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GRAIN-FILLING PATTERN OF SUPER HYBRID RICE LIANGYOUPEIJIU UNDER DIRECT SEEDING AND TRANSPLANTING CONDITION

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Abstract

To evaluate the grain-filling pattern, Chinese first super hybrid rice, Liangyoupeijiu was grown under tillage and establishment methods at a spacing of 20 cm × 20 cm with one seedling hill^{-1} and at a seeding rate of 22.5 kg ha^{-1} in Changsha, Hunan Province, China in 2012. Our results showed that, superior grain weight in TP had always higher than DS up to 24 DAH but at 36 DAH, grain weight had similar in both TP and DS. Middle grain weight was higher in TP than DS up to 18DAH but it was higher in DS than TP at 24 – 36 DAH and at 36 DAH, grain weight of DS had significantly higher than TP. Inferior grain weight was higher in TP than DS up to 12 DAH but it was higher in DS than TP at 24 -36 DAH and at 36 DAH, grain weight of DS had significantly higher than TP. Grain-filling rate of superior grain had higher in TP than DS up to 18 DAH but it was higher in DS than TP at 30 DAH. In middle grain, it was higher in TP at 6DAH but in DS, it was higher at 30 DAH. In inferior grain, it was higher in TP at 36 DAH but in DS, it was higher at 30 DAH. The heavier grain was found in TP only in superior grain but DS had heavier grain both in middle and inferior grain. Grain-filling rate of superior grain was higher in TP than DS and it was similar in both TP and DS in middle grain. But in inferior grain, it was significantly higher in DS than TP. Transplanting method produced slightly higher grain yield due to higher sink size (more number of spikelet's caused by longer panicle and more number of spikelet per cm of panicle) but it was statistically similar with DS.

Keywords: Direct Seeding, Grain-filling Pattern, Super Hybrid Rice, Transplanting, Tillage

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Introduction

The degree and rate of grain-filling in rice spikelet's differ largely with their positions on a panicle. In general, earlier flowering superior spikelet's has usually located on apical primary branches, fill fast and produce larger and heavier grains. While later-flowering inferior spikelet's, usually located on proximal secondary branches, are either sterile or fill slowly and poorly to produce grains unsuitable for human consumption (Mohapatra *et al*., 1993; Yang *et al*., 2000; Yang *et al*., 2006). The slow grain-filling problem in inferior spikelet's is more aggravated in the newly bred 'super' rice cultivars, although they generally show a yield potential of 8–20% more than other conventional rice cultivars (Cheng *et al*., 2007; Zhang, 2007; Nakamura *et al*., 1989). Grain-filling is actually a process of starch accumulation and it has been reported that there are 33 major enzymes involved in the metabolism of carbohydrates in developing rice endosperm (Nakamura *et al*., 1989). Grain weight is determined by grain size and degree of grain-filling. The grain size is a stable cultivar characteristic determined before anthesis and it is rigidly controlled by size of the hull (Samonte *et al*., 1998). Although both grain-filling rate and duration are associated with the degree of grain-filling, some studies reported that variation in grain-filling duration was responsible for the difference in grain weight between hybrid and inbred rice (Cheng *et al*., 2007; Wang *et al*., 2004). However, there has been contradictory statement that poor grain-filling of super hybrid rice was attributed not to source limitation but to poor partitioning of assimilates to grains (i.e. low harvest index) (Yang *et al*., 2002). Rice yield depends upon not only the genetic characteristics but also the agronomic practices (Zou *et al.,* 2003). Sink size (spikelet number per unit land area), spikelet filling percentage and grain weight are the determinants of rice yield. Sink size is considered as the primary determinant of the rice yield (Kropff *et al.,* 1994). Sink size can be increased by increasing panicle number per unit land area or spikelet number per panicle or both (Ying *et al.,* 1998). There is limited information currently available on grain-filling pattern of Liangyoupeijiu but no information is available about the effect of transplanting and direct seeding on grain-filling pattern. Therefore, the objective of this study was to evaluate grain-filling pattern of super hybrid rice, Liangyoupeijiu under transplanting and direct seeding condition.

Materials and Methods

Experiment location and soil

A field experiment was conducted under moist sub-tropical monsoon climate during 2012 (May to September). Mean annual air temperature was about 17.0°C, rainfall was about 1355 mm and sunshine hour was about 1677. The soil properties of the experimental field were presented in Table 1.

Table 1. The soil properties of the experimental field, Changsha, Hunan, China

Treatments	Bulk density (g cm^{-3})	pH	Active organic carbon (mg g^{-1})	NaOH hydrolysable N (mg kg^{-1})	Double acid P (mg kg^{-1})	NH_4OAc extractable K (mg kg^{-1})
0-5 cm soil depth						
CTTP	1.06	5.94	3.01	198	27.7	44.5
NTTP	1.07	5.83	3.45	197	27.1	46.1
NTDS	1.01	5.91	4.42	239	28.7	52.8
CTDS	1.04	5.81	4.02	227	29.1	52.0
5-10 cm soil depth						
CTTP	1.08	6.01	2.62	160	30.8	33.7
NTTP	1.26	5.91	2.90	160	28.3	33.3
NTDS	1.27	6.18	2.07	136	31.6	29.7
CTDS	1.06	5.99	2.11	133	33.0	30.9

Experiment design and fertilizer management

The field experiment was conducted in a factorial randomized complete block design with four replications. The unit plot size was 30 m^2. Factor A was tillage system, viz. conventional tillage (CT) and no tillage (NT), factor B was crop establishment method, viz. transplanting (TP) and direct seeding (DS). The treatment combinations were: conventional tillage and transplanting (CTTP), no-tillage and transplanting (NTTP), conventional tillage and direct seeding (CTDS), and no tillage and direct seeding (NTDS). For CT, land was prepared by animal-drawn plough followed by harrowing, and for the plots of NT, by using non-selective herbicide and soaking. For TP, twenty five-days-old seedlings were manually transplanted at a spacing of 20 cm x 20 cm with one seedling per hill on 8th June. For DS, pre-germinated seeds were manually broadcasted on the soil surface at a seed rate of 22.5 kg ha^{-1} on 24th May. Fertilizer (ha^{-1}) was used as 150 kg N, 90 kg P_2O_5 and 180 kg K_2O. Fertilizer N was split as 90, 45 and 15 kg ha^{-1} at basal, mid-tillering and panicle initiation, respectively. Fertilizer P_2O_5 was applied at basal. K_2O was split equally at basal and panicle initiation (PI). Weeds, insects and diseases were controlled by recommended methods.

Sampling and method

Ten (10) representative panicles were sampled for each replication starting from 6-day after heading (DAH) to 36 DAH. Grains on upper (superior), middle and basal (inferior) branches (Fig. 1) of each panicle were separated and oven-dried at 70°C to constant weight to determine grain weight. At MA, 5 m^2 areas were harvested for grain yield and it was adjusted at 14% moisture level.

Heading was determined at when around 80% of the stem had more than 50% of panicle was exerted.

Data analysis

Statistical analyses were performed using Statistic 8, Analytical software, Tallahassee, FL, USA. Means of cultivation methods were compared according to the least significant difference test (LSD) at the 0.05 probability level. Figures were performed using MS Excel 2003.

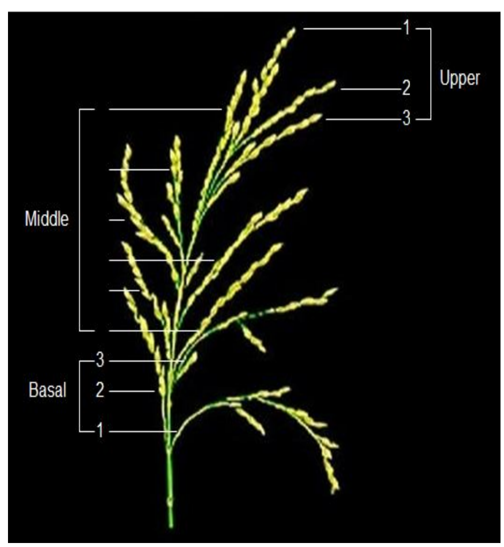

Fig. 1. Upper, middle and basal branches in a rice panicle

Results and Discussion

Weather condition

Weather (flowering to maturity) data during 2012 was presented in Fig. 1. Average highest temperature decreased sharply at 6 DAH and then increased up to 18 DAH then again sharply decreased at 24 DAH and then decreased up to 36 DAH. Average lowest temperature sharply decreased at 6 DAH, then increased up to 18 DAH and then decreased up to 36 DAH. There was a continuous fluctuating tendency in sunshine hour during whole sampling period and at 36 DAH there was no sun hour. Average rainfall had very small up to 24 DAH and then drastically increased at 30 DAH and then no rainfall at 36 DAH (Fig. 2).

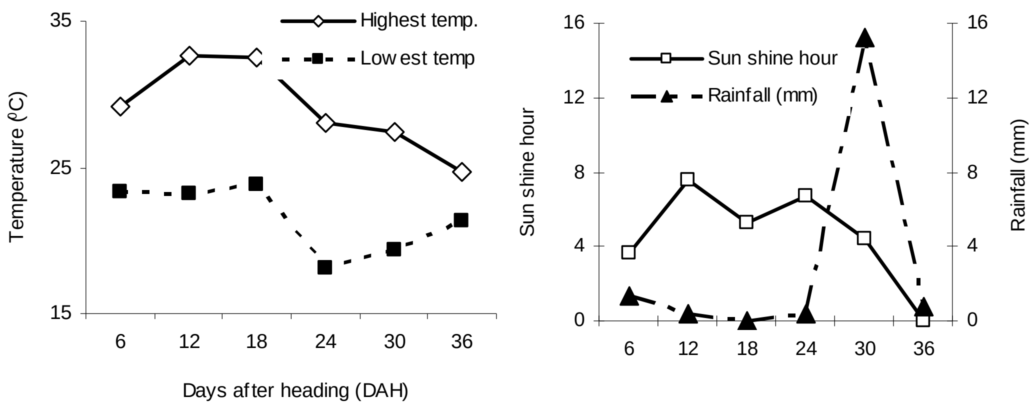

Fig. 2. Temperature, Sunshine hour and Rainfall at different days after heading (DAH)

Grain-filling pattern

Pattern of grain weight (mg): Superior grain weight in TP had always higher than DS up to 24 DAH and DS had higher grain weight at 30 DAH. At 36 DAH, both in TP and DS had similar weight of grain. In TP, grain weight gradually increased up to 30 DAH and then sharply increased at 30 – 36 DAH but in DS, it increased gradually up to 24 DAH and sharply increased at 24-30 DAH. Grain weight of superior grain was higher in TP than DS up to 24 DAH due to higher source capacity (more functional leaf/stem) but it was higher in DS than TP at 30 DAH due to higher source- sink ratio in DS. Grain weight is determined not only by the grain capacity to receive assimilates, but also by the source capacity (photosynthetic leaves) to supply assimilates (Ntanos and Koutroubas, 2002) and by the partitioning of assimilates to grains (Yang *et al*., 2002).

Middle grain weight was higher in TP than DS up to 18 DAH but it was higher in DS than TP at 24 – 36 DAH. Grain weight of TP gradually increased up to 24 DAH and then slightly decreased at 30 and 36 DAH but DS increased gradually up to 30DAH and then slightly decreased at 36 DAH. At 36 DAH, grain weight of DS had significantly higher than TP.

Inferior grain weight was higher in TP than DS up to 12 DAH but it was higher in DS than TP at 24 - 36 DAH. Grain weight of TP gradually increased up to 24 DAH and then slightly decreased at 30 DAH and then sharply increased at 36 DAH but grain weight in DS, increased gradually up to 30 DAH and then slightly decreased at 36 DAH. At 36 DAH, grain weight of DS had significantly higher than TP. Mohapatra *et al*. (1993) reported that inferior spikelet's accumulated higher concentrations of soluble assimilates than superior spikelet's during the grain-filling period. These results suggest that assimilate supply is not the main factor that leads to poor grain-filling and that there are other, unknown, factors resulting in slow or aborted grain-filling in inferior spikelet's. Inferior grain weight increased slowly at early grain-filling stage but grain-filling increased sharply at later grain-filling period and was closed to superior grain in DS. The slow grain-filling rate and low grain weight of inferior spikelet's have often been attributed to a limitation in carbohydrate supply (Sikder and Das Gupta, 1976).

Grain weight of superior grain was higher than middle and inferior grain and it was 27.7 mg in TP and 27.5 mg in DS. For middle grain weight, it was 20.1 mg in TP and 22.3 mg in DS. However, in inferior grain, it was 24.3 mg in TP and 27.6 mg in DS (Fig 3).

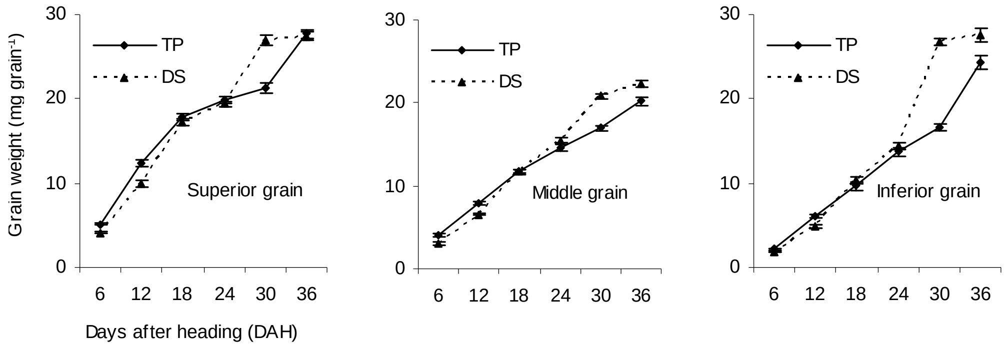

Fig. 3. Grain weight of Liangyoupeijiu (superior, middle and inferior grains) at different DAH

Grain-filling rate (mg grain^{-1} day^{-1})

Grain-filling rate of superior grain had higher in TP than DS up to 18 DAH but it was higher in DS than TP at 30 DAH. Grain-filling rate of TP increased up to 12 DAH, then decreased up to 30 DAH and again slightly increased at 36 DAH. In DS, grain-filling rate increased up to 18 DAH, then decreased at 24 DAH and again slightly increased at 30 DAH.

In middle grain, it was higher in TP at 6 DAH but in DS, it was higher at 30 DAH. In TP, grain-filling rate was higher at 6 DAH and then gradually decreased up to 36 DAH. However, in DS, it increased up to 30 DAH and then decreased at 36 DAH.

In inferior grain, it was higher in TP at 36 DAH but in DS, it was higher at 30 DAH. In TP, grain-filling rate increased up to 24 DAH, then decreased at 30 DAH and again increased at 36 DAH. However, in DS, it increased up to 30 DAH and then decreased at 36 DAH.

In superior grain, grain-filling rate in TP had 1.03 mg grain^{-1} day^{-1} and in DS, it was 0.96 mg grain^{-1} day^{-1}. In middle grain, it was 0.68 mg grain^{-1} day^{-1} in TP and 0.70 mg grain^{-1} day^{-1} in DS. However, in inferior grain, it was 0.68 mg grain^{-1} day^{-1} in TP and 0.90 mg grain^{-1} day^{-1} in DS (Fig. 4).

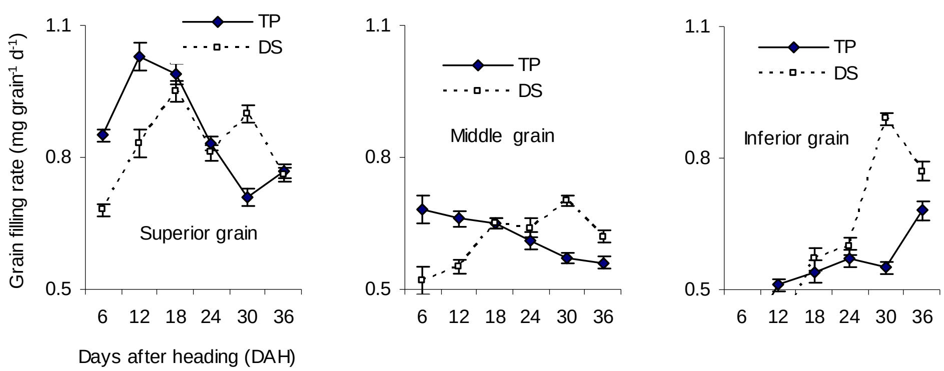

Fig. 4. Grain-filling rate of Liangyoupeijiu (superior, middle and inferior grains) at different DAH

Relationship between yield and yield components

TP had significantly higher number of spikelet's (per m^2) than DS. There was no significant difference in spikelet filling rate between TP and DS. TP produced significantly longer panicle than DS also higher number of spikelet per cm of panicle was observed in TP than DS. Although, average grain weight (weight of superior, middle and inferior grain) had higher in DS but TP produced slightly higher grain yield due to higher sink size (more number of spikelet's caused by longer panicle and more number of spikelet per cm of panicle) but it was statistically similar with DS. Sink size (spikelet number per unit land area), spikelet filling percentage and grain weight are the determinants of rice yield. However, sink size is considered as the primary determinant of the rice yield (Kropff *et al.,* 1994) (Table 2).

Table. 2 Yield and yield components of super hybrid rice Liangyoupeijiu during 2012

Treatments	Total spikelet (m^{-2})	Spikelet filling rate (%)	Panicle length (cm)	spikelet per cm of panicle	Grain yield (t/ha)
TP	48869 a	72.5	24.9 a	9 a	9.7
DS	42713 b	74.3	22.1 b	6 b	9.4
Analysis of variance					
Establishment method (A)	*	NS	*	*	NS
Tillage (B)	NS	NS	NS	NS	NS
A X B	*	NS	*	*	*
CV (%)	4.28	3.79	1.9	8.6	4.49
SE	1387.3	1.96	0.32	0.44	0.30

Conclusion

The heavier grain was found in TP only in superior grain but DS had heavier grain both in middle and inferior grain. Grain-filling rate of superior grain was higher in TP than DS and it was similar in both TP and DS in middle grain. However, in inferior grain, it was significantly higher in DS than TP. Transplanting method produced slightly higher grain yield due to higher sink size (more number of spikelet is caused by longer panicle and more number of spikelet per cm of panicle) but it was statistically similar with DS.

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