Effect of Land Preparation, Water Management Practices and Planting Operation on Planting Quality in Rice Production

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Abstract

Water irrigation management, drainage, with land preparation in paddy field has crucial effects on rice planting quality and rice production. This study investigated the effects of water and land management on the performance of mechanical transplanting machines and the quality of planting. The investigation included the effect of land preparation before planting, soil condition during planting, and water management. Long field flooding periods combined with short sedimentation periods reduce the soil penetration resistance and soil bulk density which affect negatively the mechanical transplanting performance causing planting losses. The result showed the soil's physical properties penetration resistance and bulk density have a negative relation to planting losses. When the sedimentation period increased, the soil penetration resistance increased. There were strong relationships between the flooding period, sedimentation period, field water depth, and soil physical properties with transplanting speed, planting density, planting spacing, planting losses, and the depth of planting. About 50.5% of the farmers used the right required amount of water irrigation, and also the right time for irrigation.

Introduction

Water management is a crucial factor in rice production, whether it is used in land preparations or plant irrigation. Improve water control to achieve a full potential yield of rice through continuous flooding with 10–15 irrigation (De Datta, 1981). Optimum grain yield, optimum nutrient supply, and excellent weed control can be achieved by water depth Perfect water control increases grain quality as well as improves the efficiency of other inputs such as fertilizer, herbicide, and pesticides (Nori et al., 2008). (Sharma and De Datta, 1986) reported that puddling tillage is a traditional practice that farmers used to follow in wetland rice cultivation areas, it always destructs the soil's natural structure and disperses the soil particles. Plowing the soil or harrowing it repeatedly or even using the puddlers partially or destroy soil aggregates, depending on their stability. (Lal, 1985) reported that the purpose of puddling is to kill weeds by burying them, to reduce water percolation loss by forming a hardpan layer below the topsoil, and to prepare field beds to ease and smooth the mechanical transplanting of rice, which is a very costlier operation. As reported by many researchers the main problems with the self-propelled transplanting machine performance were excessive sinkages of the traction wheels of the transplanting machines and bogging in the puddled soil. This sinkage causes a reduction of the uniform establishment of the rice seedling, hill density per square meter, and increases the missing hills. Previous researches reported that the soil preparation practices of wetland tillage were not consistent with the performance of the self-propelled transplanting machines. The previous study showed that when the mechanical transplanting operation was done into very soft and loosened soil that prepared by puddling, the rice transplanted seedlings were buried in the mud, and vice versa, when the soil became firmer after a few days, the transplanting machine performed well in compacted plots. This was due to not having a soft surface soil for seedling establishment (Hemmat and Taki, 2003).

One of the most important factors for improving crop productivity and increasing production and crop yield is improved water efficiency, and that is by controlling and managing irrigation systems, and the drainage system which is crucial in achieving a full potential yield of rice. Produce optimum rice yields through continuous flowing flooding irrigation, with 10 to 15 cm depth of water and that is perfect to achieve the optimum output of grain yield, availability of optimum supply of nutrients, and control weeds excellently with this depth and with using herbicides. It is recommended that water depth be maintained at 5 to 10 cm until panicle initiation to promote tillering and early growth. After this stage, the depth should be increased as far as the banks will allow, to protect the developing panicle from the effects of low minimum temperatures at the critical early microspore stage. The time of drainage is a critical decision for rice growers. Early drainage results in lodging, and reduced grain weight, while delayed drainage leads to wet harvest conditions and lower milling quality. It is recommended that, for most soil types, water be drained when the lower grains on the panicle are at the late dough stage. For heavier soils, which can supply water to the crop for a longer period, draining can be completed when there are some milky grains at the base of each panicle. An advantage of water use efficiency is that it can reduce nitrate leaching (Choudhury and Kennedy, 2005).

Seeding rates and planting density, panicle density. and optimum plant spacings are crucial roles in improving plant and crop population and rice yield (Nakano, et al., 2012; Gravois, et al., 1992; Clerget et al., 2016; Hayashi et al., 2006; San-Oh et al., 2008; Wang, et al., 2014; Xu, et al., 2014; Gravois and Helms 1992; Fageria et al, 2014; Ottis and Talbert, 2005; Wells and Faw 1978; Qin et al., 2013; Hayashi et al., 2006; Huang et al., 2013; Huang et al., 2018; Chen et al., 2016). All These mentioned factors depend mainly on the land preparation, water irrigation and drainage technique, and method of planting. In paddy fields, land preparation is done by flooding the field with water and drainage the field before puddling. The practices of farmers to prepare the land have a significant effect on planting quality and mechanical transplanting performance.

In this study, Rice Check was used as a benchmarking standard for the farming practices and operations, and that because Rice Check is a comprehensive standard that includes all agricultural operations quality keys is perfect scheduling showing the source of materials, tools, and machines, the amount of material and machines that should be used, in a detailed time to cover specific are (placing). According to Rice Check the irrigation water should be scheduled as follow, from the sixth to tenth day after planting, farmers must insert water into the field, water should be added 2 to 3 days after herbicide spraying is carried out. The water level should be 3 to 5 cm, and the water should be added gradually according to the growth of the tree. Farmers should retain water for up to 15 days before harvest and should use a measuring device to determine the water level. This study was conducted under actual field operations in the real field conditions for two cultivation seasons in 30 plots of rice to evaluate and assess the quality and field performance of the practices and machinery operations of the self-propelled transplanting machine and the broadcasted direct seeding including the field performance and to relate these variables to operations planting density, planting spacing, planting losses and uniformity, the effect of field situation and land preparation on planting quality.

Materials And Methods

2.1. Description of the study area

The experiments were conducted during the first season which is the main season, started from June and finished in November 2017, and the second season which is off-season started from January and finished in May 2018 at the chosen study area located at Jalan Tali Air Dua in Sungei Burong paddy production area (3°29´47´´N, 101°09´56´´E) in, Kuala Selangor, Malaysia. This paddy area is one of the important rice production areas in Malaysia is located within the total area that is under the management of the North West Integrated Agricultural Development Authority (BLS IADA) Rice Scheme which is considered as one of the ten major rice production that called granary areas, and this area especially is considered as the highest yield production area. Each of these ten granary areas is being supported with infrastructures such as irrigation and drainage canals, agricultural machinery services, access roads, agricultural extension services by the government, and rice drying facilities.

2.2. Cultural Management

The farming management system in this area includes three tillage every season, first and second tillage was performed in dry soil using a 2.7-meter rotavator, while the third tillage was performed in saturated and post-flooded soil using a 3-meter rotavator. Implementation of tillage using rotary tillage is following the standard for land preparation among the rice farmers in the lowland and wetland rice cultivation sector in Malaysia. Farmers use a KUBOTA M9540 4WD tractor with a diesel engine that has a maximum power of 70.9 kW at 2500 rpm in their tillage operations (Mairghany, et al., 2019). For transplanting, farmers use KUBOTA NSPU-68C 6 rows riding self-propelled transplanting machine. The transplanted plots were 17 in the first season 2017 and 23 plots in the second season 2018. Specifications of self-propelled paddy transplanting machines are presented in Table 1. The adjustments involved in the mechanical transplanting machine were the number of seedlings/hill, transplanting depth, the distance between hills in deferent rows, the number of seedlings per hill was adjusted to 6 seedlings/hill, depth of transplanting was adjusted to 5 cm, the hill spacing in the same row was adjusted to 30 cm, and the hill to hill spacing was adjusted and to 20 cm, and the operating speed was maintained to be from 0.00 to 1.62 m/s.

Table 1
Technical specifications of rice transplanting machine and mist duster broadcaster

Specification	Transplanting machine	Broadcaster
Name	KUBOTA Rice transplanting machine	HARRY Mist Duster
Model	NSPU68C	3WF28
Max power, kW	12.5	2.13
Rated speed, rpm	3600	7500
Weight, kg	590	12.5
Drive type	4WD	Portable
Fuel type	Gasoline	Gasoline
Fuel tank capacity, l	17	1.8
Tray capacity /Material Tank	12 Mats	28 l
Planting rows/Outlet distance	6 Rows	12 m
Worker, person	2	1
Row to row spacing, cm	30	
Hill space, cm	12,14,16,18,21	
Planting Depth, cm	2–5	
Number of hills per, m2	90,80,70,60,50	
Seedlings height, cm	8 to 25	
Number of leaves	2-4.5	
Operation speed, m/s	0-1.62	

2.2. Soil Characteristics

The soil type in the study area is predominantly silty clay, belonging to the Selangor soil series (Vertic to Typic Dystropept) (Bockari et al., 2004). The conducted analysis showed that the size particle distribution was 1.22% sand (2000-50 μm), 45.44% silt (2–50 μm), and 53.33% clay (< 2μm) on average of all samples. The soil texture was classified based on the percentage of the sand, silt, and clay contents using the soil textural triangle. The textural classes were Clay 44.14%, Clay Loam5.1%, Silty Clay 43.36%, and Silty Clay Loam 7.4%. The soil material is composed of two main constituents, i.e. organic material and clay. There is some silt, but sand is either very little or absent. This soil has a moderate, medium, crumb structure (Shamshuddin et al., 1985). Soil taxonomy in this area includes Andisols and Ultisols. As mentioned in our publisher paper Mairganny et al., 2019 the soils of Sungai Burong Tanjung Karang Irrigation Project area are classified into fifteen soil series.

2.2. Data Collection

To test the suitability of the soil to transplanting, soil physical properties including bulk density, penetration resistance, and water content were collected before starting transplanting. For collecting mechanical transplanting data twelve locations were selected randomly in every plot immediately after transplanting and they were marked with wood sticks for monitoring and collecting the data for the whole season. The collected data included the number of plants per hill, seeds per meter, hill per square meter, the plant height, and lost plant per square meter, these factors were determined and recorded at 15-day intervals from planting day till harvesting day.

2.4. Bulk Density

Soil bulk density was determined from oven-dried undisturbed cores as mass per volume of oven-dried soil as in Eq. (1):

$$BulkDensity\left(g/cm^3\right) = M_d/V$$

1

$\mathrm{M_d}$ = Mass of dry soil sample (grams).

V = Soil volume (cm^3)

2.5. Penetration Resistance

Soil penetration resistance was measured using a penetrometer (Penetrologger, Eijkelkamp) with a cone angle of 60° and a conical point of 2 cm^2 (ASAE Standards, 2002). Each season SPR was measured to a depth of 80 cm after tillage. Each term had 30 measurements per farm. Cone index data were compiled and individual values were averaged for soil layers of 0–10 cm, 11–20 cm, 21–30 cm, 31–40 cm, 41–50 cm, 51–60 cm, 61–70 cm, and 71–80 cm.

2.6. Soil Water Content

The water content was measured was determined by weighing a moist sample, placing it in an oven at 105°C for 24 hours. The percentage of water in the soil on a dry basis is taken as the gravimetric water content. The water content in this method is measured as a percentage of the weight of water content to the weight of soil content (g/g) as in Eq. (2).

$$GMC\left(\frac{g}{g}\right) = \frac{Massofwetsoil - Massofdrysoil(g)}{Massofdrysoil(g)}$$

2

The flooding period is the period that the farmer submerges the field with water, flooding term was used here because the farmer uses too much water with very high water depth. The day date of inserting the water to flood the field after the second tillage, the depth of water, and the drainage of the water before puddling was recorded to determine the flooding period and the water depth. The sedimentation period is the time between water drainage from the field and the field puddling, as the soil settle and sediment. The day date of the third tillage which is puddling, and the planting date (transplanting or seeds broadcasting) was recorded to determine the sedimentation period which is the time between puddling and planting.

Immediately after transplanting the number of plant per hill, plant per square meter, hill per square meter, the plant height, lost hill per square meter included buried floated and missing hill per square meter, lost plant per square meter including buried, floated, and missing seedling per square meter, the distance between hill in the same row, and between hills in two rows, and the planting depth cm were determined and recorded using 0.5 m × 0.5 m frame that was placed at the 12 known locations mentioned above and the following data were collected till harvesting. For measuring transplanting parameters for the hectare, six planting lines which equal one transplanting working row in the two length edge was designed in each plot; and in each line, the number of the transplanted hill, number of missing hills per line, the number of floating hills, and the number of the buried hill, were counted, and recorded following and determined as a percentage to the total planted hills.

2.7. Water Irrigation Management Data

Irrigation gate data open and closed, water leakage, water drainage, and water depth in the field were recorded every week and before during, and after every fertilizer broadcasting and pesticide spraying operation. Boundary height m and width m and bunds weakness were noticed and recorded every week and before, during, and after every fertilizer and pesticide spraying operation. Water depth cm was measured before during and after the third tillage and transplanting using a metal ruler taking 30 measurements from each plot. The right amount was determined by measuring the water depth in several locations, if there was any location that has a lesser depth than what was mentioned in Rice Check that means the farmer does not follow Rice Check in terms of the right water amount. The water depth was measured by using a ruler by inserting the ruler carefully in the water until it reaches the top edge of the soil and then read from the soil top till the top of the water.

To determine the right time of irrigation and drainage, the time of inserting the water opening the irrigation gate, and opening the drainage gates was recorded for each plot, with recording the puddling and the planting day to determine if the farmer follows the schedule of Rice Check. To determine the right place that water should cover, the depth of water was measured in 30 different locations to determine if the depth is according to what required in Rice Check if there were some locations with a lesser depth that means the field was not fully covered and thus the farmer considered as not covered the whole area. During most times of the season, the water depth should be 10 cm, the water level should not be lesser than that.

2.8. Statistical Analysis Data

Data collected from the experiment were analyzed statistically using analysis of variance (ANOVA), which was performed using the Minitab 18 statistical analysis package. Differences between means were tested by using the least significant difference (LSD) test at the 0.05 level of probability. Pearson's Correlation Coefficient technique was used for investigating the relationship between the parameters. The strength of the association between the two variables was determined by using an MS excel sheet. The mean and coefficient of variation of all planting factors were computed to measure the variation.

Results And Discussions

3.1. Land preparation

Land flooding period range from 1 to 5 days with an average of (3.2 and 3) days with a high coefficient of variation CV (38.9 and 36.2) for the first and second season respectively, while the sedimentation period range from 4 hours to 24 hours with an average of (14.2 and 14.3) hours with a very high coefficient of variation CV (50 and 43.1) for first and second season respectively (Table 2), high coefficient of variation is an indication of inconsistency planting managing and land preparation which has a negative effect of mechanical transplanting performance. For high transplanting quality, the flooding periods should be shorter than the current ones, and the sedimentation periods should be longer than the current ones, which allow the soil to settle down and to be hard enough to hold and catch the desired number of seedlings in a vertical standing forming high standing angle (range from 80^{o} to 90^{o}), with the standardized spacing, and the least planting losses.

Table 2
Summary of data for land preparation and soil physical properties

Parameter	Mean	St. Dev.	CV	Uniformity	Max	Min
Flooding period, day	3.1 ± 0.4	1.2	38.5	61.5	5	1
Sedimentation period, hour	14.25 ± 2.01	6.5	45.5	54.5	24	4
[a] Penetration resistance, MPa 10 cm	0.12 ± 0.01	0.05	42.49	57.51	0.20	0.03
[a] Penetration resistance, MPa 20 cm	0.38 ± 0.02	0.11	30.07	69.93	0.60	0.20
[b] Penetration resistance, MPa 10 cm	0.17 ± 0.01	0.07	44.15	55.85	0.31	0.07
[b] Penetration resistance, MPa 20 cm	0.24 ± 0.02	0.16	67.13	32.87	0.59	0.05
[a] Bulk density, g/cm^3 10 cm	0.82 ± 9.01	0.09	10.43	89.57	1.05	0.65
[a] Bulk density, g/cm^3 20 cm	0.83 ± 0.01	0.08	9.97	90.03	1.05	0.67
[b] Bulk density, g/cm^3 10 cm	0.84 ± 0.01	0.10	0.01	11.50	88.50	1.05
[b] Bulk density, g/cm^3 20 cm	0.85 ± 0.01	0.09	0.01	10.16	89.84	1.05
[a] Mechanical Transplanting Speed	5.06 ± 0.18	1.07	21.21	78.79	6.84	2.34
[b] Mechanical Transplanting Speed	5.04 ± 0.14	0.98	19.37	80.63	6.84	2.34
[a] Water content % 10 cm	78.67 ± 1.02	6.24	1.02	7.93	92.07	94.63
[a] Water content % 20 cm	76.99 ± 0.99	6.07	0.99	7.88	92.12	94.63
[b] Water content % 10 cm	77.43 ± 1.12	7.95	10.27	89.73	94.63	62.71
[b] Water content % 20 cm	73.13 ± 1.19	8.48	11.60	88.40	94.63	58.66
Missing hill/ha	5735.0 ± 683.8 (2.9%)	2206.7	38.5	61.5	9000	1600
Floating hill/ha	991.4 ± 89.2 (0.51%)	287.9	29	71.3	1700	366.7
Buried hill/ha	578.7 ± 20.9 (0.3%)	67.3	11.6	88.4	737	453

[a] for the first season, [b] for the second season

Parameter	Mean	St. Dev.	CV	Uniformity	Max	Min
Total lost hill/ha	7305.1 ± 780. 0 (3.7%)	2517	34.5	65.5	11437	2587
[a] for the first season, [b] for the second season						

3.2. Effect of flooding and sedimentation periods on SPR

Flooding the field for 2 to 5 days led to increasing the soil water content up to 100% which led to softening the soil and as it reported in many types of research the negative relation between soil water content and penetration resistance so increasing water content resulted in decrease the soil penetration resistance. Flooding period reduction showed a negative significant effect on soil penetration resistance in 0 to 10 cm depth $P < 0.001$ and in 11 to 20 cm depth $P < 0.001$ for both seasons, while it was decreased with the increased flooding period. There was a high negative linear correlation between the flooding period and soil penetration resistance in the topsoil 10 cm $R^2 = 0.90$ and 0.91 and in hardpan 20 cm $R^2 = 0.83$ and 0.85 for the first and second season respectively (Fig. 1). Sedimentation period of the soil also significantly affect the soil penetration resistance positively $P < 0.001$ for both seasons if soil sedimentation period increased soil penetration resistance increased for, strong positive linear correlation topsoil 10 cm $R^2 = 0.94$ and 0.94 and for hardpan 20 cm $R^2 = 0.87$ and 0.90 for first and second season respectively (Fig. 1). The increase in soil penetration resistance with sedimentation period and that may because the dispersed particles of soil have settled again over time and also the water level in the field has decreased resulting in compacted soil and stable medium of soil layer which following that the soil strength increased and became high (Behera, et al., 2009).

Fig. 1 Linear correlation of penetration resistance versus flooding period (a) first season (b) second season, and versus sedimentation period (c) first season (d) second season

3.3. Effect of soil condition on transplanting working speed

The results of mechanical transplanting working speed showed a big variation as the coefficient of variation was 21.4%, which is very high (Table 2). The working speed of the transplanting machine was affected by the field condition, as the soil was very soft, the speed would be lower, and if the soil was hard enough to carry the machine the speed would be higher.

Soil penetration resistance affects the mechanical transplanting strongly, when the penetration resistance is high, the speed of transplanting becomes high, as the situation facilitates the running of the transplanting machines due to the ability of the top layer of the soil to hold the transplanting machine without sinking or bogging in the mud. The result showed that there was a very strong relationship between soil penetration resistance and mechanical transplanting working speed for both soil depth, R^2 was 0.88 and 0.86 for 0 to 10 cm depth, and 0.85 and 0.96 for 11 to 20 cm depth for the first and second season respectively (Fig. 2 and 3). It has been suggested by Singh et al., (1985) that soil penetration resistance values below 0.243 MPa represent the soft soil conditions, while values above 0.490 MPa represent the firm soil conditions. In the study area the mean soil penetration resistance at topsoil 0 to10 cm depth was 0.09 and 0.24 MPa and for the first and second season respectively, while the mean soil penetration resistance at hardpan 11 to 20 cm depth was (0. 0.17 and 0.38 MPa) for first and second season respectively which mean that these soils are too soft.

Fig. 2 The correlation between penetration resistance MPa and mechanical transplanting speed km/h for the depth of 0 to 10 cm for the first season

Fig. 3 The correlation between penetration resistance MPa and mechanical transplanting speed km/h for the depth of 11 to 20 cm for the second season

Soil bulk density affects the speed of mechanical transplanting, where the bulk density was high the speed of the mechanical transplanting will be high. The result showed that there was a strong positive linear correlation ship between bulk density and mechanical transplanting working speed for both soil depth, R^2 was 0.56 and 0.52 for 0 to 10 cm depth, and 0.58 and 0.57 for 11 to 20 cm depth for the first and second season respectively (Fig. 4 and 5). The highest bulk density facilitates the working of the mechanical transplanting without bogging or sinking in the soil mud, as the soil was settled and compacted to a certain limit, so the machines work easily and in a straight line. There was a negative effect of water content in the field and the transplanting working speed, as the water content increases, the working speed of mechanical transplanting, and the troubles of working increase. More water content means more soften and loosened soil which abandons the transplanting working. There was a very strong relationship between soil water content and mechanical transplanting working speed for both soil depth, R^2 was 0.51 and 0.69 for 0 to 10 cm depth, and 0.52 and 0.70 for 11 to 20 cm depth for the first and second season respectively (Fig. 6 and 7). The statistical analysis showed a positive relationship between transplanting working speed and row spacing R^2 = 0.86, planting distance R^2 = 0.84, hill/m^2, R^2 = 0.81, seedlings/hill, R^2 = 0.82, and seedlings/m^2, R^2 = 0.79. The result showed a negative relationship between speed and missing hill/m^2, R^2 = 0.83, floating hill/m^2, R^2 = 0.83, buried hill/m^2, R^2 = 0.73, and total lost hill/m^2, R^2 = 0.84 (Fig. 8). The highest working speed became an indicator for a well and perfect prepared land, and the lowest working speed and bogging in the soil is an indicator for bad and imperfect land preparation.

Fig. 4 The correlation between bulk density g/cm3 and mechanical transplanting speed km/h for the depth of 0 to 10 cm

Fig. 5 The correlation between bulk density g/cm3 and mechanical transplanting speed km/h for the depth of 11 to 20 cm

Fig. 6 The correlation between water content % and mechanical transplanting speed km/h for the depth of 0 to 10 cm for the first season

Fig.7 The correlation between water content % and mechanical transplanting speed km/h for the depth of 11 to 20 cm for the second season

Fig.8 The correlation between mechanical transplanting speed km/h vs. floating hills/m2, buried hills/m2, missing hills/m2, and total lost hills/m2

For broadcasted direct seeding, there were big variations in the working speed in general, but it was lesser than those of transplanting machines. Even for the same operator, there were big variations in the working speed CV = 14.9%, which affect the flow rates of the seeds that are directed to a certain equal area and that affect the seed distribution seeds/m^2, which means uneven plant density per square meter.

3.4. Depth of Transplanting

The maximum depth of transplanting was recorded as 4.4 and 4.8 cm for the first and second seasons respectively. Depth of transplanting was found to decrease with the sedimentation period, there was no significant difference in transplanting depth among treatments. A strong positive linear correlation between depth of planting with sedimentation period R^2 = 0.95 and 0.94 for the first and second season respectively. It was noticed that the depth of transplanting was affected negatively by the flooding period. The higher the flooding period the lower the depth of transplanting and vice versa. There was a strong negative correlation between transplanting depth with flooding period, R^2 = 0.95 and 0.91 for the first and second season respectively. Also, the depth of transplanting is affected severely by the soil penetration resistance. In this study, the higher the soil penetration resistance the higher the depth of transplanting. In the present study, the depth of transplanting was set at 5 cm. There was a strong positive linear correlation between depth of planting and penetration resistance in topsoil layer 10 cm R^2 = 0.97 and 0.98 and in the hardpan layer, 20 cm R^2 = 0.83 and 0.97 for first and second season respectively. Depth of transplanting is also affected by water depth in the field where the depth of water increased the depth of transplanting decreased and vice versa. There was a strong positive linear correlation between depth of transplanting and water depth during transplanting R^2 = 0.79 and 0.67 for the first and second season respectively.

3.5. Effect of soil properties on planting losses

Puddling harms the topsoil layer by loosening it more than the required level because the puddling operation performed in very high moisture content, it also, consumes a large quantity of the total water requirement in rice because farmers flood the field up to 10 cm for more than 2 days avoiding following Rice Check standard requirement. For efficient working of self-propelled rice transplanting machine, a suitable puddle soil condition, degree of puddling, an optimum depth of puddling, optimum bulk density, the standardized water depth, and soil strength of the puddle wheel should be done following the standard. This affects the spacing of transplanted paddy in the rows and between rows, the number of planting seedlings within the hill, degree of vertical standing, and depth of planting which should be maintained within the standardized system to obtain high quality of transplanting.

The means, standard deviation, and coefficient of variation of missing, buried, floating, and total lost hills per hectare are shown in and per square meter of transplanting performance are shown in Table 2 and Table 3 respectively. The percentage of total hill losses/ha was (3.6 and 3.9%) for the first and second season respectively (Fig. 9) and this amount of losses still within the permitted limit as the Japanese test code for transplanting machines using the mat type of seedlings prescribes a maximum of 5% defective hills for acceptable transplanting (Singh et al., (1985). Percentage of missing seedling/ha was (3 and 3.2%), floating hill (0.5 and 0.5%), and buried seedling (0.3 and 0.30%) for the first and second season respectively.

The important field parameters that affect transplanting quality are water depth, degree and depth of soil puddling, and soil flooding and sedimentation periods. The result showed strong negative correlation between missing hills with soil penetration resistance, the number of missing hill increases with reduction of soil penetration resistance in depth of 10 cm R^2 = 0.95 and 0.98, and in-depth 20 cm R^2 = 0.90 and = 0.98, strong negative correlation between floating hills with soil penetration resistance in depth of 10 cm R^2 = 0.92 and 0.77, and in-depth 11 to 20 cm (R^2 = 0. 0.88 and 0.64), strong negative correlation between buried hills with soil penetration resistance in depth of 10 cm R^2 = 0.89 and 0.91, and in-depth 20 cm R^2 = 0.77 and 0.82 strong negative correlation between total lost hills with soil penetration resistance, in-depth of 10 cm R^2 = 0.95 and 0.98, and in-depth 20 cm R^2 = 0.90 and 0.96 for first and second season respectively (Fig. 10).

Fig. 9 Percentage of hill planting losses of transplanting for the first and second season

Fig. 10 Linear correlation between penetration resistance and planting losses for transplanting (a) for the first season and (b) for the second season

3.7. Effect of water depth on planting losses

Flooding the field to a depth of 10 to 15 cm for long period leads to insufficient bearing strength to carry the machine and support the planted seedlings by creating softened and loosened soil and thus decreasing the penetration resistance and that is the main reason for planting losses. The result showed a strong positive linear correlation between water depth and missing hill but it is clear that polynomial correlation is stronger than the linear correlation. The linear correlation between water depth and missing hill/ha was strong R^2 =0.79 and 0.65 and the polynomial correlation R^2 =0.92 and 0.87, the linear correlation between water depth and floating hill R^2 =0.85 and 0.91 and the polynomial correlation R^2 =0.94 and 0.93, and the linear correlation between water depth and buried hill R^2 =0.94 and 0.85 and the polynomial correlation R^2 =0.94 and 0.91, and for total lost hill/ha there was a strong linear correlation with water depth R^2 =0.80 and 0.70 and the polynomial correlation R^2 =0.93 and 0.89, for first and second respectively (Fig. 11). The study showed that when the water depth is high and the soil is too soft and loosened, which lead the soil to stick with the transplanting machine wheels and planting becomes difficult and the transplanting machine bogged several times which led to more hill losses and unplanted area and messy field soil that need hand replanting which is normally not done with the same quality and density and spacing uniformity as transplanting machine does. It was concluded that maximum water depth should not be more than 2.5 cm in the field at the time of transplanting to reduce the drag force for the self-propelled transplanting machine. (Islam et al. 2015) reported that care should be taken to level the land before transplanting and water height should be maintained uniformly to avoid seedling submergence and floating hill.

Fig 11 Linear correlation between water depth and planting losses for transplanting (a) in the first season (b) in the second season

The study showed that the mean water depth in the field at the time of transplanting was 3.01 and 3 cm for the first and second season respectively, and the maximum water depth was 7 cm in low areas in the fields and this is considered as high water depth and it made many troubles for machine performance. The result showed that there was a big variation in water depth the coefficient variation CV was 14.24 and 16.63% for the first and second season respectively, the farmers do not follow the guidelines and instructions that included in Rice Check to flood the field for two days up to 5 cm water depth and the water level should not exceed 5 cm, and there should not be stagnant water, whereas the farmers flood the fields for 4 to 5 days up to 10 to 15 cm water depth and the drainage is very poor due to unlevelled land. In IRRI standard fields may need to be drained for two days to stop seedlings floating. Well puddled and leveled field is required with no standing water on the surface because it creates more floating hills (Guru et al., 2018). When the water in the field is more at the time of transplanting, the seedlings are not fixed properly in the soil and start floating. In general, for mechanical transplanting, it has been recommended that the depth of the puddle should be 5 cm and water depth not more than 2.5 cm.

3.9. Effect of flooding and sedimentation period on planting losses

The result showed that the flooding period has a significant effect on the percentage of floating hills $P < 0.001$, buried hills $P < 0.001$, missing hills $P < 0.001$, total lost hills significantly $P < 0.001$ in both seasons. The lower percentages of floating hills, buried hills, missing hills, and total lost hills were observed for one-day flooding periods, they decreased with the increase of the flooding period. There were a strong positive linear correlations between flooding period vs. floating hills, $R^2 = 0.91$ and 0.82, buried hills, $R^2 = 0.85$ and 0.92, missing hills, $R^2 = 0.91$ and 0.90, and total lost hill $R^2 = 0.92$ and 0.92 for first and second season respectively (Fig. 12). The highest percentage of floating hills, buried hills, missing hills, and total lost hills were observed after the longest flooding period which was 5 days. Those planting losses might be reduced by sufficient settlement of soil after the final preparation of the land by decreasing of flooding period from 5 to 1 day because surface soil of field avoided to became too soft and loosening whereas the soil of was settled down enough to reduce floating and buried hills and to reduce the picker missing hills.

Fig. 12 Linear correlation of planting losses versus flooding period for the first season (a), second season (b), and versus sedimentation period for the first season (c) and second season (d)

For perfect machine performance, the soil sedimentation period after puddle should be at least about 48 hours for heavy soils. The result showed a big variation in the sedimentation period between a different field with a high coefficient of variation 49.95 and 43.13% and that due to scarce of the number of tractors and the farmers need to till their fields. For ease of transplanting machine, soil sedimentation period after puddle should be enough to avoid machine bogging and inefficient performance. The sedimentation period has a significant effect on floating hills $P \leq 0.001$ and < 0.001 for the first and second season respectively, buried hills highly significant $P < 0.001$ for both seasons, missing hills/ha, and lost hills/ha $P < 0.001$ for both seasons. The percentage of floating hills, buried hills, missing hills/ha, and total lost hills/ha decreased with an increase in the sedimentation period. The highest percentages of mean floating hills, buried hills, missing hills, and total lost hills were after the shortest sedimentation period of 4 hours, and that may be due to the weakness of the seedling anchorage in wet soils and the movement of soil and water along with buoyancy. The lowest percentage of floating hills, buried hills, missing hills, and total lost hills were observed after 24 hours of sedimentation period and that due to the proper anchorage of seedlings with soil and less flow of puddled soil and water with the float at this sedimentation period. With the increase in sedimentation period soil got more strength and it became more coherent over time, also the flowing of the soil decreased along with buoyancy, this caused and led to the decrease in the buried and floating hills direct (Garg 1976; Kanoksak et al. 1988; Khan and Gunkel 1988). There was a high negative correlation between the sedimentation period and floating hills/ha, R^2 = 0.89 and 0.77, buried hills/ha, R^2 = 0.81 and 0.91, missing hills/ha, R^2 = 0.97 and 0.94, and total lost hill, R^2 = 0.96 and 0.95 for the first and second season respectively (Fig 12).

4.3. Water Irrigation Practices Quality

Table 6. Shows the water irrigation practices. Water management is a very important and crucial role in achieving a high grain yield.

Table 6
Practice Quality of Water Irrigation

DAY LAST DAY	Water level	Right source		Right amount		Right time		Right place		Quality Index
		P	N	P	N	P	N	P	P	
5–7 DAP	5	100	0	100	0	100	0	100	0	100
1–5 DAT	5	100	0	100	0	100	0	100	0	100
15–40	5	100	0	63.3	36.7	56.7	43.3	66.7	33.3	71.7
40–50	10	100	0	36.7	63.3	40.0	60.0	36.7	63.3	53.3
70	10	100	0	36.7	63.3	40.0	60.0	36.7	63.3	53.3
80–90	10	100	0	43.3	56.7	36.7	63.3	33.3	66.7	53.3
90–100	0	100	0	36.7	63.3	40.0	60.0	33.3	66.7	52.5
110–120	0	100	0	36.7	63.3	40.0	60.0	33.3	66.7	52.5
Average		**100**	**0**	**50.5**	**49.5**	**50.5**	**49.5**	**48.6**	**51.4**	**62.4**
• 5–7 DAP = for direct seeding method, 1–5 DAT = for transplanting method										
• P = positive. N = negative										

Water management is a very important and crucial role in achieving a high grain yield. In terms of choosing the right source which means here the right equipment and tool to irrigate the field in a short time, all farmers use the right sources, in terms of the right amount as mentioned very specifically with the required in Rice Check as in Table 6. About 50.5% of the farmers follow the standard, in terms of the time of irrigating the field, 50.5% follow the right time as mentioned in Rice Check, and for the place that water should cover which should be all the area through the field, 48.6% of the farmers covered the whole area with the adequate amount of water, whereas 51.4% of them do not perfectly cover the field because the amount of water is not enough besides the leveling of the land is not like the standard mentioned in Rice Check as it should be 100% leveled ± 5 cm and this degree of leveling could not be achieved unless farmers use laser leveling and that is costlier and not available in a wide range.

Farmers do not follow Rice Check in terms of the required water depth, and there was a big variation of water depth through the fields due to the imperfect land leveling. There were much water drainage and leakage during pesticide spraying and fertilizer broadcasting and that leads to losses, leaching, and environmental contamination. Most of the farmers do not drain the water 15 days before harvesting, this leads to destroying the soil by combine passing, and making grooves that prevent the whole drainage after harvesting thus delaying the tillage operation for the next season. Many times during the season, there was a low level of water, which may affect the grain filling, and reduce the fertilizer efficiency, and farmers should take more tension to maintain the level of water at 10 cm, this is very important for increasing the yield.

Farmers do not care about the required schedule of water irrigation for the rice plant and the required depth of water. Many times during the season, plants suffer from insufficient and inadequate water, which affects the grain yield. Also during fertilizers broadcasting and pesticide spraying operations, all the gates in or out of irrigation or drainage should be closed, but in reality, many times during these operations the gates were open because farmers forgot that. Also, the farmers do not keep the depth of water at the required level during these operations, which affects the quality of operations, especially during fertilizer broadcasting operations, and that share and cause fertility losses. Improve water control by better irrigation and drainage to achieve full potential yield rice is missing in the farming system. Producing optimum rice yields through continuous flooding irrigation with 10 to 15 cm of water depth is optimum for fertility efficiency, fighting weeds, grain filling, and high grain yield. Land leveling also affects the uniform and even distribution of the water in the field.

In terms of water irrigation efficient practices, 47.38% of farmers follow Rice Check. About 49.52% of farmers do not give the rice the adequate water amount, about 49.52% do not open the irrigation gate or close the drainage gate at the right time especially before and after fertilizer broadcasting and pesticides spraying operations, about 51.43% of them do not cover the whole area of the field with water due to unleveled land and inadequate water amount. About 63.33% do not drainage their field before harvesting and about 60% of them do not drain the field before harvesting at the right time, which cause a big problem in preventing drainage of the field after harvesting and preventing burning the straws and slashing the field and delaying first plowing due to the high water level.

Conclusion

For mechanical transplanting machines, the land must be well prepared for machine transplanting. The soil needs to be well leveled and has sufficient bearing strength to carry the machine and support the planted seedlings. Fields may need to be drained one or two days longer than the farmers do to stop seedlings from floating. The farmers should ensure that fields are well-puddled and well-leveled drain fields and allow mud to settle at least for 1 to 2 days after the final puddling. The topsoil layers need to be hard enough to support the transplanting machine. The soil should be able to hold the seedlings upright.

The percentage of floating and buried hills were affected by the level of field preparation. The farmers performed harvesting operations in saturated soil because do not follow the instructions of the Rice Check that stated for draining the field from the water before the harvesting operation at least 15 days to guarantee dried soil before harvesting. Harvesting the paddy in very high water content prevents perfect draining because of the grooves caused by the machine's tires. This field situation forces farmers to delay first plowing weighting the field to dry. In Rice Check first plowing should be done one week after harvesting if the farmers follow this requirement so the field will dry earlier but the farmers always delay the first plowing until one month or less before planting for the new season, and the field is still saturated with water thus the plowing lead to soften the soil to unintended level and result in very soft soil and had too low penetration resistance values for the upper top layer where plants are set.

Soil penetration resistance was measured to study the strength characteristics of puddled soil and its subsequent effect on transplanting machine performance. It was found that soil strength reduced severely after puddling to a depth of 20 cm, according to the land preparation practices. When the sedimentation period increased, the soil penetration resistance increased. The transplanting machines should be calibrated in the same situation of the working in terms of soil condition, soil type, seedling height, seedling density, actual plating distance between seedlings, row spacing between every two rows, and the number of missing seedlings and seedlings that dispensed in each stroke. Farmers should learn and gain agricultural engineering background to be qualified to monitor the transplanting quality for planting density adjustment, depth setting, and machine movement.

The finest preparation of land and field by performing a short flooding period (1 to 2 days) and long sedimentation period (2 to 3 days) pre transplanting is a crucial factor in enhancing quality planting with perfect uniformity and lesser planting losses. The main problems that occur during paddy transplanting are poor traction, sinkage, and steerability. For efficient working of self-propelled rice transplanter a suitable puddle soil condition, degree of puddling, optimum depth of puddling, optimum bulk density and soil strength of puddle wheel should be done following the standard.

The optimal soil physical properties are favorable for successful transplanting. The optimal seedling development and pre-treatments are necessary for successful transplanting. Puddling harms the topsoil layer by loosening it more than the required level because the puddling operation performed in a very high moisture content also consumes a large quantity of the total water requirement in rice. After all, farmers flood the field up to 10 cm for more than 2 days.

The performance of a rice transplanting machine largely depends on some parameters which should be in proper values to achieve the best output result after field performance. Further proper adjustment of the plant to plant distance can minimize the percent of skidding as well. Percent of missing hill floating hill, damaged hill, and buried hill can be minimized by maintaining proper transplanting depth and transplanting speed with a well-prepared field having the optimum bulk density and soil penetration resistance

Improve water control by better irrigation and drainage to achieve the full potential yield of rice. Produce optimum rice yields through continuous flowing irrigation. Continuous flooding with 10 to 15 cm of water depth is best for optimum grain yield, optimum nutrient supply, and excellent weed control with water depth and herbicides. Perfect water control increases grain quality as well as improves the efficiency of other inputs such as fertilizer, herbicide, and pesticides.

Declarations

We are the authors of this manuscript and we certify that there is no conflict of interest of this manuscript for all authors and this is a certification of that. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Tables 3-5

Tables 3-5 not available with this version

Figures

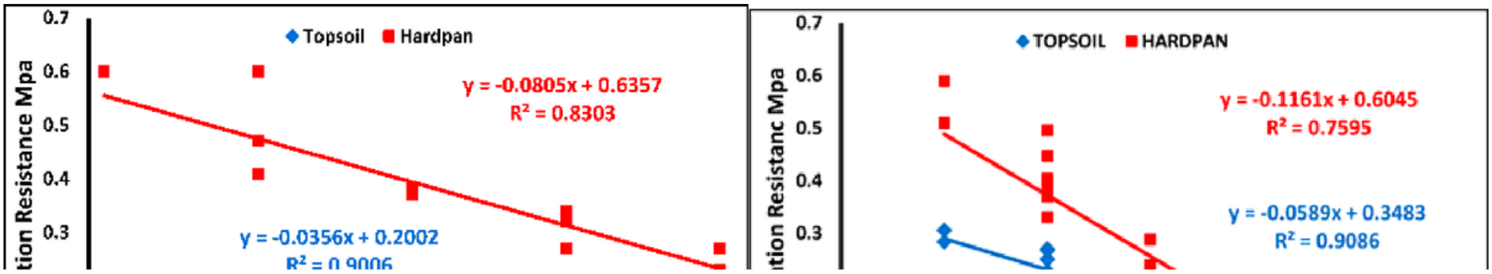


Figure 1

Linear correlation of penetration resistance versus flooding period (a) first season (b) second season, and versus sedimentation period (c) first season (d) second season

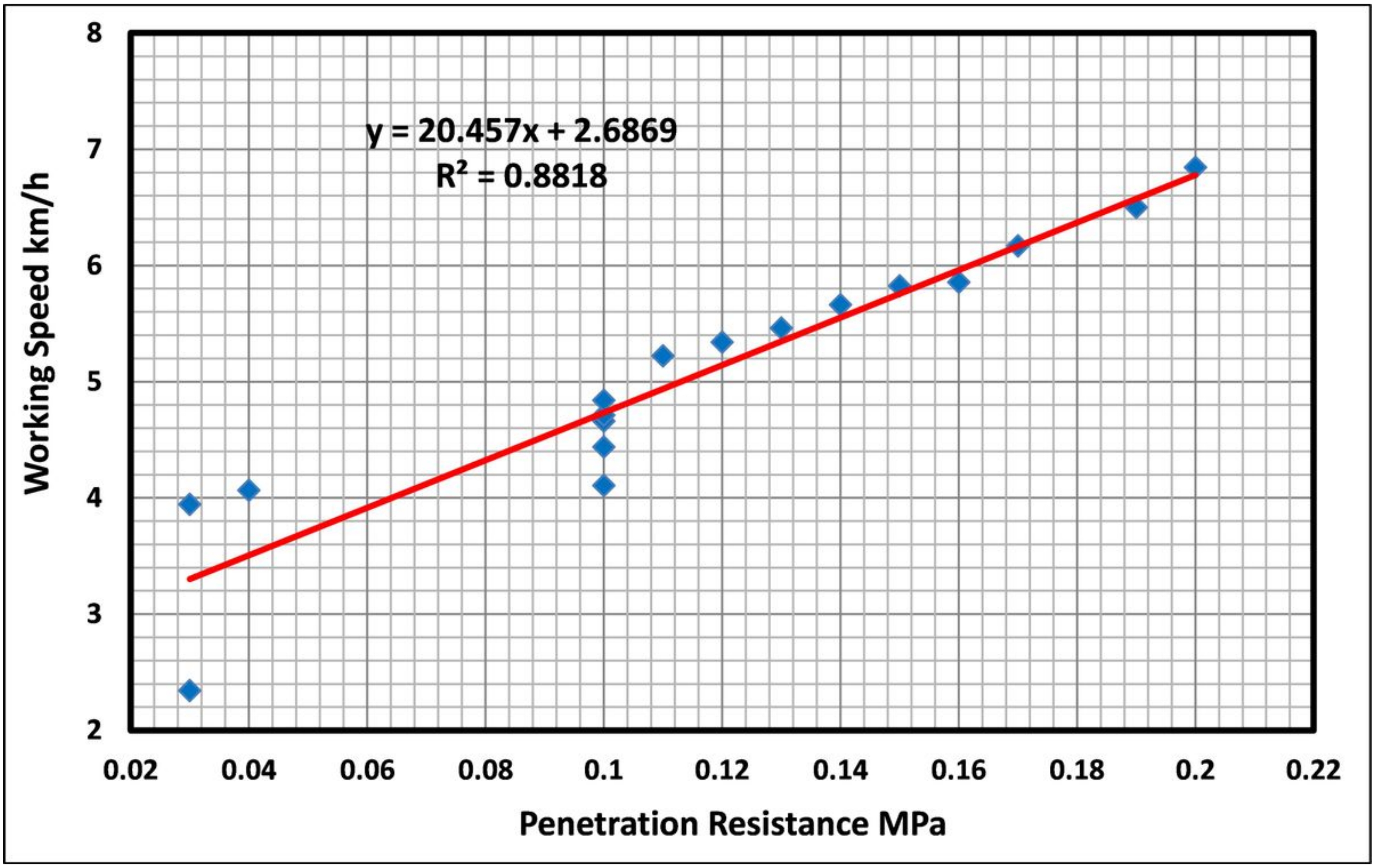


Figure 2

The correlation between penetration resistance MPa and mechanical transplanting speed km/h for the depth of 0 to 10 cm for the first season

Figure 3

The correlation between penetration resistance MPa and mechanical transplanting speed km/h for the depth of 11 to 20 cm for the second season

Figure 4

The correlation between bulk density g/cm^3 and mechanical transplanting speed km/h for the depth of 0 to 10 cm

Figure 5

The correlation between bulk density g/cm^3 and mechanical transplanting speed km/h for the depth of 11 to 20 cm

Figure 6

The correlation between water content % and mechanical transplanting speed km/h for the depth of 0 to 10 cm for the first season

Figure 7

The correlation between water content % and mechanical transplanting speed km/h for the depth of 11 to 20 cm for the second season

Figure 8

The correlation between mechanical transplanting speed km/h vs. floating hills/m^2, buried hills/m^2, missing hills/m^2, and total lost hills/m^2

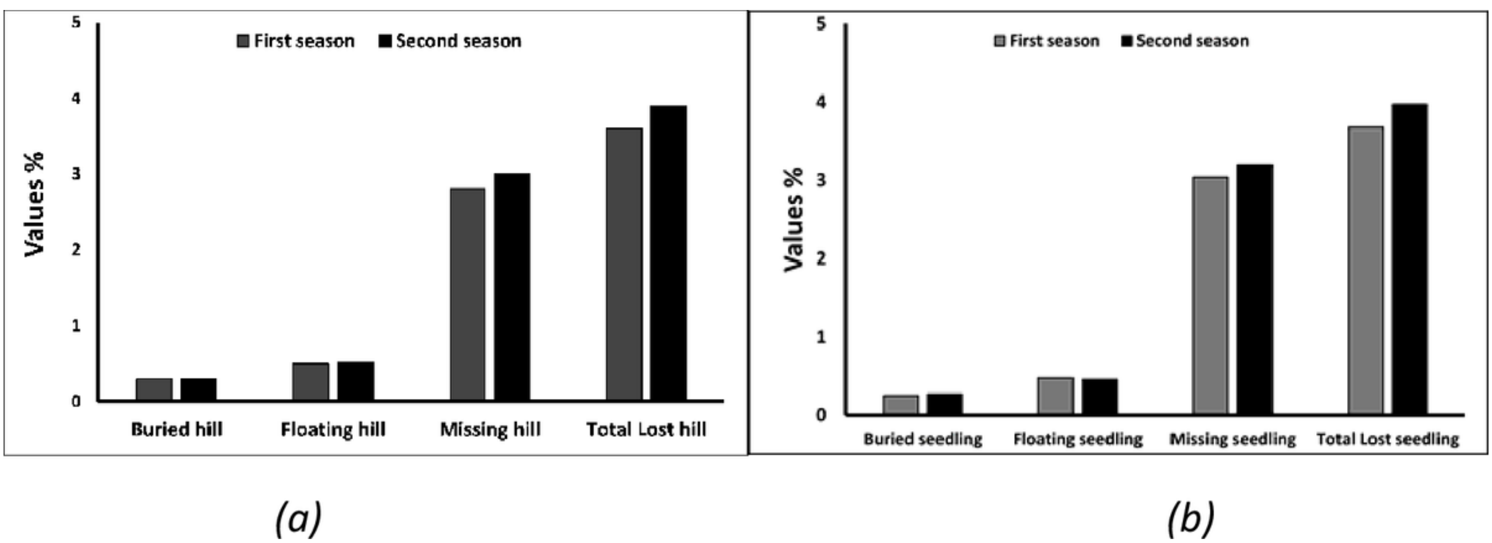
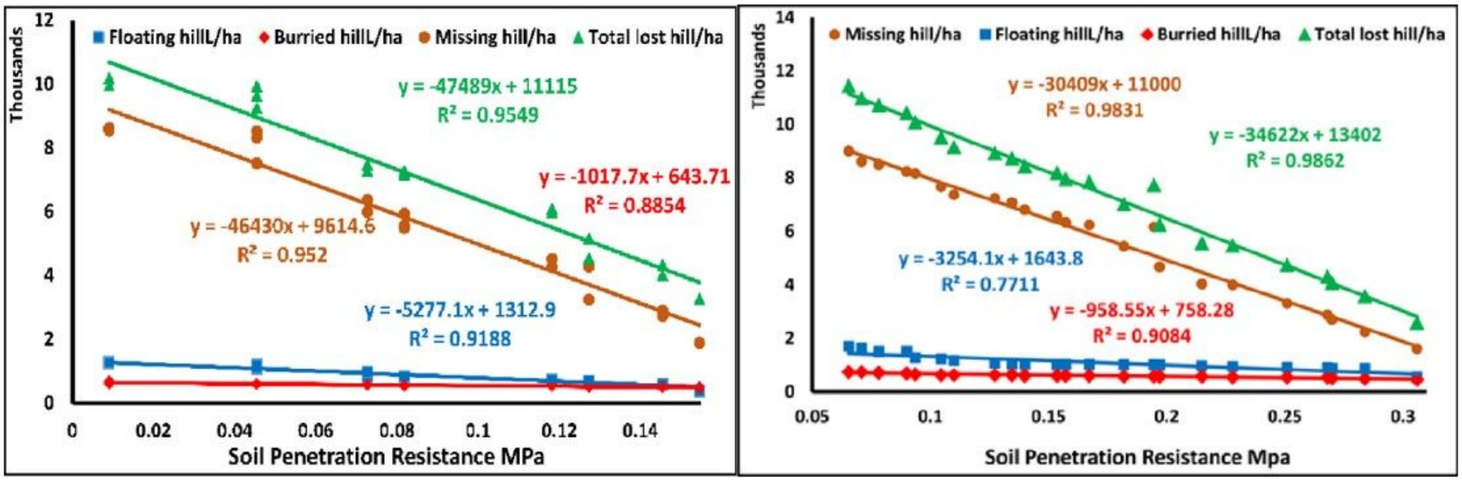


Figure 9

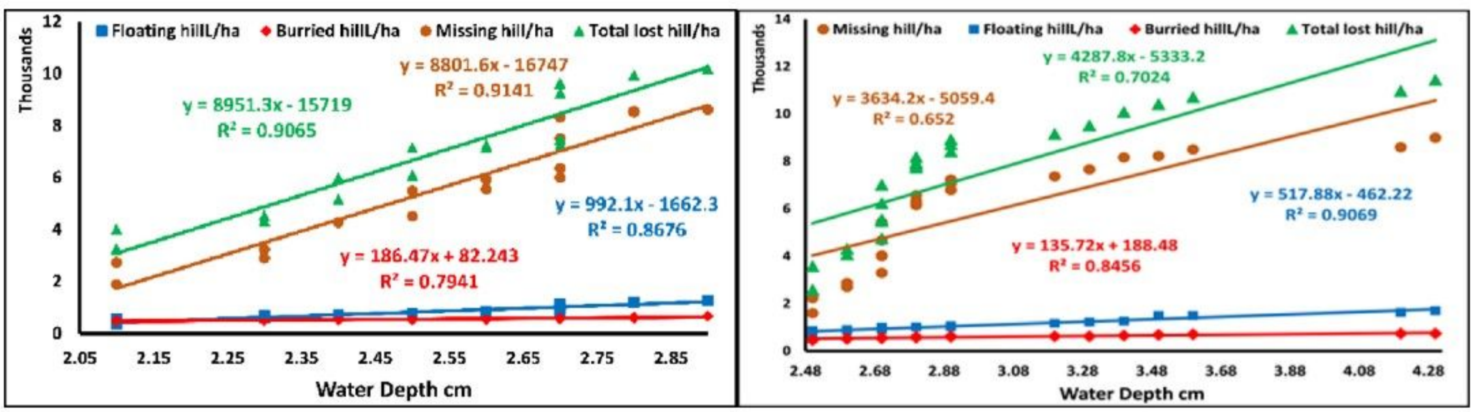
Percentage of hill planting losses of transplanting for the first and second season



(a) *(b)*

Figure 10

Linear correlation between penetration resistance and planting losses for transplanting (a) for the first season and (b) for the second season



(a) *(b)*

Figure 11

Linear correlation between water depth and planting losses for transplanting (a) in the first season (b) in the second season

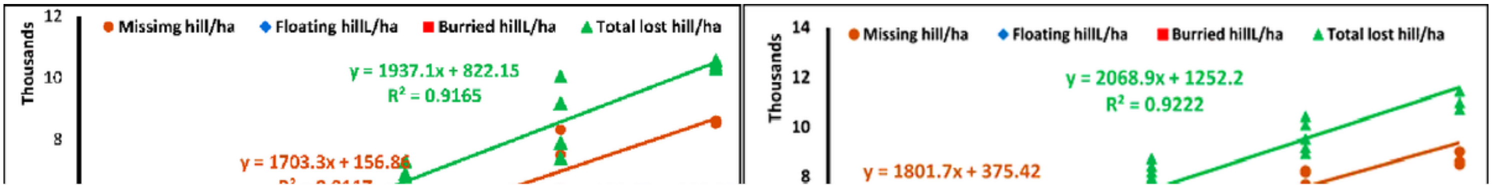


Figure 12

Linear correlation of planting losses versus flooding period for the first season (a), second season (b), and versus sedimentation period for the first season (c) and second season (d)

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