Research article

Physiological Variables Associated with Yield of Improved Rice (*Oryza sativa* L.) Genotypes in Normal and Late Growing Seasons

ZUN PHOO WAI*
Yezin Agricultural University, Nay Pyi Taw, Myanmar
Email: zunphoowai.yezin@gmail.com

NYO MAR HTWE
Yezin Agricultural University, Nay Pyi Taw, Myanmar

SU LATT PHYU
Yezin Agricultural University, Nay Pyi Taw, Myanmar

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Abstract Genotypic selection for higher total dry weight has become a key method of research and experimentation to increase grain yield. Therefore, this experiment was carried out to determine the relationship of leaf area index (LAI) and yield and its components for ten genotypes of improved rice, for normal and late growing seasons. The experiments were conducted in the experimental fields of the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University. The study was undertaken from December 2016 to May 2017 for testing normal growing season plants and March 2018 to July 2018 for late growing season plants. A randomized complete block design with three replications was used. For the relationship among all the traits tested, positive associations were found ($R^2 > 0.5$) for LAI at harvest and yield ($R^2 = 0.574$), for panicle weight at harvest and yield ($R^2 = 0.558$), and for harvest index (HI) and yield ($R^2 = 0.61$). The study showed that yields increase along with an increase in LAI and panicle weight, for the improved rice genotypes that were tested. There was a positive and significant correlation found between LAI at heading stage and percent of filled grains in normal season, and LAI at heading and number of panicles per meter square in late season. In late season, the correlation between LAI at harvesting stage and yield was significant; HI was also significantly correlated with percent of filled grains and yield. As LAI and harvest index contribute to yield and yield component characters, breeders may successfully attempt to boost potential yields by increasing growth traits such as plant foliar surface and harvest index.

Keywords yield, LAI, correlation

INTRODUCTION

Rice is the most important food crop in the world and serves as a staple food for more than one third of the world's population (Singh and Singh, 2008). About 90% of the world' rice growing area is on the Asian continent (Salim et al., 2003). It is estimated, farmers in the world need to produce about 60% more rice than at present to meet the food demands of the world population expected by 2025 (Thakur et al., 2011).

In Myanmar, rice is a staple food and is cultivated in an area of 7.28 million hectares. Total production is 28.09 million metric tons, giving a yield of 3.92 ton/ha (Department of Planning, Ministry of Agriculture, Livestock and Irrigation, 2018). Rice makes up 33 % of total area cropped with 84% (6,474,970 ha) of rice grown during monsoon and 16% (1,214,056 ha) grown during summer (Sein, 2014). Okamoto (2004) affirms that rice production is very important for both the economic livelihood and food security for the population of Myanmar.

Increases in rice production have mainly relied on the expansion of the area of cultivable land used to grow rice, and increases in yield per unit area (Evans, 1993). Climate change and urbanization can result in decreases in rice cropping areas. Therefore, the increase of yield per unit area has become the focus to achieve increases in production. The grain yield of rice is a complex trait, controlled by many genes and highly affected by the environment (Jennings et al., 1979). Grain yield is also related to other characteristics, such as plant type, growth duration, and yield components (Yoshida, 1981). In comparing semi-dwarf and traditional rice cultivars, the increase in harvest index is the contributing factor improving yield potential, rather than any increase in production of biomass (Takeda et al., 1983; Evans et al., 1984). However, modern cereal breeding programs have provided evidence of the possibility of boosting grain yields by selecting genotypes exhibiting higher biomass production (Boukerrou and Rasmusson, 1990; Damisch and Wiberg, 1991). The efficiency with which dry matter is accumulated and allocated to harvestable organs, the grains in rice, determines the size of yield components and final yield (Fageria et al., 2006).

There are two rice growing seasons in Myanmar; summer and monsoon or dry and wet. The summer (dry) rice growing season is from December to May and the monsoon season (wet) from June to November. Sometimes summer rice growing is delayed because of labour scarcities, delays in obtaining irrigation water or due to a late harvesting time for the previous crop.

OBJECTIVE

The aim of this research is to determine the relationship of LAI and yield, and yield related traits of improved rice genotypes, under normal and late growing seasons.

MATERIALS AND METHOD

The experiment was carried out in the experimental fields of the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University from December 2016 to May 2017 for normal season rice and March 2018 to July 2018 for late growing rice. Experimental field is located at longitude 19º 10′ N and latitude 96º 07′ E with the elevation of 102 meters (m) above sea level. Ten improved rice genotypes which were preliminary selected based on agronomic traits and yield, were grown and yield estimated (Table 1) by using randomized complete block design with three replications. Each plot was (4m × 4m) with a spacing of 20cm × 20cm. Each genotype was planted with 20 rows, and 20 plants per row (total 400 plants per plot). Twenty-one-day-old seedlings were transplanted with one seedling per hill. Other agronomic practices were followed as required by using recommended cultural practices.

Table 1 List of tested improved rice genotypes in this study

No.	Improved Genotype
1	YAU- 1201-1-2-1
2	YAU-1201-202-1-2
3	YAU-1214-183-3-1-1-1-1
4	YAU-1214-183-35-1-1-1-1
5	YAU-1215-S-S-S-40-2-1
6	YAU-1215-S-S-S-41-1-1
7	YAU-1211-116-3-4
8	YAU-1211-71-1-1
9	YAU-1201-151-1-1
10	YAU-1201-151-1-3

In this study, LAI and dry weight were measured at heading stage and at harvesting stage. Heading stage was defined as the time when the main stem panicle had emerged and the harvesting stage was defined as the stage of the plants' physiological maturity. Two rows in border areas were left out of the sample collected to avoid the border effect. Three representative hills (hills with a mean value of tillers per hill) from each plot were sampled for the determination of dry weight. All plant samples were separated into green leaf blades (leaf), culm plus sheath (stem), and panicles. All samples were oven-dried at 80°C for 72 hours to obtain a constant weight. At the time of harvest, five representative hills were selected to measure yield and yield component traits. The weight of filled spikelets was adjusted for a moisture content of 14%. Leaf area index (LAI) was calculated as the ratio of the sum of the leaf area of all leaves to the ground area of the field where the leaves had been collected (Watson, 1947).

$$\text{LAI}= \frac{\text{Sum of the leaf area of all leaves}}{\text{Ground area of field where the leaves have been collected}}$$

$$\text{Yield per plant (g)}= \frac{\text{1000 grains weight}\times\text{Filled grain \%}\times\text{Spikelet number/panicle}\times\text{Panicle number}}{1000\times100}$$

The data were analyzed with Microsoft Excel (2007) and correlation analysis was also performed by using Statistical Tool for Agricultural Research (STAR) 2.0.1 (2014).

RESULTS AND DISCUSSION

Temperature regimes were different during vegetative, reproductive and ripening stages during two growing seasons (Table 2).

Table 2 Average of daily temperature and total rainfall during different growth stages of rice

Growth stage	Daily temperature (°C) during NS		Daily temperature (°C) during LS		Daily maximum temperature ≥35°C		Total rainfall(mm)	
	max	min	max	min	NS	LS	NS	LS
Vegetative	35.2	18.5	37.3	22.9	50	89	44	311
Reproductive	37.4	24.4	31.8	24.9	24	1	58	264
Ripening	38.4	26.2	31.5	24.7	28	0	93	272

Source: Weather Station of Department of Agricultural Research, Yezin. NS=Normal Season, LS=Late Season

Correlations between physiological variables and yield and yield components for improved rice genotypes in both NS and LS are showed in Table 3. In NS, there was no significant correlation between the variables except LAI at heading and percentage of filled grain. It could be suggested that percentage filled grain correlates with optimum LAI at heading. For LS crops, LAI at heading was positively and significantly correlated with the number of panicles per meter square. Also, filled grains percentage was positively and significantly correlated with harvest index (HI). LAI at harvesting stage, and harvest index (HI) were positively and significantly correlated with yield/m^2. A positive correlation between LAI and yield has been reported in the literature (Xie et al., 2011; Moraditochaee et al., 2014). An increase in harvest index results in an increase in grain yield that produces heavier grain in improved rice cultivars (Kiniry et al., 2001). Yield/m^2 is demonstrably affected by LAI and HI.

Regression analysis showed that yield/m^2 is associated with dry weight at heading stage in LS with an R^2 of 0.027 though this relationship is relatively weak in NS (R^2=0.038) (Fig. 1). The relationship between yield and dry weight at harvesting stage is associated in both NS and LS with R^2s of 0.154 and 0.054 respectively (Fig. 2) . Van der Werf (1996) stated that above-ground total dry matter (ATDM) accumulation (areal total dry weight) along with its partitioning to various parts of the plant determined crop productivity. Under favorable growing conditions, the increased yield of F1 hybrid rice was associated with increased total dry weight (Song et al., 1990; Yamauchi, 1994). Yield/m^2 was positively related with HI in both seasons and this was a strong relationship with an R^2 of 0.61 (Fig. 3). Increasing the harvest index and dry weight can achieve an increase in grain yield.

An association between yield/m^2 and panicle weight in both growing seasons (Fig. 4) was found and there was a moderate relationship with an R^2 of 0.558 in LS. Panicle weight is positively related to increased dry weight from heading to harvesting with an R^2 of 0.223 in NS and R^2 of 0.175 for LS (Fig. 5). Weng et al. (1982) reported a similar result. The result showed that yield can be increased with increased dry weight through the increase of panicle weight.

It was found that yield/m^2 was positively related with LAI at heading stage in both NS and LS (Fig. 6). This indicates that an increase in LAI at heading stage results in an increase in yield. In NS, yield had no relationship to LAI at harvesting stage but there was positive association of yield with LAI at harvesting stage with an R^2 of 0.574 (Fig. 7) for LS. Yield/m^2 was positively related with decreased LAI from heading to the harvesting stage with an R^2 of 0.141 in NS, but there was a negative association for LS (Fig. 8). Moradpour et al. (2013) stated that a strong relationship between yield and LAI was observed. An increase in LAI at harvesting stage contributes to an increased yield for the late season rice.

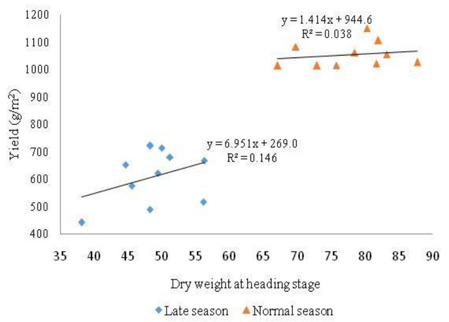

Fig. 1 Relationship between yield/m^2 and dry weight at heading stage in NS and LS

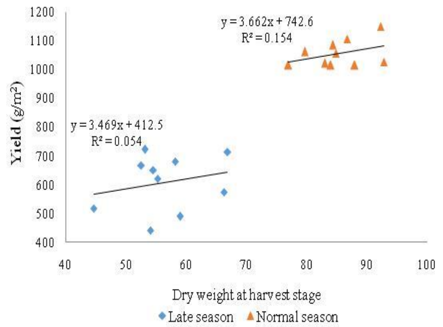

Fig. 2 Relationship between yield/m^2 and dry weight at harvesting stage in NS and LS

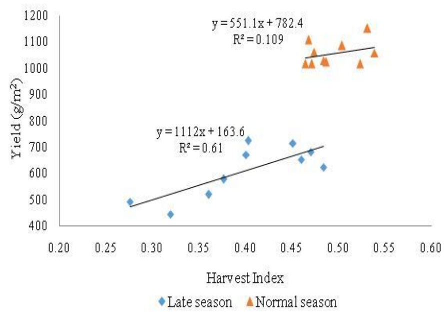

Fig. 3 Relationship between yield/m^2 and HI in NS and LS

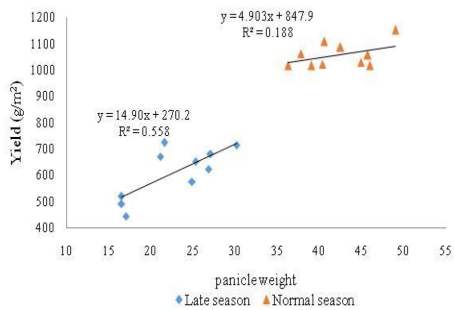

Fig. 4 Relationship between yield/m^2 and panicle dry weight in NS and LS

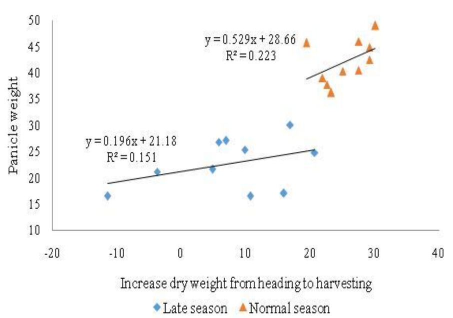

Fig. 5 Relationship between panicle weight and increased dry weight from heading to harvesting in NS and LS

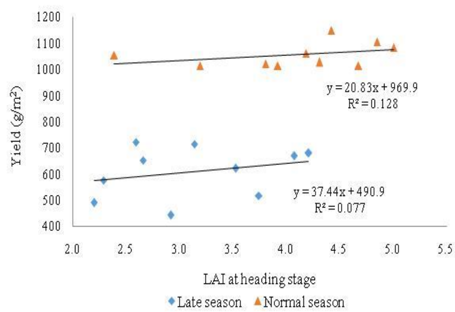

Fig. 6 Relationship between yield/m^2 and LAI at heading stage of in NS and LS

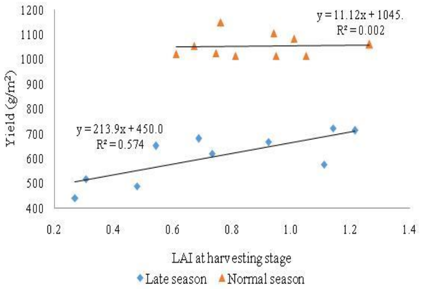

Fig. 7 Relationship between yield/m^2 and LAI at harvesting stage in NS and LS

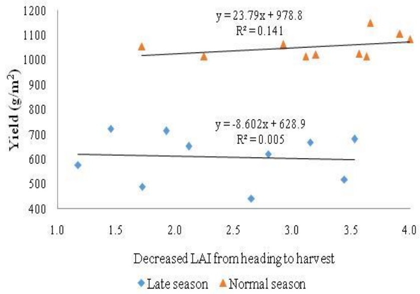

Fig. 8 Relationship between yield/m^2 and decreased LAI from heading to harvesting in NS and LS

Table 3 Correlation between physiological variables and yield and yield components of improves rice genotypes during two seasons

Yield and yield components	No. of panicles (/m^2)		No. of grains (/m^2)		Filled grains percent		Yield (g/m^2)	
	NS 2017	LS 2018	NS 2017	LS 2018	NS 2017	LS 2018	NS 2017	LS 2018
LAI at heading	0.3283	0.7166*	-0.4555	-0.1294	0.6856*	0.4794	0.3581	0.2769
LAI at harvesting	-0.1478	0.13	-0.5454	0.4476	0.5515	0.2231	0.0475	0.7574*
Decrease of LAI from heading to harvesting	0.3966	0.5672	-0.3475	-0.2992	0.596	0.3238	0.3763	-0.0752
Dry weight at heading (g/m^2)	-0.4797	0.5474	0.4413	0.1823	-0.1628	0.5917	0.1963	0.3822
Dry weight at harvesting (g/m^2)	-0.2881	-0.4026	0.1281	0.4363	-0.056	-0.2051	0.393	0.234
Increase of dry weight from heading to harvesting (g/m^2)	0.3093	-0.5767	-0.412	0.1955	0.1439	-0.467	0.1293	-0.0527
HI	-0.1639	0.5034	0.1662	0.2456	0.0683	0.7413*	0.3348	0.6840*

NS= Normal growing season, LS= Late growing season

CONCLUSION

In this study, correlation analysis showed that yield and yield components correlated with LAI, dry weight and HI, especially for late growing season crops. According to regression results, yield increasing was influenced by the increase of HI, LAI and panicle weight, especially in late season and panicle weight was contributed by dry weight. As yield and yield components are correlated with LAI, dry weight and HI, tall varieties of rice, susceptible to lodging rice should not be grown in the late season and breeders should attempt to increase growth traits such as plant foliar surface and HI in order to boost potential yields.

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