was 4 x 5 m^2 with the distance among plot was 50 cm. Every hill was planted by three seeds and then thinned to be 2 plants/hill at 10 days after planting (DAP). Fertilizers, as urea, SP36, and KCl were fertilized in the plot according to the recommended dose from Balai Pusat Informasi Pertanian Bandar Lampung, as 200 kg/ha, 150 kg ha^{-1}, and 100 kg ha^{-1}, respectively. All of the dosages of SP36 and KCl were fertilized at 7 DAP, yet urea was separately fertilized two parts. First application was half dosage of urea given at 7 DAP together with SP36 and KCl, and then the remnant dosage of urea was given at 56 DAP (at the very early of reproductive stage). The variables observed in this study were flag leaf characters (length, width, and area), plant height, leaf number, plant number, dry matter (leaf, stem, and root), panicle length, panicle number, the number of spikilet per panicle, seed number, seed size (the weight of seed/1000 seeds), yield, and the leaf content of nitrogen, phosphor, potassium, and magnesium. The analysis of nutrient contents was carried out at milky ripening stage and at yellow ripening stage. These nutrients were analyzed in the Laboratory of Soil Science, Department of Soil Science, University of Lampung. Data were analyzed by the software of SAS (N.C. Release 6.12) and the treatment means were analyzed by LSD in 5% significant level of difference. The correlation values were analyzed by the simple analysis of Steel & Torrie (1980). Additionally, the content of nutrients in leaves was described as histogram.

RESULTS AND DISCUSSION

There was a varietal difference of flag leaf characters among 18 upland genotypes (Table 1). TB165-TB-6 had longer flag leaf and higher flag leaf area, as 39.2 cm and 53.1 cm^2, respectively. However, Dodokan showed shorter flag leaf and lower flag leaf area, as 25.2 cm and 25.8 cm^2, respectively. Interestingly, TB154E-TB-1 produced higher plant number and leaf number, as 34.4 and 146.0, respectively (Table 2). This means that flag leaf characters has no relation with the plant and leaf number. Such condition was supported by analysis of correlation from Table 6 which showed no correlation between flag leaf characters and plant number. Yet, flag leaf area had a positive correlation with leaf dry weight (r=0.19*). This probably means that higher flag leaf area will produce the heavier leaf dry weight which in turn associates with high photoassimilate production. Such condition was supported by the data that TB 165-TB-6 showed higher flag leaf area and longer flag leaf, as a result, TB 165-TB-6 also produced high leaf and stem dry matter, as 12.9 g and 26.9 g, respectively (Table 3). In contrast, Dodokan had shorter flag leaf and smaller flag leaf area, it also produced lighter leaf and stem dry matter, as 5.69 g and 12.8 g, respectively. Consequently, Dodokan showed lighter root dry weight, as 4.39 g. Higher plant and leaf number does not mean longer flag leaf and higher flag leaf area. However, higher plant number positively correlated with leaf number, as shown by TB 154E-TB-1. This upland rice genotype had higher plant and leaf number, as 34.4 and 146.0 no/group, respectively (Table 2), but showed low flag leaf area. Additionally, higher leaf dry weight of TB 154E-TB-1was due mainly to higher leaf number. This genotype also showed higher panicle number, as 17.9 no./group (Table 4). In contrast, Kalimutu produced lower plant number and also showed lower leaf number, as 59.7 and 12.2 no/group, respectively.

In dry matter characters, TB165-TB-6 genotype showed the same weight as TB17 7E-TB-30-B-2 and Jatiluhur genotypes (Table 3). However, Kalimutu produced the high stem and root dry matters, as 32.3 g and 9.49 g per group, respectively. Interestingly, Dodokan genotype was able to produce much lower leaf, stem, and root dry weight, as 5.69 g, 12.8 g, and 4.39 g per group, respectively. It seems that Dodokan genotype has low capacity to produce high photoassimilate compared to TB165-TB-6 genotype. This condition could be observed in the leaf number of both genotypes, because both genotypes of TB165-TB-6 and Dodokan produce the same leaf number. Yet, leaf dry weight of TB165-TB-6 genotype was weigher than that of Dodokan genotype It seems that there is varietal differences of yield components (Table 4) which is the same condition as that of flag leaf characters in Table 1. Ishimaru *et al*. (2005) had already reported that yield components of rice correlated with sink activity and depended on its genetic background. TB 165-TB-6 genotype could produce higher spikelet number, as 13.2 no./group but Dodokan genotype showed lower spikelet number, as 8.04 no./group. On the other hand, Kalimutu genotype that produced higher stem and root dry weight had lower panicle number/group, as 10.3 no./group. It seems that weigher root dry weight did not have to produce higher number of panicle. Based on the plant number or tillering, Kalimutu genotype showed lower capacity of tillering production, yield it as 281.5 $g\ m^{-2}$, respectively (Table 5).

It means that upland rice genotypes significantly affect tillering ability. This was

Table 1. The flag leaf characters, as length, width, and area of different upland rice genotypes measured at milky ripening stage of reproductive phase

Upland rice genotypes	Flag leaf characters		
	Length	Width	Area
	---------------- cm ----------------		------ cm^2 ------
Jatiluhur	31.3de	2.08ab	46.9bcd
B2966-N7-MR-2-PN-4	30.8de	1.87efg	39.0gh
TB 177E-TB-30-B-2	24.9g	1.97cde	33.0i
TB 165-TB-6	39.2a	1.99bcd	53.1a
B 9048C-TB-4-B-2	30.0de	1.99bcd	45.1de
TB 154E-TB-1	32.4cd	1.67i	46.5b-e
S 3613F-PN-1-1	31.6de	1.92def	44.5def
C 22	30.1de	1.77h	46.1cde
B 8503E-TB-19-3-10	29.1ef	2.03bc	39.6fgh
Kalimutu	35.3b	2.16a	51.4abc
Cirata	29.9de	1.83fgh	42.1d-h
Limboto	36.0b	2.15a	51.5ab
Danau Tempe	30.4de	1.81gh	44.4def
Way Rarem	30.3de	2.05bc	41.4e-h
Bio 530A-5-14-2-8	30.9de	1.75hi	42.7d-g
TB 47H-MR-10	34.3bc	1.97cd	46.6b-e
Dodokan	25.2g	1.44j	25.8j
Bio 528 B-TB-12-1-1	26.9fg	1.95cde	36.9hi
$LSD_{0.05}$	1.24	0.11	5.21

The values followed by the same letter in the same column indicated not significant difference with LSD under 5% significant level

Tabel 2. Vegetative plant characters as plant height, leaf number, and plant number of different upland rice genotypes measured at milky ripening stage of reproductive phase

Upland rice genotypes	Plant height	Leaf number	Plant number
	------ cm --------	-------------- no./group --------------	
Jatiluhur	107.5f	114.3b	21.4fg
B2966-N7-MR-2-PN-4	100.3gh	106.7b-e	25.3bc
TB 177E-TB-30-B-2	119.3c	107.7bcd	19.2fg
TB 165-TB-6	132.6a	90.6efg	20.0fg
B 9048C-TB-4-B-2	113.0d	106.7b-e	18.8fgh
TB 154E-TB-1	91.8i	146.0a	34.4a
S 3613F-PN-1-1	111.de4	112.4b	27.6b
C 22	101.7g	95.3fg	22.0def
B 8503E-TB-19-3-10	118.1c	98.5d-g	24.1cd
Kalimutu	120.3c	59.7h	12.2i
Cirata	85.1j	108.5bc	21.2fg
Limboto	96.6h	90.7fg	19.5fg
Danau Tempe	108.6ef	96.1efg	16.5h
Way Rarem	119.0c	92.1fg	20.2fg
Bio 530A-5-14-2-8	91.5i	105.5b-e	24.0cde
TB 47H-MR-10	102.0g	88.0g	18.6gh
Dodokan	77.7k	100.5def	24.3cd
Bio 528 B-TB-12-1-1	127.2b	87.7g	21.6ef
$LSD_{0.05}$	4.27	16.2	3.21

The values followed by the same letter in the same column indicated not significant difference with LSD under 5% significant level

Table 3. Dry matter characters, as leaf dry weight, stem dry weight, and root dry weight of different upland rice genotypes measured at milky ripening stage of reproductive phase

Upland rice genotypes	Dry matter		
	Leaves	Stem	Root
	---------------------- g/group ----------------------		
Jatiluhur	13.3abc	24.0cde	8.24b
B2966-N7-MR-2-PN-4	10.7d	22.7def	5.73de
TB 177E-TB-30-B-2	14.4a	25.5bc	6.77cd
TB 165-TB-6	12.9abc	26.9b	6.37cde
B 9048C-TB-4-B-2	11.6cd	24.1cd	6.78cd
TB 154E-TB-1	14.1ab	26.0b	6.75cd
S 3613F-PN-1-1	13.2abc	25.4bc	7.26bc
C 22	13.4abc	20.1f	6.17cde
B 8503E-TB-19-3-10	13.4abc	24.7cd	8.31ab
Kalimutu	11.9cd	32.3a	9.49a
Cirata	13.4abc	21.0f	7.01c
Limboto	11.8cd	21.5ef	5.78de
Danau Tempe	10.6d	20.6f	5.35e
Way Rarem	12.7bc	25.5bc	6.28cde
Bio 530A-5-14-2-8	12.4cd	21.5def	7.01c
TB 47H-MR-10	11.7cd	21.3f	5.77de
Dodokan	5.69f	12.8h	4.39f
Bio 528 B-TB-12-1-1	8.72e	17.9g	6.07cde
$LSD_{0.05}$	1.90	2.51	1.20

The values followed by the same letter in the same column indicated not significant difference with LSD under 5% significant level

Table 4. The panicle characters, as panicle number per group, spikilet number per panicle, and panicle length of different upland rice genotypes

Upland rice genotypes	Panicles per group		
	Number	Spikelet	Length
	---------------- no. ----------------		------- cm -------
Jatiluhur	14.0cd	12.3b	19.4h
B2966-N7-MR-2-PN-4	13.9cd	11.0cd	21.0ef
TB 177E-TB-30-B-2	12.6def	9.85f	19.0h
TB 165-TB-6	11.6efg	13.2a	24.6b
B 9048C-TB-4-B-2	14.4bc	10.9de	22.8cd
TB 154E-TB-1	17.9a	8.63g	19.1h
S 3613F-PN-1-1	17.6a	10.2def	21.2ef
C 22	11.0fg	11.1cd	20.6fg
B 8503E-TB-19-3-10	15.4bc	10.6def	24.0bc
Kalimutu	10.3g	12.1b	22.4de
Cirata	12.2ef	10.9de	21.9def
Limboto	11.1efg	13.6a	26.7a
Danau Tempe	12.1ef	11.9bc	21.9def
Way Rarem	12.7de	13.2a	22.1de
Bio 530A-5-14-2-8	14.7bc	9.93f	20.4gh
TB 47H-MR-10	11.0fg	12.0b	26.0a
Dodokan	15.7b	8.04g	19.9gh
Bio 528 B-TB-12-1-1	12.1ef	9.98ef	22.4de
$LSD_{0.05}$	1.60	0.91	1.42

The values followed by the same letter in the same column indicated not significant difference with LSD under 5% significant level

concomitant with Tivet *et al.* (2000) who reported that the capacity of tiller production in rice depended on genotype and the level of physiological stress as well. Moreover, Wu *et al.* (1998) also reported that Teqing cultivar produced more tiller resulted in accumulating more dry matter production than Gulfmont cultivar.

TB 165-TB-6 genotype had lower seed number/panicle than Limboto and Danau Tempe genotypes (Table 5). Yet, TB 165-TB-6 genotype was able to produce higher seed size, as 34.3 g. The high seed size of TB165-TB-6 genotype was not concomitant with high yield capacity. Such condition could also be observed in Kalimutu genotype which showed weigher seed size but produced much lower yield. Lower yield of TB 165-TB-6 genotype compared to B 8503E-TB-19-3-10 genotype was due probably to reduction harvested plant number of TB 165-TB-6 genotype in the harvested plot (1 m^2). Unfortunately, there was no such data attached in this report. Such condition could cause TB 165-TB-6 genotype produced lower yield although its genotype had high seed number.

As shown in Table 6, flag leaf area positively correlated with seed number and seed size, as $r = 0.40^{**}$ and $r = 0.31^{**}$, respectively. It means that the higher flag leaf area, the more seed number and the weigher seed size would be. As a matter of fact, flag leaf area would indirectly affect yield. This was supported by Erik *et al.* (2002) who reported that the activity of photosynthesis in flag leaf would decrease yet the rate of grain filling period increased. They also claimed that there was a reduction in protein and rubisco content of the leaves from flag leaves during grain filling period. As a result, direct effect could be seen from the positive correlation between seed number and yield, as $r = 0.27^{**}$. Consequently, it can be described that rice grain yield is the product of yield components, as the number of seeds per harvested area, and seed size, and flag leaf characters, as flag leaf length, flag leaf width, and flag leaf area. Interestingly, the content of leaf nutrients, particularly phosphor and magnesium relatively did not change between milky ripening stage (10 weeks after planting) and yellow ripening stage (13 weeks after

Table 5. The seed number per panicle, seed size, and yield of different upland rice genotypes

Upland rice genotypes	Seed number	Seed size	Yield
	-------- no. --------	----- g/1000-----	---- g/1m^2 ----
Jatiluhur	159.0b	21.7ef	782.7b-e
B2966-N7-MR-2-PN-4	118.1d	30.6a-d	877.3a-d
TB 177E-TB-30-B-2	86.4e	28.3a-e	644.3de
TB 165-TB-6	159.9b	34.3a	657.7cde
B 9048C-TB-4-B-2	136.1c	28.3a-e	827.8bcd
TB 154E-TB-1	86.1e	30.8a-d	520.8ef
S 3613F-PN-1-1	127.4cd	21.6ef	795.0b-e
C 22	128.1cd	24.5def	901.7abc
B 8503E-TB-19-3-10	136.5c	32.0abc	1086.7a
Kalimutu	120.4d	33.3ab	281.5f
Cirata	138.9c	20.0f	892.0a-d
Limboto	177.1a	27.4a-e	904.1abc
Danau Tempe	174.3a	21.7ef	854.5a-d
Way Rarem	158.1b	27.2b-e	700.4cde
Bio 530A-5-14-2-8	114.9d	25.6c-f	883.3a-d
TB 47H-MR-10	154.9b	30.0a-d	770.0cde
Dodokan	73.7e	25.7c-f	527.3ef
Bio 528 B-TB-12-1-1	117.6d	32.5abc	995.0ab
$LSD_{0.05}$	15.3	6.92	258.3

The values followed by the same letter in the same column indicated not significant difference with LSD under 5% significant level

planting) of grains. However, there was the decrease in the leaf nutrients of nitrogen and potassium from milky ripening stage to yellow ripening stage of grains. This probably means that there was such translocation for nutrients, particularly nitrogen and potassium from the leaves to reproductive parts, as grains at reproductive stage. It seems that both nitrogen and potassium have the pivotal role for photoassimilate translocation at reproductive stage. During grain filling period in wheat, nitrogen metabolism might play an important role for grain development (Xu & Yu 2006). Yet, such condition still needs to be clarified in detail observation thru further research. Furthermore, according to Longxing *et al.* (2002) stomatal resistance increased at milky ripening stage and then decreased at yellow ripening stage. It seems that there will be such reduction in the rate of photosynthesis activity at yellow ripening stage. In further reproductive stage, the senescence of flag leaf did not contribute to the provision of carbohydrate to the developing grain (Murchie *et al.* 1999).

CONCLUSION

It is the fact that there is varietal differences of flag leaf characters and yield components, particularly seed size. TB 165-TB-6 genotype showed high flag leaf length (39.2 cm), flag leaf area (53.1 cm^2), and seed size (34.3 g/1000 grain). Flag leaf area had a positive correlation with seed size, as r=0.31**. Moreover, Flag leaf length also significantly correlated with seed number and seed size, as r=0.30** and 0.22*, respectively.

The nutrient contents of nitrogen and

Table 6. The correlation values between flag leaf characters and yield components of different upland rice genotypes

	FLL	FLW	FLA	PN	LDW	SN	SS	Yield
FLL	-	0.43**	0.36**	- 0.07	0.08	0.30**	0.22*	- 0.10
FLW		-	0.27*	- 0.01	0.05	0.35**	0.10	0.03
FLA			-	- 0.11	0.19*	0.40**	0.31**	- 0.08
PN				-	0.32**	- 0.08	0.03	0.08
LDW					-	0.17*	0.09	0.13*
SN						-	- 0.12	0.27*
SS							-	0.02
Yield								-

FLL=Flag Leaf Length; FLW=Flag Leaf Width; FLA=Flag leaf area; PN=Plant Number; LDW=Leaf Dry Weight; SN=Seed Number; SS=Seed Size
*= significant difference at 5% level
**= significant difference at 1% level

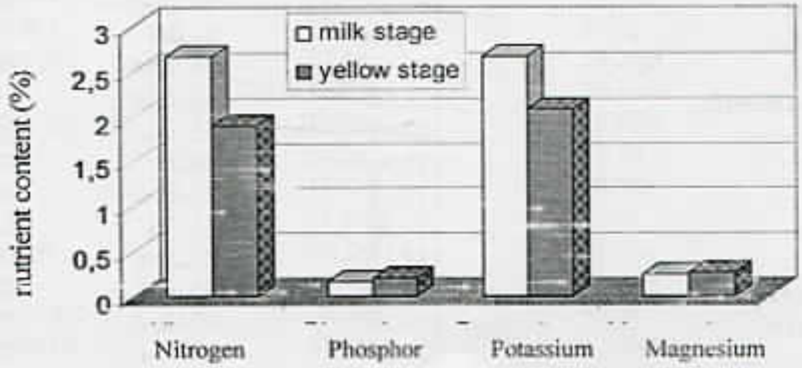

Fig 1. The condition of leaf nutrient contents, as nitrogen, phosphor, potassium, and magnesium of upland rice measured at milky ripening stage and yellow ripening stage of reproductive phases

potassium in leaves drastically decreased from milky ripening stage to yellow ripening stage. It seems that there is such transport mechanism of both nutrients from leaves to the reproductive parts, particularly grains.

In this study, flag leaf characters seem in-directly correlate with grain yield. For further information, it is better to analyze simple carbohydrate structures, as glucose, fructose, and sucrose to identify the source translocation from flag leaf to reproductive parts, especially grains. Additionally, the analysis of plant nutrients, particularly nitrogen and potassium in the leaves and grains at milky ripening stage and at yellow ripening stage would be a reliable idea to detect the translocation of these nutrients from leaves to grains.

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