Identification of puddling settling period of various soil textures for mechanical rice transplanting

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Abstract: Ideal puddling and settling period of soil could improve the seedling transplanting performance of the mechanical rice transplanter. This study was conducted to characterize the optimum puddling settling period for various soil textures. The plots were prepared by following all the possible operations to provide a favorable field condition. Each plot was transplanted at eight different times for settling period of 4 to 32 h in clay, sandy clay loam and silty clay loam textured soil. Primarily 76 hills were counted in each plot. Average planting depth was 6 cm while plants per hill were 7 in each field. The transplanting performance of the studied transplanter varied with the soil type and settling period of the soil before transplanting. It was observed that percentage of missing, damage and floating hills were 9.87%, 19.07% and 10.53%, respectively as the maximum values were found in clay soil at 4 h of settling period. With the passes of time, percentages of losses decreased and sandy clay loam soil gave the lowest percentage of losses. In sandy clay loam soil, the lowest percentage of missing hills was 1.32% in 8 h of settling period. The lowest percentage of damaged hills 2.63% was also observed in sandy clay loam soil while 1.32% of floating hills was found in clay, sandy clay loam and silty clay loam soil at 32 h of settling period. It is concluded that in clay soil transplanting is suitable after 20 h of land preparation and in sandy clay loam soil transplanting can be done at any time after land preparation. With the increase of settling period, the losses were decreased and planting efficiency increased. The highest percentage of planting efficiency was found in sandy clay loam soil (94.08%) in 8 h of settling period and the lowest was found in clay soil (60.52%) in 4 h of settling period. In this experiment, minimum missing hills and maximum planting efficiency were found in sandy clay loam soil. Irrespective of soil type, at the beginning of the settling period, the highest losses reduced the planting efficiency of the transplanter. Results suggested that 8 to 20 h of settling period reduced the seedling transplanting losses and therefore increased rice yield.

Keywords: transplanting, puddling, settling period, soil texture, optimum time, yield

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1 Introduction

Rice (*Oryza sativa* L.) is a major crop mostly in Asian countries, in which new technologies and improved appliances are developing very fast nowadays. Bangladesh is an agricultural country and agriculture is a major driving sector that contributes about 14.2% to the gross domestic product (GDP) of the country with a growth rate of 0.5% (Independent Review of Bangladesh Development ［IRDP］, 2017). From the Bangladesh independence in 1971, the rice production is increasing 0.5% per year for providing self-sufficiency depending on

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agricultural land (Food and Agriculture Organization [FAO], 2014) due to appropriate planning, management and mechanization of rice production. Accordingly, puddling and settling period largely influence the transplanting mechanism of the transplanter which is also associated with the production (Rautaray et al., 1997).

Puddling refers the action of forming a puddle or the process of working clay, loam, pulverized soil with water, to render it compact, or impervious to liquids by changing soil texture (Ghildyal, 1978). Puddling is done on rice field for controlling weeds and conserving water. Approximately 2 to 4 tillage operations are done to prepare puddle soil in Bangladesh (Hossen et al., 2017). After making puddling on field, it extremely changes the soil properties (Pandya, 1962). As it breaks down the non-capillary pore spaces, water holding capacity increases whereas decrease the evaporation losses as well as permeability and hydraulic conductivity (Sharma et al., 1985). All the essential inputs build up a good combination for better transplanting after settlement of puddled soil. Settling period refers how much time is required for settlement of puddled soil. Puddling settling period may vary on the basis of soil texture, soil physical structure, water availability in field, clay content, climatic conditions, tilling depth, puddling equipment and the level of puddling (De Datta et al., 1988). To regain the lost strength of soil after field levelling it takes time for settling as well as puddled soil particles can make a minimum bond with each other and can provide regained strength for standing a rice plant.The soil goes to under suspension/settle in water causes puddling which takes 48-72 h (Chhina, 2015). In this regard the large size particles (sand) settle first and lighter ones (clay) later with the passage of time (Matsubayashi, 1968). As a result, an impervious clay layer is formed over the top of sand surface and also the clay particles plugged in the pores between the sand particles. This impervious clay layer helps to reduce infiltration rate and also decreases deep percolation losses (Sharma et al., 1991). Again, excess tillage operation or puddling largely reduces soil strength and takes more times to settle (Awadhwal et al., 1985). Resulting rice transplanting will be hampered due to lacking of proper settling of puddled soil.

On the above discussion the study was undertaken with the following objectives:

1. To find out the suitable puddling settling period

2. To identify the rate of losses due to variable settling period

2 Materials and methods

2.1 Study location

The experiment was conducted at Jagotpur in Habiganj district, Sylhet (Latitude: N 24°18'30.48768" and Longitude: E 91°26'57.32844"), Bangladesh.

2.2 Weather condition

Habiganj has the tropical savanna climate prevailing.It is warm every month with both a wet and dry season. This experiment was conducted in August 2018, with an average temperature of 31ºC and total rainfall of 270 mm. Wind speed was recorded maximum 6.5 kmh^{-1}, minimum 3.25 kmh^{-1} and average 5.42 kmh^{-1} as well as average relative humidity was 83% (World Weather Online, 2018).

2.3 Soil characteristics

Experimental site belongs to Eastern Surma Kushiara Floodplain Agro-ecological zone. This experiment was conducted in various soil textures at different plots.

2.4 Land preparation

Primary and secondary tillage operation was performed for manipulation of soil to prepare land in different irrigated field by two-wheeler tractor and levelled the land following same process in various periods of time. Water levels were also varied with respect to time in selected plots.

2.5 Rice transplanter

Walking type four rows rice transplanter was used for seedling transplanting in the selected experimental field whose details are shown in Table 1.

Table 1 Specifications of rice transplanter (Daedong, 2000)

Item		Character
Trade name		Deadong Rice Transplanter
Model		DP488
Weight (kg)		185
Origin		Korea
Engine	Model	GT600PN
	Type	Gasoline
	RPM	3200
	Total displacement (cc)	181
	Fuel tank (l)	4
	No. of engine stroke	4
	Wheel type	Rubber tread wheel

Driving unit	Wheel diameter (mm)	600
	Transmission level	Forward: 2 levels, Reverse: 1 level
Travelling speed (forward, ms^{-1})		0.6-1.12
Travelling speed (reverse, ms^{-1})		0.2-0.44
Transplanting speed (ms^{-1})		0.4-0.75
Operating capacity ($min1000m^{-2}$)		30
Transplanting depth (cm)		1.0-4.5

2.6 Seedling

Fifteen days aged mat-type rice seedling of BRRI dhan46 (Figure 1) was used to conduct the study. Healthy, vigorous and 14.5 cm height seedlings were transplanted to evaluate the transplanter under different soil textures and different settling periods.

Figure 1 Mat type seedling

2.7 Soil sample analysis

A 50 mm height and 50 mm diameter metal core were used to collect soil samples depthof 0-5cm, 5-10cm and 10-15 cm from three different places of the selected field to measure soil texture. Soil characteristics and textural classification are shown in Table 2.

Table 2 Soil characteristics of the experimental fields

Field	% clay	% sand	% silt	Textural class
1	48	22	30	Clay
2	28	54	18	Sandy clay loam
3	34	17	49	Silty clay loam

2.8 Experimental design and treatments

This experiment was carried out following the Randomized Complete Block Design (RCBD) and conducted in a two-factor design, (Gomez and Gomez, 1984) with two replications (Figure 2).

Table 3 Experimental designs and treatments

Factor A (soil texture)	Factor B (settling period, h)
Clay soil (ST1)	0-4 (SP_1)
Sandy clay loam soil (ST2)	0-8 (SP_2)
Silty clay loam soil (ST3)	0-12 (SP_3)
	0-16 (SP_4)
	0-20 (SP_5)
	0-24 (SP_6)
	0-28 (SP_7)
	0-32 (SP_8)

The first factor (factor A) was texture of soil which varied with sandy clay loam, silty clay loam and clay and the second factor (factor B) was settling period. After final land preparation, the settling period was taken from 4 to 32 h having 4 h interval as shown in Table3.

2.9 Experimental procedure

A total of 48 plots were made by dividing each soil textural area into 16 experimental plots of 5m x 1m dimensional area (Figure 2). Approximately 0.35 m buffer spacing was maintained among the plots. For sandy clay loam texture, the experimental field was selected in different location and all experimental procedures were maintained as follows as clay and silty clay loam soil texture. Transplanter was operated in the field thoroughly for getting specific settling period. Seedlings were transplanted in each plot at a time having 4 h interval. Before operation, plant to plant spacing was adjusted at 18 cm while line to line spacing 30 cm is fixed in the studied transplanter. Number of plants per hill and depth of planting were measured during transplanting. The number of missing hills, damage hills and floating hills were recorded during the experiment. Planting efficiency was calculated in terms of seedling placement. Finally, the percentage of missing, damage and floating hills were analyzed.

2.10 Mathematical calculation

The collected data was calculated from different plots using the following Equations 1-4.

$$Percentage\ of\ missing\ hill\ (\%) = \frac{No.\ of\ missing\ hills}{Total\ hills} \times 100 \quad (1)$$

$$Percentage\ of\ damage\ hill\ (\%) = \frac{No.\ of\ damage\ hills}{Total\ hills} \times 100 \quad (2)$$

$$Percentage\ of\ floating\ hill\ (\%) = \frac{No.\ of\ floating\ hills}{Total\ hills} \times 100 \quad (3)$$

$$Planting\ efficiency,\ \eta_{pe}(\%) = \frac{Total\ hills - No.\ of\ (missing + damage + floating)\ hills}{Total\ hills} \times 100 \quad (4)$$

2.11 Statistical analysis

Data were analyzed using Statistix 10 program (Statistix 10 software, 2018, USA) as an LSD two-way factorial design. Excel worksheet (Microsoft, USA) was used to determine a correlation between data from different soil texture and settling period.

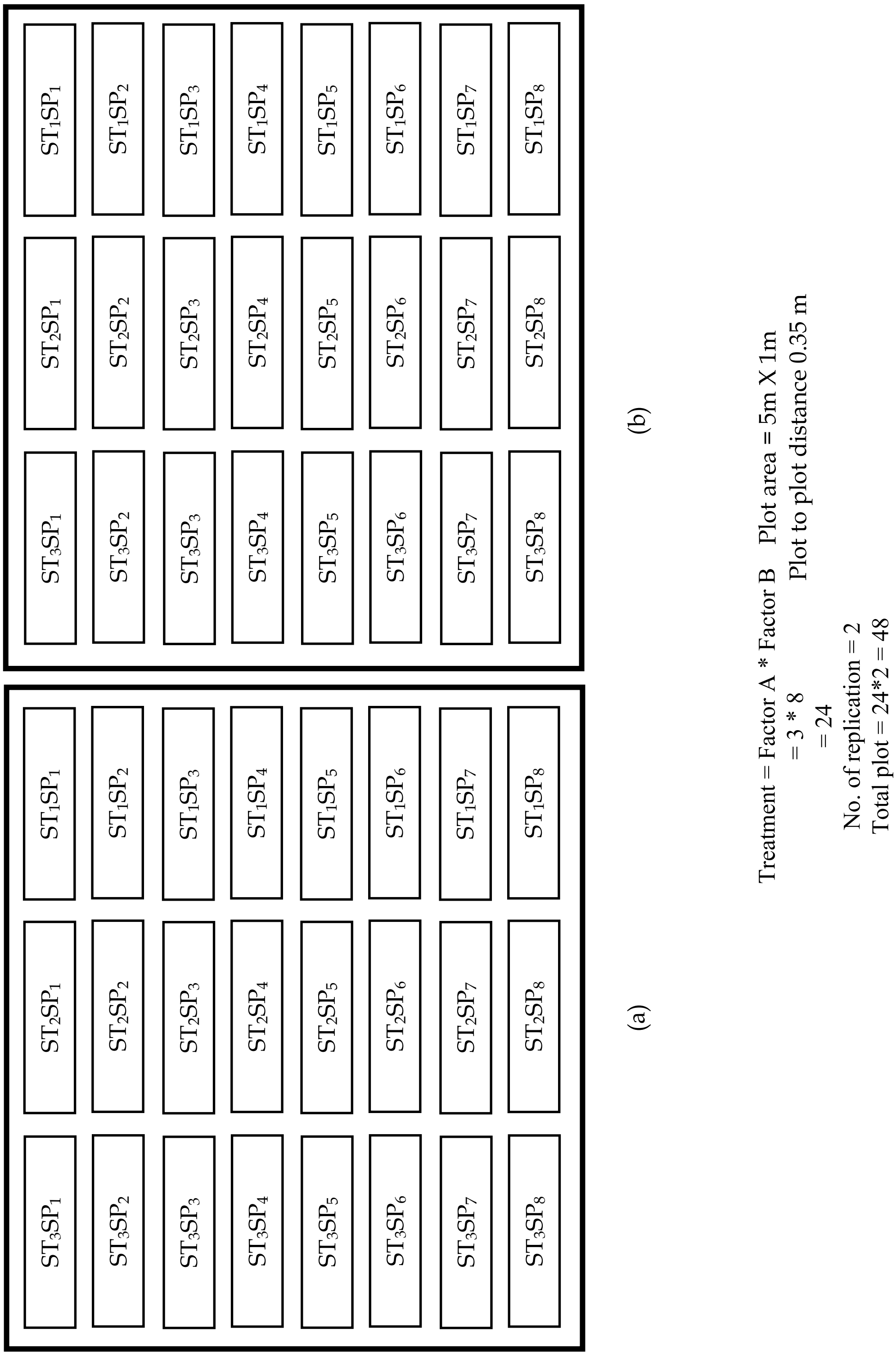

Figure 2 Replication of experiment

3 Results and discussion

3.1 Primary observation

During transplanting in different plots, total number of hills was 76 per plot and average number of plants per hill was 7. Average planting depth was found 6 cm.

3.2 Effect of settling period on missing hills

Two-way interaction of soil settling period and soil texture showed significant effect (Table 4) on missing hills of transplanting. The highest number of missing hills at 4 h (9.87%) of settling period was found in clay soil followed by 8 h (8.55%) and 12 h (7.89%) of settling period in the same soil texture. Four hours of settling period in silty clay loam soil also showed significantly higher missing hills (9.21%). From Table 4, significantly lower number of missing hill was found in 8 h (1.32%) and 16 h (1.32%) of settling period in sandy clay loam soil. Similarly, the lowest number of missing hills also observed in sandy clay loam soil which ranged from 1.32% to 2.63%.

Table 4 Effect of settling period and soil texture on missing hills (seedlingsm^{-2}) of rice seedling transplanting

Settling period	Soil texture			Mean
	Clay	Sandy clay loam	Silty clay loam	
SP_1	1.5	0.3	1.4	1.07
SP_2	1.3	0.2	1.1	0.87
SP_3	1.2	0.3	0.8	0.77
SP_4	0.9	0.2	0.8	0.63
SP_5	0.6	0.3	0.7	0.53
SP_6	0.6	0.4	0.7	0.57
SP_7	0.7	0.4	0.7	0.60
SP_8	0.6	0.3	0.7	0.53
Mean	0.93	0.3	0.86	-
% of CV value	25.65			
$LSD_{0.05}$	ST=0.13, SP=0.21 and ST × SP=0.37			
LoS	*	*	*	-

Note: ST- Soil Texture, SP- Settling Period, LoS- Level of Significance and *= Level of Significance at 1% .

Single effect of soil settling period and soil texture also showed significant effect on missing hills in mechanical transplanting.

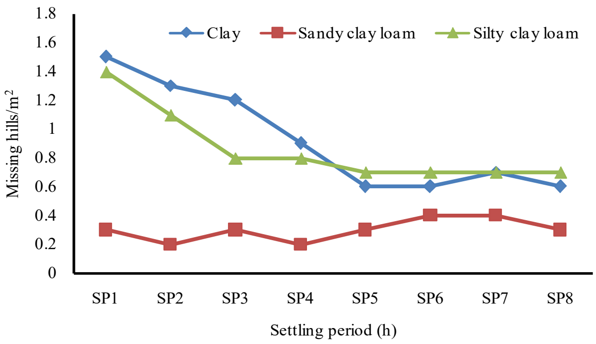

Figure 3 Missing hills of mechanical rice seedling transplanting in different settling periods and soil textures

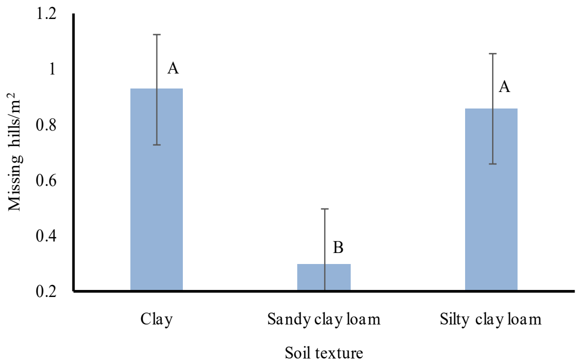

Figure 4 Average and error bar for missing hills of mechanical rice seedling transplanting under different soil textures.

Note: Different letters mean significant differences (p<0.01)

From Figure 3, the maximum average missing hills were found 7.03% and 5.72% for 4 and 8 h of settling period, respectively. The lowest percentage of missing hill (3.49%) was observed after 20 and 32 h of settling period. However, at 28 h settling period, it was increased to 3.95% because of failure of picking hills in rotational placement of seedlings.

Figure 4 showed that the lowest (1.97%) and the highest (6.11%) number of missing hillsof mechanical transplanting were observed in sandy clay loam and clay soil, respectively.

3.3 Effect of settling period on damage hills

Two-way interaction (soil texture × settling period) showed significant effect (Table 5) on damaged hills of mechanical transplanting. Four hours (19.07%) of settling period in clay soil showed the highest number of damaged hills. On the other hand, 8 h (2.63%) of settling period in sandy clay loam soil showed the lowest number of damaged hills (3.33%) followed by 12 to 32 h (3.95%) of settling period in the same soil in mechanical transplanting.

Table 5 Effect of settling period and soil texture on damage hills (seedlingsm^{-2}) of mechanical rice seedling transplanting

Settling period	Soil texture			Mean
	Clay	Sandy clay loam	Silty clay loam	
SP_1	2.9	0.9	2.5	2.10
SP_2	2.5	0.4	1.7	1.53
SP_3	2	0.5	0.9	1.13
SP_4	1.5	0.5	0.8	0.93
SP_5	0.8	0.5	1.2	0.83
SP_6	1	0.6	1	0.87
SP_7	1	0.6	1	0.87
SP_8	0.9	0.6	0.9	0.8
Mean	1.58	0.58	1.25	-
% of CV value	15.17			
$LSD_{0.05}$	ST=0.13, SP=0.21 and ST × SP=0.36			
LoS	*	*	*	-

Note: ST- Soil Texture, SP- Settling Period, LoS- Level of Significance, * = Level of Significance at 1%.

The single effect of soil settling period also showed a significant effect (p<0.01) on mechanical transplanting. On an average, 4 h (13.82%) of settling period showed significantly higher number of damaged hills while 32 h (5.26%) of settling period showed the lowest number of damaged hills followed by 16 to 28 h of settling period. It is noticeable that the number of damaged hills at 24 and 28 h of settling period were slightly increased due to flow of puddled soil developed by float of transplanter and at

32 h it was decreased because of sedimentation of puddled soil (Table 5 and Figure 5).

Again the single effect of soil texture also showed significant effect ($p<0.01$) on damaged hills. Clay soil showed significantly higher number of damaged hill (10.39%) in mechanical transplanting. On the other hand, lower missing hills (3.82%) were observed in sandy clay loam soil (Table 5 and Figure 6).

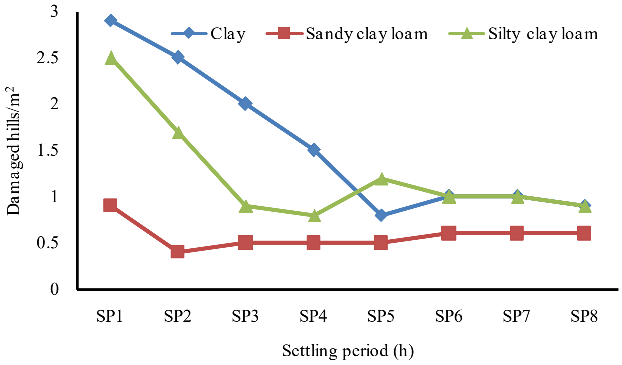

Figure 5 Damage hills of mechanical rice seedling transplanting in different settling periods and soil textures

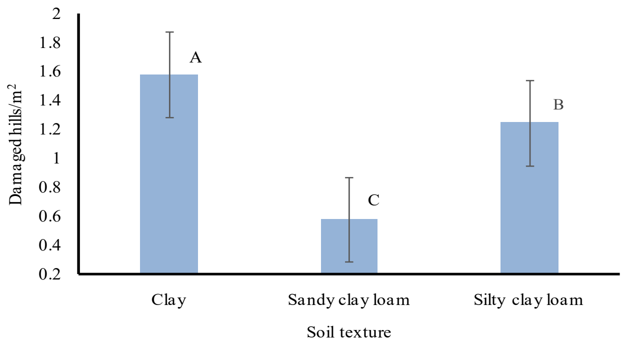

Figure 6 Average and error bars for damage hills of mechanical rice seedling transplanting in different soil textures.

Note: Different letters mean significant differences ($p<0.01$)

3.4 Effect of settling period on floating hills

Irrigation water influenced the floating hills of mechanical transplanting under different settling periods. The result showed that number of floating hills was increased due to high water level in the field. It was observed that the floating hill gradually decreased with the passes of time and decreasing water level in the field. Four hours (10.53%) of settling period in clay soil showed the higher number of floating hills in transplanting (Table 6). On the other hand, the lowest number of floating hill were observed in 32 h (1.32%) of settling period as water level was zero in the sandy clay loam and silty clay loam soil texture,

Effect of soil settling period and soil texture also showed significant effect (Table 6) on floating hills in mechanical transplanting.

Table 6 Effect of settling period and soil texture on floating hills (seedlingsm^{-2}) of rice seedling transplanting

Settling period	Soil texture			Mean
	Clay	Sandy clay loam	Silty clay loam	
SP$_1$	1.6	0.6	0.6	0.93
SP$_2$	0.8	0.3	0.8	0.63
SP$_3$	0.6	0.2	0.3	0.37
SP$_4$	0.3	0.3	0.6	0.40
SP$_5$	0.3	0.5	0.3	0.37
SP$_6$	0.2	0.2	0.2	0.20
SP$_7$	0.3	0.2	0.3	0.27
SP$_8$	0.2	0.2	0.2	0.20
Mean	0.54	0.31	0.41	-
% of CV value	39.61			
LSD$_{0.05}$	ST=0.12, SP=0.20 and ST X SP=0.34			
LoS	*	*	*	

Note: ST- Soil Texture, SP- Settling Period, LoS- Level of Significance, * = Level of Significance at 1%.

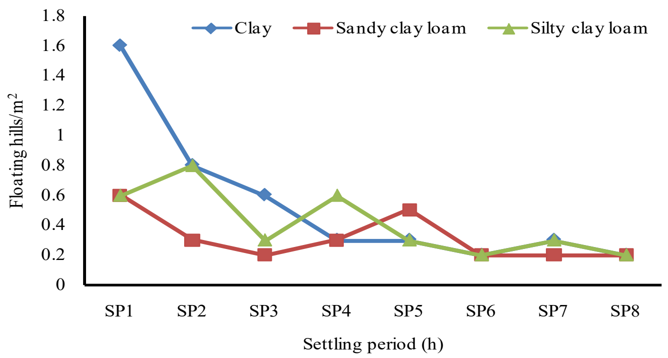

Figure 7 Floating hills of mechanical rice seedling transplanting in different settling periods and soil textures

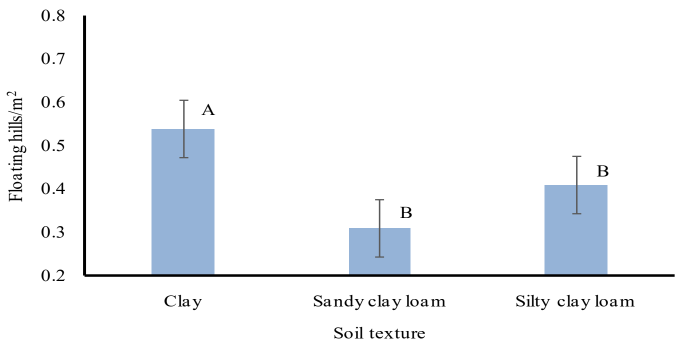

Figure 8 Average and error bars for floating hills of mechanical rice seedling transplanting in different soil textures.

Note: Different letters mean significant differences ($p<0.01$)

Figure 7 showed that 4 h (6.11%) of settling period have the maximum number of floating hills and 32 h (1.32%) the lowest. But during the settling period, floating hills from 12 to 24 h increased because of placement of seedlings in feet foot of operator, and planting nozzle did not find soil to place seedlings in feet steps. Figure 8 showed that the lowest (2.03%) and highest number of missing hills (3.55%) were found in sandy clay loam and clay soil texture, respectively.

3.5 Effect of settling period on planting efficiency

Planting efficiency (Table 7) depended on the number of damages, missing and floating hills observed from the experimental plots. If losses are high, then planting efficiency decreases. In this experiment 8 h (94.08%) of settling period in sandy clay loam soil gave the highest number of planting efficiency followed by 12 h (93.42%) and 12 h (93.42%) for the same soil texture. On the other hand, the lowest efficiency was found at 4 h (60.52%) of settling period in clay soil texture.

Table 7 Effect of settling period and soil texture on planting efficiency (%) of the studied transplanter

Settling period	Soil texture			Mean
	Clay	Sandy clay loam	Silty clay loam	
SP_1	60.52	88.16	70.4	73.03
SP_2	69.73	94.08	76.32	80.04
SP_3	74.99	93.42	86.84	85.09
SP_4	82.24	93.42	85.53	87.06
SP_5	88.82	91.45	85.52	88.60
SP_6	88.21	92.11	87.50	89.27
SP_7	86.84	92.10	86.84	88.60
SP_8	88.82	92.76	88.16	89.91
Mean	80.02	92.19	83.39	-
% of CV value	2.27			
$LSD_{0.05}$	ST=1.42, SP=2.31 and ST × SP=4.00			
LoS	*	*	*	

Note: ST- Soil Texture, SP- Settling Period, LoS- Level of Significance, * = Level of Significance at 1%.

Single effect of soil settling period and soil texture was also showed significant effect on planting efficiency. On average (Figure 9) significantly higher planting efficiency was found in 32 h (89.91%) of settling period and lower in 4 h (73.025%). Figure 10 showed that higher planting efficiency was observed in sandy clay loam soil (92.19%) while lower was observed in clay soil texture (80.02%).

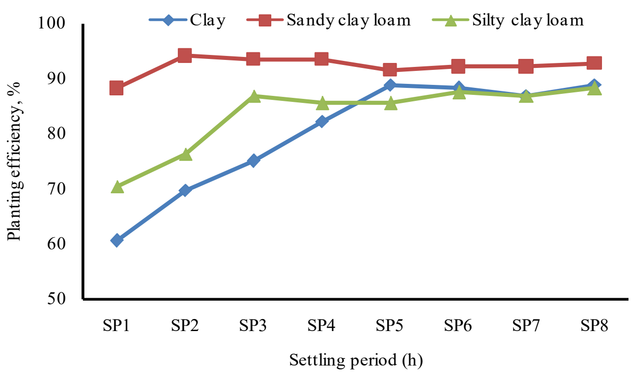

Figure 9 Planting efficiency of the studied rice transplanter in different settling periods and soil textures

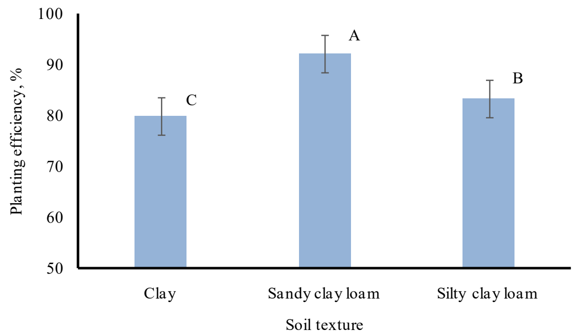

Figure 10 Planting efficiency and error bars for the studied rice transplanter in different soil textures.

Note: Different letters mean significant differences (p<0.01)

The missing hills depended on the failure of picking and placement of seedling in the position. Because of an initial period degree of puddling remain as high, puddle soil attach in the head of picker, and flowing water make a turbulence when picking seedling resultingin a resistance of the placement of seedling.

On the hand, damage hill mainly depended on the flow of puddled soil and water developed by float during transplanter operation. Seedling might not be absorbed the shock of flowing puddle soil that causes high number of damage during transplanting. Moreover, operator skill is also an associated factor for damage hills.

Water in the field is responsible for floating hills. When operator foot print lifts up from the soil, it contains some water that is why placement seedling does not get minimum soil depth for stability of seedlings.

Finally, the study showed that the planting efficiency depends on the factor of damage hill, missing fill and floating hill losses.

In this experiment, minimum losses were 5.27% and maximum planting efficiency was 94.08% for 8 h of settling period in sandy clay loam soil compared with the observation of the total losses and planting efficiency (10.33% and 95%, respectively) of self-propelled rice transplanter under conventional tillage (Munnaf et al., 2014). Behera (2000) conducted an experiment to show the puddled soil characteristics in relation to performance of rice transplanter and found that percentage of missing hill and damage hill with respect to different mat density varies from 3.13% to 14.85% and 6.63% respectively.

4 Conclusion

Rice is grown by creating favorable conditions of soil for transplanting seedlings that is why it needs an ideal puddled soil condition as well as an ideal settling period of that puddled soil for its satisfactory performance in respect to water depth, level of puddling and soil strength. In this study the percentage of damage, missing and floating hills in clay soil at earliest time was 19.07%, 9.87%, and 10.53% respectively and with the passes of time the value of losses were decreased. The lowest value of missing, damage and floating hills were 2.63%, 1.32% and 1.32% respectively in sandy clay loam soil. The minimum planting efficiency was 60.54% in clay soil and maximum were 94.08% in sandy clay loam soil at 8 h of settling period. It is suggested that transplanting might be done at any time in sandy clay loam soil. In contrast, 20 and 12 hours of settling period is suitable for mechanical transplanting in clay and silty clay loam soil, respectively to minimize the planting losses and maximize planting efficiency.

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