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Research Article
Dry Matter Production, Leaf Area Index, Yield and Yield Components of Myanmar Local Rice (*Oryza sativa* L.) Genotypes Observation

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Abstract

Background and Objective: Investigations on the differences in yield and its components, dry matter production among local rice genotypes were still limited in Myanmar. Forty-two Myanmar local rice genotypes were used as materials to study the dry matter production characteristics. **Materials and Methods:** A field experiment was conducted in a tropical environment at the Yezin Agricultural University from June-November, 2017. The data on yield and yield contributing traits and some physiological traits such as LAI, dry weight at heading and at harvesting, straw weight, panicle weight and panicle/straw weight were collected. The collected data were statistically analyzed using STAR software (version 2.0.1) for simple analysis of variance and correlation analysis. **Results:** The average yield among all tested genotypes ranged from 22-1168 g m^{-2} owing to larger variation in dry weight production at the heading and harvesting periods. In this study, Khao Pha Lin and Khao Hline were high yielding genotypes possessing their greater capacity to partition dry matter to grain. In contrast, although Kywe Chae Manaing produced high value of LAI and dry matter production, but the ability of distribution of dry matter assimilates is low resulting in low yield. **Conclusion:** The results indicated that the high yield of Myanmar local genotypes mostly comes from the assimilate production after heading, which is shown by increase of dry weight from heading to harvesting stages.

Key words: Myanmar local rice genotypes, dry weight, yield, heading, harvesting

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the cereals of major significance in the world and the main food resource, after wheat, for more than half of the world population[1] mainly in developing countries. There were many reports on the relationships between high yield and dry matter production which is accumulation and translocation. The grain yield, a result of dry matter production, is mainly determined by the amount of carbohydrates stored in plants before heading and those produced by photosynthesis after heading[2,3]. It was confirmed that dry matter production after heading and its synchronization with grain filling are the key approaches to increase rice yield[4].

The dry matter production process varies with the genotypes, environmental condition and cultivation practice. It was clarified by the amount of stored carbohydrates accumulated in the foliage and their translocation to the grains and accumulation of the amount of carbohydrate produced after heading in the rice grain and reaccumulation to the stem. Therefore, understanding the difference in dry matter production among rice genotypes is an essential step to investigate the relationship between dry matter production and high yield in different rice genotypes for the purpose of high yielding.

Leaf Area Index (LAI) is an important trait that is related to canopy photosynthetic rate and dry matter production during growing periods[5]. An evaluation of the dynamics of LAI may enable us to quantify the growth of rice plants and to explore the factors that limit the dry matter production in field. The LAI values of rice vary significantly due to differences between genotypes and it would be considerably related to the dry matter production.

High grain yields in cereals are the result of an increase in the availability of the assimilate supply (source) to achieve a grain setting and filling accompanied by an increase in the capacity of the sink[6]. The effects of stored carbohydrates (nonstructural carbohydrates) and dry matter produced after heading on grain filling was observed by Nagata *et al.*[7] and it was reported that between the two factors, the later had a stronger effect on percentage of ripened grains than the former. Haque *et al.*[8] investigated about comparative performance of hybrid and elite inbred rice varieties with respect to their source-sink relationship. In their study, the accumulation of more dry matter before heading and its higher translocation into the developing grain during filling stage resulted in higher yield of hybrids over the modern inbred. Higher dry matter accumulation before heading, longer leaf area duration, higher LAI and higher photosynthetic capability at the grain filling period are the essentials for achieving higher yield of rice[9,10].

Myanmar is listed in the centers of origin of cultivated rice[11] and there is a very broad diversity of rice cultivars is available in the country[12]. Therefore, this study investigated the dry matter production characteristics in forty-two Myanmar local rice genotypes.

MATERIALS AND METHODS

Study area: The experiment was carried out at the Department of Plant Breeding, Physiology and Ecology, Yezin Agricultural University, Myanmar which is located at 19°52'N and 96°07'E from January-June, 2017.

Research design: Forty-two Myanmar local rice genotypes (Table 1) were grown in Randomized Complete Block Design (RCBD) with three replications. The land was thoroughly with two strokes of ploughing, three strokes of harrowing with a tractor. The seeds were evenly broadcasted on the seed beds by direct seeding. Twenty-one days old seedlings were transplanted to the experimental field with the spacing of 20-20 cm keeping single seedling per hill. Water level was maintained around 1-2 inches initially and gradually increased to 2-4 inches (with increasing plant height) to help weed control and facilitate incorporation of nutrients in the soil. To minimize weed infestation, manual weeding through hand pulling and herbicides spraying was done.

Prior to paddling, compound fertilizer (N:P:K-15:15:15) at the rates of 125 kg per ha^{-1}, Urea (98 kg N ha^{-1}) were applied as equal split applications at early tillering stage, at panicle initiation stage and at booting stage. The experimental field was protected from insects by pesticides spraying and pests (birds and mouse) by staking the nets and tracking after transplanting.

The data on yield and yield contributing traits like number of panicles m^{-2}, number of grains/panicle, number of grains m^{-2}, percentage of filled grains , 1000-grain weight, yield and some physiological traits such as LAI at heading and at harvesting, dry weight at heading and at harvesting, straw weight, panicle weight and panicle/straw weight were collected.

Table 1: Name and sources of forty-two local rice genotypes used in this study

Number	Germplasm	Source	Number	Germplasm	Source
1	BaKauk	DaWai, YAU collection	22	LawThawGyi	DAR, Seed Bank
2	BayKyaung	DAR, Seed Bank	23	LetYoneGyi	DAR, Seed Bank
3	GaukRa	DAR, Seed Bank	24	LetYwesin	DAR, Seed Bank
4	KalarGyi	Mon, YAU collection	25	LopaZa	DAR, Seed Bank
5	KalarLay	DAR, Seed Bank	26	MaeKhalar-5	DAR, Seed Bank
6	KuTaungMyoTun	DAR, Seed Bank	27	MaungPhaLo	DAR, Seed Bank
7	KhaingShweWar	Myeik, YAU collection	28	MuyinSaba	DAR, Seed Bank
8	KhaoHline	DAR, Seed Bank	29	PaDinThuMa	DAR, Seed Bank
9	KhaoLai	DAR, Seed Bank	30	PhoKawGyi	DAR, Seed Bank
10	KhaoLamil	DAR, Seed Bank	31	PyawtTun	YAU collection
11	KhaoLan	DAR, Seed Bank	32	SeinGyi	DAR, Seed Bank
12	KhaoLin	DAR, Seed Bank	33	ShweHinThar	DAR, Seed Bank
13	KhaoLiPaw	DAR, Seed Bank	34	ShweYinAye	Shan, YAU collection
14	KhaoMaPhut	DAR, Seed Bank	35	TaTaungPo	DAR, Seed Bank
15	KhaoNyoHon	DAR, Seed Bank	36	TaungAtBeSaba	DAR, Seed Bank
16	KhaoPhaLin	DAR, Seed Bank	37	TaungHtakePan	Bago, YAU collection
17	KhaoPiPaung	DAR, Seed Bank	38	TaungYarSaba	DAR, Seed Bank
18	KhaoTan	DAR, Seed Bank	39	TinTayar	YAU collection
19	KhaowaA	DAR, Seed Bank	40	WetSiPhyu	DAR, Seed Bank
20	KunLone	DAR, Seed Bank	41	YarPyae	YAU collection
21	KyweChaeManaing	DAR, Seed Bank	42	YawShweWar	DaWai, YAU collection

DAR: Department of Agricultural Research

Statistical analysis: The collected data were statistically analyzed using STAR software (version 2.0.1) for simple analysis of variance and correlation analysis.

RESULTS AND DISCUSSION

Analysis of variance for yield and yield components: Genotypes of Myanmar local rice were the highly significant difference at 0.01 level with the mean square values of 36.129 for no. of panicles m^{-2}, 1222.443 for filled grain percentage, 2472.383 for no. of spikelet's/panicle, 43.433 for 1000-grain weight and 415.924 for yield, respectively (Table 2). It was suggested that there was enough genotypic variation among the genotypes and selection would be effective. Similar findings were also reported[13,14]. Among 42 genotypes, the maximum values were observed in Khao La mil for number of panicles m^{-2}, in ShweHin Thar for 1000-grain weight and in Khao Pha Lin for spikelet's/panicles, filled grain percentage and yield m^{-2}. There were many differences in yield and yield component trait among Myanmar local rice genotypes tested in this experiment.

Correlation of dry matter production traits with various traits during two growth durations

Yield, yield component traits and leaf area index: Correlation analysis is the association or relationship between two (or more) quantitative variables. It is, therefore, necessary to determine the direction of selection and the numbers of characteristics need to be considered in improving grain yield. In this study, the results showed that there was no significant correlation among growth durations and yield and yield components (Table 3). However, a negative correlation was observed between filled grain percentage and growth duration 1 (days from transplanting to heading) (-0.34*). For the correlation between dry matter production traits and growth durations, growth duration 1 showed significant relationship with dry weight at heading (0.57***), dry weight at harvesting (0.41**) and straw weight (0.36**) (Table 3). However, at growth duration 1 (days from transplanting to heading), there was significant difference at 5% level in filled grain percentage, at 1% level in dry weight at heading, straw weight and at 0.1% level in dry weight at harvesting. Early studies have also reported the importance dry matter production after heading, rather than reserve carbohydrates before heading[15]. This seems reasonable, because the fraction of carbohydrates from assimilates after heading is usually larger than that from reserves before heading. In this study, it was observed that variation among genotypes is mainly regulated by the filled grain percentage, dry weight at heading and harvesting and straw weight at growth duration 1 rather than at growth duration 2.

Figure 1 shows the relationships between LAI and yield, number of tillers, filled grain (%), grains/panicle and 1000-grains weight, respectively, at heading and at harvesting in 42 Myanmar local rice genotypes. LAI provides information on growth dynamics and is highly correlated with the crop

Table 2: Analysis of variance for yield and yield components of 42 Myanmar local rice genotypes

	Mean squares			
Source of variation	Replication	Genotypes	Error	CV (%)
Number of panicles/m^2	0.372	36.129**	1.901	10.55
Filled grain percentage	158.030	1222.443**	44.659	11.10
Number of spikelet/panicle	474.289	2472.382**	173.790	15.35
1000-grain weight	1.211	43.433**	0.452	2.74
Yield (g m^{-2})	20.047	415.924**	8.321	15.72

*,**Significant at 0.05 and 0.01 level, respectively, CV: Coefficient of variation

Table 3: Correlation between growth duration and yield or yield components or dry matter production traits of 42 Myanmar local rice genotypes

	Correlation coefficient			
Traits	Growth duration 1$^{(1)}$		Growth duration 2$^{(2)}$	
Yield and yield components				
Number of panicles m^{-2}	-0.12	NS	0.09	NS
No. of grains/panicle	0.05	NS	-0.08	NS
No. of grains m^{-2}	-0.07	NS	-0.04	NS
Filled grains (%)	-0.34	*	0.03	NS
1000-grain weight (g)	-0.09	NS	0.07	NS
Yield (g m^{-2})	-0.12	NS	0.07	NS
Dry matter production traits				
LAI at heading	0.14	NS	0.18	NS
LAI at harvesting	0.17	NS	0.03	NS
Decrease of LAI from heading to harvesting	-0.03	NS	0.12	NS
Dry weight at heading (g m^{-2})	0.57	***	0.04	NS
Dry weight at harvesting (g m^{-2})	0.41	**	0.01	NS
Increase of dry weight from heading to harvesting (g m^{-2})	-0.16	NS	-0.04	NS
Straw weight (g m^{-2})	0.36	**	0.05	NS
Panicle weight (g m^{-2})	-0.09	NS	-0.13	NS
Panicle/straw weight	-0.16	NS	-0.15	NS

1: Days from transplanting to heading, 2: Days from heading to harvesting. *,**,***Significant at 5, 1 and 0.1% level. NS: Not significant

biomass and productivity[16]. In this study, there was a negatively and highly significant relationship between LAI and number of spikelet's/panicle at harvesting (R^2 = 0.22***) and at the heading stage (R^2 = 0.07) (Fig. 1a) suggesting that increased LAI could reduce number of spikelets/panicle at harvesting stage rather than at heading stage. Number of panicles m^{-2} at harvesting stage was found to be negatively and highly significant relationship with LAI with R^2 value of 0.17*** although there was no relationship between LAI and number of panicles m^{-2} at heading stage (R^2 = 0.0014) (Fig. 1b). It could be observed that the character of number of panicles m^{-2} could be increased by reducing LAI values especially at harvesting stage. The LAI of rice increases as crop growth advances and reaches a maximum at about heading[2]. During the grain filling stage, the LAI would be decreased due to leaf senescence. Contribution of carbohydrates, which are stored in leaves of rice plants, moved to the spikelets and then the leaves gradually become senescent. Therefore, it could be pointed out that the lower the LAI values, the higher spikelets/panicle and number of panicles m^{-2} in the tested Myanmar local rice genotypes. No relationship was also observed between LAI and filled grain percentage at heading (R^2 = 0.02) but a highly significant negative relationship was observed between LAI and filled grain percentage at harvesting stage (R^2 = 0.47***) (Fig. 1c). It could be pointed out that LAI value has no effect on the filled grain percentage at heading stage while higher LAI could decline the filled grain percentage at harvesting stage. In the case of 1000-grain weight, positive relationships were investigated between LAI and 1000-grain weight at both stages with R^2 value of 0.05 at the harvesting stage and 0.02 at the heading stage (Fig. 1d) suggesting higher 1000-grain weight could be achieved by increasing LAI value. The LAI showed a negative relationship with the yield at harvesting stage (R^2 = 0.29) and no relationship with yield at heading stage (R^2 = 0.03) (Fig. 1e). It could be suggested that LAI value has a little effect on yield at harvesting stage and no effect on it at heading stage. It was also found to have a strongly negative relationship between LAI and sink size at harvesting (R^2 = 0.32***) and no relationship with sink size at heading stage (R^2 = 0.0063) (Fig. 1f). It was suggested that LAI dynamics showed a decrease at its final stage of growth, when spikelets began to grow, due mainly to leaf senescence and possible to the translocation of reserves to the growing panicle[17].

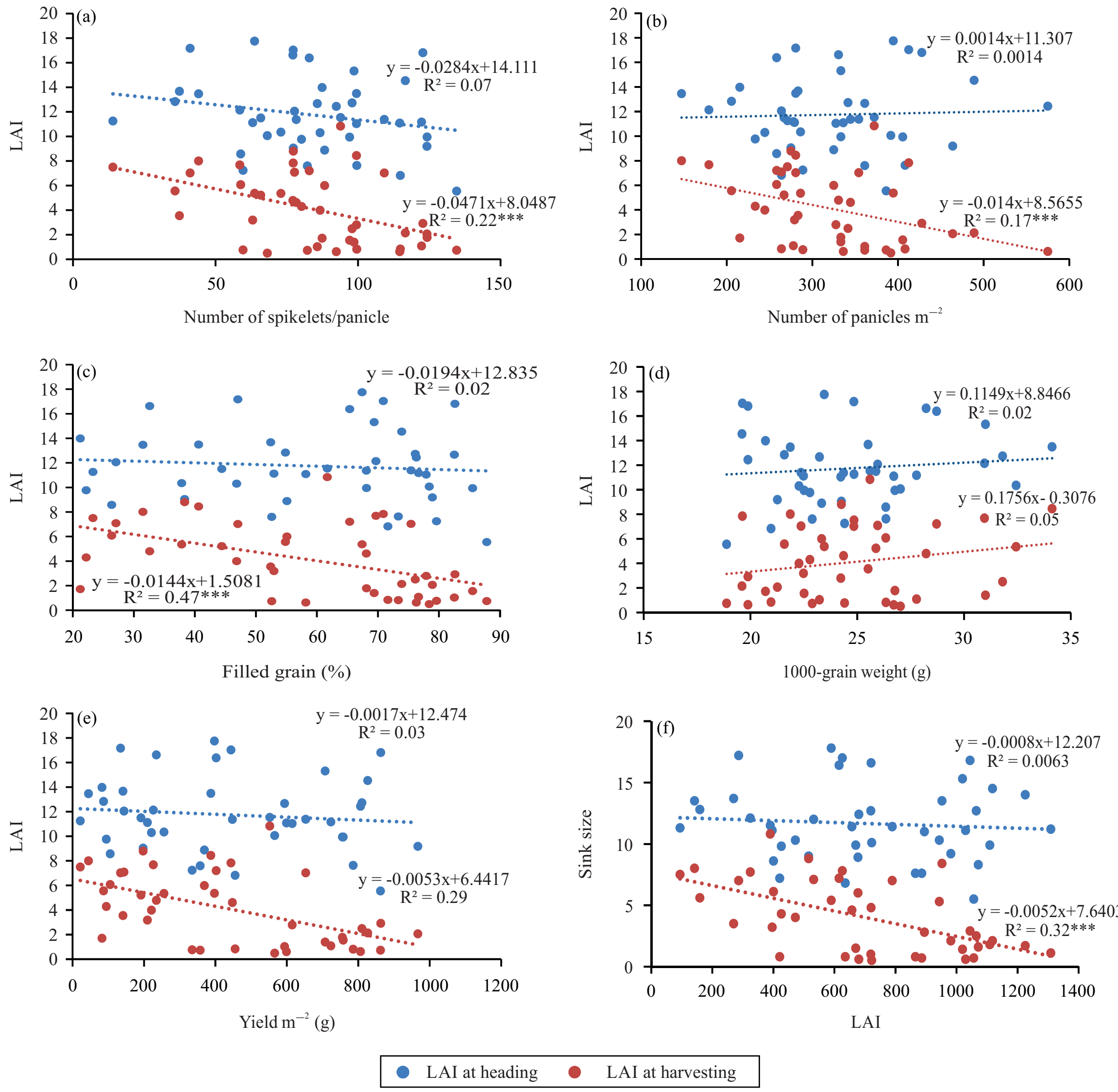

Fig. 1(a-f): (a) Relationships between LAI and number of spikelets/panicle, (b) Number of panicles m^{-2}, (c) Filled grain (%), (d) 1000-grain weight, (e) Yield and (f) Sink size at heading (days from transplanting to heading) and at harvesting (the days from heading to harvesting), respectively, in the 42 Myanmar local rice genotypes

The large amount of carbohydrate stored in the foliage were mainly translocated to the yield and its related traits during harvesting stage leading to decreasing in LAI value while increasing in the values of yield and its related traits except 1000-grain weight. Hence, the total amount of carbohydrate supply which were translocated was determined to be most important with respect to the number of spikelets/panicle, panicles m^{-2}, filled grain percentage, sink size and yield. The LAI values of rice, which have been reported in the literature using this technique, vary significantly due to differences between cultivars, the different soil and climatic conditions and the different practices in rice cultivation[18]. In this study, LAI values ranged from 5.5-17.8 at the heading stage and from 0.5-10.5 at the harvesting stage. Filled grain percentage ranged from 21-89% and spikelets/panicle from14-147 (Table 4). Among all genotypes, Khao Pha Lin produced the maximum values of spikelets/panicle (147), the highest yield (1168 g), filled grain percentage (89%), along with the LAI value of 8.3 at heading and 1.6 at harvesting. It was clear that in Khao Pha Lin and Khao Hline, the dry matter assimilates stored at the maximum LAI were mainly translocated to grain filling resulting to high yield.

Table 4: Average, maximum and minimum values for yield and yield components and dry matter production in 42 Myanmar local rice genotypes

Traits	Average	Maximum	Minimum
Yield and yield components			
Number of panicles (m^{-2})	327	575	147
Number of spikelets/panicle	86	135	14
Filled grains percentage	60	89	21
1000-grain weight (g)	25	34.1	18.9
Yield m^{-2} (g)	462	1168	22
Dry matter production			
LAI at heading	12	17.8	5.5
LAI at harvesting	4	12	0.6
Decrease of LAI from heading to harvesting (ΔT)	8	13.9	0.2
Dry weight at heading (g m^{-2})	81	130.9	26.9
Dry weight at harvesting (g m^{-2})	97	150	44.1
Increase of dry weight from heading to harvesting (g m^{-2}) (ΔW)	16	44.1	-12.3

Yield and yield components and dry weight: The dry matter accumulation is important for grain yield formation. The improvement in rice yield potential might come from increased the dry matter production[19]. In this study, dry weight was negatively and highly significant relationship with number of spikelets/panicle at both harvesting stage ($R^2 = 0.07$**) and heading stage ($R^2 = 0.16$***) (Fig. 2a). It could be observed that number of spikelets/panicle could be increased by lower dry weight. There was a strongly negative relationship between dry weight and number of panicles m^{-2} at both stages with R^2 values of 0.13*** at the heading stage and 0.20*** at the harvesting stage (Fig. 2b). It could be suggested that number of panicles m^{-2} could also be reduced by higher dry weight. The same result also found in Fig. 2c and dry weight was found to have a negatively and highly significant relationship with filled grain percentage with the R^2 value of 0.24*** at heading stage and 0.28*** at the harvesting stage. It could be investigated that decrease in dry weight could increase filled grain percentage. Therefore, decrease of dry weight has a positive effect on the spikelets/panicle, number of panicles m^{-2} and filled grain percentage. There was no significant correlation between dry weight and 1000-grain weight at both stages ($R^2 = 0.01$ at both stages) (Fig. 2d) suggesting that dry weight has no effect on 1000-grain weight in the Myanmar local rice genotypes. Strong and negative relationships were also observed between dry weight and yield at both stages ($R^2 = 0.12$** at the heading stage, ($R^2 = 0.19$*** at the harvesting stage) (Fig. 2e) and it could be suggested that yield could be achieved by reducing dry weight. A positive relationship was found between ΔW (increased total dry weight from flowering to harvesting) and ΔT (decreased dry weight of vegetative parts) and R^2 value was 0.0919 (Fig. 2f). The increase in dry matter of the panicle from full heading to maturity is derived mainly from two components: the dry matter accumulated before full heading that is then translocated to the panicle during ripening (ΔT) and the newly assimilated dry matter during ripening (ΔW)[20]. Hasegawa[21] observed that increase in dry matter accumulation and partitioning is important because it is significantly associated with grain yield. In the other hands, Laza *et al.*[22] observed a weak relationship between grain yield and biomass production. Yoshida[2] also reported that grain yield could be increased by increasing total dry matter accumulation and translocation. Similar finding was found in this study. In this study, there was a positively correlated between ΔT and ΔW (Fig. 2f). It was observed that increasing dry weight from flowering to harvesting is an important factor for increasing yield because decreasing dry weight as the result of translocation of assimilates from foliage to rice grain.

In addition, dry weight at harvesting stage was higher than that at heading stage in all the genotypes. It was concluded that to increase yield, it is more effective to increase the dry matter production after heading until harvesting than that before heading. Among all genotypes in this study, although Kywe Chae Manaing was found the highest dry weight of 130.9 g at heading and 150.0 g at harvesting but the yield m^{-2} was very low (44 g), ΔT value was 2.1. It can be suggested that the contribution of assimilates from foliage was failed in Kywe Chae Manaing and assimilates were stored or reaccumulated in the vegetative parts or leaves. In the other hands, Khao Pha Lin and Khao Hline were possessed higher dry weight of 89.2, 66.5 g at heading stage, 102.9, 87.0 g at harvesting stage, ΔT value of 12.9 and 3.3, respectively. It can be pointed out that dry matter assimilates were mainly contributed to grains rather than other parts of rice plant in Khao Pha Lin and Khao Hline. The translocation of dry matter assimilates production differed largely among genotypes.

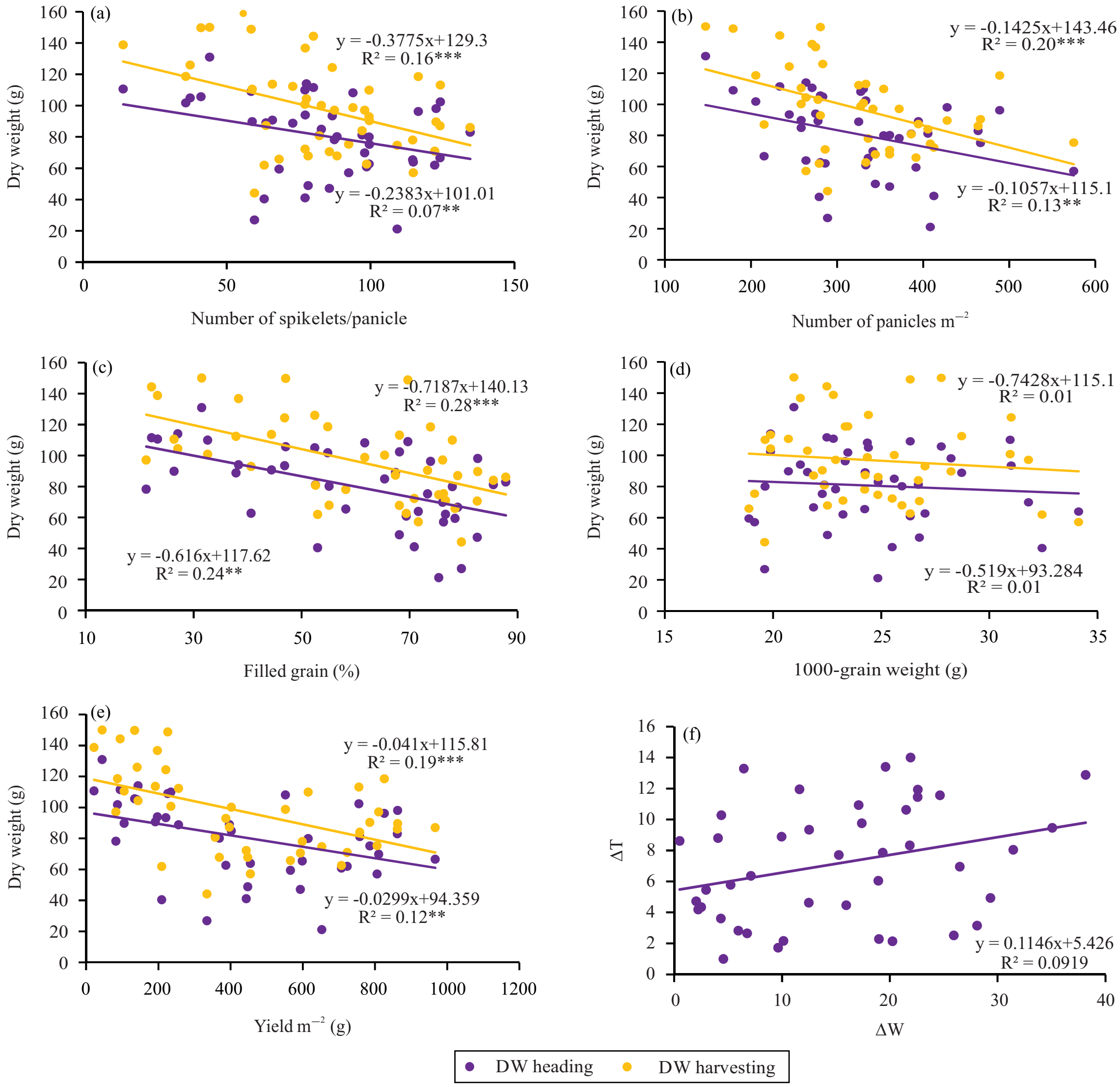

Fig. 2(a-f): (a) Relationships between dry weight number of spikelets/panicle, (b) Number of panicles/m2, (c) Filled grain (%), (d) 1000-grain weight, (e) Yield at heading (days from transplanting to heading) and at harvesting (the days from heading to harvesting) and (f) Relationship between ΔW and ΔT(F) in the 42 Myanmar local rice genotypes

ΔW: Increased total dry weight from flowering to harvesting, ΔT: Decreased dry weight of vegetative parts

CONCLUSION

It is concluded that some of the tested local rice genotypes accumulate higher amount of dry matter before heading and maintain large LAI at the grain filling period than others. The dry matter accumulated before full heading that is then translocated to the grain filling during ripening (ΔT) is the most important character to ensure the high yield. In this study, Khao Pha Lin and Khao Hline were high yielding genotypes among all due to their greater capacity to partition dry matter to grain. In contrast, although LAI and dry matter production are high in values, if the ability of distribution of dry matter assimilates is low, the yield would be low such as Kywe Chae Manaing. It can be concluded that further improvement in local rice yield potential in Myanmar (tropics) will depend mainly on the ability to increase dry weight production at heading and harvesting stages.

SIGNIFICANCE STATEMENT

This study discovered that high yield of local rice genotypes used comes from the assimilate manufacturing after heading, which's proven through the growth of dry weight from heading to harvesting stages. The information in this study could be beneficial for future breeding programs based on physiological findings. This study will help the researchers to uncover the critical areas for the dry matter production of Myanmar local rice genotypes that many researchers were able to explore.

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