

## Heat utilization and radiation interception in transplanted rice (*Oryza sativa* L.) in relation to seedling age

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### ABSTRACT

The experiment comprising of mechanical transplanting of 3, 4 and 5 weeks-old seedlings was conducted at Punjab Agricultural University, Ludhiana during 2010 and 2011 to study the effect of seedling age on heat utilization, radiation interception and productivity of rice. Mechanical transplanting of 3 weeks-old seedlings recorded highest accumulation of growing degree days (GDD) of 2045°C day resulting from highest number of days taken to maturity. The heat use efficiency (HUE) was similar in all transplanted seedlings. The growth and yield attributes in terms of plant height, tiller number, panicle length, panicle weight, leaf area index (LAI) and photosynthetically active radiation (PAR) interception by the crop declined with increasing seedling age from 3 to 5 weeks. The 3 weeks-old transplanted seedlings recorded 0.90 and 2.79 per cent higher grain yield over 4 and 5 weeks old seedlings, respectively although the differences were non-significant.

**Key words:** GDD, HUE, LAI, mechanically transplanted rice, PAR interception, seedling age

The environmental factors like solar radiation interception, air temperature, sunshine hours etc. greatly influence the crop production. The crop duration is greatly influenced by the temperature and can be estimated by using growing degree days (GDD) i.e. accumulated heat units (Gouri *et al.* 2005). Heat use efficiency (HUE) i.e. efficiency of utilization of heat in terms of dry matter accumulation or economic yield of rice depends on solar radiation interception, leaf area development and crop management practices like tillage and nutrient management (Aggarwal *et al.* 2015).

Performance of rice is largely influenced by seedling age (Ginigaddara and Ranamukhaarachchi 2011). Number of tillers plays key role in weed suppression potential of the crop through favourable effect on the competition for space, moisture, nutrients and sunlight. Transplanting of seedlings at optimum age ensures profuse tillering. The delay in transplanting or use of older seedlings than optimum age results in lesser production of tillers because of the shortening of vegetative phase due to reduced accumulation of heat units and adversely affects the crop productivity (Mobasser *et al.* 2007).

Mechanical transplanting is a viable option amidst looming water crisis and labour scarcity and has the potential to reduce cost of cultivation, energy saving, sustaining rice productivity and enhancing farm income (Singh *et al.* 2006).

The main objective of this study was to evaluate the heat utilization and radiation interception in relation to productivity of rice as affected by seedling age. As very little literature is available to fill this knowledge gap, this study has paramount importance in view of the understanding of possible effects of manipulation of the seedling age in quest to sustain rice productivity with the adoption of alternative labour saving technologies.

### MATERIALS AND METHODS

The experiment comprising of mechanical transplanting of 3, 4 and 5 weeks-old seedlings was conducted in a randomized complete block design with four replications in *kharif* season of 2010 and 2011 at Punjab Agricultural University, Ludhiana (30°56'N, 75°52'E; 247 m above sea level) to study the effect of different seedling age on heat utilization, light interception and productivity of rice. The soil was deep alluvial loamy sand, Typic Ustochrept, low in available N, medium in P and K with normal soil reaction. The sowing of mat type nursery of rice c.v. PR 115 was done on 13, 20 and 27 May in 2010 and on 16, 23 and 30 May in 2011 to have seedlings of age 3, 4 and 5 weeks old respectively, at the time of transplanting. The mats were fertilized with urea @ 300 g for 200 mats at 10 days interval after sowing. The mechanical transplanting of seedlings of rice was done on 17<sup>th</sup> June and 19<sup>th</sup> June in 2010 and 2011, respectively with Japanese transplanter, Model:

NSPU-68 C. A nutrient dose of 30, 30 and 62.5 kg of  $P_2O_5$ ,  $K_2O$   $ha^{-1}$  and  $ZnSO_4$ , respectively was applied before the last puddling or respective tillage treatment. Whereas, 125 kg N  $ha^{-1}$  was applied in three equal splits after one week, three weeks and six weeks from the date of transplanting, respectively. The water was kept standing continuously for the first two weeks after transplanting for proper establishment of seedlings. Afterwards, the plots were irrigated with 75 mm water after two days of drainage of applied water. Plant protection measures were adopted as per the recommendations of Punjab Agricultural University, Ludhiana. The crop was harvested manually during first fortnight of October.

Data on plant height was recorded from the five hills tagged randomly in each plot. Leaf area index was measured with the help of Plant Canopy Analyzer (LI-COR) Model LAI-2000, Inc., Lincoln, NE, USA. Periodic observations on dry matter accumulation were recorded by cutting the plants from the base, dried in the sun for some period and then dried in the oven at 65°. The number of tillers was counted from three fixed spots. The line quantum sensor (LI-COR Photometer model LI-191-84) which measures quantum (photon) response in the wavelength range of 400-700 nm was used to record photosynthetically active radiation (PAR) interception. The growing degree-days (GDD) were computed from the date of transplanting onwards till physiological maturity by considering the base temperature ( $T_b$ ) of crop as 10°C using the following formula:

$$\text{Accumulated GDD (°C day)} = \sum (T_{\text{mean}} - T_b)$$

Where  $T_{\text{mean}}$  is daily mean air temperature in °C =  $(T_{\text{max}} + T_{\text{min}})/2$

Heat use efficiency (HUE) was also computed with the following formula

$$\text{HUE} = \frac{\text{Grain yield}}{\text{GDD}}$$

The data were subject to analysis of variance (ANOVA) in a randomised complete block design as per the standard procedures and the comparisons were made at  $P \leq 0.05$ .

## RESULTS AND DISCUSSION

### *Growth attributes*

The data on the periodic plant height of the crop (Table 1) revealed that at 30 DAT, highest plant height was recorded in mechanical transplanting of 3 weeks-old seedlings which was significantly higher than that of 4 and 5 weeks-old seedlings. Similar trend was recorded at 60, 90

DAT (Table 1) and at harvest (Table 2). The dry matter accumulation by crop recorded at 30, 60, 90 DAT (Table 1) and at harvest (Table 2) did not vary significantly in different age of seedlings. However, 3 weeks old seedlings had a numeric edge on 4 and 5 weeks-old seedlings for dry matter accumulation at all the stages of crop growth.

### *Yield and yield attributes*

The number of tillers recorded at different time intervals (Tables 1 and 2) indicated that mechanical transplanting of 3 weeks-old seedlings produced statistically similar number of tillers as that in 4 weeks old seedlings but significantly higher than mechanical transplanting 5 weeks-old seedlings. The panicle length was significantly decreased with increasing seedling age from 3 to 5 weeks-old seedlings (Table 2). The panicle weight of 3 weeks-old seedlings was statistically similar to that in 4 weeks old seedlings but significantly higher than mechanical transplanting 5 weeks-old seedlings (Table 2). Although the differences in grain yield in mechanical transplanting of 3, 4 and 5 weeks-old seedlings were non-significant but, 3 weeks old seedlings recorded 0.90 and 2.79 per cent higher grain yield over 4 and 5 weeks old seedlings, respectively (Table 2).

### *Accumulated growing degree days (GDD) and heat use efficiency (HUE)*

Mechanical transplanting of 3 weeks-old seedlings accumulated highest GDD which was significantly higher than all other treatments (Table 2) which might be due to significantly higher number of days taken to maturity (Table 2). Further, mechanical transplanting of 3, 4 and 5 weeks-old seedlings recorded statistically similar HUE (Table 2).

### *Leaf area index and radiation interception*

The data on LAI and PAR interception recorded at different phases of the crop continued to increase up to 90 DAT (Table 1) and thereafter decreased at harvest (Table 2) due to mortality of the late formed tillers and translocation of the photo-assimilates from the leaves to the developing grains which resulted in the senescence of the leaves. At 30 DAT, highest LAI was recorded with mechanical transplanting of 3 weeks-old seedlings and was statistically at par with 4 weeks old seedlings but significantly higher than 5 weeks old seedlings. Similar results were recorded at 60, 90 DAT (Table 1) and at harvest (Table 2). These results are in line with the findings of Salem *et al.* (2011) who reported that 3 weeks-old seedlings resulted in significantly higher LAI than 5 weeks-old seedlings.

**Table 1:** Periodic growth attributes of mechanically transplanted rice as influenced by age of seedlings (Mean of two years 2010 and 2011)

Treatment	Plant height (cm)		Dry matter (g m <sup>-2</sup> )		Number of tillers		Leaf area index		PAR interception (%)						
	30 DAT	90 DAT	30 DAT	90 DAT	30 DAT	90 DAT	30 DAT	90 DAT	30 DAT	90 DAT					
3 weeks-old	49.2	80.1	88.6	170	639	1214	278.7	417.0	401.8	2.21	3.61	4.31	66.51	75.54	84.46
4 weeks-old	47.6	78.3	86.2	167	621	1185	271.0	410.9	395.2	2.15	3.53	4.16	65.66	74.19	83.38
5 weeks-old	47.3	76.2	84.7	160	605	1161	266.3	403.3	388.2	2.11	3.45	4.04	63.90	72.75	82.19
CD (p=0.05)	1.2	1.4	1.3	NS	NS	NS	8.0	9.2	9.4	0.07	0.15	0.17	1.94	1.77	1.99

\* DAT- days after transplanting

**Table 2:** Growth and yield attributes at harvest, yield and heat utilization of mechanically transplanted rice as influenced by age of seedlings (Mean of two years 2010 and 2011)

Treatment	Plant height (cm)	Dry matter accumulation (g m <sup>-2</sup> )	Number of tillers	Leaf area index	PAR interception (%)	Panicle length (cm)	Panicle weight (g)	Grain yield (kg ha <sup>-1</sup> )	Days taken to maturity	GDD (°C day)	HUE (kg ha <sup>-1</sup> °C day <sup>-1</sup> )
3 weeks-old	94.6	1460	385.4	2.69	58.24	24.6	2.76	6264	104.9	2045.1	3.06
4 weeks-old	92.1	1427	381.3	2.64	56.55	23.6	2.70	6208	102.4	2002.5	3.11
5 weeks-old	90.5	1394	374.6	2.61	54.80	22.5	2.65	6094	100.1	1963.4	3.10
CD (p=0.05)	1.5	80	8.1	0.08	2.72	0.8	0.07	NS	0.9	14.8	NS

Further, mechanical transplanting of 3 weeks-old seedlings recorded highest PAR interception (Tables 1 and 2). It was statistically at par with mechanical transplanting of 4 weeks old seedlings but significantly higher than 5 weeks old seedlings. Lesser crop growth in terms of plant height and dry matter accumulation, number of tillers and LAI (Table 1) in mechanical transplanting of 5 weeks-old seedlings resulted in significant reduction in PAR interception over 3 weeks-old seedlings.

### CONCLUSION

It is concluded from the two years study that mechanical transplanting of 3, 4 or 5 weeks-old seedlings recorded similar HUE and yield thereby enabling the farmers to have wider window period to transplant the seedlings mechanically without any significant reduction in grain yield.

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