EVALUATION ON ADAPTATION OF CUT STEM TRANSPLANT (*A SIT PHYAT*) METHOD OF RICE PRACTICED IN FLOOD PRONE AREA

YU MON

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EVALUATION ON ADAPTATION OF CUT STEM TRANSPLANT (*A SIT PHYAT*) METHOD OF RICE PRACTICED IN FLOOD PRONE AREA

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YU MON

to

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This thesis attached hereto, entitled "**Evaluation on Adaptation of Cut stem Transplant (*A Sit Phyat*) Method of Rice Practiced in Flood Prone Area"** was prepared under the direction of the chairperson of the candidate's supervisory committee and has been approved by all members of that committee and board of examiners as a requirement for the degree of Doctor of Philosophy.

Dr. Mie Mie Aung
Supervisor, Supervisory Committee
Professor and Head
Department of Plant Breeding,
Physiology and Ecology

Dr. Aung Moe Myo Tint
External Examiner
Deputy Director, Maize and Other Cereal
Crop Research Section
Department of Agricultural Research

Dr.Than Da Min
Member, Supervisory Committee
Professor and Principal
YAU (Hmawbi Campus)

Dr. Yoshinori Yamamoto
Member, Supervisory Committee
JICA expert
YAU-JICA TCP

Dr.Nyo Mar Htwe
Member, Supervisory Committee
Deputy Director
Advanced Centre Agricutural Research and Education

Dr. Soe Soe Thein
Vice-Chairperson, Board of Examiners
Pro-rector (Academic Affairs)
Yezin Agricultural University

Dr.Nang Hseng Hom
Chairperson, Board of Examiners
Rector
Yezin Agricultural University

Date----------------------

This thesis was submitted to the Rector of the Yezin Agricultural University and was accepted as a requirement for the degree of Doctor of Philosophy.

Dr. Nang Hseng Hom

Rector

Date---------------------- Yezin Agricultural University

DECLARATION OF ORIGINALITY

This thesis represents the original works of the author, except where otherwise stated. It has not been submitted previously for a degree at this or any other university.

Date--------------------- **Yu Mon**

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ABSTRACT

Rice cultivates under various ecological conditions from drought-prone to flood-prone areas in Myanmar. Among them, flood-prone area (0.8 M ha) contributes 13.5% to total rice cultivated area (622 M ha). Thanatpin Township in Bago Region is one of the typical flood-prone areas due to situation besides the Bago-Sittaung canal and total annual rainfall of about 3300 mm. In this area, some of farmers cultivate deep-water rice by a special cultivation method called cut stem transplant (*A Sit Phyat*) method. Local rice varieties are direct seeded on May after the first flash of monsoon. When the seedlings are about 4 months old, the elongated stems are cut and transplanted by using fork placing between first and second elongated internode. The height of stem cutting is about 100 cm and water depth is about 60 cm at transplant. Hence, experiments were carried out to evaluate the yielding ability of the cut stem transplant method in comparison with other cultivation methods such as normal transplanting and direct seeding and to clarify the effects of cutting position of stem on the growth performance and yielding ability and moreover, to test the possibility to application of this method in normal lowland condition. It was observed that the yield of cut stem transplant plant in Pawsan was significantly higher than normal transplant and direct seeded plant recorded in 2016 and 2017. Therefore, 5 cutting positions were carried out with randomized complete block design in Ywa Houng village, Bago region. Among the different cutting treatments, T5 (cutting at 45 cm above the soil surface) produced the lowest yield whereas T3 (cutting at 15 cm above the soil) showed the highest yield. However, when transplanted in pot under shallow water condition, Pawsan showed very poor performance among the tested varieties such as Pawsan, Yoedayar, Hnankar and Yenwe. In addition, there were varietal differences in all measured parameters. It was concluded that cut stem transplant method is applicable only to deep water areas at transplanting time and it might not be suitable to apply under lowland condition.

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LIST OF ABBREVIATION

ABA	Abscissic acid
DP	Department of Planning
DAR	Department of Agricultural Research
DOA	Department of Agriculture
DWR	Deep water rice
DZ	Differentiation zone
EZ	Elongation zone
FAO	Food and Agriculture Organization
GA	Gibberellic acid
GRiSP	Global Rice Science Partnership
IM	Intercalary meristem
MRRC	Myanmar Rice Research Centre
OD	Yoedayar direct seeded plant
PD	Pawsan direct seeded plant
PN	Pawsan normal transplant plant
PC	Pawsan cut stem transplant plant
RKB	Rice Knowledge Bank
YD	Yoesein direct seeded plant
YC	Yoesein cut stem transplant plant

CHAPTER I

GENERAL INTRODUCTION

Myanmar rice ecosystem includes four ecosystems such as irrigated lowland, rainfed lowland, deepwater and upland. Rainfed lowland (the largest of the ecosystems) and deepwater rice are confined to the delta region and coastal strip of Rakhine State (DP, 2015). Flooded (533,857 ha) and deep water (306,134 ha) account 13.5% of the total cultivated area (6,220,751 ha). Therefore, constructing of flood protection measures (GRiSP, 2013) or cultivating flood resistant varieties or climate resilient cultural practices should be done to sustain the rice yield in flooded area.

The rice genotypes can be divided into floating rice, deepwater rice, tall traditional rice, modern elongating and modern non elongating rice depending on their stem elongation in response to flooded condition (Mackill et al. 1996). Local rice landraces are adapted to extremes water availability such as progressive flooding or rapid submergence (Bailey-Serres et al. 2008). The rice genotypes which have several specialized characters such as the stem elongation enable the plant to adapt to deeply flooded conditions (Alim et al. 1962).

Bago Region, one of the flood prone areas situated in Sittaung delta region has 1,119,272 ha of rice cultivated area. Among the cultivated area, deep water area occupied 11.7% of total cultivated area (MOALI, 2016). Thanatpin is situated at Latitude 17°12'42"N, Longitude 96°18'11"E and is 9 m above sea level and is situated beside the Bago-Sittaung canal in Bago Region. Total annual rainfall of Thanatpin is more than 3300 mm every year. Therefore, rice ecosystems of Thanatpin involves lowland, flooded and deepwater ecosystems taking 54 %, 2 % and 44 % of the total cultivated area (DOA, 2017). Generally, rainfall starts in May with the onset of monsoon. The intense rainfall months are June, July and August and generally, flooding occurred in these three months. After August, rainfall decreases and generally is finished by November. Therefore, most of the deep water area starts seeding on May after the first flash of monsoon. Local rice varieties such as Pawsan, Yoesein and Yoedayar are cultivated in these areas. The rice plants elongate in response to flooding. However, the plants lodge and lay flat after water recedes around August. In such situation, the farmers from Ywa Houng village in Thanatpin Township practiced cut stem transplant method by cutting the elongated stem and transplanted. The height of stem cutting is about 100 cm and water depth is about 60 cm at transplant. The stem are cut at about 40 cm above the soil surface and transplanted by using fork when the water depth in the field was 60-70 cm. The farmers told that the yield of cut stem transplant method obtained 40-50 baskets per acre and higher yielding than direct seeding method.

Problem Statement

Climate is changing in the world and extreme weather and climate can cause drought, flood, heat weaves and heavy raining. Due to climate change, flash flood, urban flooding, river flooding and coastal flooding can occur (National climate assessment, 2014) and mostly affect to low lying coastal land. Thus, flooding damage happened in 2018 monsoon season in Myanmar affects the 12,000 acre of farmland in delta area (Ayeyarwaddy, Bago, Mon and Yangon). Flooding is worst year by year and the farmers cultivated in flooded area had to select to grow only flood tolerant varieties or to follow climate resilient cultural practices to sustain the rice yield. Hence, it is necessary to study cut stem transplant method of rice which is currently practiced in Thanatpin Township. That method is applied by farmers as an alternative way if flooding damage occurred. It is interesting to examine on how the plant adapted to transplanting in deep-water area, how many roots are come out for their survival, how many node produced tillers, which node could produce more roots and tillers, which cutting position could produce better yield. Despite the production would be more than direct seeding, there is no recorded data on growth performance and yielding ability of cut stem transplant method. In addition, it was concerned to apply cut stem transplant method in shallow water condition if flooding damage occurred. Moreover, it is important to investigate on whether this method is applicable to other deepwater rice varieties which are adapted to flooded area. Hence, investigation is necessary to clarify and seeking the adaptation of this method and to identify the particular varieties applicable with this method. Therefore the experiment was conducted with the following objectives:

1.1 Objectives

1. to evaluate the yielding ability and growth performance of cut stem transplant method in comparison with other cultivation method
2. to clarify the effects of cutting position of stem on the growth performance and yielding ability
3. to test the possibility to application of cut stem transplant method in normal lowland condition

CHAPTER II
LITREATURE REVIEW

2.1 Rice Cultivation Methods

The conventional used rice crop establishment methods are direct seeding and normal transplanting (Mack ill et al. 1996). Direct seeding is practiced in some area of the tropical Asia by dry or wet seeding. Dry direct seeding is usually practiced for rain fed and deepwater ecosystems. In this method, the seeds are broadcasted onto dry soil surface and incorporated with the soil either by plowing or harrowing with the seed rate of 60-80 kg per hectare nursery field. The advantages are the plants tend to mature faster than transplanted plant and the plants are not subjected to stress caused by pulling from the soil (RKB, 2018). In some deep water area, deep water or floating rice seeds are broadcast at the seed rate of (60-130 $kgha^{-1}$) on dry soil before the rainy season start. Sometimes, peregrinated seeds are applied to the puddle soil. The rice plants have the ability to resist to flooding at 4-20 weeks after seeding (De Data, 1981). However, dry direct seeding of deepwater or floating rice has some disadvantage. Because, early drying can cause poor stand establishment and loss of seeds due to birds, rodents and ant can affect the seed. Sometimes, drought occurs after first flash of monsoon and it might cause soil crust formation and hampered the germination of the seed (Singh et al. 2004).

In transplanting method, the seeds are raised in the nursery and pulled and transplanted in puddle soil. Land is prepared by maintaining 2 to 3 cm of field water for about 3 to 7 days until the soil is soft enough for land preparation. When the soil is soft enough, the field is prepared by plow or rotary tiller. Seedlings raised in a wet, dry, or modified mat nursery are pulled out and transplanted. Transplanting was done with 2–3 seedlings per hill with the spacing at 20 x 20 cm when the seedling was 15-40 days old. The working force required to transplant 1 ha field is 30 persons per day. The advantage of this method is the plant can be grown in less than optimal leveling field and with varying water levels. Besides, transplanting ensures a uniform plant stand and ahead start over emerging weeds. Transplanting could achieve more production than direct seeding method. It is applicable to kill weed seed and volunteer rice plant. However, the laborers need to bend during transplanting and can suffer from back pain. Moreover, seedlings (especially of modern varieties) may get too old before the field is ready to be planted in the rain fed area. Older seedlings would be difficult to uproot because, the root will firmly attach to the soil (RKB, 2018).

There are some locally used methods such as double and triple transplanting in deep water area in Vietnam. In double translating, seeding was done on seed bed on June at the beginning of rainy season and transplanted them to bigger nursery bed at one month after seeding. About 2 months after transplanting (on September), the seedlings are second time transplanting to the field (Puckridge, 1988). In flood prone area of Indonesia, dry seeding locally called *Gogorancah* system is done after land preparation during dry season and flooding occurs when the plant are 5-6 weeks old and so tolerate to flooding (Fagin and Kartaatmadja 2002). In India, beushening method by laddering of the direct seeded field is practiced. In this method, tall local rice varieties were dry broadcasted to the field. When the seedlings are 25-35 days old at 15-20 cm of field water, wet pouching and laddering of the field was done to control weed. If late onset of monsoon occurred in some years, bunch planting of old aged seedlings of long duration rice cultivars are sometimes practiced (Singh et al. 2004).

2.2 Growth Habit of Deepwater Rice and Floating Rice

Rice plant which can survive in flooding deeper than 50 cm for 1 month or longer is called DWR. It was cultivated in water depth of 50-100 cm. Most of the deep water rice are traditional cultivars and the plant length is more than 140 cm. It has thick stems with a massive lumen or hollow section and large air sacs inside the stem. These varieties are strongly photoperiod sensitive varieties and stem elongation will cease after flowering. They flower after peak flooding, regardless of the time of planting. Floating rice is well grown in water depth above 100 cm which has strong elongation capacity of 5-8 cm per day for 7-10 days. Some cultivars with very strong elongation ability may grow up to 5-6 m long in the water depths of 3.5-4.0 m (Castling et al. 1988). Isozyme analysis of DWR reveals that most of Asian DWR is indicia type. However, Myanmar, Bangladesh and India had (25.0%), (19.5%), (5.3%) of japonica type respectively among the tested varieties (Hakoda and Inouye 1988).

When comparing the growth habit of different type of rice, floating contains 8-6 internodes which are more than 6 cm long. DWR possess 7 or 6 internodes of which 5 internodes are elongated while tall traditional rice bears five or six internodes, four are elongated among them. Modern elongated varieties present four internodes but most are non elongated. Modern non-elongating type has only two to three elongated internodes. The order in length of elongated internodes are floating rice, DWR, tall traditional, modern elongating and modern no elongating respectively. Thus, rice could be grouped on the basis of 1) total number of internodes, 2) number of elongated internodes, and 3) length of elongated internodes (Thakur and HilleRisLambers 1988).

Moreover, Takeda and Takahashi (1972) observed that *Oryza sativa* varieties with fewer than 15 leaves produced 4-5 elongated internodes whereas rice varieties bearing 15 leaves have 4-6 elongated internodes. Moreover, varieties with more than 15 leaves possess increasing number of elongated internodes parallel to the number of leaves on the main calm. DWR belonged to this last group (Maritime, 1959).

Rooting from the elongated nodes is commonly observed (Vergara et al. 1977; Inoue and Mochizuki 1980; Nitta et al. 1999) as is rooting from internodes (Nitta et al. 1999). DWR produces roots on a stem or tiller above the soil surface. These roots are not basal roots and called nodal root. It bears clusters of nodal roots from the upper nodes (Castling et al. 1988; Kende et al. 1988). As the root mature, these adventitious roots mature to root primordial bearing all characteristic produced in primary or lateral roots (Lorbiecke and Saunter 1991). Moreover, Sophonsakulkaew et al. (1977) conducted in the screening for elongation ability of DWRs; some promising lines were transplanted by cutting the top part of the plant (the second node from the top).

When the water level reached maximum (150 cm), the DWR plants produced more dry matter in deep water. High growth rates in deep water indicated that well-developed tillers grow with rising water level due to their shoot above the water could photosynthesize (Kupkanchanakul et al. 1987). Tolerant varieties can survive even after prolonged submergence owing to the starch reserves which are not exhausted during submergence. The carbohydrate reserves remained after submergence may maintain the plant’s recovery (Eames et al. 1988).

2.3 The Strategies of the Plant in Response to Flooding

Plant is responses to flooding with 2 strategies. These two are escape strategy and sit- and-wait strategy. Escape strategy is the elongation of the shoots to restore the leaf contact with atmosphere and it is suitable for shallow; prolong floods

(Headway et al. 2012). Sit-and-wait strategy is the the plant quiescence during the submergence period by conserving the reserve carbohydrate for plant survival. When water recedes, plants resume their growth (Striker, 2012). Aquatic species which stem elongate surprisingly include deepwater and floating rice from Southeast Asia and the dicotyledonous Rumex species from European flood. *Nymphaea gigantea* from tropical Australia produce petioles more than 2 m long to raise their leaves and flowers to the water surface (Atwell et al. 1999).

2.4 Stem Elongation under Flooded Condition

Stem elongation strategy proceeds mainly by internode elongation, together with terminal leaf blade and sheath lengthening. Moreover, additional nodes may be occurred during elongation (Alim et al. 1962; Vergara 1985). In addition, the numbers of internode increase obviously with an increase in submergence depth (Haque and Hossain 1988). However, height differences between submerged and non submerged condition are mainly due to increased in internode length not by internode number (Kupkanchanakul et al. 1987). Internode elongation is primary importance, since leaf elongation is limited in rapidly rising water (Gomosta and Vergara 1988). However, some DWRs develop internodes and some develop leaves under submergence (Takahashi, 1988). Plant height is important for testing elongation ability. Rice lines should be tested separately according to their heights. If short and tall lines are planted together, short lines will get lower score for elongation. Thus, tested lines should be grouped according to plant height (Sophonsakulkaew et al. 1977).

Individual internode of rice can be divided into three regions such as Intercalary Meristem (IM), Elongation Zone (EZ) and Differentiation Zone (DZ). IM situated at the base and where cell division occurs. In EZ, the cell reached their final length and cell growth ceased in the DZ. IM is characterized by small, bricklike cells and which occurred about 2 mm above the node. From IM to EZ, cell sizes increase and constant in the DZ. During submergence, new cells are produced 3 folds, the EZ expands about 3-5 fold, hence the cells attain 3-5 fold greater final length (Kende et al. 1998). The average duration of the cell cycle within the intercalary meristem is 24 h in air-grown and 7 h in submerged plants. The length of cells increases linearly to a maximum of 40 µm in air-grown and 150 µm in submerged plants. Therefore cell-elongation zone expand from 5 mm to about 15 mm (Kende and Rankin 1988).

The degree of submergence stress will depend on plant growth stage (eg. seedlings and adult plants) and growth habit (eg. erect plant and creeping plant). Different seedling age affect to submergence tolerance (Eames et al. 1988; Haque and Hossain 1988). It is evaluated that the survival of single species could be change depending on the flooding depth, water turbidity and flooded duration. It is interpreted that a single species of a similar age and size that could survive to short flooding period may perish if exposed to a longer one (Striker, 2012).

2.4.1 Environment effect for stem elongation

Environmental factors such as O_2 also affect internode elongation to a large degree (Gomosta 1985; Vergara 1985). During submergence, water depth and its physio-chemical characteristics (oxygen and carbon dioxide concentration, pH, turbidity, temperature, etc.) affect plant survival. Altering the quality of the floodwater affects plant survival as well. Low floodwater pH, enhanced concentration of CO_2 and increased concentration of O_2 cause prolong plant survival. Degradation of chlorophyll content in susceptible rice cultivars is faster than tolerant ones and it can be used as a parameter for submergence tolerance (Sacker et al. 2006).

Elongation ability is a varietal character and it is affected by several factors. The plant age, the degree of submergence, the nutrition availability of the plant and environmental condition such as O_2 also concern to internode elongation (Vergara, 1985). Light affects to internode elongation too. Light quality and quantity will differ above water and below water. As the light intensity decreases under water, elongation of internodes increases. There is negative correlation between the carbohydrate content and elongation ability. The optimum temperature for both elongation and dry matter accumulation seemed to be 30°C. As temperature increase, photosynthesis at low light intensity increases while solubility of O_2 decreases. Nitrogen content had a parallel relationship with the internode elongation under submerged conditions (Gomosta, 1985).

If screening for elongation was carried out in the pond, the floor of the pond should be leveled. If the bottom of the pond is uneven with deep and shallow depths, plants growing on shallow water depth may show lower elongation than those growing on deeper depth. The soil with varying fertility might cause unequal elongation. Water quality is important as well. If the irrigated water is quite turbid, it limits the light. Sometimes, floodwater is much clearer than canal water. Therefore, plant would perform better elongation in flooded water (Sophonsakulkaew et al. 1977).

2.4.2 Hormone effect for stem elongation

Ethylene does not promote growth in the absence of gibberellins. Gibberellins (GA) can stimulate growth independently of ethylene, but ethylene can promote growth only in the presence of GA. Ethylene promotes responsiveness to GA in DWR. Low partial pressure of O_2 is the signal for increase growth. Stimulation of 1- aminocyclopropane 1-caboxylic acid (ACC)-synthase activity is occurred in the intercalary meristem. This activity starts enhance after 2 h of submergence and showed a peak after 4 h. Reduced levels of atmospheric O_2 also enhanced the activity of ACC synthase (Kende and Rankin 1998).

Elongation of internode is formed by the increase cell division and cell elongation of the intermodal cell. Lowered O_2 and increased CO_2 in flooded water promote ethylene synthesis and also increase the growth promoting effect of ethylene. Stem elongation was occurred by an interaction of ethylene and GA. Hence, GA is the main candidate for the hormone that could promote internode elongation of DWR (Sage 1988; Nagai et al. 2014). Sage (1988) and Takahashi (1977) observed that the combined application of GA, ABA, and ethylene induce elongation in the seedling stage whereas GA and ethylene are most promoting factor for internode elongation during the late vegetative phase of DWR. IM formation may be the result of the interaction among GA, ABA, and ethylene whereas GA is most likely a major factor in elongation.

2.4.3 Gene action for stem elongation

Two Qualitative Traits Loci (QTL) which controlling the gene on internode elongation during vegetative stage are situated on chromosomes 2 and 4 (Nagai et al. 2010). Among these two QTLs, the most effective for internode elongation is situated on chromosome 12 and which contain SNORKEL1 (SK1) and SNORKEL2 (SK2) gene (Hattori et al. 2009). These genes encode ethylene-responsive factor-type transcription factors, and their expression is induced by ethylene (Nagai et al. 2014). SNORKEL 1 and 2 genes are absent in non DWR varieties and present in some wild Oryza species that show deepwater responses (Hattori et al. 2009).

Intermodal elongation of DWR under submergence is supposed to control by a number of minor gene and two major genes (Castling, 1992). Sage (1988) proposed that elongation during submergence is depends not only on the capacity to elongation of an internode, but also degree of elongation. It is formed by one gene with incomplete dominance. The expensing genes which is a wall loosening protein that promote long term extension of cell wall are occurred along the developmental regions of the coleoptiles, root and internode. The expression of these genes in DWR is controlled by hormone and environment (Cho and Kende 1997).

2.5 Response to Water Logging by Rice Root

Rice is a semi aquatic plant and in general it is well adapted to submergence by the growth of adventitious roots. Adventitious roots functionally replace the basal roots under submerged condition. In DWR, adventitious root primordial are formed at the nodes as part of the normal developmental program (Lorbiecke and Saunter 1991).

During submerged, the cortex of the root disintegrates forming continuous gas channels from the base to the tip. This allows gas transport from the base to the aerial parts of the plant and reduces the amount of respiring tissue per unit root volume. Moreover, thickenings and suberization of the root reduces the permeability of the root wall to gases. Furthermore, short fine laterals (1-2 cm long and 0.1-0.2 mm in diameter) branches develop along the primary roots. The aerenchyma cell of this root is less than the primary roots. Although it accounts for a small the root mass, their external surface area is larger and adheres directly into the water and solute transport vessels in the stele of the primary root. Therefore the lateral roots are responsible for the nutrient absorption to compensate for absorption by the primary roots. Although there is no direct measurement, lateral roots would likely be important in gas transfer (James et al. 2002; Kirk, 2003).

Adaptation to waterlogged soils by the root is due to the presence of aerenchyma in the root. The cortex area where aerenchyma developed have large diameter nodal roots which help in ventilating gases such as ethylene and carbon dioxide (Vassar et al. 1997, 2000). Due to aerenchyma formation, ethylene entrapped within submerged tissues could enhance stem elongation in rice (Rankin and Kende 1984). Root length was correlated with number of nodal roots, root dry weight, shoot length, stem dry weight and leaf dry weight. Root dry weight positively and highly correlated with root shoot ratio, shoot length and leaf dry weight. The results imply that the greater the root dries weight, the more nutrients will be transported from root to shoot (Myat Moe Hlaing, 2016).

2.6 Root Growth after Root Pruning

When the rice roots are cut off and panicle is removed at full heading stage, the length of the dormant tiller buds is markedly increased. It proves that the growth of tiller buds is not regulated by a substance derived from roots (Liu et al. 2011, Xu et al. 2015). When primary root tips are excised, lateral roots become dominant due to root apical dominance in *Arabidopsis* (Lioret and Caseros 2002).

CHAPTER III
THE ASSESSMENT ON CUT STEM TRANSPLANT METHOD OF RICE PRACTICED IN DEEP WATER AREA OF BAGO REGION

3.1 Introduction

The rice ecosystems of Myanmar can be classified into lowland (rain fed and irrigated), submerged, deepwater, upland or *Taungya* (upland field with slope) and sea water intrusion areas (MOALI, 2016). Delta and coastal zone are frequently suffered from flooding damage especially during monsoon season. It is necessary to sustain the rice production in submerged and deep-water area as it occupied 13.5% of the total cultivated area (MOALI, 2016). Therefore, the strategies such as construction of drainage channel or growing resistant variety or flood resilient cultural practices should be carried out to sustain the rice yield.

In addition, most of the cultivated varieties in delta and costal area are selected to grow only tall traditional varieties (Ritzier et al. 2015). Normally, DWR varieties are transplanted in this area starting on August to September called the late monsoon rice, *Ma Yin.* (Win, 1991).

The conventionally used rice establishment methods in the world are roughly divided into direct seeding and transplanting (De Data, 1981). However, there are some locally used method in Asia such as beushening, root pruning before transplanting and double and triple transplanting of seedlings (Singh et al. 2004; Noorsyamsi et al. 1984; Puck ridge, 1988). Likewise, there is locally used method" Cut Stem Transplant Method" in deepwater area in Thana pin Township, Bago Region in Myanmar. Thana pin is located at Latitude 17^{o}12'42"N, Longitude 96^{o}18'11"E and is 9 m above sea level and is situated besides the Bago-Sittaung canal which is used to flow inundated water from Bago river to Sittaung river. Moreover, total annual rainfall of Thana pin is averaged 3300 mm per annum. Hence, most of the rice fields are flooded during rainy season owing to overflow water from Bago-Sittaung canal and Sittaung river. Therefore, among the rice cultivated area of Thana pin (60,000 ha), submerged and deep water areas engage 44% of the cultivated area (DOA, 2017).

Cut stem transplant method is originated in Zee Pin village which is situated at 10 km south of Thana pin. At 1960's, 5 miles long embankment was constructed to prevent inundated water from Bago-Sittaung canal. However, flooding was worst due to miss-management. Deep water area became deeper and crop damages was severe. In such case, the farmers disappointed to his damaged nursery field and cut and throw the elongated stem. After that, rooting was observed from the stem cutting and this method was initiated. This method is currently practiced in Yaw Hong village, Thana pin Township. The cultivated field in Yaw Hong village is also situated in the deep water area and farmers from this village practiced dry seeding on May after the first flash of monsoon. The cultivated varieties are local varieties such as Paws an, Yesenin and Yoedayar. About 1 month after seeding, the waste depth starts to increase. Generally, flooding happened in June, July and August and so, the DWR varieties are elongating in the internode to escape from flooding stress (Mazaredo and Vergara 1977). Although the plant elongates during flooding, it will lodge after flood water recedes. In such occasion, the stems are cut and transplanted by using transplanting fork. No fertilizer was applied at the nursery stage. However, compound fertilizer (15:15:15) was applied at the rate of 50kg ac^{-1} about 1 month after transplanting on September. The plants are harvested when fully ripe. As the cultivated varieties are photoperiod sensitive local varieties, the harvesting time is not the same. Yoedayar and Yoesein can harvest on the last week of November and Paws an on the second week of December.

Conventional transplanting of rice is done with intact seedlings (seedlings with attached roots). The longer seedling period (more than thirty days) will be suffered from transplant shock due to root breakage because, root is important for plant growth and development (Yamamoto et al. 1978). However, transplanting without root in this method is very concerned. Nevertheless, rooting from elongated internode in the deep-water rice had been recorded (Vergara et al. 1976; Inoue and Mochizuki 1980; Khan and Vergara 1982; Saran et al. 1982; Nitta et al. 1998; Nitta et al. 1999; Lorbiecke and Saunter 1999). Therefore, to clarify the plant growth and productivity of this method, survey was conducted with the following objectives-

(1) To understand the plant development after transplanting

(2) To clarify the growth and yield parameters at harvest.

3.2 Materials and Methods

3.2.1 Site of survey

Survey was conducted in farmer's cultivated field situated in Yaw Hung village, Thanatpin Township where the farmers are used to transplant with cut stem transplant method.

3.2.2 Study period

Survey was conducted in 2016 and 2017 August to December.

3.2.3 Data collection

In both years, samples were taken at 3 growth stages such as transplanting, an early growth stage after transplanting and harvesting. At transplant, randomly selected stem cut seedlings were compared with normal seedlings (with attached roots). Moreover, to understand the growth of plant after transplanting, sampling was taken 3 times; 3days after transplanting (3DAT), 7DAT and 15DAT. Samples were embedded in 50% methanol and checked in Yezin Agricultural University for plant characteristics. At harvest, $1m^2$ (1m x 1m) plots were taken diagonally across the field to determine the weight yield (g). For yield component data, representative plant samples were taken near $1m^2$ plot. In 2016, sampling was done by taking five plants from each $1m^2$ plot for direct seeded field and three plants for cut stem transplant field. In 2017, sampling was done by taking ten plants from each $1m^2$ plot for direct seeded field and five plants from cut stem transplant field (Table 3.1).

3.2.3.1 Collection at transplanting

1. **Rooting node**

   Rooting node was counted on the stem from stem base to upward.
2. **Root number**

   Root number was counted in each rooting node.
3. **Tillering node**

   Tillering node was counted on the stem from the stem base to upward.
4. **Tiller number**

   Tiller number was counted on each node.

Table 3.1 Number of sampling plot harvested from each field in 2016 and 2017

Variety	Cultivation method	2016		2017	
		field	Plots /field	field	Plots /field
Pawsan	Direct seeding (PD)	1	7 [1)]	2	7
Pawsan	Normal transplant (PN)	-	-	3	7
Pawsan	Cut stem transplant (PC)	3	7	3	9,7,7 [2)]
Yoesein	Direct seeding (YD)	2	6,5	3	7
Yoesein	Cut stem transplant (YC)	-	-	1	7
Yoedayar	Direct seeding (OD)	1	5	-	-

[1)] Missed the data on filled grain (%) , 100 grain weight (g) and yield (g /m^2),

[2)] Numbers of sampled plots were different among the fields

Table 3.2 Comparing the seedling's characters at transplant in 2016 and 2017

Types of seedlings	2016		2017	
	Stem length (cm)	No. of node	Stem length (cm)	No. of node
Whole seedlings	145.8±15.2	6.1±1.2	117.0 ± 6.0	5.0 ±1.0
stem cut seedlings	106.2±10.3	3.0±0.0	125.3 ± 7.6	5.3 ±0.7

3.2.3.2 Collection at harvest

(1) Hill m^{-2}

The number of hill m^{-2} was counted within $1m^2$ plot.

(2) Plant height (cm)

Plant height was measured from the stem base to the top of the plant in all representative plant samples.

(3) Panicle length (cm)

Panicle length was measured from the neck node to the tip of panicle in all representative plant samples.

(4) Culm length (cm)

Culm length was measured from the stem base to the neck node in all plant samples.

(5) Internode length (cm)

The length of each internode was measured by using ruler in all internode produced in all representative plant samples.

(6) Root number

The representative plant samples were dig up by using shovel. The roots were cleaned with running water and root number was counted manually only primary adventitious root in all representative plant samples.

(7) Tillering node

Tiller bearing node on the main culm was recorded in all representative plant samples.

(8) No. of tiller

Tiller was separated according to the tillering node on the main stem and counted the number of tillers produced in all representative plant samples.

(9) No. of panicle

The numbers of panicle from all representative plant samples were counted.

(10) No. of grains per panicle

All grains from each representative plant samples were counted separately by using grain counter WAVER made from Daidex company, Japan and averaged the grains panicle^{-1} by dividing with panicle number.

(11) Filled grain (%)

Filled grain (%) for each representative plant samples were measured separately by dipping all the grains in water (Specific gravity 1) and separated the filled and unfilled grain. The grain sank at the bottom was assumed as filled grain and those of the floated grains was realized as unfilled grain (Gomez, 1972). Filled grain (%) was calculated by using the following formula.

$$\text{Filled grain (\%)} = \frac{\text{filled grain x 100}}{\text{total grain}}$$

(12) Hundred grain weight (gm^{-2})

Hundred grain weights (gm^{-2}) were measured by using digital balance AMD Type GF 400. After that, the grain moisture content was immediately measured by using MOISTEX type SS-7 made from Satake Company and adjusted the weight to 14% moisture by using the formula of (Gomez, 1972).

$$\text{Hundred grain weight (g)} = \frac{G \times (100\text{-}M)}{100\text{-}14}$$

in which G = Measured grain weight (g)

M = Measured grain moisture

(13) Weight yield (g m^{-2})

Weight yield (g m^{2}) was determined by threshing the grains from all harvested panicle obtained from 1m^{2} plot. Threshed the unfilled grain from filled grain and determine the weight yield.

(14) Yield (g m^{-2})

Yield (g m^{-2}) was calculated based on the yield component characters as the following formula.

$$\text{Yield} = \frac{A \times B \times C \times D \times E}{100 \times 100}$$

Where, A = No. of hill m^{-2}

B = Panicle no. hill^{-1}

C = Grains panicle^{-1}

D = Filled grain (%)

E = 100 grain weight (g)

3.2.4 Data analysis

The collected data were analyzed by using excel, 2007.

3.3 Results and Discussion

3.3.1 Seedling characters at transplant

Both types of seedlings were sampled from the same field in 2016 and 2017. When comparing the seedling characters of stem cut seedling with normal seedlings, the stem cut seedling was 40 cm shorter and 3 nodes lesser than normal seedling in 2016 while in 2017, the same seedling length and number of node was observed (Table 3.2). Differences between the two types of seedlings were owing to the cutting position of the stem cut seedlings. In 2016, water depth at transplant was 60 cm so, the stems were cut at 40 cm above the soil and there would be 3 nodes between soil surface and 40 cm above the soil. However in 2017, the seedlings length was almost the same or even higher seedling length was observed in stem cut seedlings. Water depth at transplant was about 30 cm and so the seedlings were cut at the soil surface. Little difference in seedling height was due to the field condition such as deep and shallow spot in the same field. Depending on the water depth, the cutting length above the soil will be different and it can be decided that the water depth at transplant in 2017 was shallower than 2016.

3.3.2 The number of tillers and roots produced from each node after transplanting

The no. of tillers and roots produced from each node was recorded 3DAT, 7DAT and 15DAT. The trend of rooting and tillering from each node and the number of the tillers were shown in Figure (3.1) for 2016 and Figure (3.2) for 2017. In both years, tiller and root started to produce by 3DAT. In 2016, only 2 nodes initiated tillers at 3DAT and gradually increased the tillering node to 5 nodes at 15DAT. In 2017, tillering node at 3DAT was only 4 nodes and increased to 5 nodes at 15DAT as well. In addition, rooting node at 3DAT in 2016 was only 2 nodes and increased to 4 nodes at 7DAT and 15DAT. Moreover, rooting node at 2017 was only 2 nodes and increased to 5 nodes at 7DAT and 15DAT. Therefore, it could be interpreted that the number of tillering node and rooting node increased gradually from 3 DAT to 15DAT. In observing tiller number, the number of tillers produced by 3DAT and increased by the time taken after transplanting in both years.

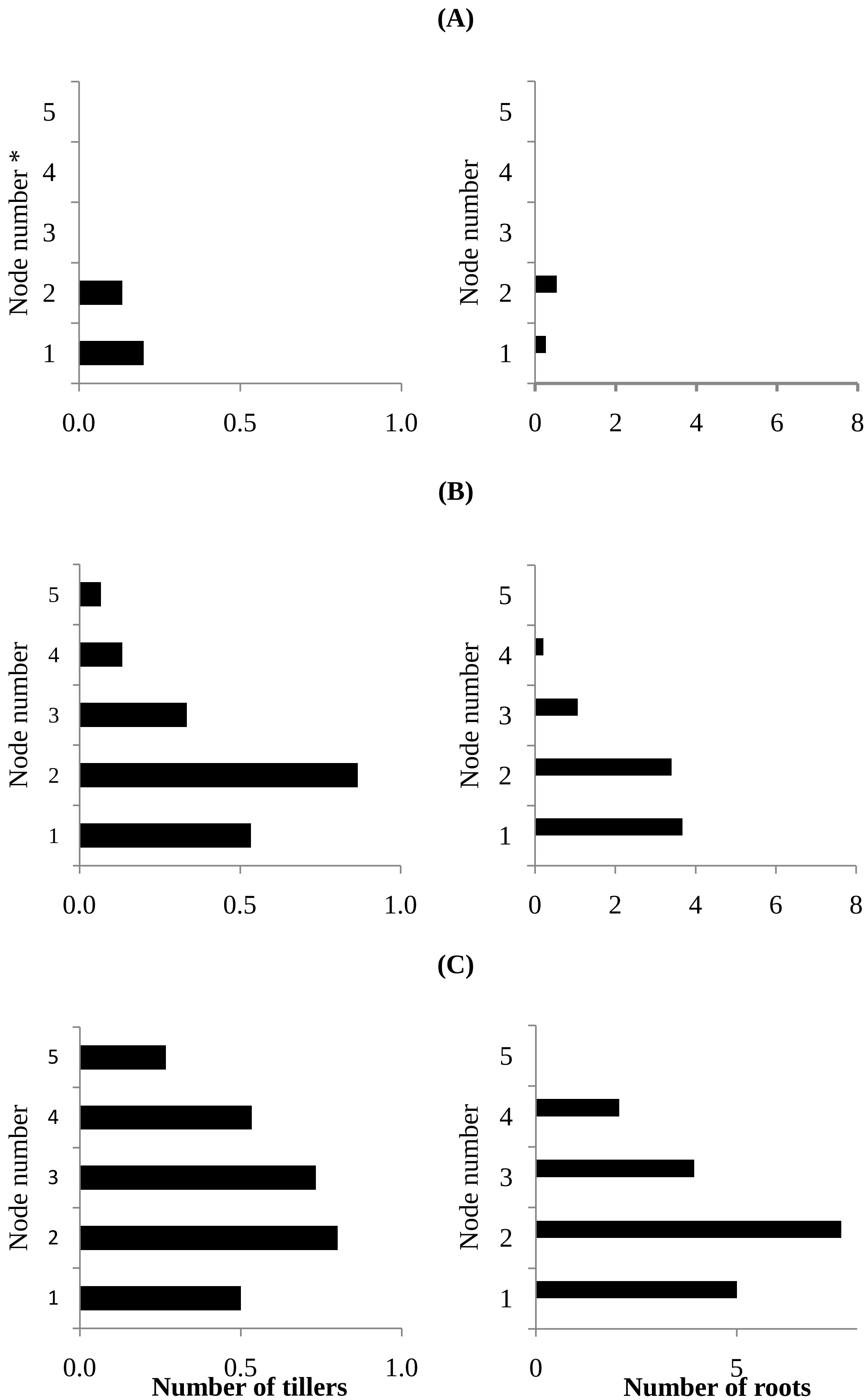

Figure 3.1 Numbers of tillers and roots emerged from each node after transplanting.*Count from base. (A) 3Days After Transplanting (DAT), (B) 7DAT and (C) 15DAT in 2016.

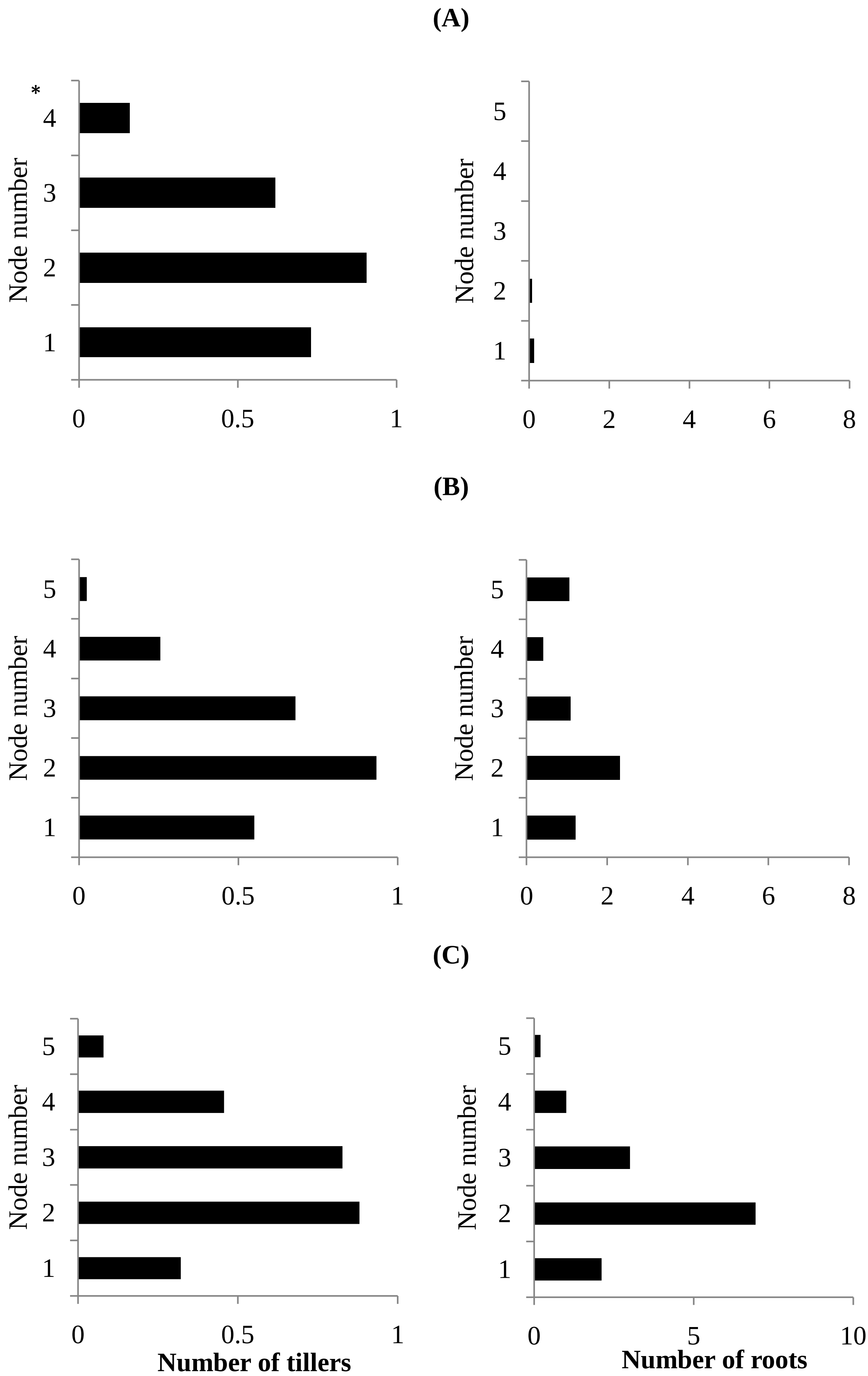

Figure 3.2 Number of tillers and roots emerged from each node after transplanting.*Count from base. (A) 3Days after Transplanting (DAT), (B) 7DAT and (C) 15DAT in 2017.

Root number also initiated by 3DAT and increased by the time taken after transplanting in both years. The most surprising fact is that among tillering and rooting node, the 2nd node produced the highest number of tillers and roots among the node in all observed period in both years. In DWR, ethylene biosynthesis increased (Sage, 1985) due to limited diffusion of gas in water and so, promotes adventitious and lateral root formation (Castling et al.1988; Lorbiecke and Saunter 1999; Fukao and Bailey-Series 2008). Ethylene diffuses centrifugally in the bundle sheath cell and retard polar auxin movement. Moreover, it cause epidermal cell death and auxin initiate rooting from the dead cell (Lorbiecke and Saunter 1999; Alone et al. 2006; Steffen et al. 2012; Steffens and Rasmussen 2016). Adventitious roots are produced in response to stress condition and can produce from non root tissue (Steffen and Rasmussen 2016) and it perform all characteristic produced in primary and lateral roots (Lorbiecke and Saunter 1999). In DWR, adventitious root could outgrowth from the elongated node (Inoue and Mochizuki 1980; Nitta et al. 1998; Nitta et al. 1999). Sophonsakulkaew et al. (1977) conducted the experiment by transplanting the cutting of the top part of the floating rice (the second node from the top) and allowed to grow into normal plant to check the plant characteristics. Therefore, it is obvious that stem cutting from the elongated internode of DWR can be used for plant propagation.

Lorbiecke and Saunter (1999) revealed that the adventitious root growth initiated at 8 to 10 hr after submergence. Rooting was visible in the older node except the youngest node at 10 hr after submergence treatment. Similarly, rooting and tillering from the stem cutting was observed in this experiment by 3 days after transplanting. In addition, the number of roots and tillers produced from second node is higher than those produced from other nodes especially the first node (the lowest node) when checked at 3DAT, 7DAT and 15DAT. Akita (1976), Yamamoto and Ikeuchi (1990) and Yamamoto et al. (1994) revealed that the two lowest tillering nodes produced the larger number of tillers than those produced from upper nodes. In cut stem transplant method, transplanting fork was placed between the first and second elongated internodes (Plate 1.A) and inserted to the soil. Therefore, the stem cutting inside the soil was folded between first and second node (Plate 1.B). When the stem is cut and transplanting with folded internode, the auxin flow will be interfered and accumulated in the second node. In such occasion, cytokinin appears to synthesis in nodal stem or shoots (Cline, 1991; Shimizu- Sato and Mori 2011).

Therefore, tillering and rooting from second node is favored. Furthermore, tillering and rooting node was observed to be started by 3 DAT. Similarly, in *Vicia faba*, *Helianthus annus, Pisum sativum* (dwarf) and *Phaseolus* v*ulgaris*, the lateral bud starts visible at 1 days after decapitation, *Ipomea nil* at 4-8 hr after decapitation (Cline, 1996) and Pea at 24 hr after decapitation (Blazkova et al. 1999).

3.3.3 Growth and yield recorded at harvest

3.3.3.1 Plant height, culm length and internode length

Plant height (cm), panicle length (cm) and culm length (cm) observed in 2016 was shown in Table (3.3) and 2017 in Table (3.4). In 2016, the plant height of PD (147.69± 9.1) was shorter than those observed in PC (152.10 ±11.0). However, culm length of PD (124.1 ±9.1) was not different from PC (124.6 ±10.7). Therefore, the height difference between PD and PC was mainly due to panicle length. In 2017, the plant height of PD (160.07 ±16.55) was higher than those of PC (136.98 ±5.7) and PN (140.57 ±8.27). Furthermore, the culm length of PD (132.03 ±17.1) was higher than those of PC (110.3 ± 5.13) and PN (112.79 ±8.2). Similar to Pawsan, the culm length of YD (151.1 ±15.1) was higher than those of YC (131.0 ±3.0). There was no difference in the panicle length. Hence, the culm length of direct seeded plants was similar to or higher than those of cut stem transplant and normal transplant method in both years.

Not only plant height, the length of each internode was recorded too. The pattern of internode elongation in 2016 was shown in Figure (3.3 A) and 2017 in Figure (3.3 B). Yoshida (1981) defined two lowest internodes as basal node. In both years, basal internode of all direct seeded plant was longer than those of cut stem transplant and normal transplant. Pham et al. (2004) classified the lowland rice into upper and lower node (count basipetally), 1-3 as upper internode and 4-5 as lower internode and there was direct correlation between culm length and lodging index. The reduction of plant height and shorter basal internode is important for lodging resistant (De Datta 1981; Ookawa et al. 1993; Zhang et al. 2016; Liu et al. 2018). In this experiment, the culm length and basal internodes of all direct seeded plants were longer than cut stem transplant and normal transplant plant. Therefore, all direct seeded plant would susceptible to lodging. As lodging affects the rice yield and so, the yield of direct seeded plant would ensure lesser than those of cut stem transplant and normal.

Table 3.3 Growth of rice plant followed with direct seeding and cut stem transplant method in Pawsan, Yoesein and Yoedayar in 2016

Variety	Cultivation method	Plant height (cm)	Panicle length (cm)	Culm length(cm)
Pawsan	Direct seeding	147.69 ± 9.1	23.58 ±23.6	124.10 ±9.1
Yoesein	Direct seeding	165.95 ± 8.7	27.22 ±1.5	138.73 ±8.4
Yoedayar	Direct seeding	169.12 ± 9.7	21.20 ±1.6	147.92 ±11.2
Pawsan	Cut stem transplant	152.10 ±11.0	27.50 ±2.2	124.6 0 ±10.7

Table 3.4 Growth of rice plant followed with direct seeding, cut stem transplant and normal transplant in Pawsan and Yoesein in 2017

Variety	Cultivation method	Plant height (cm)	Panicle length (cm)	Culm length (cm)
Pawsan	Direct seeding	160.1 ±16.6	28.03 ±1.3	132.1 ±17.1
Pawsan	Cut stem transplant	137.0 ±5.7	26.67 ±1.6	110.3 ±5.1
Pawsan	Normal transplant	140.6 ±8.3	27.78 ±1.2	112.8 ±8.2
Yoesein	Direct seeding	174.8 ±15.7	23.69 ±1.8	151.1 ±15.1
Yoesein	Cut stem transplant	158.0 ±13.8	26.97 ±1.8	131.0 ±3.0

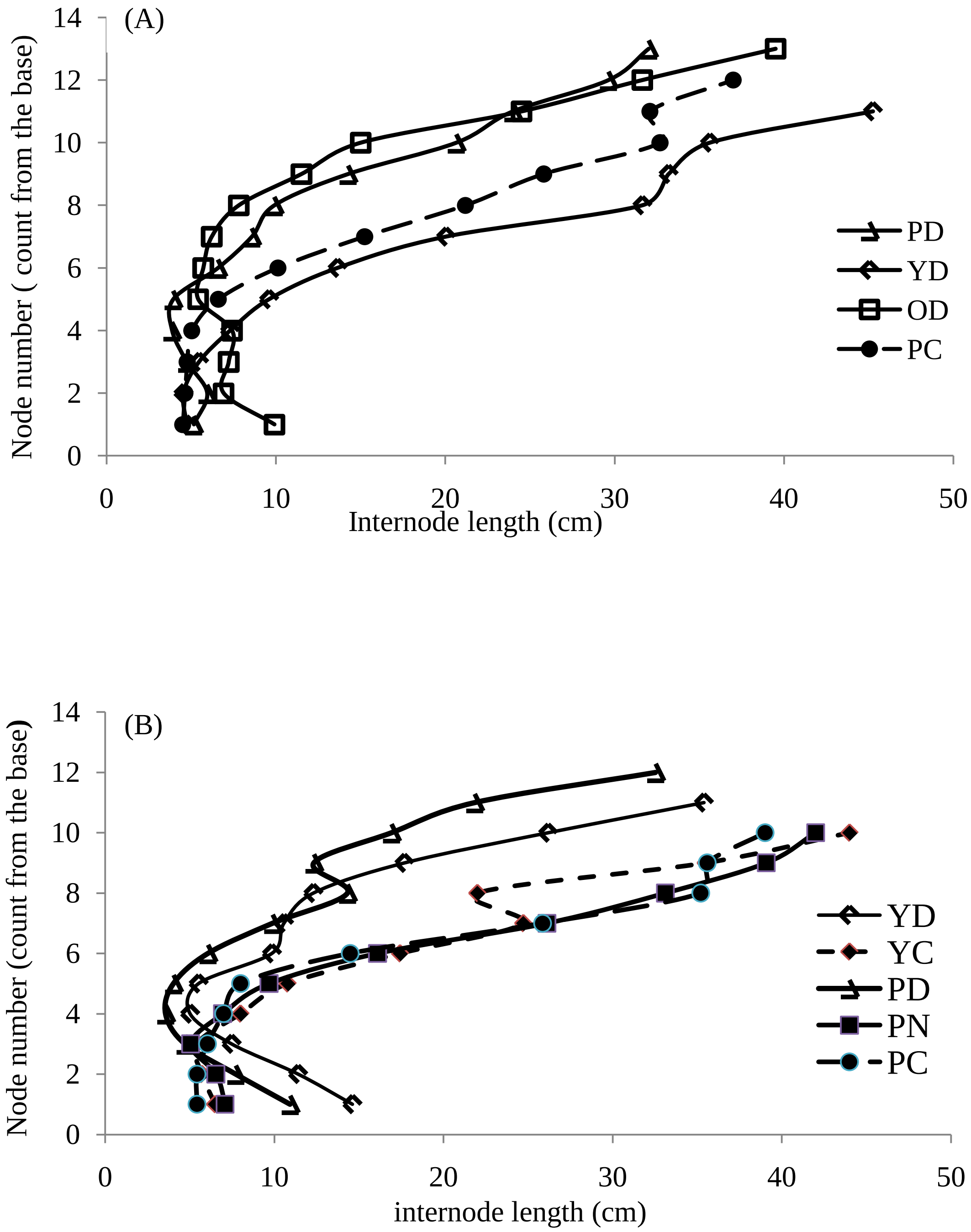

Figure 3.3 Internode elongation pattern (A) in 2016 and (B) in 2017.

Moreover, the pattern of internode elongation observed in 2016 and 2017 (Figure 3.3) showed that in all direct seeded plant, the length of internodes were not developed sequentially while those of cut stem transplant and normal transplant shown sequential development. DWR and floating rice tried to escape from flooding stress by vigorous growth of its internode (Nasiruddin et al. 1977; Nasiruddin et al. 1977; Nasiruddin et al. 1988; Thakur and HilleRisLambers 1988; Islam and Inouye 1988; Annandan et al. 2012). Difference in internode development pattern between direct seeded plant and transplanted plant is owing to flooding damage. Because, direct seeded plants are dry seeded on May before flooding occurs and the plants are suffered from flooding damage. However, in case of transplanted rice, it was done on August to September when the flood water starts to recede. Therefore, the internode elongation pattern pursued with normal and cut stem transplant method shown sequential development pattern. In addition, internode development in all direct seeded plant in 2016 and 2017 were not the same. It was due to the different water depth during plant development in cultivated field. Generally, internode development in direct seeded plant in 2017 was more curve and wavy than 2016. It might due to the flooding damage occurred at early growth stages in 2017 was more severe than 2016.

3.3.3.2 Root number recorded at harvest

Root number produced from the harvested plant in 2016 was shown in Table (3.5) and 2017 in Table (3.6). Among the Pawsan cultivated with direct seeded, cut stem transplant and normal transplant, the root no. stem^{-1} of PD was higher than other 2 methods in both 2016 and 2017. However, the root no. hill^{-1} of PC and PN achieved higher number than direct seeded in both 2016 and 2017. The same trend was observed in Yoesein in 2017. Although the root no. tiller^{-1} of direct seeded plant was higher, cut stem transplant and normal transplant had many tillers than direct seeded plant and hence, the root no. hill^{-1} was higher in cut stem transplant and normal transplant.

3.3.3.3 The number of tillers produced from each node on the main stem

When comparing the number of tillers produced from each node in cut stem transplant and normal transplant of Pawsan in 2017, the highest tiller bearing node in PC was node 2 while those of PN was node 1 (Figure 3.4) although these two methods shown the sequential development pattern.

Table 3.5 Average root number produced from Pawsan, Yoesein and Yoedayar in 2016 monsoon season

Variety	Cultivation method	Root no. stem^{-1}	Root no. hill^{-1}
Pawsan	Direct seeding	97.1 ±14.7	101.6 ±11.0
Yoesein	Direct seeding	67.1 ±18.5	88.6 ±18.2
Yoedayar	Direct seeding	121.0 ±26.0	109.0 ±26.4
Pawsan	Cut stem transplant	71.4 ±35.3	832.8 ±391.4

Table 3.6 Average root number produced from Pawsan and Yoesein in 2017 monsoon season

Variety	Cultivation method	Root no. stem^{-1}	Root number hill^{-1}
Pawsan	Direct seeding	92.0 ±22.9	92.0 ±22.9
Pawsan	Cut stem transplant	17.7 ±5.5	206.8 ±70.0
Pawsan	Normal transplant	39.1 ±10.6	389.6 ±94.3
Yoesein	Direct seeding	154.9 ±43.3	154.9 ±43.3
Yoesein	Cut stem transplant	27.9 ±8.7	211.3 ±47.7

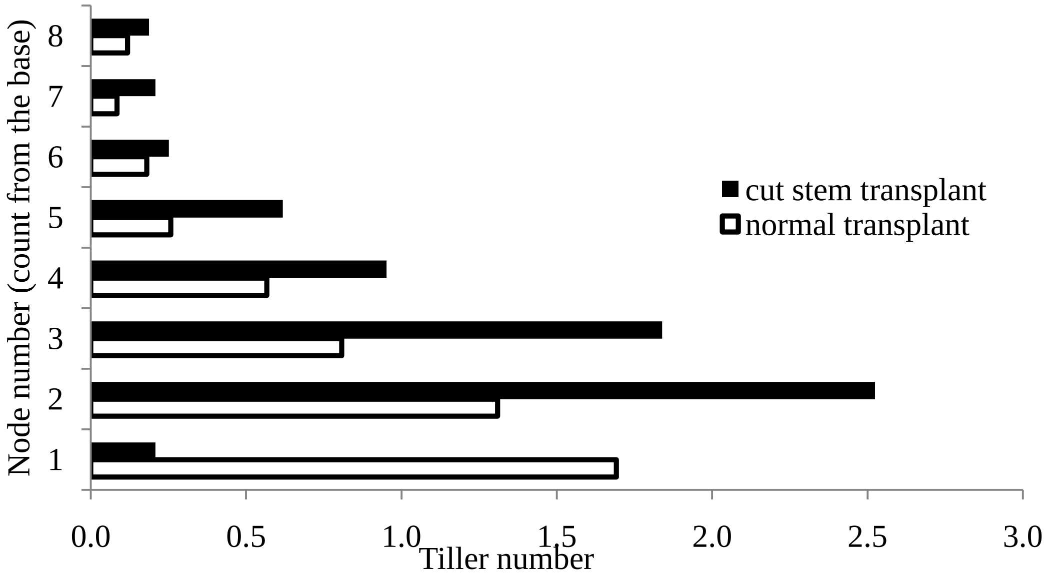

Figure 3.4 The number of tillers produced from each node in cut stem transplanted plant and normal transplanted plant and in Pawsan.

A difference in tillering pattern was due to the transplanting method. Because, PN was performed by placing transplanting fork to the root zone. However, transplanting fork was placed between the 1st and 2nd node in PC. Therefore, there was folding between 1st and 2nd node (Figure 3.3 A and B). This result was similar to the tillering and rooting from 2nd node at an early growth stage transplanting. The same phenomenon would happen in tillering from 2nd node at harvest.

3.3.3.4 The yield and yield component recorded at harvest

Yield components collected in 2016 and 2017 were shown in Table (3.7) and (3.8). In 2016, PD was missed the data on the filled grain (%), 100 grain weight (g) and yield because the grains were not fully matured at harvest. Comparing Pawsan establishment method, the no. of hill m^{-2} of PD (147.4 ±25.8) was higher than those of PC (13.24 ±3.9). However, panicle no. $plant^{-1}$ of PC (11.1±3.0) was higher than those of PD (1.1± 0.1). Therefore, panicle no. m^{-2} of PD (156.11 ±30.5) was not different from PC (145.0 ±53). In case of grains $panicle^{-1}$, the higher was achieved by PC (104.1 ±41.0) than PD (67.9 ±9.4). In addition, the highest no. of grains m^{-2} was attained by PC than YD and OD. The highest yield m^{-2} was observed in PC (296.4±102.3) followed subsequently by YD (209.8 ± 33.0) and OD (158.4 ± 41.8).

Harvested data were collected again in 2017 (Table 3.8). Among the Pawsan harvested plant, PD possessed higher population m^{-2} (48 ±26.0) than PC (15.3 ±4.6) and PN (13.0 ±3.1). However, panicle no. $plant^{-1}$of PC (11.7 ±2.2) and PN (10.8 ± 2.9) was higher than PD (1.5 ±0.3). Hence, panicle no. m^{-2} of PC (149.4 ±50) and PN (141.8 ±58) was higher than PD (67.4 ±30). Although, the grains $panicle^{-1}$ of PD (111.4 ±9.0) was higher than PC (87.6 ±9.6) and PN (95.8 ±15.7), the highest no. of grains m^{-2} showed by PC (15444 ±5349) consequently followed by PN (12970 ±3886) and the least by PD (7577 ±3693). However, there were no significant differences between 3 methods in the filled grain (%) and 100 grain weight (g). The yield (g m^{-2}) of PC was noted the highest (256.7 ±89) subsequently followed by PN (192.7 ±51) and the least by PD (107.5 ±53).

Similar to Pawsan, YD showed the higher population m^{-2} (90.3 ±28.6) than YC (14.0 ±2.1). Contrast to this parameter, panicle no. $plant^{-1}$ of YC (8.9 ±2.0) was higher than YD (1.0 ±0.08). In addition, panicle no. $m^{-2}$of YC attained (123.3 ±27.3) while YD acquired (94.0 ±29.2).

Table 3.7 Mean comparison of yield and yield components in Pawan, Yoesein and Yoedayar recorded in 2016

Variety	Cultivation method	Hill m^{-2}	Panicle no. $plant^{-1}$	Panicle no. m^{-2}	Grains $panicle^{-1}$	The no. of grains m^{-2}	Filled grain (%)	100 grain weight (g)	yield (g m^{-2})
Pawsan*	Direct seeding	147.4±25.8	1.1±0.1	156 ±31	67.9 ±9.4	10232± 2634			
Pawsan	Cut stem transplant	13.2 ±3.9	11.1±3.0	145 ±53	104.1 ±41.0	13943± 4349	67.19 ±9.2	3.17 ±0.1	296.4±102.3
Yoesein1	Direct seeding	65.4±19.7	1.4 ±0.5	85 ±16	146.0 ±21.1	12156± 2277	65.83 ±8.1	2.66 ±0.1	209.8 ± 33.0
Yoedayar	Direct seeding	81.2±11.4	1.1 ± 0.2	88 ± 21	90.4 ±10.0	7870± 1602	77.28 ±5.6	2.59 ±0.2	158.4 ± 41.8

* missed data in filled grain (%), 100 grain weight (g) and yield.

Table 3.8 Mean comparison of yield and yield components in Pawsan and Yoesein recorded in 2017

Variety	Cultivation method	Hill m^{-2}	Panicle no. $plant^{-1}$	Panicle no. m^{-2}	Grains $Panicle^{-1}$	The no. of grains m^{-2}	Filled grain (%)	100 grain weight (g)	Yield (g m^{-2})
Pawsan	Direct seeding	48±26.1	1.5±0.3	67±30.7	111± 9	7578±3693	48.66±11.9	3.02±0.1	107.5±53.3
Pawsan	Cut stem transplant	15± 4.7	11.7±2.3	149±50.3	88±10	15444±5349	54.47± 4.7	3.05±0.1	256.8± 89.1
Pawsan	Normal transplant	13± 3.1	10.8±2.9	142±57.9	96±16	12970±3886	51.37± 6.8	2.95±0.1	192.7±51.0
Yoesein	Direct seeding	90±28.6	1.0± 0.1	94±29.2	96± 20	8688±2421	67.64± 15.1	2.98± 0.1	173.3± 54.3
Yoesein	Cut stem transplant	14 ±2.1	8.9 ±2.0	123±27.3	123± 10	15231 ±4006	67.92± 6.7	2.89±0.1	294.7 ±59.8

Similarly, YC possessed higher no. of grains m^{-2} (15231 ±4005) than YD (8688 ±2421). However, there were no significant differences between filled grain (%) and 100 grain weight (g). Similar to Pawsan, the yield of YC (g m^{-2}) was (294.7 ±60) and higher than YD (173.2 ±54). If comparing the yield on 2 years (2016 and 2017), cut stem transplant yield higher than normal transplant and direct seeded plant in both Pawsan and Yoesein.

Moreover, relationship between yield and yield related parameters were observed in 2016 (Table 3.9) and in 2017 (Table 3.10). Regarding data in 2016, yield was correlated with grains $panicle^{-1}$ (r=0.530*) and the no. of grains m^{-2} (r=0.879**) and 100 grains weight (r=0.594*) in PC. In case of YD, yield (g m^{-2}) was related with panicle no. m^{-2} (r= 0.621*) and the no. of grains m^{-2} (r= 0.675*). Concerning OD, the yield was related with panicle no. $plant^{-1}$ (r= 0.976**), the no. of grains m^{-2} (r= 0.876*). Regarding the data in 2017, the yield is correlated with hill m^{-2} (r= 0.873**), panicle no. $plant^{-1}$ (r=0.548*) and panicle no. m^{-2} (r= 0.847**) in PD. In addition, yield in PC is positively and significantly related with hill m^{-2} (r= 0.671**), panicle no. m^{-2} (r= 0.929**), grains $panicle^{-1}$ (r= 0.490*) and the no. of grains m^{-2} (r= 0.970**). Similarly yield is related with hill m^{-2} (r= 0.478*), panicle no. $plant^{-1}$ (r= 0.589**), panicle no. m^{-2} (r= 0.686**) and the no. of grains m^{-2} (r= 0.850**) in PN. Among Yoesein harvested plant, yield in YD is related with hill m^{-2} (r= 0.657**), panicle no. m^{-2} (r= 0.699**) and the no. of grains m^{-2} (r= 0.767**). However in YC, yield is related with panicle no. $plant^{-1}$ (r= 0.832*), panicle no. m^{-2} (r= 0.933**), the no. of grains m^{-2} (r= 0.897**). According to the result in 2017, grain yield of all harvested plant were correlated with panicle no. m^{-2}.

Grain yield is significantly and directly correlated with hill m^{-2} and panicle no. m^{-2} in direct seeded plant. Similar finding for relation with panicle no. m^{-2} is found in Surek and Beser (2003). Gravois and Helms (1991) noted that adequate panicle density per unit area of uniform maturity should be achieved. Positive relation with hill m^{-2} is contrary to the finding of Pane et al. (1996) and Tran Thi Ngoc Huan et al. (1999). In their finding, rice yield is conversely correlated with hill m^{-2}. It is due to the planting population per unit area. Close spacing is essential for high yield (De Datta, 1981) whereas optimum planting density is important for grain yield (Gravois and Helms 1991 and Tran Thi Ngoc Huan et al. 1999)). In transplanted rice, grain yield is related with hill m^{-2}, panicle no. $plant^{-1}$ and panicle no. m^{-2} in Pawsan normal transplant and Yoesein cut stem transplant in 2017.

Table 3.9 Relationship (r) between yield and yield components in Pawsan, Yoesein and Yoedayar in 2016

Variety	Cultivation method	Hill m^{-2}	Panicle no. $plant^{-1}$	Panicle no. m^{-2}	Grain $panicle^{-1}$	The no. of grains m^{-2}	Filled grain (%)	100 grain weight
Pawsan	Cut stem transplant	0.055 ns	0.354 ns	0.341 ns	0.530 *	0.879 **	0.277 ns	0.594 **
Yoesein	Direct seeding	0.000 ns	0.402 ns	0.621 *	0.000 ns	0.675 *	0.243 ns	0.122 ns
Yoedayar	Direct seeding	0.083 ns	0.976 **	0.768 ns	0.000 ns	0.876 *	0.669 ns	0.333 ns

* * Significant different at 1% level, * Significant different at 5% level, ns= Non significant

Table 3.10 Relationship (r) between yield and yield components in Pawsan and Yoesein in 2017

Varieties	Cultivation method	Hill m^{-2}	Panicle no. $plant^{-1}$	Panicle no. m^{-2}	Grains $panicle^{-1}$	The no. of grains m^{-2}	Filled grain (%)	100 grain weight
Pawsan	Direct seeding	0.873 **	0.548 *	0.847 **	0.245 ns	0.838 **	0.212 ns	0.109 ns
Pawsan	Cut stem transplant	0.671 **	0.281 ns	0.929 **	0.490 *	0.970 **	0.392 ns	0.202 ns
Pawsan	Normal transplant	0.478 *	0.589 **	0.686 **	0.210 ns	0.850 **	0.422 ns	0.063 ns
Yoesein	Direct seeding	0.657 **	0.214 ns	0.699 **	0.170 ns	0.767 **	0.402 ns	0.366 ns
Yoesein	Cut stem transplant	0.158 ns	0.832 *	0.933 **	0.349 ns	0.897 **	0.368 ns	0.237 ns

** Significant different at 1% level, * Significant different at 5% level, ns= Non significant

Direct relation with panicle no. plant^{-1} is agreed to the report of Ibraham et al. (1990), Rajeswari and Nadarajan (2004), Machunde (2013) and Srijan et al. (2016). Moreover, panicle no. m^{-2} is the multiplication of hill m^{-2}and panicle no. plant^{-1}. Direct relation with panicle no. m^{-2} and yield is found in all transplant plant in both years and is similar to the finding of many authors (Surek and Beser 2003; Surek and Beser 2005; Agahi et al. 2007; Machunde, 2013; Min et al. 2011; Fageria et al. 2011 and Li et al. 2014) in transplanted rice.

In 2016, grain yield (g m^{-2}) is significantly and directly related with grains m^{-2} in all harvested varieties. The no.of grains m^{-2} is the combine contribution of panicle no. m^{-2} and the no. of grains panicle^{-1}. Relationship between the no. of grains m^{-2}and panicle no. m^{-2}and the no. of grains panicle^{-1}were calculated (Figure 3.5). The no. of grains m^{-2} is mostly contributed by the panicle no. m^{-2} (R^2= 0.239*) in PC, (R^2= 0.542**) in YD, (R^2= 0.835*) in OD and there is no relation with gains panicle^{-1}.

3.4 Conclusion

Pawsan cut stem transplant plants with detached roots could produce roots and tillers from elongated internodes starting by three days after transplant. The number of tillers and roots were higher number that born in second node (count from the base). In comparing the three rice cultivation methods, the productivities are highest in cut stem transplant subsequently followed by normal transplant and direct seeding method. The number of grains m^{-2} is significantly correlated with yield m^{-2} in the deep water rice in Bago region. For the cut stem transplant method, the number of grains m^{-2} is mostly decided by the number of panicle m^{-2} than the number of grains panicle^{-1}.

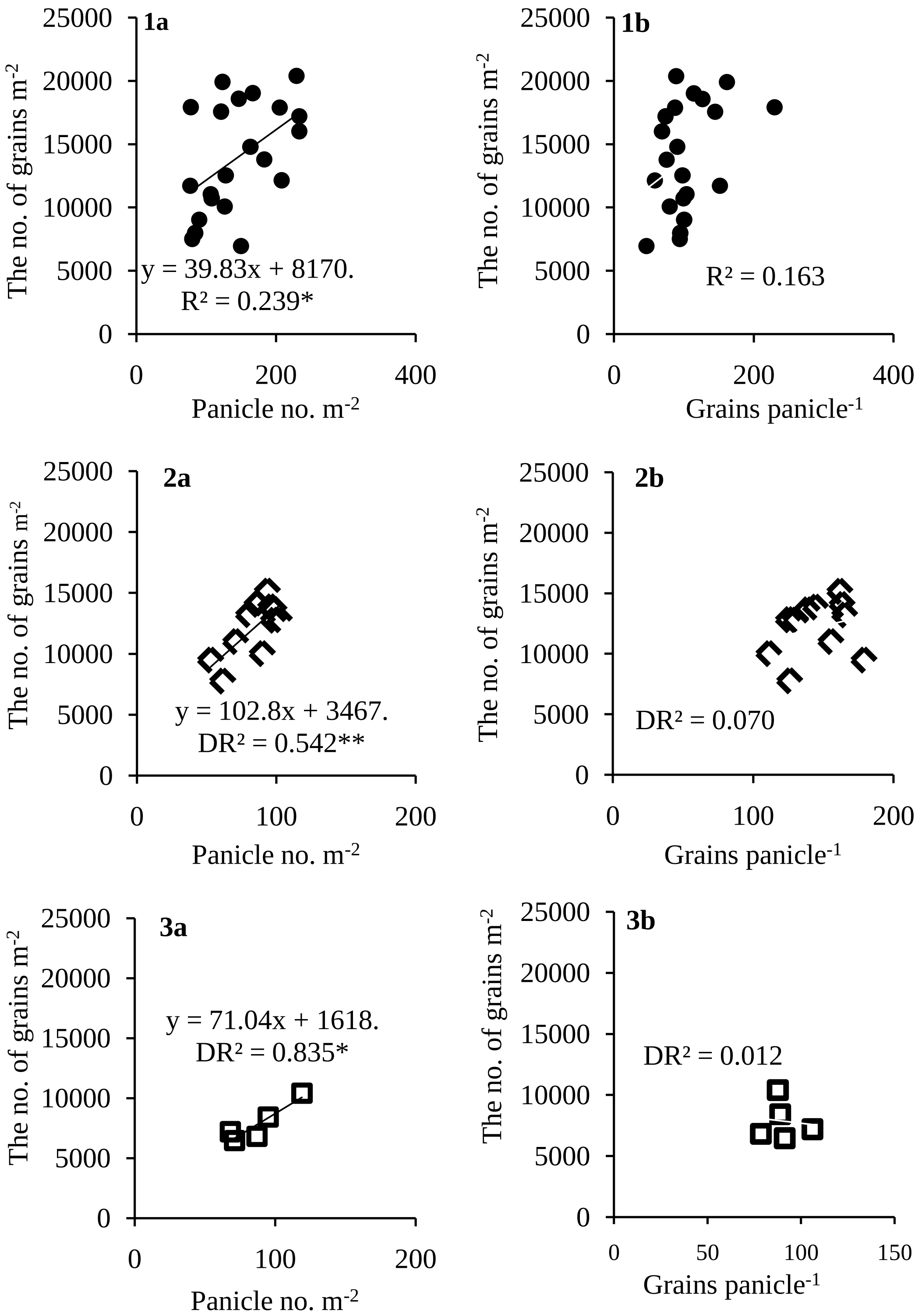

Figure 3.5 Relationship (R^2) between the no. of grains m^{-2} and panicle no. m^{-2} (1a) in Pawsan cut stem transplant plant, (2a) in Yoesein direct seeded plant, (3a) in Yoedayar direct seeded plant, Relationship (R^2) between the no. of grains $m^{-2}$and grains panicle^{-1} (1b) in Pawsan cut stem transplant plant (2b) in Yoesein direct seeded plant (3b) in Yoedayar direct seeded plant in 2016.

CHAPTER IV
EFFECT OF CUTTING POSITION ON GROWTH AND YIELD OF PAWSAN CUT STEM TRANSPLANT PLANT

4.1 Introduction

There are many conventional used rice crop establishment methods in which direct seeding and transplanting are the most commonly used methods in the world. Dry seeding is fairly common in DWR. Sometimes, transplanting or double transplanting is practiced (De Datta 1981). Double and triple transplanting is locally practiced in flooded area of Indonesia (Noorsyamsi et al. 1984), Vietnum (Puckridge 1988) and India (Singh et al. 2004) depending on land situation and weather condition. Likewise, there is locally used method which is adapted to flooded condition in Myanmar. DWR responses to flooding by stem elongation, which occurs chiefly by internode elongation together with a lengthening of the terminal leaf blade and sheath (Alim et al. 1962). Although, the plant elongates in response to flooding stress, the plant do lodge after water recedes. In this occasion, the elongated stem is cut and transplanted without roots. It is practiced in some of DWR field in Thanatpin Township, Bago Region in Myanmar. This method is the feasible way to resilient from flooding damaged. Although rooting from the stem cutting and bearing panicle in rice is a little strange, it is currently practice in deep water area in Thantpin Township, Bago Region. Moreover, it was learned that root pruning and phloem girdling stimulate suckering in Aspen root (Farmer, 1962). However, root pruning of all roots in rice at 6 leaf age affects growth and development of tiller buds (Yamamoto, 1989). Moreover, cutting of root in hybrid rice at different length at 25 and 40 days seedlings age, the longer the root cutting, the more inhibits the root growth and affects the growth and development of rice seedlings (Li et al. 2018). In contrast, root cutting treatment on high yielding rice at 40-45 days after sowing did not retard the plant growth if roots were cut after shooting of tiller buds from the main culm (Tanabe, 1982). Although transplanting with stem cutting (without root) is applied practically in some deep-water rice area in Thanatpin Township, Bago Region, it is necessary to investigate whether root cutting affects the growth and yield of DWR. In addition, there might have some effect of cutting position of the elongated stem of DWR. Decapitation of different bud in the shoot responses differently in *Ipomoea nil* (Chern et al. 1993), *Pisum sativum* (Balla et al. 2016) and

Eucalyptus globules (Wilson, 2015). Moreover, Dun et al. (2006) interpreted that buds located at different nodes showed various response to decapitation and the location of the bud on the stem determined its outgrowth potential. Although there is no decapitation of shoot of rice plant in this method, there might have some different cutting position effect owing to cutting at different bud. Therefore, to verify different cutting effect on the growth of Pawsan, experiment was carried out.

4.2 Materials and Methods

4.2.1 Experiment site

Experiment was conducted at Ywa Houng village, Thanatpin township which is situated at 17^{o}12'42"N Latitude, 96^{o}18'11"E Longitude and 9 m above sea level. It was done in 2017 wet season.

4.2.2 Experimental design

Experimental design was Randomized Complete Block (RCB) design with 4 replications. There were five treatments as follow.

T1	seedlings with root (control)
T2	cut at unelongated internode
T3	cut at 15 cm above the soil
T4	cut at 30 cm above the soil
T5	cut at 45 cm above the soil

4.2.3 Cultural practices

The ungerminated seeds of Pawsan, photoperiod sensitive cultivar flowering at mid of December, was collected from the farmer and dry seeded to the nursery field at the beginning of May, 2017 with the seed rate of 170 kg ha^{-1} (3.3 basket ac^{-1}). No fertilizer was applied during the nursery period. When the seedlings were 130 days old, the seedlings were cut as the treatment and transplanted with the spacing of 25 cm x 25 cm at the rate of one seedling per hill. The size of each plot is 2 m x 2 m and sixty four hills were transplanted in each plot. To favor rooting, at least one node per cutting was required as the root comes out from the node. The plant height at transplant was not too high and the node number was insufficient to cut because the experimental nursery was situated in the shallow water area. Therefore, to transplant T1, T2 and T3, the seedlings were taken from the experimental nursery while the cutting for T4 and T5 were collected from farmer's field situated in deeper water area. Transplanting was done by manually placing the basal node about 10 cm immersed to the puddle soil for all treatment. Water level at transplanting was 25 cm in the field. Besides, there was the top dressing application of urea fertilizer for 2 times; 52kg ha^{-1} (46lb ac^{-1}) at 18 days after transplanting and 77 kg ha^{-1} (55lb ac^{-1}) again at 80 days after transplanting. No insecticide or herbicide was applied during cultivation period. The plants were harvested on third week of December, 2017 when the rice was fully ripened.

4.2.4 Data collection

Plant growth data were collected at 2 phases. During plant growth, 5 plants per plot were sampled by taking across the field. At harvest, the weight yield was determined by harvesting $1m^2$ from the middle of the plot. Tiller no. $plant^{-1}$ was counted by skipped 2 rows from border and counted all plants. Other yield component data were taken from 3 plants $plot^{-1}$ which had the average number of panicles from that plot.

(1) Plant height (cm)

Plant height was measured from the soil surface to the tip of the plant among the 3 representative plant samples.

(2) Tiller number

Tiller number was counted only to the effective tillers. Two rows from the border were skipped and counted all the plant in that plot.

(3) Root number

Root number was counted from 3 representative plant samples. The plant samples were cleaned in running water to remove the soil and air dried for 4 days and counts manually only the primary root.

(4) Root dry weight (g)

After counting, all roots were placed inside a stamp and dried with EYELA Type WFO- 420W oven dried at 80^{o}C for 3 days and checked the weight with digital balance AND Types GF 400

(5) Shoot dry weight (g)

The shoot containing leaf and stem from 3 representative plant samples were hanging for 1 week and oven dried by using EYELA Type WFO- 420W at 80^{o}C for 3 days and checked the weight with digital balance AND Type GF 400.

(6) Root shoot ratio

The root and shoot weight (g) were measured from 3 representative plant samples by air drying the root and shoot which contains leaf, stem and panicle for one week. The the weight of root was divided with the total shoot weight to get root /shoot.

(7) Panicle no. plant^{-1}

All panicles from all plants were counted and average to get panicle no. plant^{-1}.

(8) Grains panicle^{-1}

All grains from three representative plant samples were counted by using grain counter, WAVER made from Daidex Company, Japan and divided with the panicle no. to result grains panicle^{-1}.

(9) Filled grain (%)

Filled grain (%) was recorded by dipping all the grains in water (Specific gravity 1) and separated the filled and unfilled grains realizing the floated grains as unfilled grain and sinked to the bottom of the container as filled grain. Filled grain (%) was calculated by using the following formula (Gomez, 1972)

$$\text{Filled grain (\%)} = \frac{\text{Filled grain} \times 100}{\text{Total grain}}$$

(10) Hundred grain weight (g)

Hundred grain was counted 3 times from all the grains produced from 3 representative plant samples. After counting, the weight (g) was measured by using digital balance AMD Type GF 400. After that, the grain moisture content was immediately measured by using MOISTEX Type SS-7 made from Satake company and adjusted the weight to 14% moisture by using the following formula (Gomez, 1972).

$$\text{Hundred grain weight (g)} = \frac{G \times (100-M)}{100-14}$$

in which G = Measured grain weight (g)

M = Measured grain moisture content

(11) Yield hill^{-1}

Yield hill^{-1} was calculated by using the following formula.

$$\frac{\text{Yield}}{\text{hill}} = \frac{\text{Panicle no.hill} \times \text{Grains panicle} \times \text{Filled grain (\%)} \times \text{100grain weight(g)}}{100 \times 100}$$

(12) Yield m^{-2}

Yield m^{-2} was calculated by multiplying the hill /m^2 and yield /hill.

(13) Weight yield (g m^{-2})

Weight yield was determined by threshing all the grains from 1 m^2 harvested plot. Threshed the unfilled grain from filled grain and weight with digital balance AMD Type GF 400.

4.2.5 Data analysis

The data were analyzed by using excel and statistix version 8.0 and mean separation was done with least significant distance (LSD) at 5% level.

4.3 Results and Discussion

4.3.1 Seedling height and node no. at transplant

Seedling growth at transplant was shown in Table (4.1). Among the treatments, the highest plant height (cm) was observed in T4 and those of node no. in T1 while it is not different among other treatments.

4.3.2 Plant development during growth

During the plant growth period, plant height (cm) and the number of tillers were recorded. Increase of plant height measured at 20 days after transplanting (DAT), 50DAT and 80DAT was shown in Table (4.2). At 20DAT, the highest plant (cm) was observed in T4 (107.05) and which was statistically different from T5 (95.25) and T2 (87.1).

Table 4.1 Seedling height and node no. at transplant

No.	Treatments	Node no.	Stem length (cm)	No. of nodes
1	T1	5.3	112.7	5.3
2	T2	4.1	96.0	4.1
3	T3	3.9	107.7	3.9
4	T4	4.0	124.3	4.0
5	T5	3.6	109.8	3.6

Table 4.2 Mean plant height (cm) during plant growth in Pawsan

No.	Treatment	20DAT	50DAT	80DAT
1	T1	99.5 ab	115.1 a	128.5 c
2	T2	87.1 c	119.7 a	136.5 b
3	T3	101.5 ab	122.1 a	142.5 a
4	T4	107.1 a	119.5 a	142.1 ab
5	T5	95.3 bc	123.2 a	143.8 a
	LSD	9.69	9.76	5.81
	C.V.	6.42	5.29	2.72

Means followed by the same letters are not significantly different at LSD 5% level

Table 4.3 Mean numbers of tillers producing during plant growth in Pawsan

No.	Treatment	20DAT	50DAT	80DAT
1	T1	2.8 abc	11.6 a	15.0 a
2	T2	3.0 ab	11.9 a	11.9 b
3	T3	2.7 bc	12.3 a	11.6 b
4	T4	2.4 c	11.4 a	11.7 b
5	T5	3.1 a	12.6 a	11.3 b
	LSD	0.40	2.08	2.38
	Pr>F	5.22	0.54	3.86
	C.V.	9.40	11.26	12.62

Means followed by the same letters are not significantly different at LSD 5% level

Nevertheless, no significant differences of plant height were observed in 50DAT. On the other hand, difference in plant height (cm) was observed again at 80DAT in which T5 (143.8) was achieved the highest plant height and which was significant difference from T2 (136.5) and T1 (128.5). The highest number of tillers at 20DAT was examined at T5 (3.1) and which was statistically different from T3 (2.7) and T4 (2.4) (Table 4.3). Conversely, tiller number checked at 50DAT was not significantly different each other.

When recording again at 80DAT, all of the treatments were not significantly different each other except T1 (14.95). The number of tillers was only increased unto 50DAT and remains the same or decreased in tillers from 50DAT to 80DAT. This tillering pattern is comparable to other reports. Chang et al. (1965) and Badshah et al. (2014) revealed that tiller numbers increase until maximum tillering stage and after that it decline and some of the tillers die. That reduction is due to the competition of assimilates between tillers and mother culm (Biswas and Salokhe 2005).

4.3.3 Plant growth at harvest stage

Plant height (cm) examined at harvest was shown in Table (4.4). The highest plant height (cm) was recorded in T4 (131.17) subsequently followed by T5 (127.96), T3 (126.42), T2 (126.12) and T1 (123.71) respectively. In addition, culm length (cm) of T4 (105.42) was highest succeeded by T3 (99.92), T2 (99.83), T5 (99.58) and the least by T1 (96.87) accordingly. The number of tillers produced from each node was shown in Table (4.5). In this table, transplanting with stem cut treatment T2, T3, T4 and T5 were not different in producing tillers from each node as control (T1). In addition, the number of tillers produced from each node were highest in the order of node 1> node2> node3> node4 and so on. Among the treatments, the first and second node is the largest tiller producing node. That finding was agreed to the report of Akita (1976), Yamamoto and Ikeuchi (1990) and Yamamoto et al. (1994) that the two lowest tillering nodes produced the tillers number more than those produced from upper nodes. Lowest nodal tillers are important and contribute to increasing yield (Gendua et al. 2009). Tillers emerged from lower node was earlier than those produced from middle or upper node (Ming et al. 2012). Concerning the root characters, there was no statically different among treatments in all measured characters such as root no. tiller^{-1}, root no. hill^{-1}, root dry weight (g), shoot dry weight (g) and root shoot ratio (Table 4.6). Rooting from elongated internode in DWR and the important of nodal rooting was observed in the literature (Chang et al. 1965; Vergara et al. 1976; Islam, 1977; Vergara et al. 1977; Inoue and Mochizuki 1980; Kanter et al. 1982; Saran et al. 1982; Khan and Vergara 1982; Nitta et al. 1998 and Nitta et al. 1999). Furthermore, Sophonsakulkaew et al. (1977) conducted in the screening for elongation ability of DWR by transplanting the cutting of the top part of the plant (the second node from the top) and allowed to grow into normal plant and checked the plant characteristics.

Therefore, it is obvious that stem cutting from the elongated stem of DWR can be used for plant propagation. Although the stem is cut and transplanted in this experiment, rooting from different stem cutting is not statistically different from control (T1) (Table 4.6). Not only the root number, root dry weight is not different as well. The shoot can produced from stem cutting as normal plant (control) and similar root shoot ratio was observed. Therefore, the result approved that new plant can produced from stem cutting like normal seedling in Pawsan variety under deep water condition..

Table 4.4 Mean plant height (cm) and culm length (cm) for each treatment at harvest in Pawsan

No.	Treatment	Plant height (cm)	Culm length (cm)
1	T_1	123.71 b	96.87 b
2	T_2	126.12 ab	99.83 ab
3	T_3	126.42 ab	99.92 ab
4	T_4	131.17 a	105.42 a
5	T_5	127.96 ab	99.58 ab
	LSD	6.85	6.93
	C.V.	3.68	4.48

Means followed by the same letters are not significantly different at LSD 5% level

Table 4.5 Mean number of tillers produced from each node in different treatment observed in Pawsan

No.	Treatment	Tillers on node						
		1	2	3	4	5	6	7
1	T1	3.50	4.50	2.00	2.33	1.67	1.67	-
2	T2	3.00	2.25	2.00	2.00	2.67	1.50	1.00
3	T3	3.25	3.25	2.00	1.75	1.00	1.00	-
4	T4	3.00	2.50	1.50	2.50	1.33	1.00	-
5	T5	4.00	3.75	1.75	1.50	1.50	1.00	-
	mean	3.35	3.25	1.85	2.02	1.63	1.23	1.00
	SD	0.42	0.92	0.22	0.41	0.63	0.32	-
	CV	12.50	28.30	12.10	20.30	38.50	26.30	-

Table 4.6 Mean comparison of root and shoot characteristics at harvest in Pawsan

No.	Treatment	Root no. $Tillers^{-1}$	Root no. $hill^{-1}$	Root dry weight $hill^{-1}$ (g)	Shoot dry weight $hill^{-1}$ (g)	Root Shoot ratio
1	T1	17.50 a	257.25 a	0.983 a	59.66 a	0.017 a
2	T2	21.51 a	251.33 a	0.933 a	52.45 a	0.019 a
3	T3	20.57 a	239.17 a	0.983 a	57.54 a	0.017 a
4	T4	18.69 a	213.42 a	0.925 a	54.56 a	0.017 a
5	T5	20.58 a	251.67 a	1.100 a	50.29 a	0.022 a
	LSD	8.81	89.42	0.47	14.73	0.009
	Pr>F	0.33	0.37	0.21	0.62	0.52
	C.V.	28.91	23.93	31.10	17.42	33.22

Means followed by the same letters are not significantly different at LSD 5% level

4.3.4 Yield and yield component at harvest

Yield and yield component data were recorded at harvest (Table 4.7). Regarding hill m-2, the highest number of hill m-2 was attained in T4 (17.0) and it was statistically different from T3 (16.0), T2 (15.8) and T1 (13.8). There was no statistically different among treatment in panicle no. hill-1, grain panicle-1 and filled grain (%). Besides, hundred grain weight of T5 (3.21) was the least and statistically different from T1 (3.5) and T3 (3.47). Concerning yield hill-1 (g), the highest yield was observed in T1 (26.11) successively followed by T3 (24.5), T4 (21.18), T2 (20.8) and the least by T5 (18.22). Regarding the yield m-2 (g), the highest was observed in T3 (391.42) followed by T4 (361.08), T1 (339.49), T2 (324.66) and T5 (296.72) consequently. The weight yield harvested from 1m2 sample plot was also recorded in T3 (400.6) followed accordingly by T4 (355.2), T1 (344.37), T2 (331.08) and the least by T5 (306.25). Although T1 achieved the highest in yield hill-1, it can't show the highest yield m-2 due to lesser hill no. m-2. In comparing the yield m-2 of each treatment, the treatment T3 produced the highest yield among treatments even though which is not statistically different from other treatments except T5. Besides, T5 bears the least yield among treatments although it is not statistically different from T1. Therefore, it could be interpreted though T2, T3, T4 and T5 are cut and transplanted, the stem cut treatment are not statistically different in yield from T1. Different cutting effect was observed in other crops such as pineapple (Ranawana and Eeswara 2008), Ipomoea nil (Chern et al. 1993), Pisum sativum (Balla et al. 2016), Garcinia kola (Kouakou et al. 2016). Buds located at different nodes show various response to decapitation and it confirms the fact that the location of the bud on the stem influences its outgrowth potential (Dun et al. 2006). Comparable to those finding, different cutting effect was observed in this experiment. Transplanting with stem cutting cut at 15 cm above the soil favors the higher yield among the stem cut treatment and even slightly higher yield than control.

Table 4.7 Mean comparison of yield and yield component at harvest in Pawsan

No	Treatments	Hill m^{-2}	Panicle no. $hill^{-1}$	Grain $panicle^{-1}$	Panicle no. m^{-2}	Grain m^{-2}	Filled grain (%)	100 grain weight (g)	Yield $hill^{-1}$ (g)	Yield m^{-2} (g)	Weight yield(g)
1	T1	13.8 b	15.00 a	92.5 a	206.3 a	18416 a	54.23 a	3.50 a	26.11 a	339.5 ab	344.4 a
2	T2	15.8 ab	13.58 a	85.8 a	212.0 a	18279 a	52.23 a	3.45 ab	20.80 ab	324.7 ab	331.1 ab
3	T3	16.0 ab	13.58 a	96.4 a	217.6 a	20812 a	54.61 a	3.47 a	24.50 ab	391.4 a	400.6 ab
4	T4	17.0 a	12.58 a	91.0 a	211.0 a	19246 a	53.94 a	3.41 ab	21.18 ab	361.1 ab	355.2 ab
5	T5	16.3 ab	12.58 a	88.3 a	202.5 a	17852 a	52.30 a	3.21 b	18.22 b	296.7 b	306.3 b
	C.V.	12.1	15.41	11.8	19.3	18	11.25	4.85	21.08	15.7	16.4
	LSD	2.9	3.19	16.5	62.4	5253	9.3	0.25	7.21	83.0	88.0

Furthermore, the relationship between yield and other yield component characters were shown in Figure (4.1). Yield m^{-2} is highly significantly related with panicle no. $plant^{-1}$ (R^2= 0.322**), panicle no. m^{-2} (R^2= 0.358**) and the no.of grain m^{-2} (R^2= 0.678**) (Fig. 4.1). Among the significant relation, the highest positively and significantly related with yield m^{-2} was the no. of grains m^{-2}. The no. of grains m^{-2} was the combine contribution of hill m^{-2}, panicle no. $plant^{-1}$ and grains $panicle^{-1}$ and their relations was shown in Figure (4.2). The no. of grains m^{-2} is highly and significantly related with panicle no. $hill^{-1}$ (R^2=0.498**), but it is not related with hill m^{-2} (R^2= 0.058) and grains $panicle^{-1}$ (R^2= 0.052) in this experiment. The relationship between yield m^{-2} and panicle number m^{-2}, the no. of grain m^{-2} waa reported by (Rajeswari and Nadarajan 2004). That finding was similar to the finding of Gravois and Helms (1991) and Miller (1991). Ashrafuzzaman et al. (2009) reported that grain yield is correlated with number of panicle per plant in their experiment. In addition, De Datta (1981) and Sidhu et al. (2014) evaluated that rice yield is mostly determined by the panicle no. m^{-2}. Reduced tillering is the constraint for higher yield in medium-deep water condition (Mahapatra and Reddy 1982). In addition, Yoshida (1981) interpreted that the yield increased with the increasing grains m^{-2} than filled spikelet percentage and 1000 grain weight. However, at some location and weather condition, filled spikelet (%) is more affect to the yield than the number of grains m^{-2}. Hence, the author suggests that both of grains m^{-2} and filled spikelet (%) should be examined to check the causes of yield variation.

4.4 Conclusion

Elongated stems of 130 days old seedlings of Pawsan can be cut and transplanted. Seedlings from the stem cutting at unelongated internode, 15 cm above the soil, 30 cm above the soil and 45 cm above the soil can produce roots and shoots comparable to transplanting with normal seedlings. During plant growth period, plant height and tillers produced from the stem cutting treatment (T2, T3, T4 and T5) facilitate similar trend to the development of normal seedlings. Furthermore, tillers produced from each node in stem cutting treatments bears the same trends as produced in normal seedlings. Different stem cutting effect is examined in this experiment. Transplanting with stem cutting cut at 15 cm above the soil generate the highest yield while stem cutting cut at 45 cm above the soil surface bears the lowest yield. Moreover, it is observed that the yield is highly correlated with the no. of grains m^{-2} and which in turn is related with panicle no. $plant^{-1}$ rather than grains $panicle^{-1}$ and hill m^{-2}.

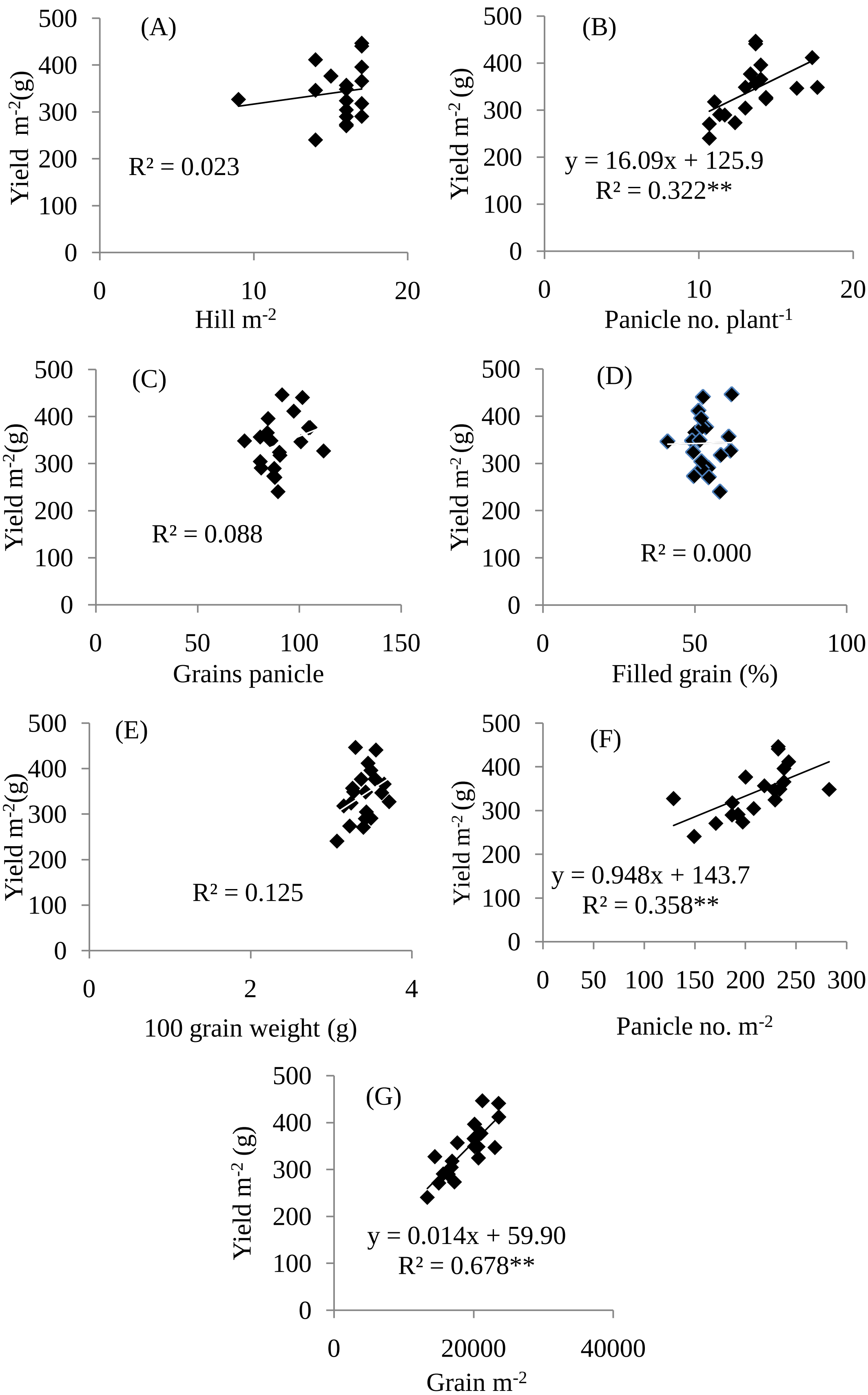

Figure 4.1 Relationship (R2) between yield m^{-2} and (A) relation with hill m^{-2} (B) panicle no. $plant^{-1}$, (C) grains $panicle^{-1}$ (D) filled grain (%), (E) 100 grain weight (g) (F) panicle no. m^{-2} and (G) grains m^{-2}

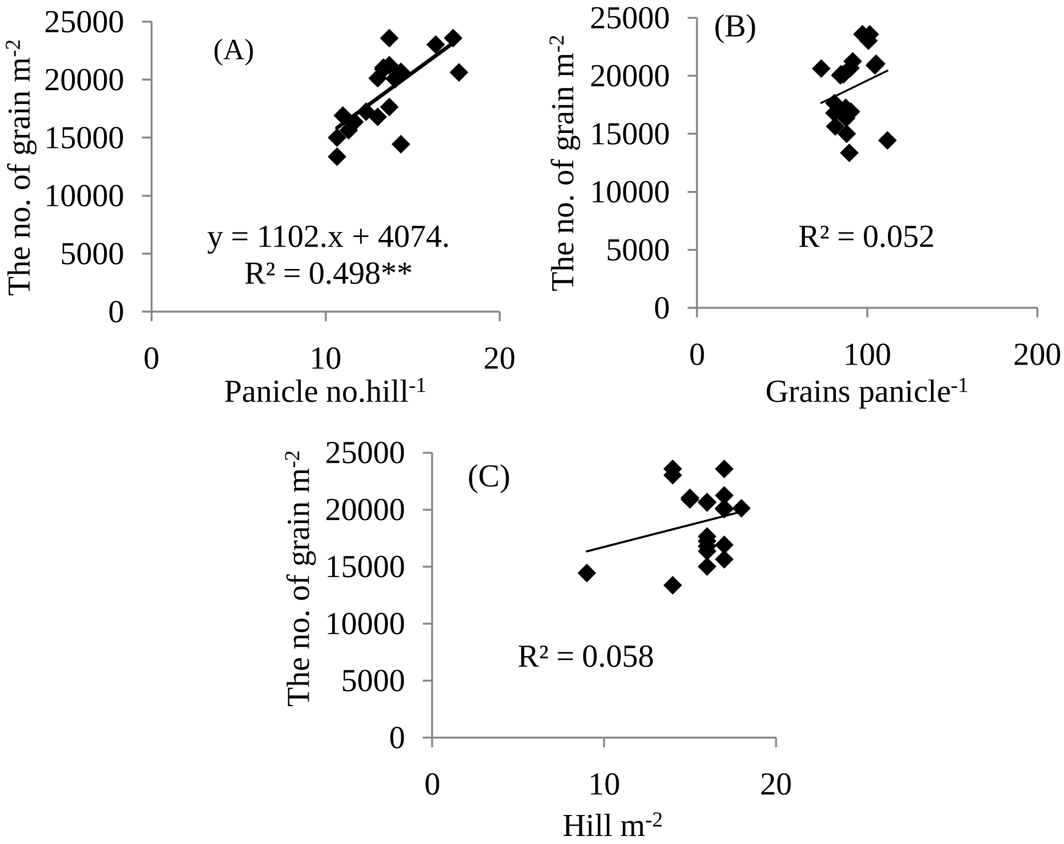

Figure 4.2 Relationship (R^2) between the no. of grains m^{-2} and (A) panicle no. hil^{-1}, (B) grains $panicle^{-1}$ (C) hill m^{-2}

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CHAPTER V
EVALUATING THE YIELDING ABILITY AND GROWTH PERFORMANCE OF CUT STEM TRANSPLANT METHOD AMONG FLOOD TOLERANT RICE UNDER SHALLOW WATER CONDITION

5.1 Introduction

Deepwater area in Myanmar is classified into shallow water, medium deepwater and deepwater area as follows. Shallow water area is the area with less than 50cm depth, while medium deep is 50-200 cm water depth and deepwater area as over 200cm water depth (Kyaw et al. 1977). Among unfavorable area (32% of the cultivated area), submerged and deep water areas are the second most devastated area after drought (DP 2015). Moreover, there are conventional used rice crop establishment methods in the world. The most commonly used methods are direct seeded and transplanted rice. Total cultivated area of Myanmar monsoon rice was 6.22 Mha in which 65% of cultivated area was established with transplanting, 25% with broadcasting (scattering of the seed) and 10% with direct seeding (line sowing) method in 2015-16 fiscal year (MOALI, 2016). Cultivation systems in flooded area are adjusted to the crop ambient condition in the world. DWR is mix- cultivated with early-maturing aus rice or other crops such as millet, sesame, jute, maize, sorghum and mungbean in Asia (Catling et al. 1988). In addition, double and triple transplanting is practiced in flooded area of Indonesia (Noorsyamsi et al. 1984) and Chau Thanh District in Vietnam (Puckridge, 1988). Likewise, cut stem transplant method in Thanatpin is followed if the direct seeded field and nursery field are lodged due to flooding damage. If this method is applicable in shallow water condition, it can apply in lowland rice field if flooding damage occurs. Moreover, it is interested to investigate whether other DWR varieties could be practiced with this method. Therefore, the objectives of this experiment were to verify the productivity of cut stem transplant method under shallow water condition, to identify the yielding ability and growth performance of cut stem transplant method in other rice varieties in comparing with Pawsan. To select the varieties which would be used to test for cut stem transplant method under shallow water condition, selection of the tolerant varieties which possessed good survival and elongation under flooding was done. After that, the selected varieties would be subjected to cut stem transplant method under shallow water condition in comparing with Pawsan which was farmer's used variety transplanted with this method.

5.2 Selection of Flood Tolerant Varieties with Good Plant Height

5.2.1 Materials and Methods

5.2.1.1 The tested varieties

There were 11 tested varieties including Swarna-Sub1as tolerant check and IR 42 as susceptible check. The tested varieties were shown in Table (5.1).

5.2.1.2 Experiment site

Experiment was conducted at the Plant Breeding, Physiology and Ecology field.

5.2.1.3 Experimental design

Experiment was conducted in Randomized Complete Block Design with three replications in both seedling stage and tillering stage. At seedling stage, four trays were seeded. Three trays were used as three replications for submerged and one tray as control. At tillering stage, four plants were planted in one pot and three pots were sown as one replication. Totally nine pots were taken as three replications for treated and another three pots for control.

5.2.1.4 Selection of flood tolerant varieties

Selection was conducted at two growth stages; seedling stage and tillering stage at 2017 dry season. For seedling stage, the seeds were breaking seed dormancy at 50oC for seven days and filled grains were selected with water (specific gravity 1.0). After that, the selected grains were germinated for two days at room temperature before sowing. The germinated seeds were placed in plastic tray (52 cm x 37 cm x 19 cm) filled with 10 cm sandy soils. Twenty five germinated seeds were seeded in two rows with the spacing of 3 cm x 3 cm inserted at 1 cm depth. Screening at seedling stage was carried out as Vergara and Mazaredo (1975). Ten days old seedlings were submerged to 50 cm water depth for 8 days. Then, the trays were taken out and placed in the screen house. The growth parameters such as plant height after submerged, shoot dry weight, root dry weight were measured immediately after taking out from the pond. Survival (%) was recorded at seven days after de-submerged when the susceptible plants were died.

Table 5.1 Tested varieties and their cultivated area

No	Varieties	Type	Cultivated area	Seed source
1	Ayeyar Min	HYV	Flooded area	MRRC
2	Shwe War Yin	Local	Flooded area	MRRC
3	Hnankar	Local	Flooded area	MRRC
4	Pawsan Baykyar (Phyar pon)	Local	Flooded area	MRRC
5	Pawsan	Local	Flooded area	Thanatpin
6	Yoedayar	Local	Flooded area	Thanatpin
7	Yoesein	Local	Flooded area	Thanatpin
8	Kamar Kyi	Local	Flooded area	MRRC
9	Yenwe	Local	Flooded area	Nyaunglebin
10	IR 42 (Susceptible Check)	HYV	-	DAR
11	Swarna-Sub 1(Resistant Check)	HYV		DAR

For testing at tillering stage, the seeds having specific gravity of 1.0 were pre-germinated for two days and grown in plastic pot (28 cm diameter x 28 cm height) filled with 20 kilogram of field soil. Three grams of (10:10:5) compound fertilizer was applied as basal. The seeds were pre-germinated for two days and sown 8 seeds per pot inserted to 1cm depth. Ten days after seeding, the seedlings were thinned to four seedlings per pot. Three pots were treated to submerged and one pot as control for each variety. At 39 days after sowing, the pots were submerged in concrete tank filled with 30 cm of water. The water level was increased to 60 cm in the next day and increased to 100 cm in the following day and maintain that water level for seven days as the method of Mazaredo and Vergara (1977). Total submerged period was nine days. After that, the water was drained and the pots were taken out.

5.2.1.5 Data collection

The following data were collected at both stages; seedling stage and tillering stage. Ten plants were recorded for one replication at seedling stage and twelve plants for one replication at tillering stage. Among the treated pots, one pot was used to measure plant length (cm), tiller number, the root and shoot dry weight (g) and measured immediately after taken out from the pond. Two pots were used to count survival (%) at 9 days after desubmerged when susceptible plants were died and the tolerant plant produced new leaves.

(1) Survival (%)

Surviving plant was determined at one week after desubmerged at seedling stage and nine days after desubemergd at tillering stage. Survival (%) was computed as the following formula.

$$\text{Survival (\%)} = \frac{\text{Surviving plant} \times 100}{\text{Tested plant}}$$

(2) Plant height (cm)

Plant height (cm) was noted from root /shoot junction to the tip of the leaf at just after desubmerged. At seedling stage, plant height was recorded from 10 plants per replication and for tillering stage, 4 plants were recorded in both treated and control pot. Measuring was done two times; one day before submerged and just after submerged.

(3) Elongation (%)

Elongation (%) was calculated based on the plant height before submerged (cm) which was recorded 1 day before submerged. Elongation (%) was computed by using the following formula.

$$\text{Elongation}(\%) = \frac{\text{Plant height after submerged-Plant height before submerged}}{\text{Plant height before submerged}}$$

(4) Root dry weight (g)

After measuring plant height and tiller number, ten plants for each replication were collected at seedling stage and four plants at tillering stage from both treated and control. The soils were washed thoroughly and the roots were dried in the incubator EYELA type WFO- 420W oven dried at 80^{o}C for three days and checked the weight with digital balance AND types GF 400.

(5) Shoot dry weight (g)

After taking the root samples, all shoots were collected and dried in the incubator EYELA type WFO- 420W oven dried at 80^{o}C for three days and checked the weight with digital balance AND types GF 400.

(6) Root shoot ratio

Root shoot ratio was computed by dividing the shoot dry weight (g) to root dry weight (g).

5.2.1.6 Data analysis

Statistix version 8.0 was used to compare the mean value and mean separation was done with Least Significant Distant (LSD) at 0.5% level. Plant response after submerged was compared with control by using t test.

5.2.2 Results and Discussion

5.2.2.1 Survival (%) and plant height (cm)

Survival (%) and growth parameters after submerged at seedling stage and tillering stage were shown in Table (5.2) and (5.3). At seedling stage, highest survival (%) was achieved by Swarna-Sub1 (95.7) followed by Yenwe (60.40), Hnankar (59.60), Yoedayar (56.50) and Pawsan (46.80) while the other varieties

Table 5.2 Survival and growth parameters at seedling stage

Variety	Survival percent	Plant height(cm)	Elongation percent	Root dry weight (g)	Shoot dry weight (g)	Root/ shoot ratio
Ayeyar Min	29.10 fg	42.70 cd	110.36 a	0.012 a	0.024 c	0.497 a
Shwe War Yin	18.80 g	47.90 bc	156.61 ab	0.008 b	0.023 c	0.353 ab
Hnankar	59.60 bc	47.30 bc	111.55 b	0.010 ab	0.036 ab	0.290 b
Pawsan Baykyar	29.60 fg	49.00 ab	184.01 ab	0.008 b	0.027 abc	0.323 b
Pawsan	46.80 bcde	54.60 a	156.94 b	0.007 b	0.028 bc	0.263 b
Yoedayar	56.50 bcd	50.20 ab	116.20 b	0.009 ab	0.039 a	0.247 b
Yoesein	37.30 ef	45.90 bcd	140.77 ab	0.008 b	0.027 bc	0.300 b
Kamar Kyi	43.50 cdef	46.10 bcd	177.10 ab	0.0088 b	0.024 c	0.337 ab
Ye Nwe	60.40 b	40.70 d	112.78 ab	0.007 b	0.023 c	0.317 b
IR42	42.00 def	42.90 cd	89.56 ab	0.010 ab	0.030 abc	0.350 ab
Swarna-Sub1	95.70 a	21.40 e	11.62 ab	0.009 ab	0.026 bc	0.346 ab
CV	20.54	7.75	19.87	22.86	23.93	28.82

Means followed by the same letter within a column are not significantly different at LSD test at 5% level

Table 5.3 Survival (%) and growth parameters at tillering stage

Variety	Survival percent	Plant height(cm)	Elongation percent	Tiller number	Root dry weight (g)	Shoot dry weight (g)	Root/ Shoot ratio
Ayeyar Min	33.33 cd	100.33 bcd	142.13 ab	14.67 a	2.21 a	6.12 ab	0.37 a
Shwe War Yin	8.33 d	92.17 de	129.90 b	6.77 c	1.60 a	3.27 bc	0.49 a
Hnankar	100.00 a	107.90 b	147.47 a	12.20 ab	2.39 a	5.74 abc	0.42 a
Pawsan Baykyar	8.33 d	100.10 bcd	133.80 ab	6.90 c	1.37 a	2.99 c	0.45 a
Pawsan	20.83 d	88.70 b	129.13 b	7.47 c	1.70 a	3.82 abc	0.45 a
Yoedayar	62.50 bc	108.37 b	142.87 ab	10.37 bc	2.28 a	5.88 abc	0.40 a
Yoesein	62.50 bc	104.60 b	138.97 ab	10.00 bc	1.85 a	4.88 abc	0.35 a
Kamar Kyi	20.83 d	87.07 e	135.73 ab	9.00 bc	1.74 a	3.69 bc	0.58 a
Ye Nwe	100.00 a	133.17 a	133.17 ab	6.60 c	1.68 a	4.37 abc	0.46 a
IR42	58.33 bc	94.10 cde	133.90 ab	9.30 bc	2.40 a	6.79 a	0.35 a
Swarna-Sub1	79.17 ab	53.17 f	106.43 c	13.20 ab	1.20 a	4.59 abc	0.34 a
CV	40.38	6.27	26.10	25.85	40.77	37.43	43.2

Means followed by the same letter within a column are not significantly different at LSD test at 5% level such as Kamarkyi (43.50), IR 42 (42.00), Yoesein (37.30), Pawsan Baykyar (29.60), Ayeyar Min (29.10), and Shwe War Yin (18.80) were less survival than Pawsan. At tillering stage, all tested varieties were higher survival than Pawsan (20.83) except Shwe war Yin and Pawsan Baykyar (8.33). The most surviving plant in both seedling and tillering stage were Swarna- Sub1, Yenwe and Hnankar. Most of the plants were elongated after submerged. Highest plant height after submerged (cm) at seedling stage was achieved by Pawsan (54.60) and no plant can't elongate like Pawsan. However at tillering stage, the highest plant height was attained by Yenwe (133.17), Yoedayar (108.37) and Hnankar (107.20) and these varieties were higher plant height than Pawsan (104.97). However, Swarna-Sub1, one of the most submergence tolerant varieties showed lowest plant height (53.17). In comparing the plant height of three most surviving varieties (Swarna-Sub1,Yenwe and Hnankar), the height of Swarna-Sub1 was shortest in both stages and even shorter than control at tillering stage (Table 5.5). There are two type of strategy that plant can withstand to submerged condition. The first strategy is upward elongation of shoots to restore the leaf contact with atmosphere (Hendawy et al. 2012**)**. The second is a sit and wait strategy, in which the plant is quiescence during the submergence period by conserving the reserve carbohydrate for plant survival. When water recedes, plants resume their growth. The first strategy is suitable for prolong flooding (more than 1 month) and second strategy for flash flooding (Striker, 2012). These 2 types of submergence tolerance mechanism were found among the tested varieties. Among the most surviving varieties, Swarna-Sub1 was the best surviving plant followed by Yenwe and Hnankar at seedling stage, while Yenwe and Hnankar were good surviving than Swarna-Sub1 at tillering stage. The plant height of Swarna-Sub1 was shortest among the submergence tolerant varieties. Because, it was genetically introgressed plant by transferring *SUB1* locus into its parent, Swarna with maker assisted backcross method (Neeraja et al. 2007; Manzoorm et al. 2013). Therefore, Swarna-Sub1 occupied the quiescence mechanism due to *SUB1*gene and so, the shortest plant height among tested varieties and same plant height at seedling stage (Table 5.4) and even shorter than control at tillering stage (Table 5.5). The expression of *SUB1* causes submergence tolerance by repression of shoot elongation and conservation of reserve carbohydrates. In this sense, *SUB1* limits the elhylene-induced shoot extension and the reduction of sucrose and starch consumption (Fukao and Bailey-Serres 2008). Singh et al. (2014) discussed that Sub1 lines maintained higher chlorophyll concentrations during submergence and lost less non-structural carbohydrates (NSC) after submergence.

Table 5.4 Survival and growth parameters of plants after submerged comparing with control at seedling stage

Varieties	Survival (%)		Plant height		Root dry weight (g)		Shoot dry wt (g)		Root/ shoot ratio	
	Control	Tested	Control	Tested	Control	Tested	Control	Tested	Control	Tested
Ayeyar Min	100	29.11**	29.53	42.9**	0.014	0.012^{ns}	0.038	0.024**	0.368	0.497^{ns}
Shwe War Yin	100	18.77**	27.20	47.9**	0.013	0.008**	0.044	0.023**	0.312	0.353^{ns}
Hnangar	100	59.63**	34.87	47.3**	0.013	0.010**	0.053	0.036**	0.247	0.290^{ns}
Pawsan Baykyar	100	29.61**	31.13	49.0**	0.013	0.008**	0.039	0.027**	0.336	0.323^{ns}
Pawsan	100	46.84**	35.63	54.6**	0.015	0.007**	0.044	0.028**	0.350	0.263^{ns}
Yoedayar	100	56.50**	35.07	50.2**	0.013	0.009**	0.054	0.039**	0.245	0.247^{ns}
Yoesein	100	37.34**	27.53	45.9**	0.011	0.008**	0.045	0.027**	0.243	0.300^{ns}
Kamar Kyi	100	43.49**	29.43	46.1**	0.014	0.008**	0.036	0.024**	0.384	0.337^{ns}
Yenwe	100	60.33**	35.17	40.9**	0.012	0.007**	0.039	0.023**	0.313	0.317^{ns}
IR42	100	41.97**	29.03	42.9**	0.014	0.010**	0.040	0.030ns	0.345	0.350^{ns}
Swarna Sub-1	100	95.65^{ns}	21.36	21.4**	0.016	0.009**	0.043	0.026*	0.359	0.346^{ns}

** Significant different at 1% level, * Significant different at 5% level, ns Non significant different

Table 5.5 Survival (%) and growth parameters of submerged plant comparing with control at tillering stage

Variety	Survival (%)		Plant height		Tiller number		Root dry weight (g)		Shoot dry weight (g)		Root shoot ratio	
	Control	Tested	Control	Tested	Control	Tested	Control	Tested	Control	Tested	Control	Tested
Ayeyar Min	100	33.33**	81.3	104.55**	13.3	14.7ns	11.24	2.21**	13.15	6.12**	0.88	0.37**
Shwe War Yin	100	8.30**	78.1	92.16**	10.8	6.8**	6.87	1.59**	11.43	3.27**	0.60	0.49^{ns}
Hnangar	100	100.00^{ns}	86.3	107.94**	13.9	12.2ns	4.43	2.39**	11.92	5.73**	0.37	0.42^{ns}
Pawsan Baykyar	100	8.33**	80.0	100.08**	12.7	6.9*	3.90	4.37^{ns}	9.35	2.99**	0.42	0.45^{ns}
Pawsan	100	20.83**	104.9	88.72**	11.3	7.4**	2.81	1.70**	9.49	3.82**	0.29	0.45**
Yoedayar	100	62.5**	87.1	108.25**	10.1	10.3ns	4.27	2.28*	12.34	5.88**	0.40	0.40^{ns}
Yoesein	100	62.5**	84.2	104.56**	12.3	10.0ns	4.32	1.80*	13.54	4.88**	0.32	0.35^{ns}
Kamar Kyi	100	20.83**	74.8	87.06**	11.8	9.0**	6.10	1.74**	11.41	3.69**	0.55	0.58^{ns}
Ye Nwe	100	100.00^{ns}	111.4	133.16^{ns}	9.0	6.6ns	6.48	1.68**	11.45	4.37**	0.56	0.46**
IR42	100	58.3**	81.3	94.11**	11.5	9.3ns	8.78	2.40**	11.75	6.79**	0.75	0.36**
Swarna-Sub1	100	79.16**	68.0	53.14**	14.0	13.2ns	4.16	1.20**	9.97	4.59**	0.42	0.35*

** Significant different at 1% level, * Significant different at 5% level, ns Non significant

Yenwe was floating rice varieties and which was adapted to grow in water depth above 100cm (Catling et al. 1988). However, if floods occurred at early growth stages, the floating rice was damaged because the plants couldn't withstand submergence; nor could they elongate rapidly (Brady, 1977). Therefore, at seedling stage, the survival (%) of Yenwe was only (60.4%). However, at tillering stage, Yenwe itself was tall variety and could escape from submersion. Hnankar was adapted to grow in delta region. Its survival was good at both stages (Table 5.2 and 5.3) and also the plant height after submerged was statistically different from control in both stage (Table 5.4 and 5.5), because the plants elongate upward to meet the leaf contact with atmosphere for oxygen. By this way, the plant obtained oxygen (O_2) and sunlight for photosynthesis and can exchange CO_2 from the shoot above the water surface so, the plant can survive well (Atwell et al. 1999). Elongation ability of leaves and internodes were essential to keep pace with increasing water levels and escaped complete submergence (Ismail, 2006). Ethylene entrapped within submerged tissues often plays a role in adaptation, for example enhancing stem elongation in rice (Raskin and Kende 1984). Kyaw et al. (1977) mentioned that in medium deep-water area (50-200 cm water depth), very tall deep-water rice with later maturing and highly photoperiod sensitive variety was suitable. Therefore, Yenwe and Hnankar would be suitable to grow in medium deepwater area. Hence, it can be concluded that Swarna-Sub1, Yenwe and Hnankar possessed two opposite mechanism at both stages. Swarna-Sub1 occupied quiescence mechanism by stunting the plant growth during flooding and Yenwe and Hnankar possessed escape mechanism by elongating of the plant height. In addition, there were other flood tolerant varieties among the tested varieties and their survival was different at different growth stages. The plant height of Yoedayar was higher and significantly different from control at both stages. In addition, elongation (%) of Yoedayar was (116.20) at seedling stage and (142.87) at tillering stage. Although it did not achieve highest survival (%), moderate survival among the tested varieties (56.50% at seedling stage and 62.5% at tillering stage) was obtained. It was due to its higher plant height than tested water depth (50 cm at seedling stage and 100 cm at tillering stage). The plant height of Pawsan variety was significantly different from control at both stages. It could elongate with rising water depth at seedling stage and couldn't escape from submergence test at tillering stage. Therefore its survival (%) was moderately high at seedling stage (46.84) and low at tillering stage (20.8). Under submerged condition, photosynthesis was restricted by low availability of light and / or CO_2 (Maberly and Spence 1989) and survival is also low. The plant height of Kamarkyi was statistically different from control at seedling stage and not significantly different at tillering stage. However, its survival was 43.49% at seedling stage and 20.8% at tillering stage. It was owing to the lesser plant height after submerged than tested water level in both growth stages. Therefore, Kamarkyi suffered from flooding and decrease in survival (%). IR 42 elongated after submerged and it was statistically different from control at both stages (Table 5.4 and 5.5). Its survival was 41.97% at seedling stage and 58.3 % at tillering stage. In both growth stages, it couldn't elongate as the water depth increases and so, the survival (%) was low. Because, shoot elongation underwater requires energy and carbohydrates for cell divisions and the synthesis of new cell-wall material (Setter and Laureles 1996). Hence, survival (%) was low owing to the consuming of reserved carbohydrate during submerged. The plant height of Yoesein was statistically different from control at both stages. Its survival was 37.34% at seedling stage and 62.5% at tillering stage. At seedling stage, Yoesein couldn't elongate as the tested water depth and the surivival (%) was low while, it could elongate as increasing water depth at tillering stage and the survival (%) was rather high. The plant height of Ayeyar Min after submerged was statistically different from control at both stages. At seedling stage, Ayeyar Min couldn't elongate and the plant height was low and elongation (%) also low while, the plant could elongate at tillering stage, tiller number also increased, elongation (%) was higher as well and survival (%) was higher. Genotypes lacking *SUB1A* such as submergence intolerant genotype produced rapid elongation of shoot during submergence and consumed leaf starch and soluble sugar during submergence for shoot elongation. Therefore, after the water recedes, few carbohydrates were left for survival and the plants were eventually dying (Hendawy et al. 2012). The plant height of Pawsan Baykyar was significantly different from control at both stages. Its elongation (%) was higher at seedling stage (184.01) than tillering stage (133.80).Thus, survival (%) was 29.61% at seedling stage and 8.3% at tillering stage. Although its plant height was not so different from the tested water level, survival (%) was very low. Das et al. (2005) observed that seedling survival was strongly related with non structural carbohydrate (NSC) maintained after submergence than with NSC before submergence. They interpreted that carbohydrates maintained after submergence is the result of both initial level and the level used during submergence. The plant height of Shwe War Yin was statistically different form non treated control in both stages while survival was 29.11% at seedling stage and 33.3% at tillering stage. It is because the plant couldn't elongate as the tested water depth and so survival (%) was low.

5.2.2.2 Root and shoot dry weight (g)

Regarding root dry weight (g), the highest was acquired in Ayeyar Min (0.012) at seedling stage and IR 42 (2.40) at tillering stage. However, neither Ayeyar Min nor IR 42 possessed good survival (%). Because for increase of root biomass, the plant had to consume the energy and after de-submerged few carbohydrate reserve might be left for survival. In comparing with control, the root dry weight of almost all varieties was decreased significantly except Ayeyar Min in seedling stage. That finding was agreed with Jaquie et al. (2012) that the surface area of roots, the length of the roots, branching and the depth of the roots were lesser in flooded than aerobic condition. Besides that water logged plant produce short roots than those in drain soil because of the restriction imposed by long distance delivery through aerenchyma (Striker, 2012). The root dry weight of Ayeyar Min itself was not statistically different from control in seedling stage (Table 5.4) but, it different in tillering stage (Table 5.5). According to the result of this study, the growth response of particular variety to submerge is different depending on their different growth stages. In terms of the shoot dry weight (g), there was statistically different among the tested varieties in both stages. The highest shoot dry weight at seedling stage was attained in Yoedayar (0.039) and IR 42 (6.79) at tillering stage. Although Yoedayar and IR 42 possessed highest shoot dry weight, their survival was not the best. Gibberd et al. (2001) found that shoot biomass or root biomass was not correlated with tolerance to water logging condition. In comparing with control, the shoot dry weight of almost all varieties was significantly different from control. The same finding was reported by Anandan et al. (2012) that number of tillers, leaf area and dry weight were more affected and decreased during submergence than its non-submergence counterpart. Similarly, Prakesh et al. (2016) resulted that seedling growth under flooding reduce root, shoot and total dry matter production. In addition, the highest root shoot ratio at seedling stage was observed in Ayeyar Min (0.497) and kamarkyi (0.58) at tillering stage. Both of the varieties occupied higher root dry weight and the lesser shoot dry weight. Therefore these varieties gained the highest root shoot ratio. Furthermore, the best variety for each parameter at both stages was not the same. For example, the best survival (%) at seedling stage was achieved by Swarna-Sub1 at seedling stage and Yenwe and Hnankar at tillering stage. Highest elongation (%) was occupied by Pawsan Baykyar at seedling stage and Hnankar at tillering stage. The highest root dry weight was possessed by Ayeyar Min at seedling stage and IR42 at tillering stage. The highest shoot dry weight was realized by Yoedayar at seedling stage and IR 42 and Ayeyar Min at tillerig stage. The highest root shoot ratio was attained by Ayeyar Min at seedling stage and kamarkyi at tillering stage. Therefore, it could be interpreted that particular varieties response differently to submerged condition at different growth stage. That finding was accepted by Ranawaky et al. (2014) that among the tested varieties, 24% of tested genotypes were submerged resistant at seedling stage and 16% were tolerant at vegetative stage under 14 days complete submergence stress. Striker (2012) discussed that the plant submergence tolerance depend on the developmental growth stages (eg. seedlings vs. adult plants) and plant growth habit (eg. creeping plant growth vs. erect plant growth) even at the same water depth. In comparing the tested varieties with Pawsan, the survival (%) of Yenwe, Hnankar and Yoedayar were higher survival than Pawsan at seedling stage. Moreover, the plant height of Pawsan (54.60) was the highest among the tested varieties at seedling stage. However in tillering stage, the survival (%) of Pawsan was very low and almost all varieties possessed higher survival than Pawsan except Pawsan Baykyar and Shwe War Yin. Concerning the plant height after submerged (cm), all tested varieties except Swarna-Sub1 possessed higher plant height than Pawsan. To test the varieties with cut stem transplant method, the varieties which had good survival (%) and good plant height was selected. Therefore, Yenwe, Hnankar and Yoedayar which have higher survival (%) at both stage and higher plant height at tillering stage than Pawsan will be selected to test for the next experiment.

5.3 Evaluating the Growth Performance of Selected Rice Varieties with Cut Stem Transplant Method under Shallow Water Condition

5.3.1 Materials and Method

5.3.1.1 The tested varieties

The three selected varieties, Yenwe, Hnankar and Yoedayar which possessed higher survival and plant height than Pawsan were used to subject cut stem transplant method.

5.3.1.2 Cultural practices

Experiment was started at the beginning of May as the farmers' practice. The seeds were selected with water (the specific gravity of 1.0). Then it was pregerminated for 2 days at room temperature. The germinated seeds were placed in the 41cm diameter bucket and filled with 1:2 sand and soil until 20cm height. Seeding was carried out with the spacing of 3 cm x 3 cm to 1 cm deep. Nine grams of compound fertilizer (10:10:5) was applied as basal to each bucket. Ten days after seeding, 10 g of urea fertilizer was top dressed to each bucket. Eighteen days after seeding, 2.3 g of Furadan 3G was applied to each bucket to control stem borer infestation. When the seedlings were 30 days old, it was submerged in the artificial pond constructed in Plant Breeding, Physilogy and Ecology field at 40cm water depth. Hundred centimeter water depth was reached within 63 days after submerged (106 days after seeding) and the buckets were taken out from the pond. Wash the soil thoroughly and select the seedlings which had the same plant height and the same number of internodes to test for cut stem transplant under shallow water condition.

5.3.1.3 Precondition of tested varieties before stem cutting

Precondition of tested varieties after submerged was shown in Table (5.6). The plant height after submerged of Pawsan, Yoedayar and Hnankar were not different while Yenwe was very tall after submerged.

5.3.1.4 Treatments and experimental design

To favor equal plant height among the tested varieties, Pawsan, Yoedayar and Hnankar were cut at the same node number while Yenwe was cut at different node number. Cutting length and cutting node in each treatment was shown in Table (5.7).

Table 5.6 Plant growth after submerged in Pawsan, Hnankar, Yoedayar and Yenwe

Variety	Plant height	Node number	Internode length (cm)										
			1	2	3	4	5	6	7	8	9	10	11
Pawsan	136	7.0	7.0	13.0	5.0	10.0	25.0	35.0	41.0	-	-	-	-
Yoedayar	138	7.0	12.5	7.5	5.5	7.5	20.5	31.0	49.5	-	-	-	-
Hnankar	136	7.0	8.3	10.0	6.7	9.5	12.0	37.7	51.5	-	-	-	-
Yenwe	207	11.0	21.0	20.0	20.0	13.0	13.0	14.0	14.0	9.0	22.0	24.0	37.0

Table 5.7 Cutting length and node in each treatment in Pawsan, Yoedayar, Hnankar and Yenwe

	T1		T2		T3		T4		T5		T6	
Variety	Length (cm)	Node *	Length (cm)	Node *	Length (cm)	Node *	Length (cm)	Node *	Length (cm)	Node *	Length (cm)	Node *
Pawsan	136	Control	136	**	129	1^{st}	116	2^{nd}	111	3^{rd}	101	4^{th}
Yoedayar	138	Control	134	**	122	1^{st}	114	2^{nd}	109	3^{rd}	101	4^{th}
Hnankar	136	Control	136	**	127	1^{st}	117	2^{nd}	111	3^{rd}	101	4^{th}
Yenwe	207	Control	207	**	186	1^{st}	146	3^{rd}	120	5^{th}	92	7^{th}

* Node number count from the bottom to top (basipetal pattern), ** Cut at unelongated internode

There were 6 treatments and experimental design was Randomized Complete Block Design with 3 replications. Two plants were transplanted in one pot and three pots were regarded as 3 replications. Thus, totally 6 plants were transplanted. Before transplanting, the pots were filled with 20 kg of field soil and 15:15:10 compound fertilizer (Armo) was applied as basal. Nylon strings were tied 2 lines at about 2 cm above the soil surface and about 60 cm above the soil surface. Each line was parallel with 2 strings to fix the plant upright. Cutting was done at 1cm below the node and transplanting was carried out within 1 hour after cutting. The cut seedlings were inserted between two parallel nylon strings and bind with wire to fix the plant upright and planted to the 4 cm soil depth. As moisture is important for rooting from stem cutting, partial shade was given until one week after transplanting.

Watering was done regularly to keep the water level at 2 cm as shallow water depth. The strings were removed at 3 weeks after transplanting. The panicles were collected individually when fully ripe and the plants were harvested at 60 days after 80% flowering.

5.3.1.5 Data collection

During the plant growth period, plant height and numbers of tillers were recorded at one week interval. Dead plant, new growth plant and alived plant were recorded daily. At flowering time, heading date, 80% heading date were recorded.

(1) Alived plant (%)

Alived plant was counted to the stock plants which were not died after transplanting and calculated as follows.

$$\text{Alived plant (\%)} = \frac{\text{Standing plant}}{\text{Total no. of tested plant}} \text{x100}$$

(2) New growth plant (%)

New growth plant was counted when the stock plant died and new tillers emerged after plant death. It was calculated as follows.

$$\text{New growth plant} = \frac{\text{New growth plant}}{\text{Total no. of tested plant}} \text{x100}$$

(3) Mortality (%)

Mortality was regarded as the stock plant was totally died and no tiller comes out again. Mortality (%) was calculated as follows.

$$\text{Mortality plant (\%)} = \frac{\text{Death plant}}{\text{Total no. of tested plant}} \text{x} 100$$

(4) Flowering duration (Days)

Flowering duration was calculated by differences between days from transplanting to 80% flowering. Eighty percent flowering was recorded when 80% of the panicles in the plant were flowered.

(5) Panicle number

Panicle was collected individually and counted after all panicles were harvested.

(6) Grains panicle^{-1}

Grains from all panicle were threshed and counted with grain counter WAVER made from Daidex Company, Japan and divided with the panicle no. to result grains / panicle.

(7) Filled grain (%)

Filled grain (%) was recorded by dipping all the grains in water (Specific gravity 1) and separated the filled and unfilled grain realizing the floated grains as unfilled grain and the grain sink to the bottom as filled grain. Filled grain (%) was calculated by using the following formula.

$$\text{Filled grain (\%)} = \frac{\text{Filled grain x 100}}{\text{Total grain}}$$

(8) Hundred grain weight (g)

Hundred grain weight (g) was counted and weight by using digital balance AMD Type GF 400. After that, the grain moisture content was immediately measured by using MOISTEX Type SS-7 made from Satake Company and adjusted the weight to 14% moisture by using the following formula.

$$\text{Hundred grain weight (g)} = \frac{G\times(100\text{-}M)}{100\text{-}14}$$

where, G =Measured grain weight (g)

M =Measured grain moisture contrent

(9) Yield plant^{-1} (g)

Yield plant^{-1} was calculated by using the following formula.

$$\text{Yield per plant} = \frac{\text{panicle no. x grains /panicle x filled grain(\%)x 100 grain weigt (g)}}{100 \text{ x } 100}$$

5.3.2 Results and Discussion

5.3.2.1 Alived plant, mortality and new growth plant (%) after transplanting

There were three types of plant development after transplanting under shallow water condition. Some of the plants were alive, some were died and some were new growth after the stock plant die. The types of plant development formed from different cutting position were shown in Table (5.8). As shown in Table (5.8), the mortality (%) was different depending on the varieties. In case of Pawsan, T1 was the highest death (100.00) and followed by T2 (83.3) T3, T4, T6 (66.70) and the least by T5 (50.00). The highest new growth (%) was obtained in T4, T5 and T6 (33.30) followed by T2 and T3 (16.70). There was less number of alived plant in Pawsan and it was observed in T3 and T5 (16.70). However, mortality (%) was very few in Yoedayar and the most death was occurred in T6 (50.00) followed by T2 (16.70). New growth was occurred in T6 (50.00) subsequently followed by T3 (33.30) and T4 and T5 (16.70). The most alived plant (%) was acquired in T1 (100.00) followed by T2, T4 and T5 (83.30) and the least by T3 (66.70). In case of Hnankar, the highest mortality (%) was found in T1, T2, T5, T6 (50.00) and T3 (16.70). There was more new growth than alived (%) among treatment in Hnankar.

Nevertheless, no significant differences of plant height were observed in 50DAT. On the other hand, difference in plant height (cm) was observed again at 80DAT in which T5 (143.8) was achieved the highest plant height and which was significant difference from T2 (136.5) and T1 (128.5). The highest number of tillers at 20DAT was examined at T5 (3.1) and which was statistically different from T3 (2.7) and T4 (2.4) (Table 4.3). Conversely, tiller number checked at 50DAT was not significantly different each other.

Table 5.8 Alive, mortality and new growth (%) produced from different cutting of Pawsan, Yoedayar, Hnankar and Yenwe

Treatment	Pawsan			Yoedayar			Hnankar			Yenwe		
	A	M	N	A	M	N	A	M	N	A	M	N
T1	-	100.0	-	100.0	-	-	-	50.0	50.0	-	83.3	16.7
T2	-	83.3	16.7	83.3	16.7	-	33.3	50.0	16.7	-	-	100.0
T3	16.7	66.7	16.7	66.7	-	33.3	50.0	16.7	33.3	-	33.3	66.7
T4	-	66.7	33.3	83.3	-	16.7	50.0	-	50.0	100.0	-	0.0
T5	16.7	50.0	33.3	83.3	-	16.7	-	50.0	50.0	66.7	16.7	16.7
T6	-	66.7	33.3	-	50.0	50.0	33.3	50.0	16.7	83.3	-	16.7
Mean	16.7	72.2	26.7	83.3	33.3	29.2	41.7	43.3	36.1	83.3	44.4	43.3
SD	0	17.2	9.1	11.8	23.6	16.0	9.6	14.9	16.4	16.7	34.7	38.4
CV	0	23.8	34.1	14.1	70.7	54.7	23.1	34.4	45.4	20.0	78.1	88.5

A= Alive plant (%), M= Mortality plant (%) and N= New growth plant (%)

When recording again at 80DAT, all of the treatments were not significantly different each other except T1 (14.95). The number of tillers was only increased unto 50DAT and remains the same or decreased in tillers from 50DAT to 80DAT. This tillering pattern is comparable to other reports. Chang et al. (1965) and Badshah et al. (2014) revealed that tiller numbers increase until maximum tillering stage and after that it decline and some of the tillers die. That reduction is due to the competition of assimilates between tillers and mother culm (Biswas and Salokhe 2005).

5.3.2.2 Days from transplanting to 80% flowering (DTF)

There was no differences in DTF between alived and new growth plant in almost all selected varieties except new growth plant (93 ±32) in Yenwe was longer than alived plant (59 ± 6.7) (Table 5.9). All tested varieties have similar DTF among the alived plant except T6 in Hnankar (94) which was different from T1, T2, T3 and T4. Similar DTF was also found among the new growth plant except T6 in Hnankar (138) and T1, T2 (134) and (111) in Yenwe. Therefore, the longest DTF among the treatment was different depending on the variety. Moreover, the longest DTF was observed in Pawsan in both plant type.

Table 5.9 Days from transplanting to 80% flowering in the tested rice varieties

Treatments	Pawsan		Yoedayar		Hnankar		Yenwe	
	Alived	New growth	Alived	New growth	Alived	New growth	Alived	New growth
T1		-	58	-	66	76	-	134
T2	-	212	65	-	64	70	-	111
T3	212	197	65	65	73	76	-	81
T4	-	213	63	61	63	65	60	-
T5	212	205	67	70	-	64	57	64
T6	-	213	-	84	94	138	60	58
mean	212	207 ±10.9	63±6.4	73±12.1	72 ±18.7	75 ±20.3	59 ±6.7	93±32.0

5.3.2.3 Yield and yield component recorded at harvest

Yield and yield component of alived and new growth plant in Pawsan, Yoedayar, Hnankar and Yenwe were shown in Table (5.10), (5.11), (5.12), (5.13), (5.14), (5.15), (5.16) and (5.17) respectively. In Pawsan, only T3 and T5 gave alived plant and the yield was 43.95 and 39.51 g plant^{-1}. In new growth plant, the highest grain yield was possessed by T6 (37.15) followed by T5 (34.00± 2.73), T4 (48.14 ± 2.10), T3 (43.95), T2 (24.05) accordingly. All of the plant from T1 was died and no yield data was resulted. In terms of alived plant in Yoedayar, the grain yield was not different among the treatment. However, in the new growth plant, the grain yield (g) of T4 (35.92), T5 (34.36) and T3 (25.03 ± 12.38) were not different except T6 which was different from T4 and T5. Concerning the yield of alived plant in Hnankar, the yield of all treatment was not different each other in which T6 achieved (23.39 ± 5.05), T2 (18.41 ± 5.88), T3 (14.89 ± 6.45) and T4 (11.95 ± 4.04) accordingly. Whereas, among the new growth plant in Hnankar, T2 (13.84 ± 4.5), T3 (14.62 ± 2.99), T4 (20.71 ± 9.74) and T5 (20.70 ± 4.86) were not different but, those were different from T6 (8.34) and T1 (1.61 ± 1.65). In case of Yenwe, the yield of alived plants were not different among the treatment such as T4 (20.95 ± 11.90), T5 (18.97 ± 4.16) and T6 (18.12 ± 7.03). However, the yield of T1 in new growth plant (50.54) was different from other treatment such as T2 (21.48 ± 7.2), T3 (17.75 ± 7.20), T5 (17.52 ± 8.76) and T6 (16.16). Therefore, the treatment which could produce the highest yield will vary depending on the tested genotypes. For example, the best yielding stem cut positions for alived and new growth plant in Pawsan are T3 and T4 while those in Yoedayar are T5 and T4, those in Hnankar are T5 and T4 and those in Yenwe are T1 only. Variation depending on the genotype is similar to the finding of Kamga et al. (2018). Shi and Brewbaker (2006) reported that rooting from stem cutting of *Leucaena* Hybrids was vary mainly depending on the variety. In addition, the yield between alived and new growth plant will be different depending on the tested varieties.

Table 5.10 Yield and yield component of alived plant in Pawsan

Treatment	Panicle number	Grain number	Grain no./ panicle	Filled grain (%)	100 grain weight (g)	Yield/ plant (g)
T3	27	1600	59.26	85.75	3.20	43.95
T5	30	1867	62.23	67.06	3.16	39.51

Table 5.11 Yield and yield component of new growth plant in Pawsan

Treatment	Panicle number	Grain no. panicle^{-1}	Filled grain (%)	100 grain weight (g)	Yield (g plant $^{-1}$)
T2	22.0	74.36	46.45	3.16	24.05
T4	37.5 ±2.1	66.19	50.01 ±12.6	3.42 ± 0.1	48.14 ± 2.1
T5	26.0 ± 9.9	87.03 ± 9.4	54.79 ±1.3	3.18 ± 0.3	34.00 ±2.7
T6	31.0	56.97	66.48	3.16	37.15

Table 5.12 Yield and yield component of alived plant in Yoedayar

Treatment	Panicle number	Grain no. panicle^{-1}	Filled grain (%)	100 grain weight (g)	Yield (g plant^{-1})
T1	6.2 ±3.5	117.23 ± 41.2	63.88 ±21.2	2.41 ±0.1	12.39 ±10.2
T2	8.3 ±3.1	111.29 ± 31.5	74.94 ±12.6	2.58 ±0.2	20.79 ±14.8
T3	8.0 ±3.6	114.75 ± 6.1	88.23 ± 6.3	2.55 ±0.1	20.73 ±10.1
T4	9.3 ±3.9	143.14 ±28.4	69.05 ±11.4	2.63 ±0.2	22.82 ±9.2
T5	12.3 ± 3.9	132.03 ±31.7	83.47 ±7.1	2.86 ±0.6	39.48 ±21.1
T6	-	-	-	-	-

Table 5.13 Yield and yield component of new growth plant in Yoedayar

Treatment	Panicle number	Grain no. panicle^{-1}	Filled grain (%)	100 grain weight (g)	Yield (g plant^{-1})
T1	-	-	-	-	-
T2	-	-	-	-	-
T3	8 ± 4.2	141.61 ±1.1	79.36 ±5.1	2.82 ± 0.1	25.03 ± 12.4
T4	7	280.57	71.94	2.54	35.92
T5	12	121.66	87.67	2.68	34.36
T6	7 ±1.0	116.50 ± 2.5	83.32 ± 1.5	3.22 ± 0.5	22.40 ± 7.4

Table 5.14 Yield and yield component of alived plant in Hnankar

Treatment	Panicle number	Grain no. panicle^{-1}	Filled grain (%)	100 grain weight (g)	Yield (g plant $^{-1}$)
T2	9.5 ±0.7	120.65 ± 34.7	83.55 ±2.8	1.92 ± 0.0	18.41 ± 5.9
T3	11.0 ±4.5	87.21± 7.7	84.36 ± 9.9	1.84 ± 0.1	14.89 ± 6.5
T4	10.7 ±2.1	79.81±16.5	75.16 ± 4.7	1.85 ± 0.1	11.95 ± 4.0
T5	-	-	-	-	-
T6	13.0 ±2.8	121.68 ±14.6	68.12 ± 19.0	2.24 ± 0.4	23.39 ± 5.1

Table 5.15 Yield and yield component of new growth plant in Hnankar

Treatment	Panicle number	Grain no. panicle^{-1}	Filled grain (%)	100 grain weight (g)	Yield (g plant $^{-1}$)
T1	2.5 ±0.7	65.42 ± 42.5	53.78 ± 45.4	1.80 ±0.1	1.61 ±1.7
T2	10.0 ±1.4	84.82 ± 9.6	85.06 ± 0.6	1.88 ±0.1	13.84 ±4.5
T3	10.0 ±2.8	92.50	82.52 ±4.5	1.94 ±0.1	14.62 ±3.0
T4	13.3 ±6.7	96.39 ± 10.2	86.90 ± 4.9	1.88 ±0.0	20.71 ±9.7
T5	13.7 ±2.5	100.55 ± 12.4	79.56 ± 2.9	1.89 ±0.0	20.70 ±4.9
T6	8.0	77.75	77.49	1.73	8.34

Table 5.16 Yield and yield component of alived plant in Yenwe

Treatment	Panicle number	Grain no. panicle^{-1}	Filled grain (%)	100 grain weight (g)	Yield (g plant $^{-1}$)
T4	11.4 ±3.0	75.67 ±25.3	84.97 ±12.3	2.72 ±0.1	20.95 ±11.9
T5	10.5 ± 1.3	86.38 ±6.2	85.39 ±12.9	2.45 ±0.3	18.97 ±4.2
T6	9.6 ± 3.1	90.13 ±14.4	80.67 ±8.2	2.59 ±0.3	18.12 ±7.0

Table 5.17 Yield and yield component of new growth plant in Yenwe

Treatment	Panicle number	Grain no. panicle^{-1}	Filled grain (%)	100 grain weight (g)	Yield (g plant $^{-1}$)
T1	38.0	64.13	80.88	2.56	50.54
T2	11.8±3.3	83.46± 15.3	80.67± 6.0	2.72± 0.1	21.48± 7.2
T3	11.0±2.0	80.86±17.2	78.48± 24.0	2.63± 0.1	17.75± 7.2
T4	-	-	-	-	-
T5	11.5±7.8	60.93± 15.0	92.50±0.9	2.92± 0.1	17.52± 8.8
T6	10.0	77.4	70.03	2.98	16.16

5.4 Conclusion

Although Pawsan variety can transplant with cut stem transplant method in deep-water area of Thanatpin, transplanting under shallow water condition is not suitable with cut stem transplant method. Therefore, many plant died after transplanting especially Pawsan among the tested plant. Not only plant died, but also flowering duration was very long because the plant had to recover from cutting damage. While the main panicle was flowered, the tillers produced were in the vegetative phase. Hence, flowering duration between main panicle flowering and tiller was long. Although, alived and new growth plant were observed, flowering duration, tiller number, root number and the yield were not different among these 2 types of plant. The best cutting position for growth and yield were different depending on the variety. From this experiment, it can be concluded that Yoedayar, Hnankar and Yenwe could be transplant with cut stem transplant method and shown better performance than Pawsan under shallow water condition.

CHAPTER VI

GENERAL DISCUSSION AND CONCLUSION

In Myanmar, flooding would frequently occur in delta region such as Ayeyarwaddy, Bago, Yangon and coastal area in Rakhine region. Local rice varieties such as Pawsan were mostly cultivated in that area and the plants elongate as the water level rises. Contrary to that, the plant lodges after water recede. Farmers from deep-water area in Thanatpin Township exploit that flooding damage by cutting the elongated stem and transplanted. According to this research, tillering and rooting from stem cutting started to seen by three days after transplanting. The tillering and rooting node increase as the time taken after transplanting. Among the tillering and rooting node, 2^{nd} node was the most tiller and root producing node than other nodes. That tillering pattern was obvious again at harvest. 2^{nd} node was the most tillers bearing node in cut stem transplant method whereas the most tiller bearing node in normal transplant was the 1^{st} node. Direct seeded plant showed uneven development pattern in basal internode due to flooding damage during its growth. In addition, the culm length and basal internodes of direct seeded plants were longer than normal transplant and cut stem transplant plant. Hence, direct seeded plants would vulnerable to lodging while cut stem transplant and normal transplant plant would resist to lodging. Although the roots can produce from cut stem transplant, the root no. tiller^{-1} of direct seeded plant was higher than those of cut stem transplant and normal transplant. However, the root number hill^{-1} was higher in the order of normal transplant followed by cut stem transplant and the least by direct seeded plant. Furthermore, the cut stem transplant plant showed the highest yield followed by normal transplant and direct seeded plant due to the highest grains number m^{-2} and number of panicle m^{-2}. Therefore, it could be interpreted that cut stem transplant is well adapted to deep water condition and the yield is higher than direct seeding and normal transplant in this experiment. The stem of DWR can be cut and transplanted and the root number m^{-2}, root no. tiller^{-1}, root no. hill^{-1}, root dry weight (g), shoot dry weight (g) and root shoot ratio of stem cutting treatments were not different from control. Among the yield component data, the number of hill m^{-2} was lowest in control and highest in the stem cut at 15 cm above the soil. There were no statistical differences in other yield component data such as panicle no. hill^{-1}, grain panicle^{-1} and filled grain (%) and 100 grain weight (g). However, the highest yield hill^{-1} was observed in control although it was not statistically different from stem cut at unelongated internode, cut at 15 cm above the soil and cut at 30 cm above the soil while the lowest yield hill^{-1} was showed in stem cut at 45 cm above the soil. Nevertheless, yield m^{-2} of stem cut at 15 cm above the soil was the highest and stem cut at 45 cm above the soil was the lowest. The weight yield also observed the same trend. Hence, different cutting position effect was observed and stem cut at 15cm above the soil would be the best cutting position to increase the yield. However, cytological studies on why the stem at 15 cm produced the highest yield is still required to explore. In selection of flood tolerant varieties with longer plant height, survival (%) of particular variety was different in seedling stage and tillering stage. Furthermore, differences among two growth stages was found in plant height (cm), elongation (%), root dry weight (g) and shoot dry weight (g) and root shoot ratio as well. Therefore, it could be interpreted that particular variety showed different response to flooded condition at different growth stages. Among the tested varieties, Yenwe, Hnankar and Yoedayar which had good surivival (%) and the plant elongation as flooding depth increased were subjected to the cut stem transplant method under shallow water condition in comparing with Pawsan. The tested varieties were induced elongation in the artificial pond starting from 40 cm water depth until 100 cm within 63 days after submerged and cut at 1cm below the node and transplant within 1 hr after cutting. Some of the plants were gradually died after transplanting, some alive and some produced new growth after the main plant died. Among the tested varieties, Pawsan showed the highest mortality (%) while Yoedayar showed the least plant death (%). Furthermore, Pawsan taken the longest days to 80% flowering followed by Hnankar, Yoedayar and the shortest in Yenwe among the alived plant. Similarly, among the new growth plant, Pawsan taken the longest flowering days and succeeded by Yenwe, Hnankar and Yoedayar respectively. Thus, it can be understand that Pawsan taken the longest flowering duration among the tested varieties in both types of plant. Tiller number, the no. of root tiller^{-1} and rooting node were also different depending on cutting position and varieties. The best yielding stem cut position was also different among the tested varieties too. Although Pawsan showed good plant growth and higher yield with cut stem transplant method in deep water condition, transplanting under shallow water condition performs very poor owing to many plant death, taking longest flowering duration. Thus, Pawsan seemed to adapt to cut stem transplant method only in deep water area. This facts point out that "Cut Stem Transplant Method" is applicable only to the deep water condition at transplanting time. Water seemed to support favorable condition for rooting and tillering from stem cutting such as moisture and cooling environment to reduce the cutting stress. Now climate is changing due to global warming and severe weather events are happened such as more severe flooding in flood prone area and drought in dry area. Therefore, climate resilient cultural practices should be practice to sustain the rice yield after damage. If flood damage is occurred this "Cut Stem Transplant Method" is one of the possible way to sustain the rice yield and even higher yield than currently practiced rice establishment methods was recorded. Although this method is applicable to deep water condition at transplanting, further studies will be necessary on how water support the good environment for rooting and tillering from stem cutting. In addition, further identification on how much water depth is necessary at transplanting time to follow this method should be tested. In conclusion, it can be confirmely interpreted that this method is one of the best way to practice in deep water area after flooding damaged.

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APPENDICES

Appendix 1 Rice ecosystem in Thanatpin

Rice ecoystem	Cultivated area (ha)
Lowland	33756
Flooded	1040
Deep- water	27844
Total area	62640

Appendix 2 Ten years average monthly rainfall in Thanatpin

No	Month	Day	Rainfall (mm)
1	January	1	4.57
2	February	0	0.25
3	March	1	8.38
4	April	2	44.70
5	May	15	368.30
6	June	24	637.29
7	July	27	782.57
8	August	27	781.81
9	September	22	509.27
10	October	10	212.60
11	November	2	35.31
12	December	1	11.68
	Total	132	3396.74

Appendix 3 Daily rainfall in 2017 in Thanatpin

Date	Jan	Feb	Mar	April	May	June	July	Aug-	Sept-	Oct-	Nov-	Dec-
1	-	-	-	-	-		0.82	0.15	0.14	0.04	-	-
2	-	-	-	-	-	0.08	1.47	1.18	1.14		-	-
3	-	-	-	-	-	-	0.90	1.00	0.32	0.04	-	-
4	-	-	-	-	-	1.71	0.90	2.24	1.50	4.30	-	-
5	-	-	-	-	-	0.25	2.45	0.40	0.77	0.43	-	-
6	0.11	-	-	-	0.22		0.89	1.66	1.33	2.28	-	-
7	-	-	-	-	-	1.00	0.31	0.70	0.73	0.39	-	-
8	-	-	-	-	-	0.90	0.03	0.74	0.52	0.03	-	-
9	-	-	-	-	-	0.28	2.75	0.53	0.03	0.50	-	-
10	-	-	-	-	-	0.93	0.71	0.07	-		-	-
11	-	-	-	-	-	0.27	0.79	0.35	0.18	0.64	-	-
12	-	-	-	-	-	0.45	0.97	0.60	2.55	0.34	-	-
13	-	-	-	-	-	3.05	1.32	2.85	-	2.60	-	-
14	-	-	-	-	0.09	2.13	0.35	0.43	1.00	0.88	-	-
15	-	-	-	-	0.18	1.17	0.44	0.03	-	0.03	-	-
16	-	-	-	0.60	1.05	0.03	0.80	0.41	0.08	0.20	-	-
17	-	-	-	2.76	2.07	0.53	0.18	2.37	1.90	0.20	-	-
18	-	-	-	-	1.58	1.00	2.07	1.07	0.91	0.90	-	-
19	-	-	-	-	-	1.58	4.45	-	0.25	0.40	-	-
20	-	-	-	-	-	0.95	0.83	0.14	0.44	0.09	-	-
21	-	-	-	-	-	1.10	3.42	5.38	0.05	0.07	-	-
22	-	-	-	-	-	0.19	0.39	0.17	-	0.62	-	-
23	-	-	-	-	-	1.00	0.89	0.15	0.29	1.33	-	-
24	-	-	-	-	-	0.41	1.95	0.05	0.03		-	-
25	-	-	-	-	1.66	1.00	0.54	0.47	-	0.13	-	-
26	-	-	-	-	0.30	0.11	1.31	0.95	1.20		-	-
27	-	-	-	-	0.55	0.15	0.92	0.07	0.48	0.05	-	-
28	-	-	-	-	0.26	2.50	0.32	-	0.98	-	-	-
29	-	-	-	-	0.70	0.09	-	0.05	0.19	-	-	-
30	-	-	-	-	2.21	1.00	1.48	0.48	-	-	-	-
31	-	-	-	-	0.05	-	0.23	0.09	-	-	-	-
Rainy day	1	-	-	2	13.00	26.00	29	23	22	18		-
Total rainfall	0.11	-	-	3.36	11.22	23.86	34.9	24.78	17.01	16.49	-	-

Plate 1 Transplanting with transplanting fork by placing between the first and second elongated internode (A); Folded internode inside the soil due to transplanting technique (B).

Plate 2 Transplanting and growth of the Pawsan rice variety following the cut stem transplant method. (A) lodged seedlings in the nursery field before transplanting, (B) men cutting the seedlings and removing the dead leaves (C) stem cut seedlings brought by boat to the transplanting field (D) holdings the seedlings between the blades (E) plant growth at 1 weeks after transplant, (F)the cut stem rice plant at grain maturity stage

Plate 3 Plant growth in Ywa Houng village, Thanatpin Township (A) transplanting stage on September (B) plant growth on October (C) plant growth on November and (D) grain maturity on December.

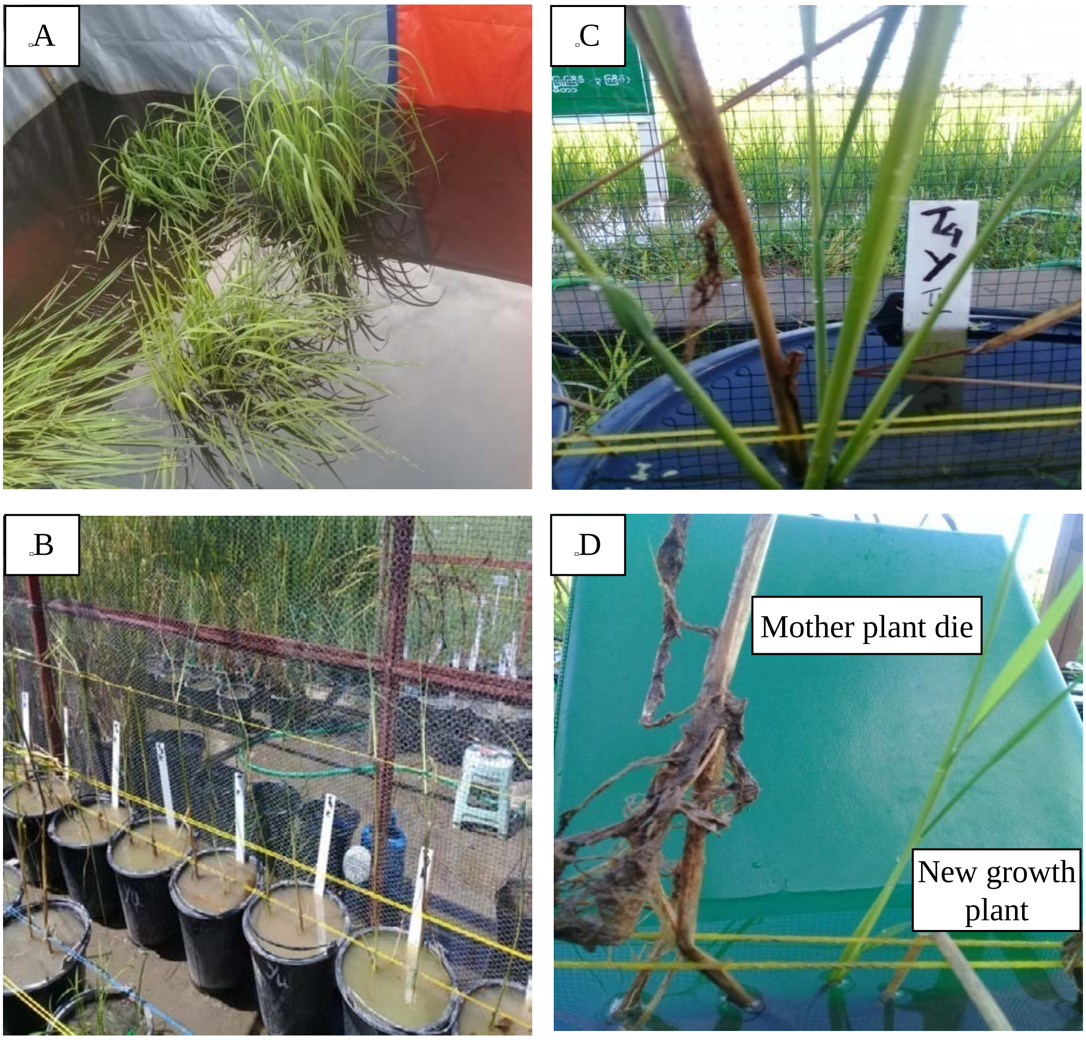

Plate 4 (A) induced stem elongation in artificial pond (B) Just after transplanting in pot (C) alived plant (D) retillering plant