IOP Conf. Series: Earth and Environmental Science **147** (2018) 012023 doi:10.1088/1755-1315/147/1/012023

Factors Affecting Planting Depth and Standing of Rice Seedling in Parachute Rice Transplanting

I W Astika[1], I D M Subrata[1] and G Pramuhadi[1]

[1] Department of Mechanical and Biosystem Engineering, Bogor Agricultural University, Indonesia

E-mail: wayanastikaipb@yahoo.co.id

Abstract. Parachute rice transplanting is a simple and practical rice transplanting method. It can be done manually or mechanically, with various possible designs of machines or tools. This research aimed at quantitatively formulating related factors to the planting depth and standing of rice seedling. Parachute seedlings of rice were grown at several sizes of parachute soil bulb sizes. The trays were specially designed with a 3D printer having bulb sizes 7, 8, 9, 10 mm in square sides and 15 mm depth. At seedling ages of 8-12 days after sowing the seedling bulbs were drops into puddled soil. Soil hardness was set at 3 levels of hardness, measured in hardness index using golf ball test. Angle of dropping was set at 3 levels: 0^o, 30^o and 45^o from the vertical axis. The height of droppings was set at 100 cm, 75 cm, and 50 cm. The relationship between bulb size, height of dropping, soil hardness, dropping angle and planting depth was formulated with ANN. Most of input variables did not significantly affect the planting depth, except that hard soil significantly differs from mild soil and soft soil. The dropping also resulted in various positions of the planted seedlings: vertical standing, sloped, and falling. However, at any position of the planted seedlings, the seedlings would recover themselves into normally vertical position. With this result, the design of planting machinery, as well as the manual planting operation, can be made easier.

1. Introduction

Mechanical rice transplanting is still facing some problems in Indonesia. The common nursery mat type transplanter is still facing infrastructure problems, where most of Indonesian rice fields do not have sufficient access road which enables the machine to get into the fields. Another main problem is that the depth of field hard so that the machine undergo many slips during the operation.

The emergence of parachute planting method has been enabling simple ways of planting, both manually and mechanically. In term of mechanical planting, it requires relatively simpler design of machinery, easier to be made by farmers, both man-driven tools or engine-powered machinery, both self-driven and attached to a hand tractor. The productivity of rice planted with parachute transplanting is considerably high. Three transplanting methods were compared: parachute, traditional, and line transplanting, it was found that parachute transplanting gave the highest yield with lowest cost[1]. Another research[2] compared traditional and parachute transplanting methods. Seedlings of parachute transplanting did'not show any stress as the roots are still covered by soil. Furthermore, parachute transplanting gave longer roots and bigger shoots. Other research[3] found that line transplanting gave better yield than parachute transplanting and then followed by random manual transplanting. Parachute method gave the highest population per hectare.

Another possibility of applying parachute rice planting is to transplant young seedling as required by SRI method. SRI method requires young seedling (around 10 days after sowing), and less number of seedling per hill (if possible 1 seedling per hill). It is possible to arrange less number of seedling per hill in parachute seedling by putting less seed per tray holes, and then transplanting the seedling earlier. These will give several advantages at the same time: enabling more number of seedling per tray making less area required for preparing the nursery and requiring less time for nursery the making more use of trays per season.

Parachute transplanting is also potentially applied with minimum tillage in which the untilled soil is just stripped with a furrowed or rotary tiller. A research has been done on strip tillage with rotary tiller and followed by direct seeding. Only the planted area is tilled[4]. As Parachute transplanting only needs soft areas at the places the seedlings are dropped, therefore the area can be untilled inundated soil, strip-tilled, or fully tilled.

This research studied dropping of seedling as the main mechanism in parachute planting, especially for the small size of parachute seedlings. The objective of the research is to observe and to formulate the effect of several factors: height of dropping, soil hardness, the size of seedling parachute, and the angle of dropping to the depth of planting and the standing of the planting.

2. Materials and method

2.1. Survey on Soil Hardness

A survey on soil hardness was done at surrounding areas of Bogor City in order to get soil hardness data of farmers rice fields, both untilled soil and pulverized soil. The data was then used as the references in preparing the soil hardness for the main experiment. Soil hardness was measured in term of soil hardness index with golf ball test, in which a golf ball dropped from 1 m height vertical from the soil surface.

2.2. Preparation of Parachute Seedlings

Parachute seedlings were prepared at several soil bulb sizes and several seedling ages. The seedling was grown in 4 sizes of trays which were specially designed and manufactured by using 3D printer. The size of tray holes and the mass of the seedlings are shown in table 1, figure 1 and figure 2.

Table 1. Sizes of tray’s holes and parachute seedlings at 8-10 days after sowing

No	Sides and depth (mm)	Mass	
		Range (g)	Average (g)
1	7 x 7 x 15	0.1 – 0.3	0.204
2	8 x 8 x 15	0.2 – 0.5	0.322
3	9 x 9 x 15	0.3 – 0.9	0.670
4	10 x 10 x 15	0.3 – 1.3	0.977

Figure 1. Seedlings in the model of tray

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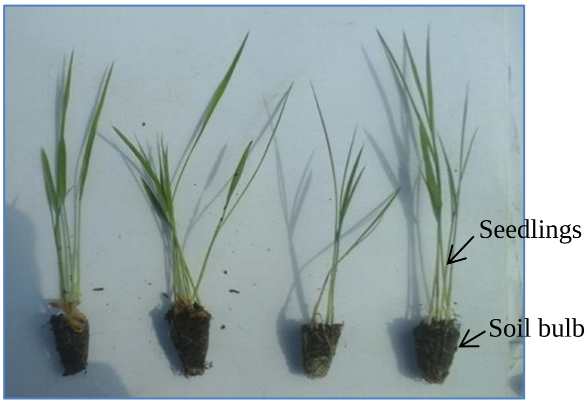


Figure 2. Sample of seedlings

2.3. Preparation of Soil

The range of soil hardness prepared for experiments was hardness index 1 - 3 as measured in soil hardness index using golf ball test. This range was made based on the result of measurements on soil hardness around Bogor City as shown in table 3. With those data, three levels of soil hardness were prepared: Level 1 (hard) where golf ball test gives the surface of golf ball 1 cm above the soil surface, Level 2 (mild) where the golf ball surface at the soil surface, and Level 3 (soft) where the golf ball surface 1 cm beneath the soil surface as shown in figure 3.

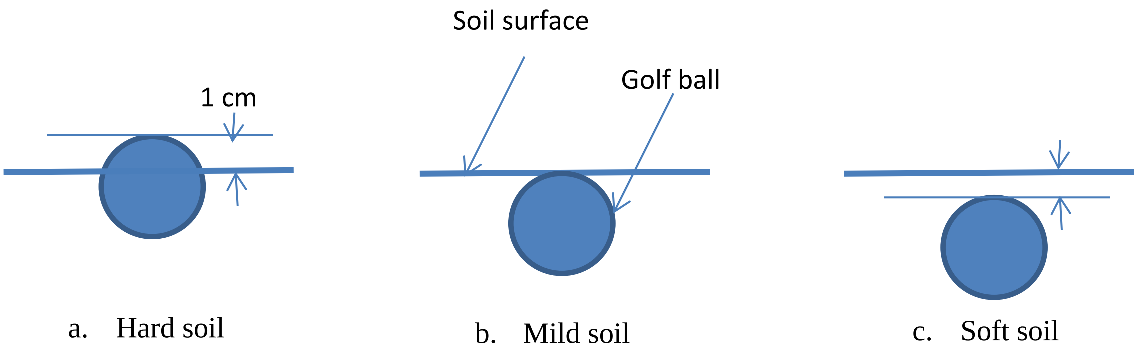


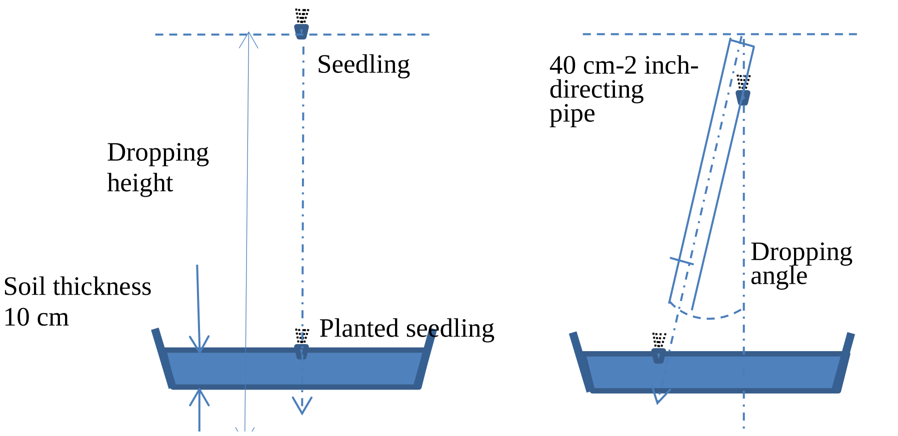
Figure 3. Soil hardnesses indicated with golf ball test, the sinking of a golf ball due to dropping from 1 m height

2.4. Planting Simulation

Planting of seedling parachutes were simulated by dropping the seedlings from a certain height to a pulverized soil surface as depicted in figure 4. Four treatments were applied in experiment in order to know the factors affecting the planting depth. The treatments and levels within the treatments are shown in table 2.

Table 2. Treatments and levels of each treatment

No	Treatments	Levels
1	Parachute seedling sizes	4 levels as shown in table 1
2	Dropping height	3 levels : 100 cm, 75 cm, 50 cm
3	Dropping angle	3 levels: 0°, 15°, 30° from vertical line
4	Soil hardness	3 levels : hard, mild, soft as shown in figure 4



a. Vertical dropping b. Sloped dropping: 15° and 30°

Figure 4. Soil hardness indicated with golf ball test, the sinking of a golf ball due to dropping from 1 m height

2.5. Planting Depth Mathematical Formulation

The relationship between input variables and the planting depth were formulated with and artificial neural network (ANN) structure as shown in figure 5. All input variables are coded in discrete numbers, while the output planting depth are coded as real numbers.

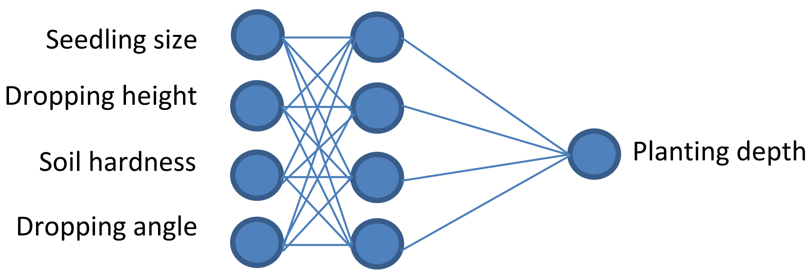


Figure 5. Artificial neural network structure

A number of 108 data were used in the training of the ANN, and no validation step was done as the error of the training were very big indicating that there is no consistency relationship between the input and the output variables.

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3. Results and discussion

3.1. Soil Hardness Survey

Survey on soil hardness was done in the beginning of there research. Four sites at Bogor Regency, Bekasi, and Karawang Regency were selected as representatives of pulverized rice field soil ready for planting. The result of soil survey is shown in table 3.

Table 3. Soil hardness of pulverized and inundated soil

Sites	Golf Ball Test (cm*)
Balumbang Jaya Village, Bogor Regency	1.18
Situgede Village, Bogor Regency	0.53
Sukatani Village, Karawang Regency	1.29
Wanajaya Village, Karawang Regency	0.55
Lengah Jaya Village, Bekasi Regency	-0.58
Setia Jaya Village, Bekasi Regency	0.74
Average	0.89
Maximum	-3.00
Minimum	2.10

*) Depth of golf ball sinking due to dropped from 1 m height, average of 10 repetitions. Negative sign means the ball upper surface is on the soil surface

Table 3 shows various values of soil hardness of pulverized and inundated soil. Inundated fields are usually softer than those the pulverized drained ones. Even some of the untilled-inundated fields are also soft as those of pulverized ones. With planting simulations done later, it seems that some untilled-inundated fields are also suitable for parachute planting. This soil condition is suitable for minimum tillage or zero tillage cultivation in which the productivity is similar to tilled soil[5][6][7]. On the other hand, some pulverized fields can also show high hardness if it is drained and exposed to sunlight for a long time.

3.2. Effect of Bulb Size on Planting Depth

The size of seedling soil bulb as shown in table 1 gave a various and inconsistent planting depths. The statistics are shown in table 4. The average of planting depth tends to increase due to the increase in bulb size, but the standard deviation is very high making the insignificant differences among the planting depths among the four level of bulb sizes. There are several possible reasons for this insignificance, among others: 1) the various sizes (or masses) of soil bulb among those in the same level of tray holes, 2) the relatively small mass of soil bulbs as compared to their seedling mass making the parachute effect becomes small. From this result, for parachute planting purpose, any of the size would be suitable for tray design, but agronomic factors such as water and nutrient holding capacity would limit the small sizes. A special research on this aspect would be required.

Table 4. Statistics of planting depth as related to soil bulb size.

Soil Bulb Size	1	2	3	4
Average Planting Depth (cm)	0.422	0.407	0.456	0.563
Standard Deviation (cm^2)	0.568	0.456	0.456	0.818
Maximum (cm)	1.9	1.5	1.4	3.2
Minimum (cm)	0	0	0	0
Mean Difference Significance*)	a	A	a	a

*) The same letters indicate no significance

3.3. Effect of Dropping Height on Planting Depth

Dropping height at 50-100 cm range also did not give a significant effect on the planting depth. The statistics are shown in table 5. The planting depth tends to increase as the dropping height increases, but again the standard deviation is very high. The reasons would probably the same as those for bulb size effect. From this results, design of parachute planters can be flexible in term of dropping height. For manual dropping, the height of 70-90 cm would be comfortable for workers, while for planting machine the height up to 150 cm would be fine.

Table 5. Statistics of planting depth as related to dropping height

Height of Dropping	50 cm	75 cm	100 cm
Average Planting Depth (cm)	0.406	0.464	0.517
Standard Deviation (cm^2)	0.439	0.475	0.804
Maximum (cm)	1.3	1.5	3.2
Minimum (cm)	0	0	0
Mean Difference Significance	a	a	a

*) The same letters indicate no significance

3.4. Effect of Soil Hardness on Planting Depth

Soil hardness apparently gave a significant effect on planting depth, especially the hard soil to mild and soft soil, while the mild and the sot soil did not show a significant difference in planting depth. The statistics are shown in table 6. Hard soil gave a very shallow planting depth that would not give strong standing of the grown plant. The suitable soil hardness for parachute planting is the mild and the soft soil. Fortunately, as shown in table 1, the hardness of pulverized soil are usually mild and soft. In short, soil hardness in the observed area is mainly suitable for parachute rice planting.

Table 6. Statistics of planting depth as related to soil hardness

Soil Hardness	Hard	Mild	Soft
Average Planting Depth (cm)	0.094	0.619	0.672
Standard Deviation (cm^2)	0.188	0.627	0.677
Maximum (cm)	0.6	2.8	3.2
Minimum (cm)	0	0	0
Mean Difference Significance	a	b	b

*) The same letters indicate no significance

3.5. Effect of Dropping Angle on Planting Depth

Slopped dropping would give less parachute effect of the seedling as the vertical force would decrease, and the expected result is that the higher dropping angle would give less planting depth. As shown in table 7, they are not consistently so, and the differences in planting depth are not significantly differ for those 3 levels of dropping angle. The reasons are probably the same as those valid for soil bulb size and dropping angle factors. Certainly, the vertical dropping would give the highest average of planting depth, but slopped dropping would be also applicable for the design of planter in which planting spaces need to be adjusted by setting the angle of directing sliding tube.

Table 7. Statistics of planting depth as related to dropping angle

Dropping angle	0^o	15^o	30^o
Average Planting Depth (cm)	0.542	0.414	0.431
Standard Deviation (cm^2)	0.817	0.430	0.458
Maximum (cm)	3.2	1.4	1.3
Minimum (cm)	0	0	0
Mean Difference Significance	a	a	a

*) The same letters indicate no significance

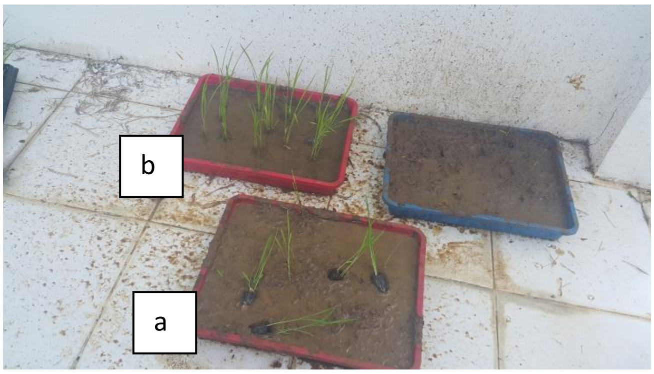
3.6. Standing of Planted Seedlings

As the parachute seedlings hit the soil, the seedling are immersed into the soil. The standing of the planted seedlings can be vertical or angled. Three categories were defined for the standing direction: vertical for the angle range 0^o-30^o, sloped for range of angle 30^o-60^o, and falling for range of angle 60^o-90^o. From the planting simulation, the standing of planted seedlings is shown in table 8.

Several results of planting simulation were grown in trays in order to have a controlled environment as shown in figure 6. As living things, rice seedlings tend to recover themselves into the proper standings. The angled planted seedling would recover themselves into the normal vertical positions in several days. Therefore, for practical application in planting work, both manually and mechanically, the standing of seedling would not be a problem, making the design of machine/tool would become easier.

Table 8. Standing of planted seedling due to dropping angle

Dropping	Standing of Seedlings (%)		
Angle	Upward	Slopped	Falling
0^o	75	25	
15^o	63.9	33.3	2.8
30^o	36.1	63.9	



a. Sloped and falling seedling
b. Recovered standing of falling and sloped seedling 4 days after planting

Figure 6. Standing of planted seedlings

3.7. Neural Network Formulation

The artificial neural network has been trained. The progress of the training is shown in figure 7. The errors were still very high at the end of the training process, and seemly could not achieve less error significantly if the training is continued. This result is consistent with the fact that almost all of the factors do not give insignificant effect to the planting depth. As the error of artificial neural network is high, the validation process was not done.

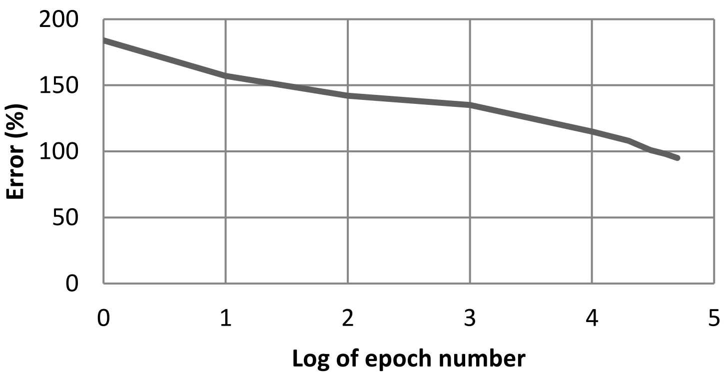


Figure 7. Progress of ANN training

4. Conclusions

Several points can be concluded from this research:

1. Among the four factors: 1) size of parachute seedlings, 2) height of dropping, 3) soil hardness, and 4) angle of dropping, only the soil hardness give significant effect to planting depth. Other factors showed reasonable trends but did not significantly affect the planting depth.
2. Artificial neural network failed to formulate seedling size, height of dropping, soil hardness, dropping angles and planting as the input factors do not consistently affect the planting depth. The training error of the ANN was very big around 90%.
3. The result of planting, aside from planting depth, also characterized by the standing of the seedlings. The standing can be vertical, sloped, or falling. Sloped dropping tends to give sloped planting. However, whatever the position of is, it will be recovered in several days into the normal vertical position.

5. Suggestion

For better result of future researchs, in order to eleminate bias on the factors, it is important to make a relatively uniform sizes in bulb size in the same levels.

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