

RESEARCH ARTICLE

EFFECT OF LAND PREPARATION, WATER MANAGEMENT PRACTICES, AND PLANTING OPERATION ON PLANTING QUALITY IN RICE PRODUCTION

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ABSTRACT

This study was conducted at Sungai Burong Tanjung Karang Kuala Selangor, Malaysia to investigate the effects of planting methods and techniques on planting quality. The problem is that the farmers do not follow Rice Check quality points in land preparations for flooding, drainage, and water depth which affects the planting quality (planting density, spacing, and planting losses). The results showed that following standardized practices has a positive effect on planting quality. Soil penetration resistance and soil bulk density decrease with the increase of the field flooding period and increase with the sedimentation period increase. Soil penetration resistance and bulk density have a negative effect on planting losses. The working speed of the transplanting machine was affected by the field condition SPR, D_b , and WC affect the transplanting speed which affects the planting quality (planting density, spacing, and planting losses). The flooding period has a positive effect on planting losses, while the sedimentation period has a negative effect. Floating hills and buried hills decrease with the increase of flooding periods, and water depth, and with the decrease of the sedimentation soil penetration resistance, and soil bulk density. Bulk density and soil penetration resistance have a positive effect on planting density and spacing as they decrease, planting density and spacing decreases, and vice versa. The flooding period has a negative effect on planting density and spacing, while the sedimentation period has a positive effect. About 50.5% of the farmers used the right required amount of water for irrigation, and also the right time for irrigation.

KEYWORDS

Flooding Period, Sedimentation Period, Planting Quality, Uniformity and Evenness, Planting Losses.

1. INTRODUCTION

One of the great challenges that face people in the world every day is how to feed the greatest growth of the global population which is rising uncontrollably and is expected to increase to nine billion by the year 2050. While the availability of agricultural arable land is declining year after year due to the huge increase in urbanization, and the soil problems caused by flooding, drought, and increasing salinity levels. Also, weather conditions and climate changes could affect the harvested yield in both quality and quantity. Nowadays, agriculture is considered as very low income and discourages the sector for people to work in, and this also affects food production. Rice is one of the most essential staple foods for a large part of the world's human population as well as Malaysia.

The country depends on imported rice to meet the shortage of domestic production against demands. Increasing production and enhancing paddy productivity could be achieved through the implementation of the best and most effective agricultural practices and the quality of output of farming practices and operations. To realize world food sufficient based on agricultural food production, agricultural practices, and machinery operations must be managed in a quality manner to achieve high output within the same input used and minimize both the losses and miss placing inputs of the crop in the field. In Malaysia, rice planting has two seasons in

a year the main season which is the wet season from October to March, and the off-season which is the dry season from April to September. Planting rice has two methods the old method which is broadcasted direct seeding and the new technique rice seedling mechanical transplanting method. For broadcasted direct seeding, the seeding operation should be done on precisely leveled fields that are well-puddled and drained or shallow flooded.

The seeds broadcasting is usually done by broadcasting pre-germinated seeds using a mounted knapsack motorized mist duster. While mechanical transplanting is done by embroidering the mat seedlings in a well-leveled flooded puddled soil using 6 rows self-propelled transplanting machine. Perfect land leveling is a crucial factor for both BDS and MTP, because permits uniform and precise water irrigation control in flooding and drainage of the field, facilitates uniform and even water distribution and full coverage for the whole area, and thus increases the cultivation area by eliminating the bunds with reducing the amount of irrigation water needed and improve input use efficiency (water, nutrients, and agrochemicals), and increases crop productivity (Jat et al., 2006, 2009; Lantikan et al., 1999; Aryal et al., 2015; Chaudhary et al., 2022; Rickman, 2002; Kumar and Ladha, 2011). Land leveling affects the performance of mechanical transplanting, perfect leveling leads to a perfect transplanting performance which results in a uniform planting density and spacing.

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Realizing the targeted yield depend mainly on uniform plant emergence with optimum plant density in perfect planting spaces, these are crucial factors in planting quality either for BDS or MTP. Perfect crop emergence depends upon land preparation, planting date, seed rate and seed preparation, type of machinery used, the skills and qualifications of the operator, and the depth of seeding and seedling planting. In broadcasted direct seeding sometimes the sowing of the seeds was done in shallow standing water, in this case, the field should be drained within one day or two days maximum to achieve a perfect crop standing and establishments because young plants can tolerate the continuous flooding water just of 2 or 3 days maximum. Drainage of the excess water from the field wet broadcasted direct seeding is a crucial factor to realize a uniform, even, and perfect planting establishment. The drainage is achieved in a traditional style by making permanent ditches inside the field. Land leveling is carried out by using a tractor with a rear bucket and too rarely by using the laser control system.

Transplanted rice showed a significant effect as compared to direct-seeded rice in plant growth characters like plant height and plant population/m². At harvest, transplanted crops recorded a significant effect in all growth characters as compared to direct-seeded which might be due to optimum spacing between every two rows and the distance between a plant that resulted in less competition between the plants, higher nutrient uptake due to even planting distribution and lesser weed infestation, light interception and so, all the characters such as plant height, plant population/m² were more in transplanting condition than direct seeding (Konwar et al., 2018). To gain satisfied crop yield, there should plant a suitable amount of seeds in a suitable prepared area uniformly.

Land preparation and water management are the principal factors in achieving the planting quality in both broadcasted direct seeding and seedlings mechanical transplanting as land is prepared and puddled in standing water and soil are kept flooded during the whole season. (Farooq et al., 2011). For mechanical transplanting, the field should be well-puddled and leveled, this should be done in no standing water on the field surface as it causes more floating hills and thus increases the planting loses and decrease planting density and affect the planting quality (Guru et al., 2018). Saleem found that transplanting with 6-rows mechanical rice transplanter at a water depth of 2.5 cm produced a rice yield higher than 5.0 cm, and this water depth of 5.0 cm has rice yield higher than that of 7.5 cm water depth (Saleem, 2015). For perfect performance, the field should be puddled uniformly for 24 hours at least before the transplanting operation to let the puddle settle down completely and avoid soil flow which ensures perfect seedling establishment (Kumar and Kumar, 2012; Singh and Vatsa, 2006).

A group researchers suggest for the mechanical transplanting machine that the ideal condition is transplanting the seedlings 48 hours after puddling if the soil was puddled using a rotary puddler with a single pass and 36 hours after puddling if the soil was puddled with peg type puddler with two passes (Behera et al., 2009). Increasing the puddled soil's sedimentation period decreases the mechanical transplanting float sinkage, they suggest that a sedimentation period of 32 hours was the best for minimizing the percentage of missing, floating, and damaged hills (Goel et al., 2008). Some researchers found that mechanical transplanting seedlings without soil puddling resulted in a higher yield than that of puddled soil-transplanted rice (Kamboj et al., 2013).

To determine if the operation of the rotary picker is smooth and the isolation of the seedling mound from the mate is successful, this could be evaluated if the seedlings are properly bound to the soil and were distributed evenly and uniformly. Minimal tillage showed an advantage over ponds on clay loam soils to maintain physical condition and save field preparation time (Brown and Quantrill, 1973). The strength of the weak soil and deeper plowing through hindered the speed of the mechanical rice seedling transplanting machine, reduced the circumference of the steering wheel, and also reduced the distance between the plant from a range of spacing due to the slippage. The excessive degree of puddling has reduced the quality of the field performance of the rice transplanting machine. The high degree of puddling takes a longer settling period to restore the strength of the soil.

The working quality of a self-propelled rice transplanter requires appropriate soil puddling condition that includes the degree of puddling, optimum depth of puddling, and soil strength of the puddled field. The high degree of soil puddling affects severely mechanical transplanting mobility and performance. For the qualified performance of transplanting operation, the sedimentation period should be longer (Behera et al., 2009). More research is needed to identify the ideal soil puddling requirement such as optimum flooding period, optimum water depth for flooding, optimum puddling level, and degree, optimum soil physical properties,

and optimum sedimentation period.

Tillage operation showed significant effects on soil physical properties soil penetration resistance and bulk density regardless of tillage depth and soil type. The field flooding period showed a significant effect on soil penetration resistance as it decreases when the inundation period increases regardless of seasons wet or dry and soil types. The causes of soil penetration resistance decrease might be the soil type, soil texture, amount of clay in the soil, and soil settlement after puddling. Soil penetration resistance varied largely with water content, soil texture, soil type and amount of clay, and soil particle density (Bhagat, 2003). Rice transplanter traction development is directly related to soil penetration resistance and depth of the hard surface of the plow pan (Behera et al., 2009).

Puddling harms the topsoil layer by loosening it more than the required level because the puddling operation is performed with 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 the efficient working of a self-propelled rice transplanting machine, a suitable puddle soil condition, degree of puddling, an optimum depth of puddling, optimum bulk density, 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, the degree of vertical standing, and the depth of planting which should be maintained within the standardized system to obtain high-quality transplanting.

Some researchers reported that puddling tillage is a traditional practice that farmers used to follow in wetland rice cultivation areas, Lal reported that the purpose of puddling is 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 (Lal, 1985; Sharma and De Datta, 1986). It is recommended that water depth be maintained at 5 to 10 cm until panicle initiation to promote tillering and early growth (Heenan, 1987). 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 (Choudhury and Kennedy, 2005). In this study, Rice Check was used as a benchmarking standard for farming practices and operations. 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.

The quality of rice mechanical transplanting depends also upon the seedling quality in the mat seedling. The seedling density, planting establishment, and the evenness and uniformity of seedlings in the seedling tray, are crucial factors that control the seedling density in the field and the missing and lost hill after transplanting. The optimal rate of rice seeding is very important for establishing and adequate plant population in a uniform and even manner (Runsick and Wilson, 2009; Hossen et al., 2018). The total number of loses hills depends mainly on the failure of the mechanical transplanting machine to pick and place the seedling in the soil that causes the damaged hills, buried hills, and floating hills. Damage hills and floating hills varied significantly with the tillage options responded irrespective of seasons and soil types. Buried hills responded significantly to the interaction between tillage operations and the inundation period.

The optimum inundation period might reduce floating hills under minimum tillage. Hills' density depends on the interaction of tillage with the inundation period. The deep depth of transplanting as a result of sinkage of the float might be another cause of buried hills. Sufficient soil settlement after puddling could reduce the buried hills. Mufti and Khan reported the seedling density and its uniformity in the mat seedling is the most reason for missing hills Mufti and Khan, 1995). The hole created by the transplanter rotary picker was not refilled by mud or loosed soil after seedling placement which result in more floating hills because of seedlings ungripped in the field. The mechanical rice transplanting operation under minimum tillage was found satisfying regardless of soil type especially rice production under strip tillage (Hossen et al., 2017). The quality of planting establishes the plant in a perfect condition that allows the crop to grow healthy and in proper spacing with an optimum density with the least seeding and planting losses.

The uneven field surface is the main factor that influences the performance

of rice seedlings' mechanical transplanting, well puddled and leveled fields with no standing water on the soil surface crucial role in planting quality as it creates more floating hills. Before the transplanting operation, the fields should be puddled uniformly and left for 24 hours at least to allow the puddled soil to settle down completely and to avoid soil flow to ensure better seedling establishment. Mechanical self-propelled rice transplanting machine has many problems with wet puddled soil in wetland cultivation areas as same as other agricultural machinery. Poor traction, sinkage, and steerability are the main problems of the transplanting machine. As reported by many researchers that 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 research 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 was 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, 2002). This problem could be avoided if the field was prepared properly and did not loosen more than the soil required level, the soil should have sufficient bearing capacity to hold the machine without sinking (Behera, 2009).

The unevenness of the land which is worst leveled associated with a lack of uniform water distribution causes large variations in planting density and spacing within the field. Applying laser-assisted precision land leveling allowed the mechanical transplanting machine and seeds broadcaster to place seedlings and seeds at a uniform spacing and distance and depth, and enabled uniform distribution of irrigation water across the field, resulting in a uniform crop stand. Rice Check has recommended the Leveling of 1.5 to 2 cm of standard deviation rice planting (Kawasaki, 1989; Kimura et al., 1999; Kumar and Ladha, 2011). Uniform and evened crop emergence with optimum plant density is the crucial factor for achieving the targeted yields for any system, including BDR or MTP.

The farmers tend to soften and loosen the topsoil too much which leads to these problems with the mechanical transplanting machine. Farmers do not follow Rice Check recommendations in drainage of the field before the harvesting operation this makes it impossible to drain the field after harvesting due to the huge grooves made by the harvester, which leads to submerging the soil with water for a long time and delay the first plowing, and that leads to softening and loosening the soil more than the required. Planting spacing has a major effect on crop yields (Kumar and Ladha, 2011). A group researchers reported that, as the seed rate increases, tillering density decreases (Huan et al., 1999). The panicle density depends mainly on the primary tillers more than on the secondary or tertiary tillers. Since panicle densities are more productive from primary tillers than those from secondary and tertiary tillers, farmers should be sure to plant the crop in an optimal spacing to produce more panicles with high density from primary tillers, because optimal spacing guarantees minimum interplant competition. Much research on plant spacing and distance should be done for optimizing transplanting performance (DeDatta, 1981). This optimal spacing should be followed by both broadcast direct seeding BDS and mechanical transplanting MTP.

Much preliminary research approved that planting density is a crucial role in improving plant population structure, facilitating, and achieving efficient solar radiation usage, organizing rice tiller distribution uniformly, and forming grain yield (Nakano, et al., 2012; Gravois, et al., 1992; Clerget et al., 2016; Hayashi et al., 2006; Nakano et al., 2012; San-Oh et al., 2008; Wang, et al., 2014; Xu, et al., 2014). Planting density and spacing reported that optimum panicle density in a uniform maturity is a crucial role in realizing optimum rice yield (Gravois and Helms 1992; Fageria et al., 2014; Ottis and Talbert, 2005; Wells and Faw (1978; Qin et al., 2013; Nakano et al., 2012; Hayashi et al., 2006; Huang et al., 2013; Huang et al., 2018; Chen et al., 2016).

Farming planting practices do not achieve the required planting density and spacing, for transplanting the soil conditions affect their performance and that lead to planting missing, number of hill per square meter, number of seedlings/hill, and number of seedlings/m², is not done as the required. Also, the field condition affects the row spacing which is not adjustable, and the distance between the plants, which were calculated based on previous research, so any negative effect could affect the performance of planting growth. The field condition and land preparation affect also the depth of planting and the planting angle which affect plant growth. So, the

imperfection of land preparation is the main reason for the weakness of mechanical transplanting performance.

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.

This study was conducted under actual field operations in 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, the output of the two operations planting density, planting spacing, planting losses and uniformity, the effect of field situation and land preparation on planting quality.

2. MATERIALS AND METHODS

2.1 Description of The Study Area

The experiments were conducted during the first season which is the main season, started in June and finished in November 2017, and the second season which is off-season started in 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 and is located within the total area that is under the management of the Northwest Integrated Agricultural Development Authority (BLS IADA) Rice Scheme which is considered 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

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, m ²	90,80,70,60,50	
Seedlings height, cm	8 to 25	
Number of leaves	2-4.5	
Operation speed, m/s	0-1.62	

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 of 2017 and 23 plots in the second season of 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.

2.3 Soil Characteristics

Soil taxonomy in this area includes Andisols and Ultisols. As mentioned in our publisher paper by the soils of the Sungai Burong Tanjung Karang Irrigation Project area are classified into fifteen soil series (Mairghany et al., 2019). These are Kranji, Banjar, Sedu, Jawa, Sempadan, Karang, Telok, Selangor, Bernam, Bakau, Serong, Brown Clay, Briah, Organic Clay and Unclassified series. Kranji, Banjar, and Karang are developed on the marine alluvium along the coast and riverine alluvium along the Bernam River (Aimrun et al., 2011). Brown Clay, Briah, and Organic Clay are transition soils between the mineral soils and the peat soils in the swamp. They are composed of brown clays derived from brackish water deposits and organic clays and muck which originated from peat soil. Within Block C however, there are only two major soil series namely, Telok Series (Typic Sulfaquept) and Jawa Series (Fine, Mixed isohyperthermic Sulfic Tropaquept). The soil type in the study area is predominantly silty clay, belonging to the Selangor soil series (Vertic to Typic Dystrypept) (Bockari et al., 2004).

2.4 Data Collection

To test the suitability of the soil for 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.

2.5 Bulk density D_b

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

$$\text{Bulk Density } D_b \text{ (g/cm}^3\text{)} = M_d/V \quad (1)$$

M_d = Mass of dry soil sample (grams).

V = Soil volume (cm³)

2.6 Penetration Resistance

Soil penetration resistance was measured using a penetrometer (Penetrologger, Eijkelkamp) with a cone angle of 60° and a conical point of 2 cm² (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.

2.7 Soil Water Content WC

The water content measured was determined by weighing a moist sample and 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 equation (2).

$$GMC \left(\frac{g}{g} \right) = \frac{\text{Mass of wet soil} - \text{Mass of dry soil (g)}}{\text{Mass of dry soil (g)}} \quad (2)$$

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 a 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) were recorded to determine the sedimentation period which is the time between puddling and planting.

Immediately after transplanting the number of plants 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 were designed in each plot; and in each line, the number of the transplanted hill, the number of missing hills per line, the number of floating hills, and the number of the buried hill, were counted, and recorded.

Missing hills is defined as the ratio of the number of missed hills to the total number of transplanted hills per square meter it is expressed in percentage and it can be calculated by the following equation (3).

$$\text{Missing hills} = \frac{H_m}{H_t} \times 100 \quad (3)$$

Where:

H_m = Number of missing hills per square meter area.

H_t = Total number of transplanted hills per square meter area.

The missing hills are defined as the ratio of the number of hills missed during the transplanting operation to the total number of planted hills per square meter and are expressed in percentage and calculated by the following equation (4).

$$\text{Floating hills (\%)} = \frac{H_f}{H_t} \times 100 \quad (4)$$

Where:

H_f = number of floating hills/m².

H_t = Total number of hills/m² in the sampling area.

Buried hills are defined as the ratio of the number of hills buried in the mud during transplanting to the total assumed number of hills in a specific area and are expressed in percentage. They were calculated using the following formula (5).

$$\text{Buried hills (\%)} = \frac{H_b}{H_t} \quad (5)$$

Where:

H_b = number of buried hills/m²

H_t = Total number of transplanted hills/m²

Total hills is the number of hills enclosed in the 1 × 1m area.

2.8 Water Irrigation Management

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 into the water until it reaches the top edge of the soil and then read from the soil top to the top of the water.

To determine the right time of irrigation and drainage, the time of putting the water and opening the irrigation gate and opening the drainage gates

was recorded for each plot, with a recording of 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 was 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.

2.9 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.

3. RESULTS AND DISCUSSIONS

3.1 Land Preparation

The 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° to 90°), 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	3.10±0.40	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 % 10 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 % 10 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
Total lost hill/ha	7305.1±780.0 (3.7%)	2517	34.5	65.5	11437	2587

^afor the first season, ^b for the second season.

3.2 Effect of Flooding and Sedimentation Periods on SPR

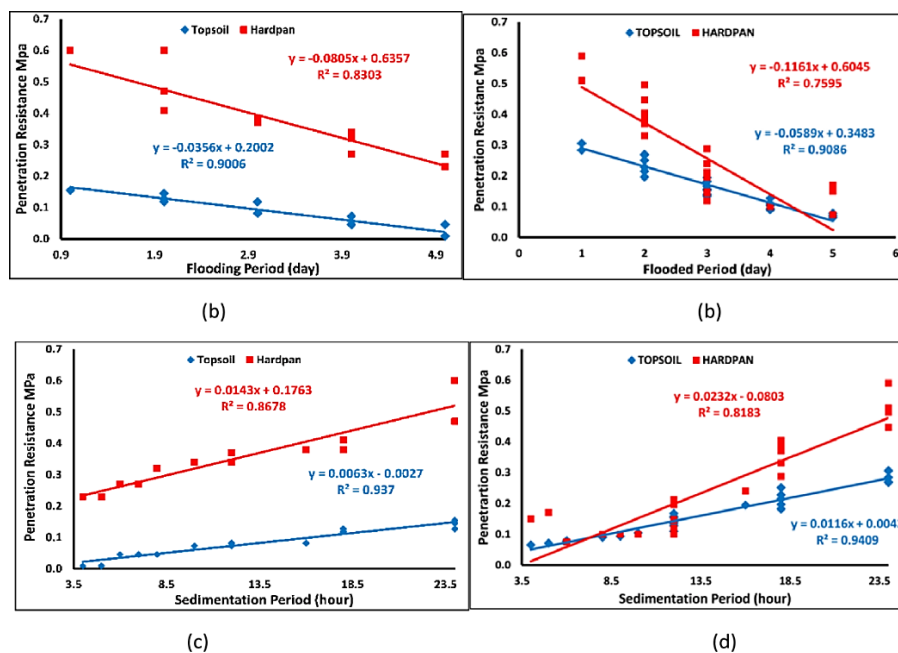


Figure 1: Linear correlation of penetration resistance versus flooding period (a) first season (b) second season, and versus sedimentation period (c) first season (d) second season

Flooding the field for 2 to 5 days led to increasing the soil water content up to 100% which led to softening the soil as reported in many types of research the negative relation between soil water content and penetration resistance so increasing water content resulted in a 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 seasons respectively (Figure 1).

The sedimentation period of the soil also significantly affects 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 (Figure 1). The increase in soil penetration resistance with the sedimentation period may be 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 a stable medium of soil layer which following that the soil strength increased and became high (Behera et al., 2009).

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 3). 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.

Table 3: Planting Working Speed km/h For Mechanical Transplanting and Broadcasted Direct Seeding						
Planting Method	Mean	Size	St. Dev.	C.I	CV	Uniformity
Mechanical Transplanting	5.01	14.00	1.07	0.19	21.41	78.59
Broadcasted Direct Seeding	5.07	9.00	0.80	0.18	15.74	84.26

Soil penetration resistance affects 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 depths, 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 (Figures 2 and 3).

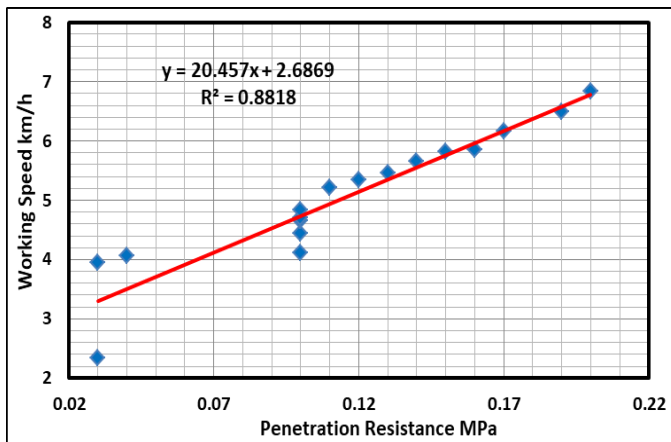


Figure 2: The correlation between penetration resistance MPa and mechanical transplanting speed km/h for the depth of 0 to 10 cm for the first season

It has been suggested by a group researcher that soil penetration resistance values below 0.243 MPa represent soft soil conditions, while values above 0.490 MPa represent firm soil conditions (Singh et al., 1985).

In the study area, the mean soil penetration resistance at topsoil 0 to 10 cm depth was 0.09 and 0.24 MPa for the first and second seasons respectively, while the mean soil penetration resistance at hardpan 11 to 20 cm depth was (0.17 and 0.38 MPa) for first and second season respectively which mean that these soils are too soft.

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 (Figure 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.

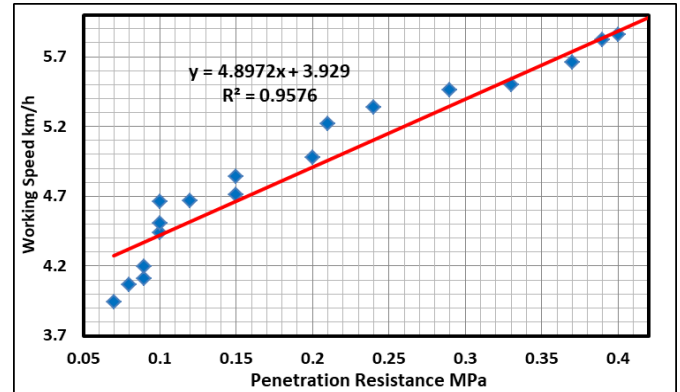


Figure 3: The correlation between penetration resistance MPa and mechanical transplanting speed km/h for the depth of 11 to 20 cm for the second season

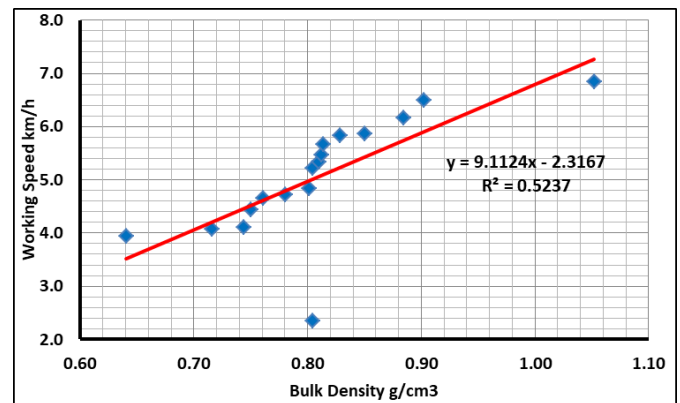


Figure 4: The correlation between bulk density g/cm³ and mechanical transplanting speed km/h for the depth of 0 to 10 cm

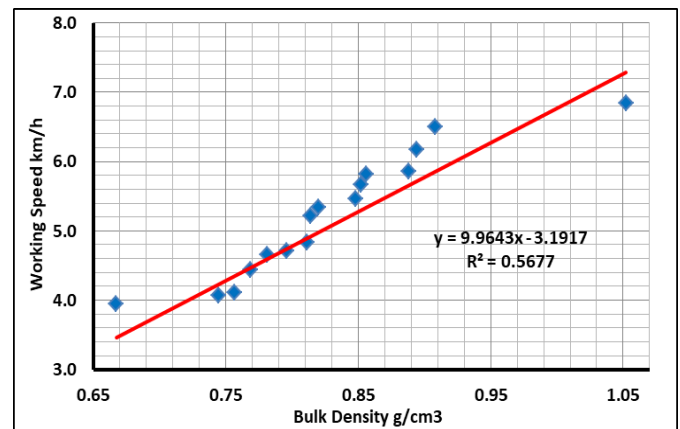


Figure 5: The correlation between bulk density g/cm³ and mechanical transplanting speed km/h for the depth of 11 to 20 cm

There was a negative effect on the 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 increased.

More water content means more softened 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 depths, 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 (Figures 6 and 7).

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 increased. More water content means more softened 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 depths, 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 (Figure 6 and 7).

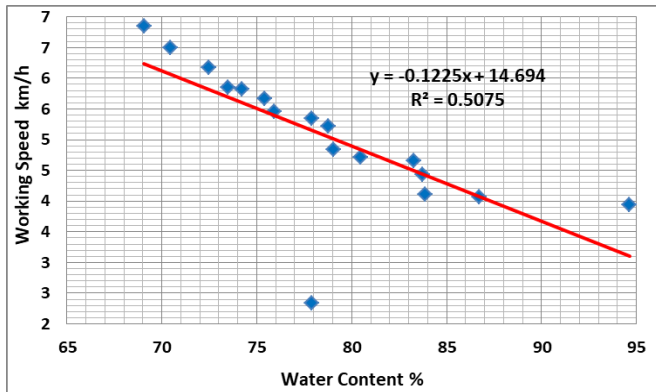


Figure 6: The correlation between water content % and mechanical transplanting speed km/h for the depth of 0 to 10 cm for the first season

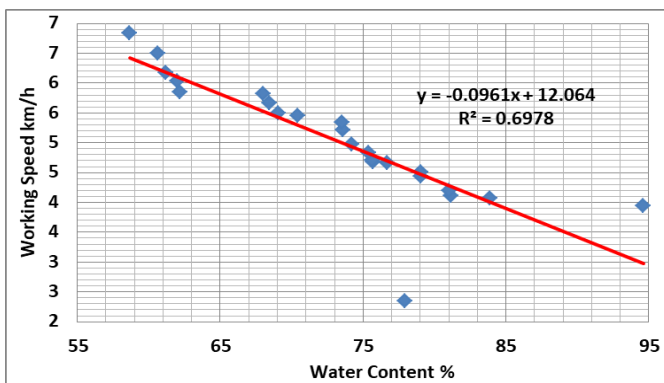


Figure 7: The correlation between water content % and mechanical transplanting speed km/h for the depth of 11 to 20 cm for the second season

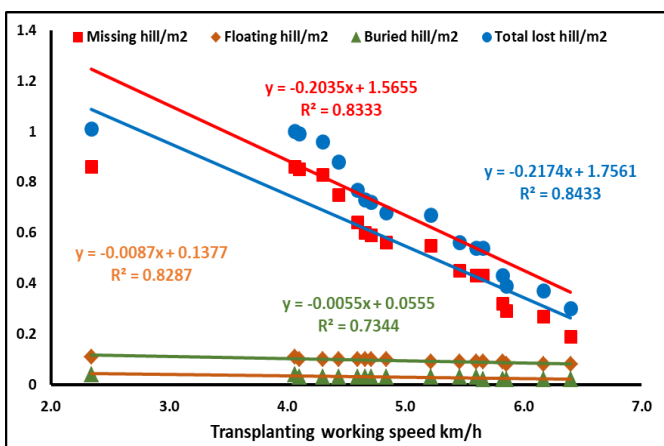


Figure 8: The correlation between mechanical transplanting speed km/h vs. floating hills/m², buried hills/m², missing hills/m², and total lost hills/m²

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/m², $R^2 = 0.81$, seedlings/hill, $R^2 = 0.82$, and seedlings/m², $R^2 = 0.79$. The result showed a negative relationship between speed and missing hill/m², $R^2 = 0.83$, floating hill/m², $R^2 = 0.83$, buried hill/m², $R^2 = 0.73$, and total lost hill/m², $R^2 = 0.84$ (Figure 8). The highest working speed became an indicator of a well and perfectly prepared land, and the lowest working speed and bogging in the soil is an indicator of bad and imperfect land preparation.

For broadcast 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 affects the flow rates of the seeds that are directed to a certain equal area and that affects the seed distribution seeds/m², 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. The 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 the depth of planting with sedimentation period $R^2 = 0.95$ and 0.94 for the first and second seasons 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 during the flooding period, $R^2 = 0.95$ and 0.91 for the first and second seasons 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 the depth of planting and penetration resistance in the 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 the first and second seasons respectively. The 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 the depth of transplanting and water depth during transplanting $R^2 = 0.79$ and 0.67 for the first and second seasons 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 is performed with 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 a self-propelled rice transplanting machine, a suitable puddle soil condition, degree of puddling, an optimum depth of puddling, optimum bulk density, 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, the degree of vertical standing, and the depth of planting which should be maintained within the standardized system to obtain high-quality transplanting.

The means, standard deviation, coefficient of variation of missing buried floating, and total lost hills per square meter and per hectare of transplanting performance are shown in Table 3. The percentage of total hill losses/ha was (3.6 and 3.9%) for the first and second seasons respectively (Figure 9) and this amount of losses is 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). The percentage of missing seedling/ha was (3 and 3.2%), floating hill (0.5 and 0.5%), and buried seedlings (0.3 and 0.30%) for the first and second seasons 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 hills 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 ($R^2 = 0.88$ 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 (Figure 10).

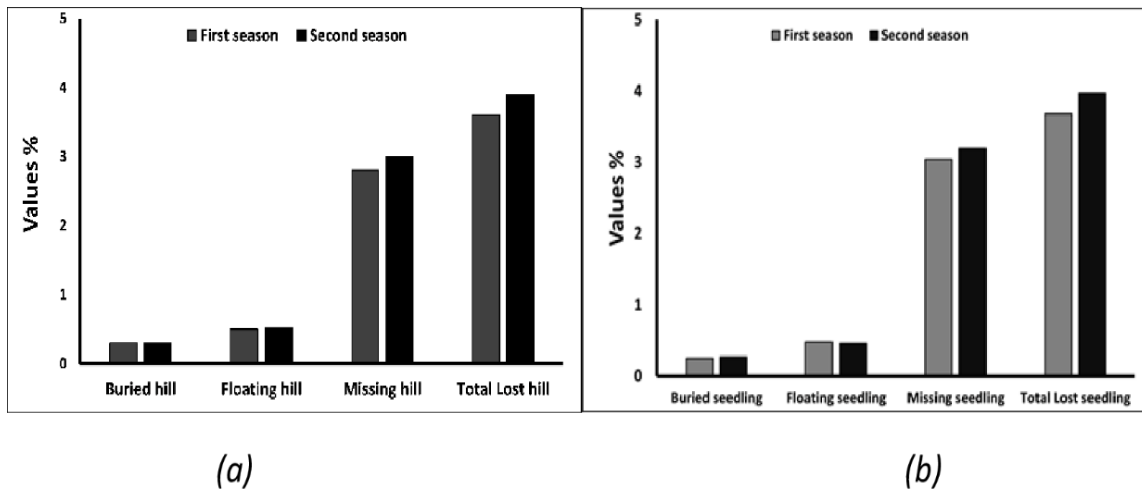


Figure 9: Percentage of hill planting losses of transplanting for the first and second season

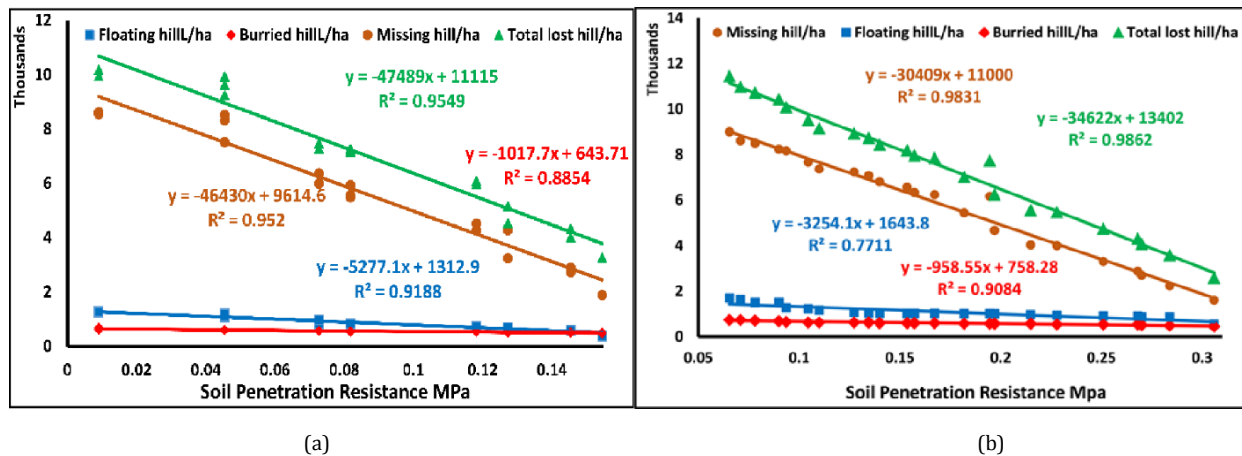


Figure 10: Linear correlation between penetration resistance and planting losses for transplanting (a) for the first season and (b) for the second season

3.6 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 the 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 (Figure 11).

The study showed that when the water depth is high and the soil is too soft and loosened, which lead the soil sticks to 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 needs hand replanting which is normally not done with the same quality and density and spacing uniformity as transplanting machine does. It was concluded that the 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. A group researchers 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 (Islam et al., 2015).

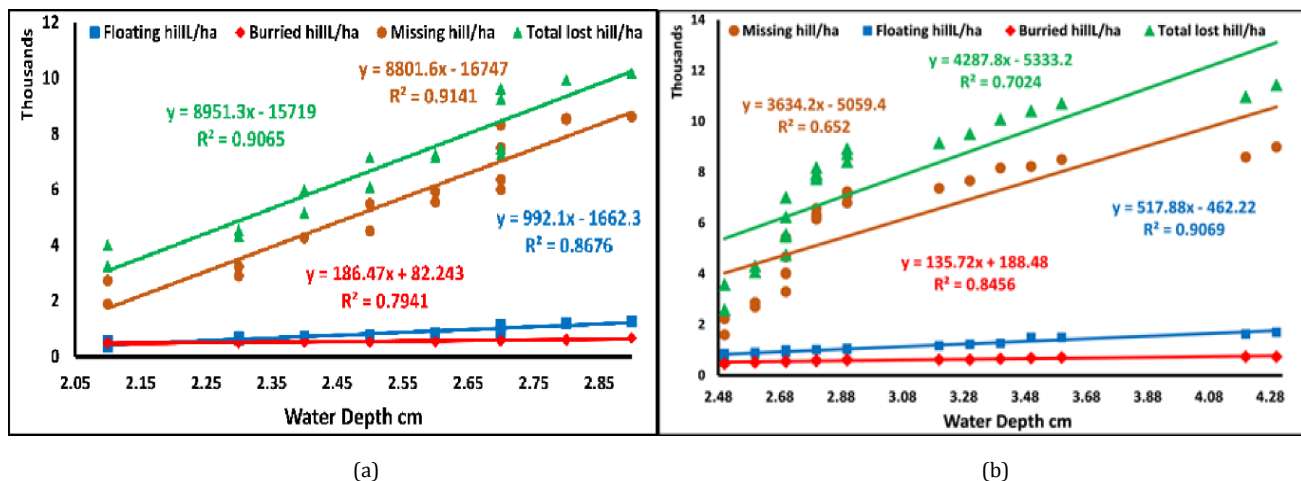


Figure 11: Linear correlation between water depth and planting losses for transplanting (a) in the first season and (b) in the second season

The mean water depth in the field at the time of transplanting was 3.01 and 3 cm for the first and second seasons respectively, and the maximum water depth was 7 cm in low areas in the fields this is considered a 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 seasons respectively, the farmers do not follow the guidelines and instructions 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 from 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.

3.7 Effect of Flooding and Sedimentation Period on Planting Losses

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 (Figure 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 the sufficient settlement of soil after the final preparation of the land by decreasing of flooding period from 5 to 1 day because the surface soil of the field avoided to become too soft and loosening whereas the soil was settled down enough to reduce floating and buried hills and to reduce the picker missing hills.

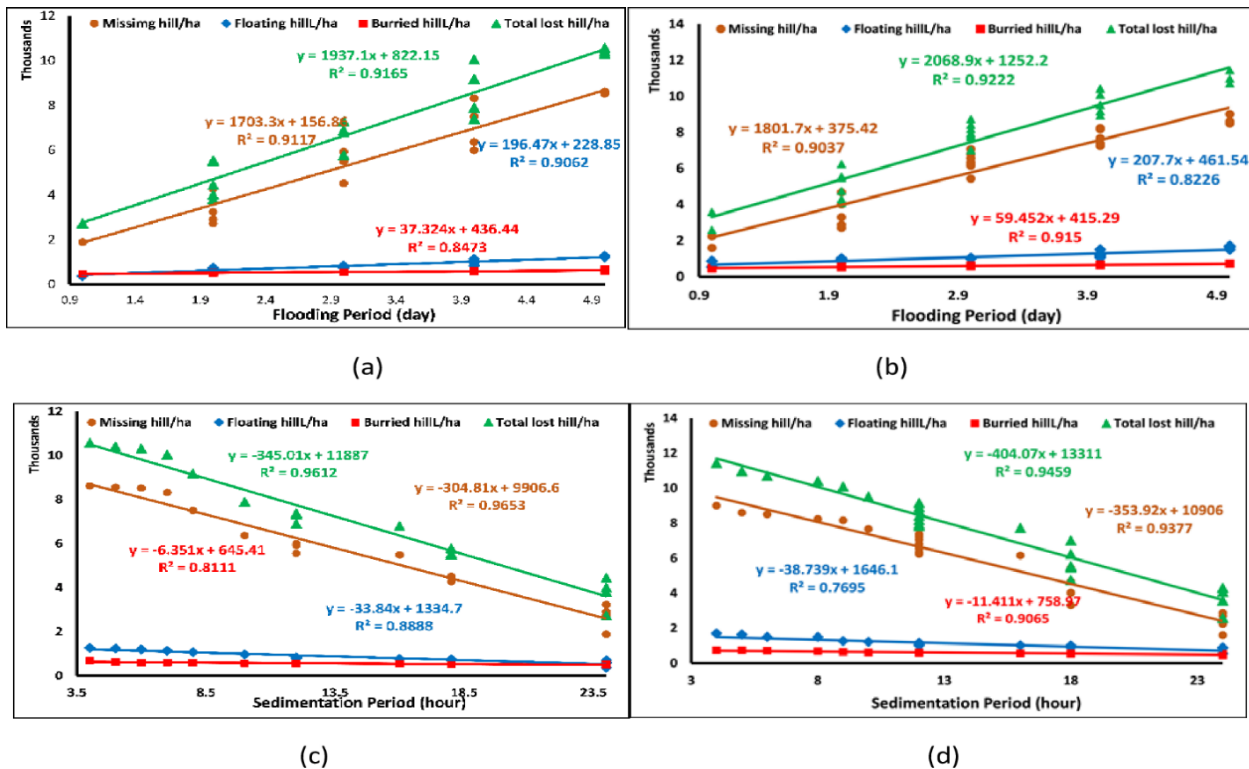


Figure 12: Linear correlation of planting losses versus flooding period for the first season (a), second season (b), and versus sedimentation period for the first season (c) and second season (d)

For perfect machine performance, the soil sedimentation period after the puddle should be at least about 48 hours for heavy soils. The result showed a big variation in the sedimentation period between different fields with a high coefficient of variation of 49.95 and 43.13% due to the scarcity of the number of tractors and 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 first and second seasons 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 the sedimentation period due to the proper anchorage of seedlings with soil and less flow of puddled soil and water during the float during this sedimentation period.

With the increase in sedimentation, period soil got more strength and became more coherent over time, also the flowing of the soil decreased along with buoyancy, which 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 (Figure 12).

3.8 Planting Density and Spacing

The result of work quality and accuracy of the planting including planting density, spacing, planting uniformity, planting depth, and planting losses for mechanical transplanting for the first and second seasons are presented in Table 3. For mechanical seedling transplanting, the mean number of 281 hill/m² was 23.4 and 23.5, seedling/hill 5.6 and 5.5, and seedling/m² 139.1 and 139.4 for the first and second seasons respectively. The coefficient of variation of seedlings per hill was 2.70 with a standard deviation of 0.13, showing that the agronomical requirement of 5-6 seedlings per hill was achieved in the study. Establishing high planting density is very important to gain higher tillers density that 285 can achieve high grain yield as stated that grain yield increased either linearly or curvilinearly with increased plant density (Nguu and De Datta., 1979). Ensuring good crop stands through optimal combinations of agronomic practices is important for improving yields (Sharma, 1985).

The flooding period affects the planting density of hill/m², seedling/hill, and seedling/m² negatively, whereas the flooding period increases, the planting density of mechanical transplanting decreases and vice versa.

There were a strong negative correlation between flooding period and hill/m², R² = 0.90 and 0.74, seedling/hill R² = 0.92 and 0.75, and seedling/m², R² = 0.88 and 0.81, for the first and second season, respectively. On the contrary, the sedimentation period affects the planting density of hill/m², seedling/hill, and seedling/m² positively

whereas the sedimentation period increases, the planting density of mechanical transplanting increases, and vice versa. There were a strong negative correlation between sedimentation period and hill/m², R² = 0.93 and 0.69, seedling/hill, R² = 0.94 and 0.66, and seedling/m², R² = 0.92 and 0.81, for the first and second season, respectively.

Table 4: The Work Quality And Accuracy of Planting for Transplanted Farms During The Main and Off-Season 2017 and 2018

Factor	First Season			Second Season			P-value
	Mean	St. Dev.	C.V %	Mean	St. Dev.	C. V.	
Row Distance cm	29.5±0.1	0.25	0.8	29.5±0.11	0.3	0.9	0.5 ns
Hill Distance cm	17.0±0.5	1.15	6.7	17.2±0.41	1.0	6	0.6ns
Planting depth cm	3.96±0.1	0.3	7.7	4.0±0.2	0.4	9.5	0.6 ns
Plant Height cm	10.8±0.2	0.4	3.8	10.8±0.2	0.5	4.7	0.9 ns
Seedling/hill	5.6±0.2	0.4	7.1	5.5±0.1	0.3	6.2	0.5ns
Hill per/m ²	23.4±0.1	0.19	0.8	23.5±0.1	0.16	0.7	0.1ns
Hill per/ha	(2.3±0.3)×10 ⁵	0.62×10 ⁵	2.7	(2.3±0.22)×10 ⁵	0.54×10 ⁵	2.3	0.7ns
Seedling/m ²	139.1±1.4	3.03	2.2	139.4±1.4	3.4	2.4	0.8 ns
Seedling/ha	(12.9±0.5)×10 ⁵	0.95×10 ⁵	7.35	(12.7±0.3)×10 ⁵	0.85×10 ⁵	6.7	0.6ns
Missed hill/m ²	0.6±0.1	0.21	38.4	0.6±0.1	0.2	37.5	0.7ns
Missed seedling/m ²	3.3±0.6	1.28	38.4	3.5±0.5	1.3	37.5	0.7ns
Buried hill/m ²	0.03±0.00	0.01	19.49	0.03±0.00	0.01	28.01	0.6ns
Buried seedling/m ²	0.14±0.01	0.03	19.49	0.14±0.02	0.04	28.01	0.6ns
Buried hill/ha	278.43±26.24	55.2	19.83	238.86±38.76	94.84	39.71	01ns
Buried seedling/ha	1364.31±128.6	270.5	19.83	1194.28±193.70	474.2	39.71	0.2ns
Floating hill/m ²	0.09±0.00	0.01	9.82	0.08±0.01	0.02	21.03	0.04*
Floating seedling/m ²	0.47±0.02	0.05	9.82	0.43±0.04	0.09	21.03	0.04*
Floating hill/ha	941.18±43.94	92.4	9.82	921.74±35.00	85.64	9.29	0.5ns
Floating seedling/ha	4677.65±218.40	459.4	9.82	4605.13±173.69	425.01	9.23	0.6ns
Missed hill/ha	5567.4±1017.4	2140.3	38.4	5858.9±898.6	2198.8	37.5	0.7ns
Missed seedling/ha	33404.6±6104.4	12841.5	38.4	35153.2±5391.7	13193.0	37.5	0.7ns
Total Lost hill/m ²	0.7±0.1	0.2	32.8	0.7±0.1	0.2	32.4	0.8ns
Total Lost seedling/m ²	4.0±0.6	1.3	34	4.1±0.6	1.4	33.2	0.8ns
Total Lost hill/ha	6787.05±1064.98	2238.7	32.98	7033.21±935.50	2289.08	32.55	0.7ns
Total Lost seedling/ha	39446.60±6368.28	13396.72	33.96	41021.35±5593.66	13687.13	33.37	0.7ns

In compacted soil, the firmer soil with higher soil penetration resistance at the topsoil layer exactly in the depth of 0 to 10 cm was the main factor contributing to better stand establishment and planting density for the propelled transplanting machines, and vice versa for the very soft and loosened soil was the main cause of the lower stand establishment and planting density, that mainly due to the poor anchorage of seedlings in soft soil. This finding was supported by who found that in the compacted soil, the planting density and the percentage of hills seedlings established were 13 to 14% greater than seedlings density in the puddled soil (Hemmat, and Taki 2003). They reported that soil puddling destroyed the soil aggregations, broke capillary pores, dispersed fine clay particles, and reduced soil strength in the topsoil layer.

The coefficient of variation of seedling/hill was 2.70% with a standard deviation of 0.13, showing that the agronomical requirement of 5 to 6 seedlings per hill was achieved in the study. The mean row spacing was (29.5 cm) for both the first and second seasons. During the experiment row to row, the distance was maintained at nearly 30 cm which the machine performance was adjusted to work with, which considers much closed to the adjusted row spacing of 30 cm, the performance of the transplanting machine in-row spacing was much more uniform as the coefficient of variation was 0.8 and 0.9% for the first and second season respectively, the actual spacing was 98.33% of the adjusted row spacing, the standard deviation of row spacing was too small 0.3% for both seasons. Generally, the row spacing is consistent and very near to the standardized spacing and there was no significant effect on it by the soil condition such as soil penetration resistance, water depth, and flooding and sedimentation periods.

The mean hill spacing was (17.0 and 17.2 cm) for the first and second seasons respectively, and this distance was ranged from 18 to 20 cm in the population data because the hill or plant-to-plant spacing accuracy affected by operators' skills and soil condition, in general, hill spacing was

observed lesser than the prefixed spacing of 18 cm for the transplanted fields and thereafter, it became closer to the prefixed spacing with the decrease in flooding period, water depth, and increase in sedimentation period and penetration resistance. However, it was typical of the preset spacing in some fields with medium soil penetration resistance, zero water depth, long sedimentation period, and short flooding period. The sedimentation period had a significant effect on hill spacing. Hill spacing depends on the traction wheel slip. Higher hill spacing might be due to a low wheel slip than the designed slip for the transplanting machine. As the sedimentation period increased the wheel slip increased resulting in a decrease in hill spacing. The subsurface soil layers need to be hard enough to support the transplanting machine.

The result of the work quality and accuracy of planting including seeding/planting density, spacing, planting uniformity, planting depth, and planting losses for broadcasted direct seeding rice for the first and second seasons are presented in Table 4. The broadcasted seeds rate was 138.4 and 138.6 kg/ha which equals 13.8 and 13.9 g/m² for the first and second seasons respectively, there was no difference in seed rate between saturated and flooded fields as it should be higher for the flooded field due to the expected loss. The seeding density of seeds/m² in the saturated field was 414.8 and 467, the established plant/m² 416.3 and 470.2 with germination 88.8 and 88.5%, while for flooded fields 441.9 and 448.3, the established plant was 401.5 and 408.50 with germination 90.9 and 91.1 for first and second season respectively.

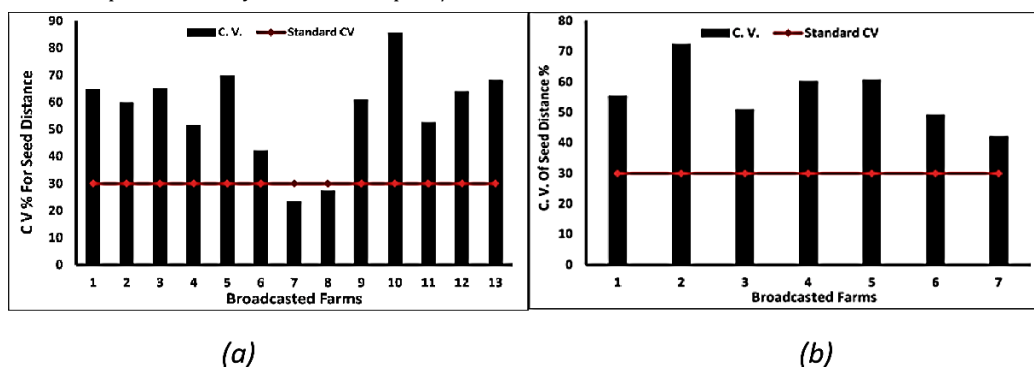
Farmers flow the flooded field technique instead of the saturated field when they feel that the germination ratio of the seeds is too low, so staying the seeds in the water for a long time improved the germination ratio. The mean distance between seeds was 7.3 and 6.7 cm for the first and second seasons respectively. Based on the broadcasted seeds and 1000 grain weight, the standardized distance between seeds should be 5.4 cm (4.5 and 6.4 cm as the nearest and furthest distance), and the current distance is 35.2 and 241% more than the standardized distance.

Table 5: The Work Quality and Accuracy of Planting for Broadcasted Direct Seeding Farms During the Main and Off-Season 2017 and 2018

Parameter	First season			Second season			P-value
	Mean	St. Dev.	C.V %	Mean	St. Dev.	C.V	
Broadcasted seeds kg/ha	138.4±3.4	6.2	4.5	138.6±4.4	5.9	4.3	1 ns
Sowing rate g/m ²	13.8±0.3	0.6	4.5	13.9±0.4	0.6	4.3	1 ns
Seeds distance cm	7.3±2.0	1.6	22.2	6.7±1.5	2.8	23.0	0.5 ns
Seeds/m ² (saturated)	467.0±55.2	74.6	16.0	470.2±41.3	76.0	16.2	0.9 ns
Seeds/ha (saturated)	(4.9±0.1)×10 ⁶	0.2×10 ⁶	4.5	(5.0±0.2)×10 ⁶	0.2×10 ⁶	4.3	1 ns
Seeds/m ² (flooded)	441.9±38.8	71.5	16.2	448.3±53.0	71.6	16	0.5 ns
Seeds/ha (flooded)	(4.9±0.1)×10 ⁶	0.2×10 ⁶	4.5	(5.0±0.2)×10 ⁶	0.2×10 ⁶	4.3	1 ns
Missing seeds/m ² (saturated)	40.0±19.7	36.3	90.6	39.3±28.5	38.5	98.1	1 ns
Missing seeds/ha (saturated)	(0.4±0.2)×10 ⁶	0.4×10 ⁶	90.6	(0.4±0.3)×10 ⁶	0.4×10 ⁶	98.1	1 ns
Missing seeds/m ² (flooded)	40.0±19.7	36.3	90.6	39.3±28.5	38.5	98.1	1 ns
Established plant/m ² (saturated)	414.8±44.9	82.55	19.9	416.27±63.62	85.88	20.63	1 ns
Established plant/m ² (flooded)	401.5±31.7	58.3	14.5	408.5±48.9	61.2	15	0.8 ns
Germinated seeds/ha (Saturated)	(4.2±0.3)×10 ⁶	0.6×10 ⁶	14.0	(4.2±0.4)×10 ⁶	57×10 ⁶	13.6	1 ns
Established plants% (saturated)	88.2%	5.7	6.4	89.1%	3.9	4.4	0.7 ns
Missing plant/m ²	55.4±19.5	35.85	64.71	50.69±23.51	31.74	62.61	0.7 ns
Missing plant/ha	(52±0.2)×10 ⁶	0.3	64.6	(0.5±0.2)×10 ⁶	0.3	51.9	0.7 ns
The standing angle of the plant	84.9±1.0	1.8	2.1	85.6±1.1	1.5	1.7	0.3 ns

The number of established plants per square meter was significantly increased by increasing seeding rates for both seasons. The result showed a strong positive polynomial correlation between the seeding rate and established plant $R^2 = 0.72$ and a moderate positive linear correlation $R^2 = 0.60$. Some researchers suggested that optimum seeding stands for direct-seeded rice ranging from 160 to 215 established plant/m², but in the Rice Check standard, the optimum density of established plant/m² is

400 (Jones and Snyder 1987). The actual plant stand established with seed broadcasting was uneven due to the uneven broadcasting of the seed, and the main reason for uneven and ununiformed seed distribution is uneven seed spacing. The seeding spacing in broadcasting has a wide variation, the coefficient of variations of seeding space ranges from 23.38% to 85.62% which is considered very high (Figure 13).

**Figure 13:** Coefficient variation of seed distance for the first season (a) and second season (b)

3.9 Planting Establishing Uniformity

Mechanical transplanting of rice seedlings into well-puddled waterlogged and drained soils gives an even established plant for seedling/hill the coefficient variation was 7.1 and 6.2%, for hill/m² coefficient of variation was 0.8 and 0.7%, for hill/ha coefficient of variation was 2.7% and 2.3%, for seedling/m² coefficient of variation was 2.2 and 2.4%, and for and for seedling/ha coefficient of variation was 7.35 and 6.7%, for the distance between rows coefficient variation was 0.8 and 0.9%, while for the distance between hills coefficient of variation was 6.7 and 6% for first and second season respectively (Table 4). Coefficient variation for row distance is quietly lower than that of plant spacing because it is unadjustable, while the distance between hills is adjustable and affected by machine speed, field condition, water depth, and soil penetration resistance. The optimum planting density (hill/m², seedling/hill, and seedling/m²), and plant spacing between transplanted rice make them mature uniformly taking enough water, fertility, and sunlight without high competition from other plants, in contrast to direct seeding where there is a high competition due to uneven distribution, high density, and too narrow plant spacing. Due to this, a significant increase in the yield of transplanted rice which features a highly uniform density.

In contrast, broadcasting germinated seeds into well-puddled waterlogged flooded or drained soils gives an uneven established plant due to uniformity of broadcasted seeds/m² which had a coefficient of variation of 16.2 and 16%, uneven spacing between seeds with the

coefficient of variation of 23 and 22.1% for first and second season respectively, which led to uneven stand establishment in the plant within areas where the land is not well leveled or water is not well controlled and drained, coefficient of variation for saturated field 19.9 and 20.6%, and flooded field 14.5 and 15% for first and second season respectively (Table 5). Commonly, lowland fields are not well leveled, which means that they can neither be completely drained nor flooded to an even depth.

3.10 Water Irrigation Practices Quality

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.

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

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 which 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 combining passing, and making grooves that prevent the whole drainage after harvesting and 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 uniformity and even distribution of the water in the field.

4. 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 and 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 harvesting operations at least 15 days before 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 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 mechanical transplanting machines performed planting giving high uniformity and even planting density and spacing, although there was a weakness in land preparation and it can achieve an amazing performance percentage with more care to the land preparation. 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. As a solution to these problems, recommendations of the four right (4Rs) right resource, the right amount, the right time, and the right place were attached in Appendix A. These rights were concluded from Rice Check, farmers are strongly recommended to strictly follow them.

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