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Heat utilization vis-à-vis crop performance of mechanically transplanted rice (*Oryza sativa* L.) as affected by tillage systems and nitrogen levels

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ABSTRACT

The experiment comprising of four tillage methods *viz.*, puddling (PTR), conventional tillage without puddling (CT), reduced tillage (RT) and zero tillage (ZT) and four nitrogen levels at 0, 100, 125 and 150 kg ha^{-1} was conducted in a strip plot design with four replications at Punjab Agricultural University, Ludhiana during 2010 and 2011 to study the effect of tillage and nitrogen levels on productivity and heat utilization in mechanically transplanted rice. Results revealed that periodic plant height and dry matter accumulation by the crop recorded at 30, 60, 90 DAT and at harvest, leaf area index (LAI) and photosynthetically active radiation (PAR) interception by the crop at panicle emergence stage and the grain yield were statistically at par in mechanical transplanting in CT and PTR but significantly higher than that in RT and ZT. Application of 150 kg N ha^{-1} recorded significantly higher LAI, PAR interception, number of tillers and grain yield than that in 0, 100 and 125 kg N ha^{-1}. Mechanical transplanting in CT recorded highest accumulation of growing degree days (GDD) and highest heat use efficiency (HUE). The accumulated GDD and HUE increased significantly with each successive increase in nitrogen dose from 0 to 150 kg ha^{-1}.

Key words: HUE, LAI, PAR, mechanically transplanted rice, tillage systems, nitrogen levels, weed flora, weed suppressing ability

The conventional method of rice establishment under puddled conditions with the main intention of controlling weeds, minimizing percolation rate of water and preparing a soft bed for crop establishment involves intensive tillage operations and requires large proportions of water, labour and energy. All these inputs are becoming scarce and expensive in agriculture with each passing day. Besides these benefits, puddling had adverse effects on soil physical conditions due to intensive churning of the soil and promotes the formation of hard pan at a shallow depth of 15-25 cm (Kukal and Aggarwal 2003a). It creates difficulties in seed bed preparation for succeeding wheat crop in rotation and reduces its root growth, resulting in poor nutrient and water absorption (Boparai *et al.* 1992; Kukal and Aggarwal 2003b).

Tillage plays an important role for developing a desired soil structure and improving the physical conditions of soil which favors the rooting characteristics of plants and thus leads to enhanced nutrient uptake and better yield of crop. Nitrogen is another important component of rice production technology with high yielding varieties and influences the crop growth and its smothering effect on weeds. Chander and Pandey (1996) observed that application of 120 kg N ha^{-1} significantly increased the yield attributes and yield with corresponding decrease in weed dry matter compared with 60 kg N ha^{-1} in manual transplanted rice under puddled conditions.

There is a growing concern to reduce the cost of cultivation by minimizing the expenditure on land preparation. Nowadays, major emphasis is given on resource conservation technologies like mechanical transplanting which helps immensely in reducing cultivation costs, labour and energy requirements, sustaining the agricultural productivity and enhance profitability for the farmers (Singh *et al.* 2006). Designing strategies in mechanically transplanted rice for higher productivity is gaining importance for obtaining higher productivity under labour scarce situations, requires a study of differential responses of tillage systems and nitrogen levels for rice productivity and weed growth. It is important that any manipulation of the puddling intensity should not affect the growth and yield of the rice crop. But, little information is available that describes effect of tillage methods and nitrogen management on the heat utilization and yield of mechanically transplanted rice. Therefore this study was carried out to fill this knowledge gap and to showcase the production potential of mechanically transplanted rice in pursuit to develop sustainable, eco-friendly and labour saving technologies of rice production.

MATERIALS AND METHODS

A field experiment was conducted in *kharif* season of 2010 and 2011 at Punjab Agricultural University, Ludhiana (30º56´N, 75º52´E; 247 m above sea level) to study the effect of different tillage systems and nitrogen levels on weed dynamics and performance of mechanically transplanted rice. The experiment comprising of sixteen treatments formed by the combinations of four tillage methods [mechanical transplanting after puddling (PTR), conventional tillage without puddling (CT), reduced tillage (RT) and zero tillage (ZT)] and four nitrogen levels (0, 100, 125 and 150 kg N ha^{-1}) was conducted in a strip plot design with four replications. Puddling was done with two passes of cultivator in the standing water condition whereas, in CT, two times disc harrowing was followed by cultivation with field cultivator and then planking was done. In RT, field was prepared by one cultivation with cultivator followed by planking, whereas, crop was directly transplanted without any preparatory tillage in ZT.

The soil of the experimental site was deep alluvial loamy sand, Typic Ustochrept, low in available nitrogen, medium in phosphorus and potassium with normal soil reaction. The weekly mean minimum temperature during the crop growing period ranged between 20.6 to 29.1˚C and 19.1 to 27.3˚C, whereas the weekly mean maximum temperature ranged between 30.1 to 43.5˚C and 29.9 to 41.8˚C during the 2010, and 2011crop season, respectively. A total rainfall of 652 mm and 1190 mm was received against open pan evaporation of 947 mm and 806 mm during two crop growing season, respectively.

The sowing of mat type nursery of rice cultivar PR 115 was done on 20th and 23rd May in 2010 and 2011, respectively. A perforated polythene sheet of 50-60 gauge was spread on properly levelled field and plastic trays of dimensions 58 cm × 28 cm × 2 cm filled with properly sieved soil were placed on it. About 100 g of pre-germinated seeds of rice were uniformly spread in each tray. The seeds were then covered with very thin layer of soil and water was sprinkled with hand sprayer for proper setting of the soil and seeds. The nursery was irrigated twice a day, during morning and evening hours to keep the trays wet. Urea was applied @ 300 g for 200 mats at an interval of 10 days after sowing. The mechanical transplanting of seedlings of rice was done on 17th June and 19th June in 2010 and 2011, respectively with mechanical transplanter, Model NSPU- 68 C. Sufficient water level for washing of front fingers of mechanical transplanter was maintained in the field. A uniform application of nutrients like phosphorus (30 kg P_2O_5 ha^{-1}) through single super phosphate, potassium (30 kg K_2O ha^{-1}) through muriate of potash and zinc sulphate tetrahydrate (62.5 kg ha^{-1}) were applied before the last puddling or respective tillage treatment. Whereas, nitrogen in different doses was applied in three equal splits after one week, three weeks and six weeks from the date of transplanting. Foliar application of 1% ferrous sulphate was done on 8th July and 11th July in 2010 and 2011, respectively. For proper establishment of the seedlings, water was kept standing continuously for the first two weeks after transplanting. Afterwards, the plots were irrigated after two days of drainage of applied irrigation water. The depth for each irrigation was 75 mm. Plant protection measures were adopted as per the recommendations of Punjab Agricultural University, Ludhiana. The crop was harvested manually during first fortnight of October in both the years.

Data on plant height was recorded at 30, 60 and 90 days after transplanting (DAT) and at harvest from the five hills tagged randomly in each plot. Leaf area index was measured at panicle emergence stage of crop with the help of Plant Canopy Analyzer (LI-COR) Model LAI-2000, Inc., Lincoln, NE, USA. Periodic observations on dry matter accumulation were recorded at 30, 60, 90 DAT and at harvest stage of the crop by cutting the plants from 50 cm row length from the base, dried in the sun for some period and then dried in the oven at 65 °C till constant dry weight was achieved and then converted to g m^{-2}. Total number of tillers were counted at 30, 60, 90 DAT and at harvest stage from three fixed spots measuring one meter length in each plot and average number of tillers was divided by 0.3 for converting the data to number of tillers m^{-2}. Photosynthetically active radiation (PAR) interception was measured using line quantum sensor (L1-COR Photometer model LI-191-84) PAR was recorded as quantum (photon) response in the wavelength range of 400-700 nm. PAR interception was calculated by using the following formula:

PAR interception (%) = PAR above crop canopy - PAR at soil surface-radiation reflected by crop canopy)x100 / PAR above the canopy

The growing degree-days (GDD) were computed considering the base temperature (T_b) of 10 °C. The sum of the degree days from sowing to physiological maturity were obtained by using the following formula:

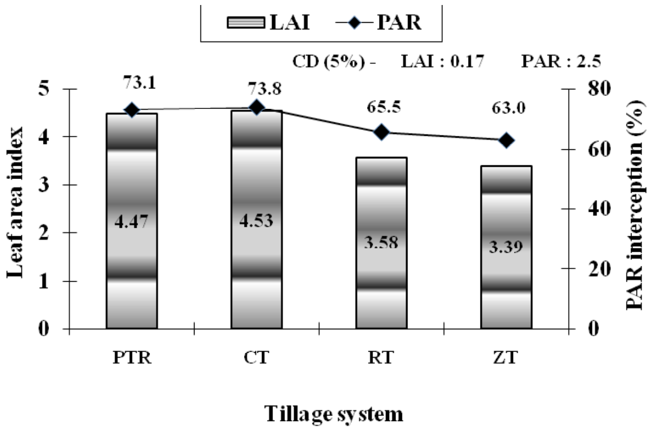

Fig. 1: Effect of tillage systems on LAI and PAR interception by mechanically transplanted rice

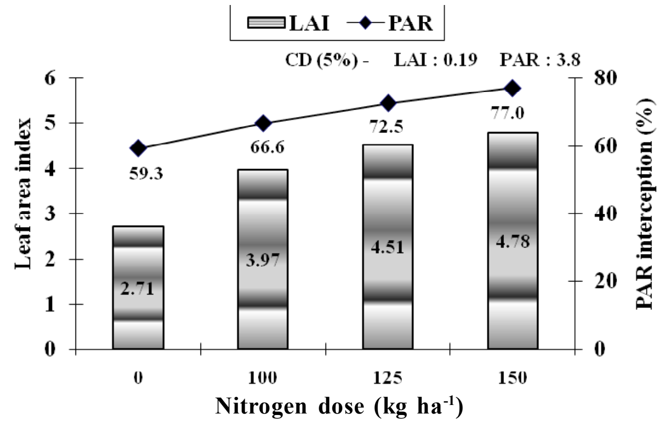

Fig. 2: Effect of nitrogen on LAI and PAR interception by mechanically transplanted rice

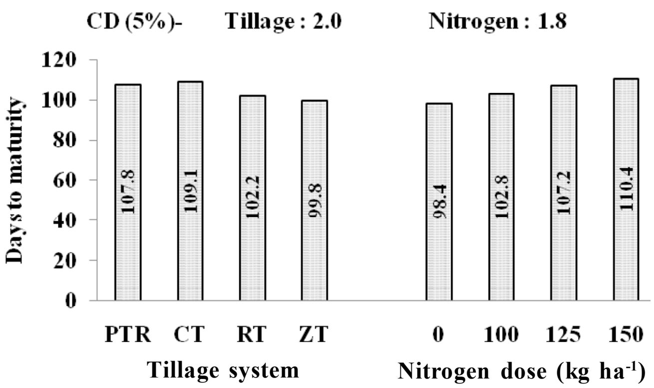

Fig. 3: Effect of tillage systems and nitrogen on days taken to maturity

Accumulated GDD (°C day) = Σ (T_{mean} - T_b)

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

Heat Use Efficiency (HUE) was computed using the following formula

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

All the data were subject to analysis of variance (ANOVA) as per the standard procedures. The comparison of treatment means was made by critical difference (CD) at P ≥0.05.

RESULTS AND DISCUSSION

Growth and yield

Tillage systems had a significant effect on the plant height at all the stages of growth (Table 1). At 30 DAT, maximum plant height was recorded in PTR which was statistically at par with that of CT but significantly higher than RT and ZT conditions. A similar trend was observed at all subsequent growth stages of crop. The higher plant height under PTR and CT might be due to better physical, chemical, and biological soil conditions than those under reduced and zero tillage conditions. Different N levels significantly influenced plant height at all stages of crop growth (Table 1). Plant height recorded at 30, 60 and 90 DAT and at harvest with 150 kg N ha^{-1} was statistically at par with 125 kg N ha^{-1} but significantly higher than 100 kg N ha^{-1} and control. The increase in plant height with increasing doses of N may be attributed to higher availability of N for growth and development to the plants. The present results are in conformity of the one reported by Yang *et al*. (2009).

The data recorded on dry matter accumulation at 30, 60, 90 DAT and at harvest (Table 1) clearly show that it continued to increase till the maturity of the crop. However, the crop showed higher rate of dry matter accumulation during 60-90 DAT irrespective of the treatments. Dry matter accumulation varied significantly in different tillage systems at all the intervals of observation. At 30 DAT, PTR and CT recorded statistically similar dry matter accumulation with each other but significantly higher than RT and ZT conditions. Similar results were observed at 60, 90 DAT and at harvest. At harvest, highest dry matter accumulation was noticed in mechanical transplanting of rice in CT and magnitude of gain was 2.9, 17.9 and 36.3% higher over the PTR, RT and ZT, respectively. Dry matter accumulation also increased significantly with each incremental level of N from 0 to 150 kg N ha^{-1} at all stages of crop growth. At harvest, application of 100, 125 and 150 kg N ha^{-1} showed 17.9, 32.5 and 47.5% increase in dry matter accumulation over control, respectively. Similar results have been reported

Table 1 : Effect of tillage systems and nitrogen levels on plant height and dry matter accumulation of mechanically transplanted rice (mean of two years)

Treatment	Plant height (cm)				Dry matter accumulation (g m^{-2})			
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
Tillage system								
PTR	57.8	85.4	93.8	96.8	169.3	610.0	1174.4	1465.3
CT	56.8	84.8	93.0	96.2	167.1	614.4	1207.3	1507.5
RT	51.8	80.3	88.7	91.6	137.1	518.6	1023.7	1278.6
ZT	50.0	76.8	84.4	86.9	124.8	464.4	908.0	1106.4
CD (p=0.05)	3.1	3.3	2.6	2.5	10.4	17.3	41.7	36.1
Nitrogen level (kg ha^{-1})								
0	48.4	73.2	82.3	84.0	99.9	417.9	874.7	1076.1
100	53.8	80.9	89.0	91.6	141.2	521.2	1025.0	1268.5
125	56.7	85.1	93.1	96.1	166.8	601.9	1147.5	1425.6
150	57.5	88.0	95.5	99.8	190.4	666.2	1266.3	1587.7
CD (p=0.05)	3.0	4.0	2.8	4.6	7.8	30.1	38.6	32.2

Table 2 : Effect of tillage systems and nitrogen levels on number of tillers, yield and heat utilization of mechanically transplanted rice (mean of two years)

Treatment	Periodic tiller count (m^{-2})				Grain yield	Accumulated	HUE
	30 DAT	60 DAT	90 DAT	At harvest	(kg ha^{-1})	GDD (°C day)	(kg ha^{-1} °C day^{1})
Tillage system							
PTR	299.1	430.5	407.2	392.5	6382	2096	3.04
CT	302.9	434.7	411.9	395.8	6465	2103	3.07
RT	260.0	399.6	372.7	359.6	5808	1992	2.91
ZT	242.3	372.4	353.1	340.9	4494	1953	2.30
CD (p=0.05)	17.4	15.5	13.6	17.5	332	22	0.17
Nitrogen level (kg ha^{-1})							
0	225.4	345.9	327.1	316.6	4724	1932	2.45
100	271.1	403.2	376.9	367.4	5646	2002	2.82
125	294.1	431.6	408.8	393.7	6295	2077	3.02
150	313.7	456.4	432.2	411.2	6484	2133	3.03
CD (p=0.05)	11.6	11.4	10.9	13.0	149	17	0.08

by Ghorbanli *et al.* (2006) and Munnujan *et al*. (2001). The increase in dry matter accumulation in rice with increasing levels of N might be due to higher availability of this nutrient which led to enhanced vegetative growth of plants.

Number of tillers is one of the most important yield attributing characters of rice. The perusal of the data revealed that the number of tillers increased up to 60 DAT, but registered a progressive decline thereafter (Table 2). The mortality of the tillers was observed latter in the season which might be the reason for decline in tiller number at 60 DAT and afterwards. Pandey *et al.* (2001) also reported similar trend of first increase and then decline in the tiller number during the growing season of rice crop.

Different tillage systems showed significant effect on the number of tillers at all the stages of crop growth. At 30 DAT, mechanical transplanting in CT registered the highest number of tillers which was statistically at par with PTR but significantly superior over RT and ZT. Similar results were observed at all subsequent growth stages of the crop. At harvest, transplanting in CT registered 0.8, 10.1

and 16.1% higher tiller number than PTR, RT and ZT conditions. Number of tillers was also significantly influenced by different N levels as application of 150 kg N ha^{-1} resulted in highest number of tillers at 30, 60, 90 DAT and at harvest and it was significantly superior to all lesser levels of N (Table 2). Further, each incremental N level registered significantly higher number of tillers than the preceding lower level. These results are in line with the findings of Gunri *et al*. (2004).

Highest grain yield was recorded in mechanical transplanting of rice after CT but was statistically at par with PTR (Table 2). Further, mechanical transplanting in RT and ZT system resulted in significant reduction in grain yield of rice as compared to CT. The increase in the grain yield in PTR and CT might be due to the increase in growth and yield parameters like plant height, dry matter accumulation (Table 1) and number of tillers (Table 2) as compared to RT and ZT systems. The grain yield of rice differed significantly under different N levels. The highest grain yield of rice was recorded with 150 kg N ha^{-1} (Table 2). The grain yield increased significantly with each successive increment in N level from 0 to 150 kg N ha^{-1}. These results are supported by the findings of Qian *et al*. (2009).

Leaf area index (LAI) and photosynthetically active radiation (PAR) interception

The LAI and PAR interception recorded at panicle emergence stage was significantly influenced by different tillage systems and nitrogen levels (Figs. 1 and 2). It was observed that mechanical transplanting in CT recorded highest LAI and PAR interception which was statistically at par with that in PTR. Poor crop growth in terms of plant height and dry matter accumulation (Table 1) and number of tillers (Table 2) in rice crop in RT and ZT conditions resulted in significant reduction in LAI and PAR interception as compared to transplanting in CT as well as PTR. The crop intercepted significantly higher PAR with each successive increment in N dose. Increased LAI with increasing doses of N might have resulted in higher PAR interception. Nitrogen an essential element for plant growth that plays prominent role in building new meristematic cells, enhancing cell elongation and increasing photosynthetic activities of the plant and ultimately encourages the biomass development. These results are supported with the findings of Salem *et al.* (2011). They have observed that PAR interception increased significantly with increase in N dose from 0 to 164 kg ha^{-1}.

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

Mechanical transplanted rice in CT accumulated highest GDD and HUE which was statistically at par with that in PTR but significantly higher than RT and ZT conditions (Table 2). This might be attributed to significantly higher grain yield (Table 2) and days taken to maturity (Fig. 3) in PTR and CT as compared to RT and ZT. The accumulated GDD and HUE increased significantly with each successive increase in nitrogen dose from 0 to 150 kg ha^{-1} which might be due to corresponding significant increase of days taken to maturity (Fig. 3) and in grain yield (Table 2).

It is concluded from the two years study that rice can be transplanted mechanically after puddling or conventional tillage without puddling for obtaining enhanced rice yield, higher HUE and better suppression of associated weeds. Application of 150 kg N ha^{-1} was found optimum for proper growth and development of mechanically transplanted rice and enhancing its competitiveness against associated weeds.

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