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Influence of Cultivation Techniques on Dry Matter Partitioning, Nitrogen Distribution Pattern and Yield of Super Hybrid Rice Liangyoupeijiu

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ABSTRACT

Liangyoupeijiu was grown under different crop cultivation techniques viz conventional tillage and transplanting (CTTP), no tillage and transplanting (NTTP), conventional tillage and direct seeding (CTDS) and no- tillage and direct seeding (NTDS) during 2011 and 2012. Results showed that, CTTP had higher leaf dry weight than NTTP. Maximum leaf dry weight reduced in direct seeded than transplanted rice. Shoot dry weight reduced by 6% both in transplanted and direct seeded rice from heading to 12 days after heading (DAH) in both the years. No tillage and transplanting had higher export percentage of dry matter and transport percentage of dry matter among the cultivation techniques in both the years. At heading, leaf nitrogen concentration (%) and nitrogen uptake (g m^{-2}) were higher in transplanted than direct seeded rice and significantly higher nitrogen uptake was observed under conventional tillage and transplanting in both the years. The physiological nitrogen use efficiency was higher in no-tillage than conventional tillage in both the years. Total nitrogen (kg ha^{-1}) uptake was higher in conventional tillage than no tillage either in transplanted or in direct seeded rice and was higher under conventional tillage and transplanting among the cultivation techniques in both the years. Grain yield was closely associated with uptake of total nitrogen at heading. Although, direct seeded rice had more than 23% higher panicle number than transplanted rice, conventional tillage and transplanting produced higher grain yield due to higher uptake of nitrogen by grain at maturity and bigger sink size.

Key words: Crop establishment method, dry matter partitioning, N distribution pattern, super hybrid rice

INTRODUCTION

The productivity of cereal depends on the accumulation of dry matter and effective partitioning. Dry matter translocation to grain is critical for satisfactory grain yield when plants experience with nitrogen deficiency during grain filling period (Ladha *et al.*, 1998). Accumulation and translocation of pre-anthesis assimilates to grain is more important in direct seeding rice because of high plant density (Farooq *et al.*, 2011). Rice yield is the function of biomass production before heading and translocation to grains after heading (Yang *et al.*, 2008). Sink size, spikelet filling percentage and grain weight are the determining factors for rice yield and sink size is the primary determinant (Kropff *et al.*, 1994). Sink size could be improved by increasing higher number of panicle or more spikelet per panicle or both (Ying *et al.*, 1998). A higher yield is generally achieved either by increasing panicles per unit land area (Lin *et al.*, 2002; Wu *et al.*, 2007) or more number of panicle (Chen *et al.*, 2008; Lu *et al.*, 2008). Sink size could be increased by enhancing sink formation efficiency per unit biomass at flowering (Yang *et al.*, 2008). So, this study was

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undertaken to evaluate the effect of cultivation techniques on dry matter partitioning and nitrogen distribution pattern in relation to grain yield of Liangyoupeijiu.

MATERIALS AND METHODS

The experiment was conducted in the research farm of Hunan Agricultural University, Hunan, China during 2011-2012 (May to September).

MEASUREMENT AND METHODS

Nitrogen concentration (%) It was measured by micro-Kjeldahl digestion, distillation, and titration (Bremneret al., 1982).

Nitrogen translocation ratio (NTR) Nitrogen translocation ratio was calculated following Ying et al., (1998).
NTR = (Nvo – Nstraw)/Nvo
Where, Nvo= N uptake by vegetative organ (leaf and shoot) at heading
Nstraw = N uptake by straw at maturity.

Export percentage of dry matter (EPMCS) was calculated as EPMCS (%) = (dry weight of leaf and shoot at heading - dry weight of straw at maturity) / dry weight of leaf and shoot at heading×100

Transformation percentage of dry matter (TPMCS) was calculated as TPMCS (%) = (dry weight of leaf and shoot at heading - dry weight of straw at maturity)/dry weight of panicle at maturity × 100

RESULTS

Dry matter partitioning

Leaf dry weight There was significant difference in leaf dry weight among the treatments at all growth stages of crop in both years. Leaf dry weight gradually increased up to booting stage and then decreased with advancement of time. Direct seeding had higher leaf dry weight than transplanting at panicle initiation, booting and heading stage during 2011 but was higher with transplanting than direct seeding in 2012. At booting stage, conventional tillage and transplanting produced higher leaf dry weight than no tillage and transplanting in both the years. Similarly, no tillage and direct seeding had higher leaf dry weight than conventional tillage and direct seeding in 2011 but CTDS and NTDS had statistically similar in 2012 (Fig. 1).

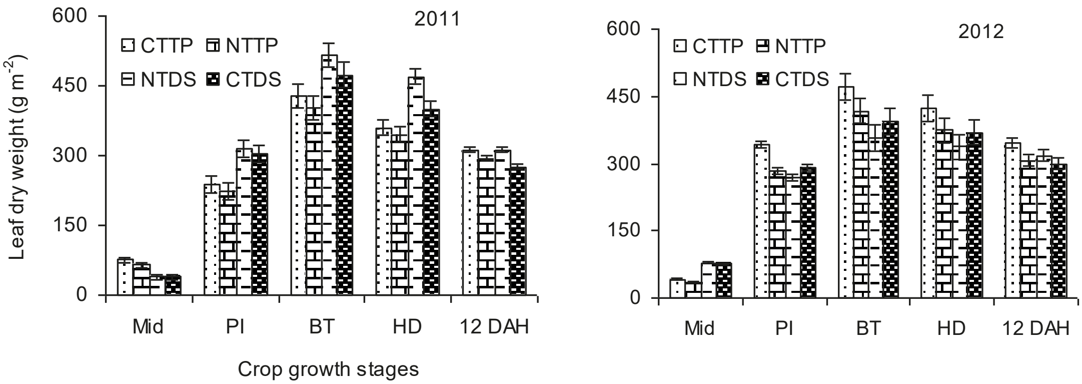

Fig. 1. Leaf dry weight of Liangyoupeijiu at different growth stages. Bar represents Standard Error (SE).

Shoot dry weight Shoot dry weight varied significantly at all sampling dates in both the years except 12DAH in 2012. Shoot dry weight increased up to heading stage and slightly decreased at 12DAH. Direct seeding had higher shoot dry weight than transplanting at all growth stages except at mid tillering stage in 2011 but was higher in transplanting than direct seeding during 2012. At heading stage, significantly higher shoot dry weight was observed in CTDS among the cultivation techniques in 2011 but NTTP produced higher shoot dry weight in 2012. Conventional tillage and transplanting produced higher shoot dry weight than NTTP almost all sampling dates in both the years. Conventional tillage and direct seeding produced higher shoot dry weight than NTDS at heading and 12DAH stage during 2011 but was higher at panicle initiation and booting stage during 2012 (Fig. 2).

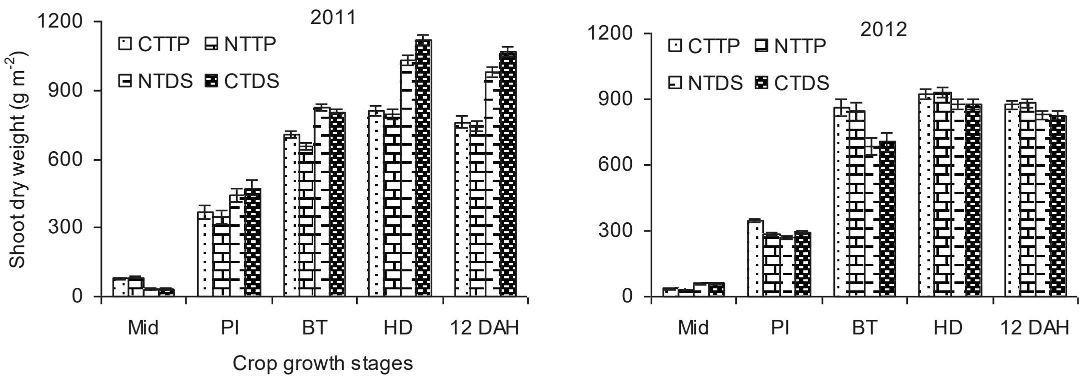

Fig. 2. Shoot dry weight of Liangyoupeijiu at different growth stage. Bar represents SE.

Dry weight of panicle It increased with advancement of time and varied significantly among the cultivation techniques at all growth stages of crop except booting in 2011 and at 12DAH in 2012. At heading, it was significantly higher in direct seeding than transplanting in 2011 but transplanting had higher panicle dry weight than direct seeding in 2012. At 12DAH, statistically similar panicle dry matter was observed in conventional tillage and transplanting, no tillage and direct seeding, conventional tillage and direct seeding during 2011 but was significant difference in 2012 (Fig. 3).

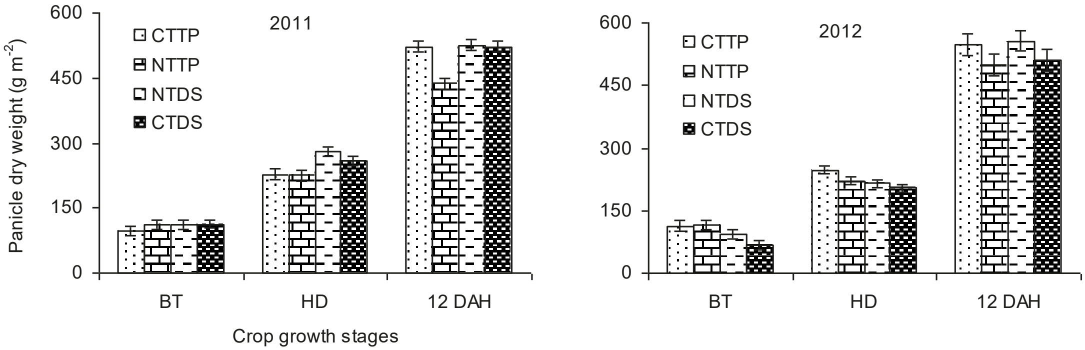

Fig. 3. Panicle dry weight of Liangyoupeijiu at different growth stage. Bar represents SE.

Export percentage of dry matter (EPMCS) and transport percentage of dry matter (TPMCS)
Export percentage of dry matter varied significantly among the cultivation techniques in both the years but not in transport percentage of dry matter. The EPMCS and TPMCS were higher in transplanting than direct seeding in both the years. Export percentage of dry matter was higher in no tillage system either in transplanting or direct seeding in both the years but transport percentage of dry matter was higher in conventional tillage than no tillage. No tillage and transplanting had higher EPMCS and TPMCS among the cultivation techniques in both the years (Fig. 4).

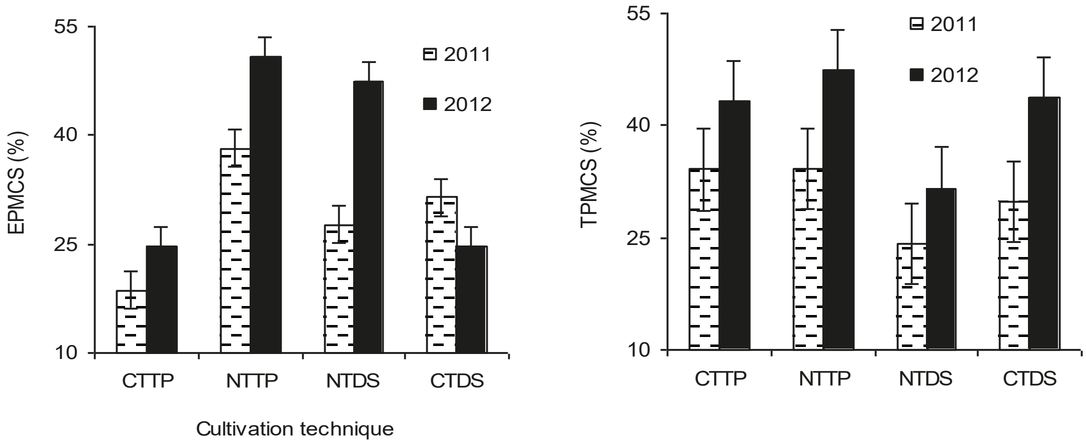

Fig. 4. Influence of cultivation techniques on export percentage of dry matter (EPMCS) and transport percentage of dry matter (TPMCS). Bar represents SE.

Nitrogen distribution pattern at heading
leaf Nitrogen concentration (%) and uptake (g m^{-2}) varied significantly in both the years. Conventional tillage either in transplanting or direct seeding had significantly higher nitrogen concentration than no tillage in 2011 but CTTP, NTTP and NTDS had higher nitrogen concentration during 2012. Nitrogen uptake was higher in transplanting than direct seeding and significantly higher N uptake was observed in CTTP in both the years (fig. 5).

Shoot Nitrogen concentration (%) and uptake (g m^{-2}) varied significantly among the cultivation techniques and CTTP, NTTP and CTDS had statistically similar nitrogen concentration and NTDS had the lowest nitrogen (%) during 2011. Conventional tillage and direct seeding had higher nitrogen (%) in 2012. Nitrogen uptake was higher in 2012 than 2011 and significantly higher N uptake was observed under CTDS in both the years (Fig. 5).

Panicle Grain nitrogen concentration (%) was higher in direct seeding method compare to transplanting. Nitrogen uptake varied significantly in the year 2011. Nitrogen uptake was significantly higher in CTDS in both the years and difference between direct seeding and transplanting during 2012 was lower (Fig. 5).

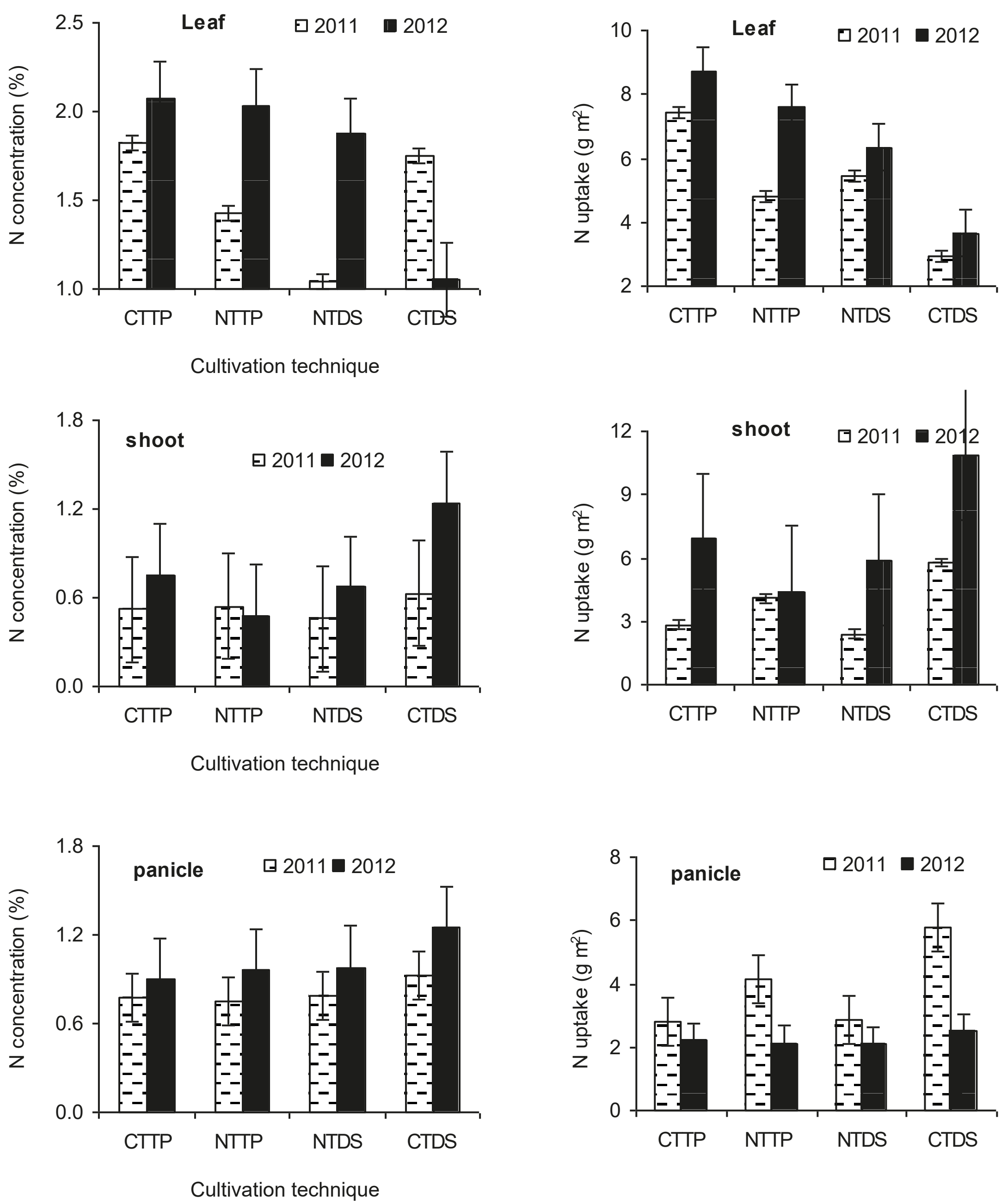

Fig. 5. Nitrogen concentration and uptake by Liangyoupeijiu at HD stage. Bar represents SE.

Nitrogen distribution pattern at maturity

Nitrogen concentration (%) in grain and straw varied significantly for cultivation techniques in 2011 but not in 2012. Nitrogen concentration (%) was higher in conventional tillage than no tillage in both the years. Conventional tillage and transplanting had significantly higher nitrogen (%) among the cultivation techniques in 2011 and had higher nitrogen (%) in straw during 2012. In grain, NTDS had significantly higher nitrogen (%) among cultivation techniques in 2011 and CTDS in 2012. No tillage had higher nitrogen (%) than conventional tillage in both the years (Fig. 6).

In straw, nitrogen uptake (kg ha^{-1}) was significantly higher in CTDS in 2011 and CTTP in 2012. In grains, nitrogen uptake (kg ha^{-1}) was similar in CTTP, NTTP and NTDS during 2011 and CTTP, NTTP and CTDS in 2012 (Fig. 6).

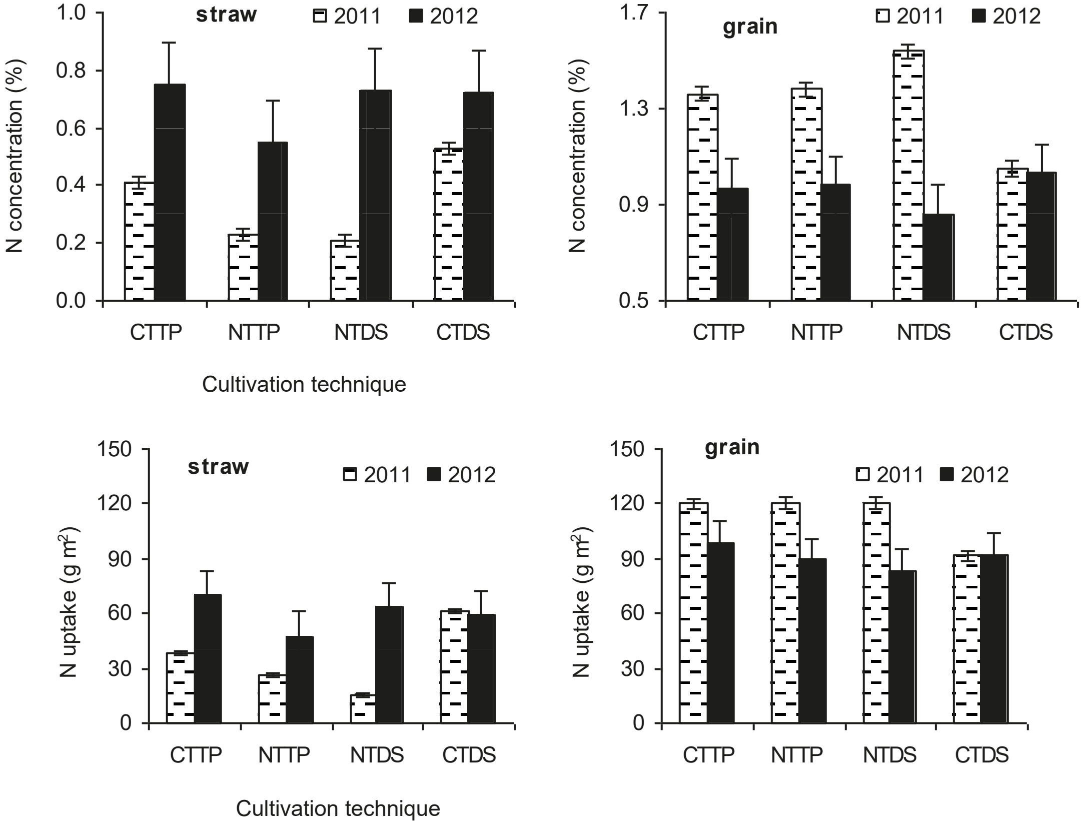

Fig. 6. Nitrogen concentration and uptake by Liangyoupeijiu at MA stage. Bar represents SE.

Nitrogen translocation ratio (NTR)

Nitrogen translocation ratio varied significantly due to cultivation techniques in 2011 and higher amount of nitrogen was translocated from NTDS and the lowest amount was in CTDS. In 2012, it had higher in CTTP and NTTP among the cultivation techniques. It was also higher in transplanting than direct seeding, similarly no tillage than conventional tillage in both the years (Fig. 7).

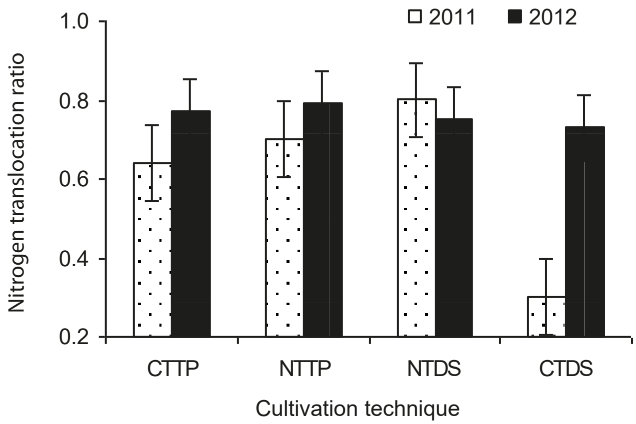

Fig. 7. Influence of cultivation technique on nitrogen translocation ratio (NTR) of Liangyoupeijiu. Bar represent SE.

Physiological N use efficiency (kg kg^{-1})

Physiological nitrogen use efficiency varied significantly among the cultivation techniques in 2011 but not in 2012. It varied significantly between conventional tillage and no tillage and NTTP, NTDS and CTDS were statistically similar in physiological nitrogen use efficiency in 2011. The physiological nitrogen use efficiency was higher in no tillage than conventional tillage in both the years (Fig. 8).

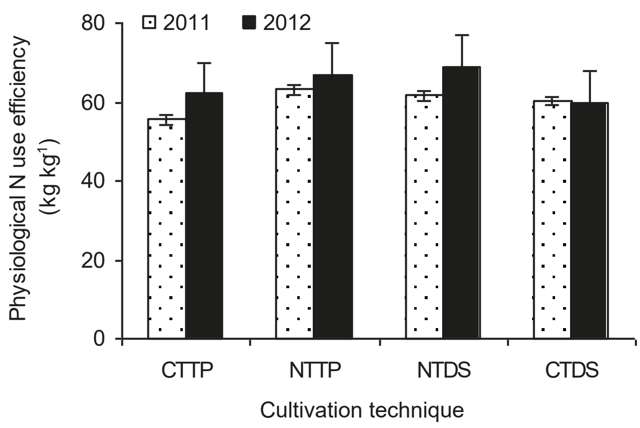

Fig. 8. Physiological N use efficiency of Liangyoupeijiu. Bar represents SE.

Total nitrogen(kg ha^{-1}) uptake at maturity

Total nitrogen uptake was higher in conventional tillage than no tillage either in transplanting or direct seeding in both the years and CTTP had higher among the cultivation techniques in both the years (Fig. 9).

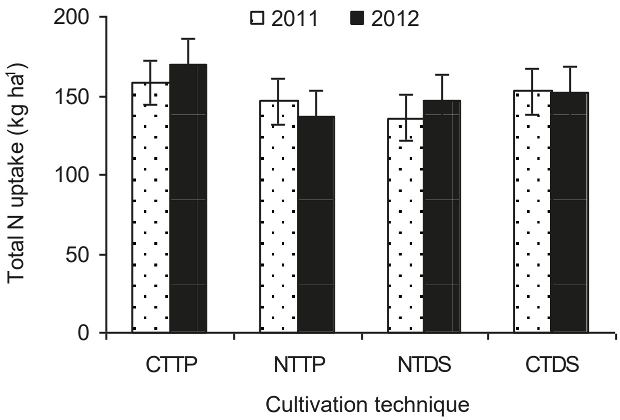

Fig. 9. Influence of cultivation technique on total N uptake of Liangyoupeijiu. Bar represents SE.

Relationship of grain yield and total nitrogen uptake at heading and maturity

Grain yield was positively associated with uptake of total nitrogen at heading (Fig. 10).

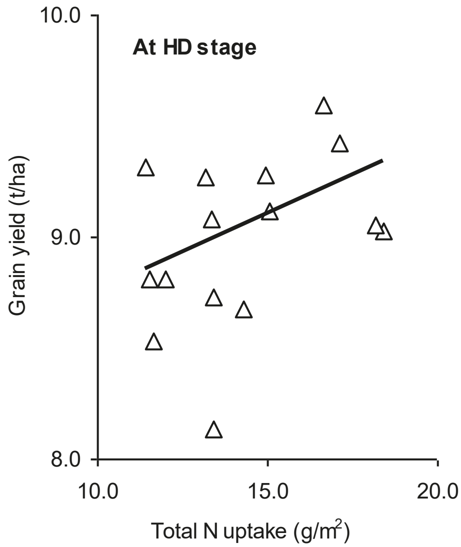

Fig. 10. Relationship of grain yield and total N uptake by Liangyoupeijiu at heading and maturity

RELATIONSHIP BETWEEN GRAIN YIELD AND YIELD COMPONENTS

Panicle (m^{-2}) Panicle number varied significantly among the cultivation techniques and directed seeded either in conventional tillage or no tillage produced more number of panicles than transplanting. No tillage and direct seeding produced higher number of panicle and was lower in NTTP in both the years.

Total spikelet (m^{-2}) Total number of spikelet varied significantly among the cultivation techniques and bigger sink size was observed in transplanting than direct seeding. Conventional tillage and transplanting produced significantly higher number of spikelet in both the years.

Grain yield Conventional tillage produced higher economic yield than direct seeding and was higher under CTTP followed by CTDS but cultivation techniques were insignificant in 2011. Similarly, CTTP had significantly higher grain yield followed by NTDS in 2012. The difference between transplanting and direct seeding in grain yield was lower but conventional tillage had higher grain yield than no tillage in 2011. Conventional tillage and transplanting produced higher grain yield due to bigger sink size in both the years (Table 1).

Table. 1. Yield and yield components of super hybrid rice Liangyoupeijiu, Hunan, China.

Treatment	Panicle (m^{-2})	Total spikelet (m^{-2})	Grain yield (t ha^{-1})
2011			
CTTP	261 bc	47529 a	8.82
NTTP	242 c	44367 c	8.54
NTDS	333 a	42119 d	8.30
CTDS	297 ab	45664 b	8.73
Analysis of variance			
Establishment method (A)	*	*	NS
Tillage (B)	NS	*	NS
A X B	*	*	NS
SE (0.05)	16.47	481.31	0.359
2012			
CTTP	238 b	52736 a	10.30 a
NTTP	220 b	45001 b	9.10 b
NTDS	325 a	45198 b	9.70 ab
CTDS	306 a	40228 c	9.00 b
Analysis of variance			
Establishment method (A)	*	*	NS
Tillage (B)	NS	NS	NS
A X B	*	*	*
SE (0.05)	19.02	1387.3	0.30

DISCUSSION

Translocation of pre-anthesis reserve to grain is more important in direct seeded rice because of high plant density (Farooq *et al.*, 2011). Leaf dry weight gradually increased up to booting stage and CTTP had 7% -12% higher leaf dry weight than NTTP owing to more number of tillers per unit land area. Badshah *et al.*, (2013) reported that, tiller number was always higher under CTTP than NTTP from maximum tillering to maturity stage. Maximum leaf dry weight reduced in direct seeding than transplanting due to high population caused by mutual shading (Monneveux *et al.*, 2008) and a consequent acceleration in leaf senescence (Baylis and Dicks, 1983). Shoot dry weight increased up to heading stage and slightly reduced at 12DAH due to translocation of reserved materials to sink. Rice yield is the function of biomass production before heading and translocation to grains after heading (Yang *et al.*, 2008). Direct seeded rice produced more shoot biomass than transplanted rice at heading and was 26% higher than transplanted rice in 2011 but was 6% higher under transplanting in 2012. Shoot dry weight reduced about 6% both in transplanting and direct seeding from heading to 12DAH in both the years due to translocation of reserved materials to sink. Higher grain yield depends on higher dry matter accumulation and translocation that influence by numerous factors like cultural practices, climate and genotype (Dingkuhn *et al.*, 1990a). At 12DAH, direct seeding had about 9 % more panicle dry weight than transplanting in 2011 due to more number of tillers per unit land area. At heading, leaf nitrogen concentration (%) in transplanted rice was 31% and 75% and nitrogen uptake (g m^{-2}) was 32% and 39% higher than direct seeding during 2011 and 2012 respectively. Direct seeding had lower leaf nitrogen content due to greater mutual shading of canopy (Dingkuhn *et al.*, 1990b). In shoot, nitrogen concentration in transplanting and direct seeding was similar in 2011 but direct seeding had about 36% higher nitrogen (%) than transplanting in 2012. Nitrogen uptake was higher in direct seeding than transplanting and was 16% and 33% higher in direct seeding due to rapid leaf area development and dry matter accumulation but growth rates and N uptake decreased during the grain filling period. In panicle, direct seeding had slightly higher nitrogen (%) than transplanting in 2011 but was 17% higher nitrogen (%) than transplanting in 2012. Nitrogen uptake was 19% higher in direct seeding than transplanting in 2011 but difference between direct seeding and transplanting in 2012 was lower. In straw, transplanted rice had 14% and 11% higher nitrogen (%) than direct seeded rice and conventional tillage had 53% and 13% higher nitrogen (%) than no tillage during 2011 and 2012 respectively. Nitrogen uptake (kg ha^{-1}) was 16% higher in direct seeding than transplanting during 2011. In grain, NTDS had significantly higher nitrogen (%) among the cultivation techniques during 2011 and was higher under CTDS in 2012. Transplanted rice had 6% and 3% higher nitrogen (%) than direct seeded rice and no tillage had 18% and 8% higher nitrogen (%) than conventional tillage in 2011 and 2012 respectively. Nitrogen uptake (kg ha^{-1}) was higher in transplanted than direct seeded by 12% and 7% during 2011and 2012 respectively. The physiological nitrogen use efficiency was higher in no tillage than conventional tillage in both the years due to total nitrogen uptake was lower but grain yield was close to conventional tillage. Nitrogen translocation ratio was higher in no tillage than conventional tillage due to source–sink relationship. The export percentage of dry matter and transport percentage of dry matter were higher in no tillage either in transplanted or direct seeded in both the years due to higher sink-source ratio. No tillage direct seeding produced higher number of panicle and NTTP was lower in both the years. Direct seeding rice had more number of panicle than transplanting due to more tillers per unit area. Badshah *et al.*, (2013) showed that at maximum tillering and maturity stage, direct seeded showed 22% more tiller than transplanted irrespective of tillage system. Sink size (more number of spikelet) was bigger in transplanting than direct seeding and CTTP produced significantly higher number of spikelet in both the years due to longer panicle and more number of spikelet per inch of panicle. Badshah *et al.*, (2013) reported that, transplanted rice had about 12% longer and larger sink (heavier panicle) than direct seeded rice. Conventional tillage and transplanting had higher economic yield because of bigger sink size in both the years caused by total uptake of nitrogen at maturity.

CONCLUSION

Nitrogen translocation ratio and physiological nitrogen use efficiency were higher in no tillage over conventional tillage in both the years. Although, direct seeded rice had more than 23% higher panicle than transplanting but higher grain yield was observed in CTTP in both the years due to higher uptake of nitrogen by grain at maturity and bigger sink size (more number of spikelet per unit land area).

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