PERFORMANCE OF RICE (*Oryza sativa*) SINGLE SEEDLING UNDER ALTERNATE WETTING AND DRYING IRRIGATION METHOD

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ABSTRACT

Rice seedlings are prone to root disturbance during transplanting. This can affect the growth performance and yield of the crop. Yield reduction is a common problem under alternate wetting and drying (AWD) irrigation. A study was conducted to compare the growth performance of different single seedlings under AWD irrigation. Single seedlings used are CSS (conventional single seedling), SISS (shallow isolated seedling), and DISS (deep isolated single seedling). Constant saturation (CS) was tested as yield and water use check under AWD. Aluminum attachments with 14mm square isolated cells were constructed to produce isolate single seedling. The use of isolated single seedlings was aimed to reduce the 'transplanting shock' in rice transplanting. TR-8 variety was used because it is commonly cultivated in Sabah. Pot trial was carried out under rainshelter from July to November 2016. Statistical analysis shows no interaction between seedlings used and irrigation method. The results showed CSS performed better among the seedlings and CS performed better under AWD although the differences are not statistically significant. Further investigation on field using different soil should be carried to determine the performance of different single seedling under AWD as previous studies had reported almost no yield reduction under AWD. Optimum level of wetting and drying should be identified using TR-8 using different soil under similar climate condition.

PRESTASI ANAK BENIH TUNGGAL PADI (Oryza sativa) BAWAH KAEDAH PENGAIRAN BASAH DAN KERING SELANG SELI

ABSTRAK

Anak benih padi sangat terdedah kepada gangguan akar masa pemindahan. Ini akan menjejaskan pertumbuhan dan hasil tanaman tersebut. Pengurangan hasil adalah masalah yang sering dihadapi sistem pengairan basah kering selang-seli (AWD). Anak benih yang digunakan dalam kajian adalah CSS (anak benih tunggal konventional), SISS (anak benih tunggal), and DISS (anak benih tunggal panjang). Tepu berterusan (CS) juga dikaji sebagai perbandingan hasil dan pengunaan air dengan AWD. Sangkar aluminium dengan sel empat segi yang berasingan telah dibina untuk menghasilkan anak benih tunggal berasingan. Penggunaan anak benih tunggal berasingan bertujuan untuk mengurangkan gangguan akar semasa pemindahan. Variati TR-8 telah digunakan kerana TR-8 biasa ditanam dalam Sabah. Kajian pasu telah dijalankan bawah pelindung hujian dari Julai hingga November 2016. Analisa statistik menunjukkan bahawa tiada interaksi antara jenis anak benih dan pengairan. Hasil kajian menunjukkan bahawa CSS mempunyai prestasi yang lebih tinggi berbanding dengan anak benih lain, CS mempunyai pretasi yang lebih tinggi berbanding dengan AWD walaupun perbezaan yang tidak ketara. Kajian lanjutan perlu dilakukan dengan tanah lain untuk menentukan pretasi anak benih tunggal bawah AWD kerana kajian sebelumnya menunjukkan bahawa tiada pengurangan hasil bawah AWD. Paras optima AWD untuk TR-8 patut dikenalpasti dengan jenis tanah berlainan di bawah keadaan cuaca yang sama.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

-	Negative
%	Percent
:	To (for ratio)
±	Confidence interval
°	Degree
°C	Degree Celcius
ANOVA	Analysis of variance
AWD	Alternate wetting and drying
AWD	Alternate wetting and drying
AWDI	Alternate wetting and drying irrigation
C	Carbon
CEC	Cation exchange capacity
CF	Continuous Flooding
cm	Centimeter
$Cmol_ckg^{-1}$	Contimole per kilogram
CS	Constant Saturation
CS	Constant Saturation
CSS	Conventional Single Seedling
CSS	Conventional Single Seedling
DAS	Days after sowing
DAT	Days after transplant
DISS	Deep Isolated Single Seedling
DISS	Deep Isolated Single Seedling
ET	Evapotranspiration
FAO	Food and Agriculture Organization
FAPRI	Food and Agricultural Policy Research Institute
FSA	Faculty of Sustainable Agriculture
g	Gram
g/L	Gram per liter
g/m^2	Gram per m^2
GRiSP	Global Rice Science Partnership
H	Hydrogen
H_0	Null hypothesis
H_1	Alternate hypothesis
H_20	Water
HSD	Honest Significant difference
in.	inch
IRRI	International Rice Research Institute
IRRI	International Rice Research Institute
K	Potassium
K_2O	Potassium oxide
kg/ha	Kilogram per hectare
kPA	Pascal
L	Liter
LSD	Least Significant Difference
m	Meter
ml	Milli liter
ml	milliliter
mm	Millimeter

MOA	Ministry of Agriculture
MOP	Muriate of Potash
N	Nitrogen
NaCl	Sodium Chloride
ns	No significant
O_2	Oxygen
P	Phosphorus
P_2O_5	Phosphorus pentoxide
R	Replicate
SAS	Statistical Analysis Software
SISS	Shallow Isolated Single Seedling
SISS	Shallow Isolated Single Seedling
SSP	Single Super Phosphate
t/ha	Tons per hectare
TOC	Total Organic Carbon
TSP	Triple Super Phosphate
UMS	University Malaysia Sabah
Vol.	Volume
WAT	Week After Transplanting
WMD	Wetting and Moderate Soil Drying
WSD	Wetting and Severe Soil Drying
WUE	Water Use Efficiency
X	Times

LIST OF FORMULAE

CHAPTER 1

INTRODUCTION

1.1 Background

Rice (*Oryza sativa*) being one of the most successful crops cultivated by mankind. It is able to survive or even productive under broad range of environmental condition where most other crops would fail. Generally, rice cultivation is classified based on the broad categories which are altitude (upland and lowland) and water source (irrigated or rainfed).

Rice is one of the top three leading food crops of the world other than maize and wheat. It is the main source of carbohydrates of 3.5 billion people (more than half of world population) which account for 20% or above of their daily calories intake. Asia is the main consumers of rice which accounts more than 90% of global rice consumption, where rice is the staple diet of majority (GRiSP, 2013). According to GRiSP, rice consumption of Asia exceeds 100kg per capita annually in most of the countries. Although high income and middle-income countries had shown the decline in consumption per capita, the total consumption of the continent continue to rise due to the growth of population. Malaysia is one of the countries that experience decreased consumption per capita as there is an increase in choice of food to supply our daily calories need. Other than Asian countries, the other parts of the world also experience increase in demand and also consumption per capita. For example in Africa, many had adapted rice as their staple food replacing other sources of carbohydrates had led to increasing demand per capita.

In order to meet the huge demand of rice consumption, a vast area of land is used for rice cultivation. Based on GRiSP (2013) the irrigated lowland rice provides 75% of rice supply which is cultivated on 93 million hectares of land while about 52 million hectares of rainfed lowland rice contributes another 19% rice supply. Rice is generally more productive when irrigated, irrigated produces average yield about 5.4 t/ha per cycle. The productivity varies greatly based on the variety, area and most importantly management and practices by farmers. Many well-educated farmers are able to achieve a yield of more than 10t/ha by using good quality seeds of high yielding variety along with good agronomic practices.

Rice is a "thirsty" crop which requires a lot of water to produce due to their high rate of evapotranspiration rate especially irrigated rice. Based on Tomar & O'Toole (1980) review, the average (ET/EP) ratio of rice crop throughout the growing season is 1.2 in Asia. On average, irrigated lowland requires 1, 432 liters of water to produce a 1kg of rice.

Alternate wetting and drying (AWD) irrigation method are recommended by IRRI to address the problem of water scarcity. Most of the earlier studies on AWD showed yield reduction (Bouman and Tuong, 2001). Bouman *et al.* (2007) report no significant yield loss in later studies on AWD whereby 15-30% was saved. AWD is also known as water management practice applied with System of Rice Intensification (SRI) promoted by Stoop *et al.* (2002). An average yield of 7-8 t ha^{-1} was widely reported among SRI farmers, some even produced beyond 15 tons ha^{-1} (Uphoff, 2007).

1.2 Justification

GRiSP (2013) had made a projection of the increase in rise demand from 439 million tons (milled rice) in 2010 to 496 million t in 2020 and further increase to 555 million in 2035 based on the population projections from the United Nations and income projections from Food and Agricultural Policy Research Institute (FAPRI). GRiSP (2013) also estimated that the irrigated lowland rice cultivation consumed 34-43% of global irrigation water and up to 30% of world's developed fresh water resource.

With the growing trend of rice demand globally and reducing the availability of water source, rice cultivation will soon face very serious matter in production in terms of water use. It is estimated about 15-20% of irrigated rice will run into some degree of water scarcity by 2025, which resulted from climate change and water allocation (Tuong and Bouman, 2003). To address the potential problem, alternate wetting and drying (AWD) irrigation is introduced to reduce the water consumption of irrigated lowland rice up to 50%. AWD and SRI practices can be very labour intensive in order to reduce water without compromising the yield. It requires manual transplanting of single seedlings to ensure vigourous seedling growth which in return increases the yield and reduces the water lost. The practice of transplanting young single seedling with is essential under AWD irrigation method in order to achieve the potential yield of the rice variety of the region (Bouman *et al.*, 2007).

However, the decreasing availability of labour in agriculture sector caused this method to be impractical to many countries. Having Malaysia as an example, Labour shortage in agricultural sector had been in an increasing trend since 1970, direct seeding had become the main crop establishing method together with mechanisation for all field activities had become the only solution to address the problem of labour shortage (Najim *et al.*, 2007). Rajamoorthy *et al.*, (2015) stated Malaysia is a net importer of rice and the demand will continue to rise as the population increases. There is a need to reduce dependence on rice import by increasing local production. (Rajamoorthy *et al.*, 2015).

There is no readily available implement or machinery to transplant rice single seedling. This causes farmers reluctant to adopt AWD irrigation methods despite knowing the problem of resource scarcity especially water source. Therefore, there is a need for a seedling raising method that enables mechanized transplanting of single seedling which produces good yield or at least no significant yield loss. Therefore, there is need to compare the growth and yield performance of single seedlings with disturbed and undisturbed root under AWD irrigation method. Initial study on performance of seedling using different raising methods of both disturbed and undisturbed root

1.3 Significance of the Study

This study may encourage the adoption of SRI practices especially the practice of transplanting young single seedlings and alternate wetting and drying irrigation (AWDI) among Malaysian farmers, particularly in TR-8 cultivation. This study will provide insight on the performance of young single-seedling of both disturbed and undisturbed root of TR-8 rice variety compared to conventional seedling raising method for transplanting. Undisturbed root is expected to have better recovery from transplant to minimise the impact of 'transplanting shock". As water for agriculture become increasingly scarce (Rijberman, 2006), there is a need for water saving practice without compromising yield. Implementation of AWD imposed serious weed problem as there is no constant standing water to inhibit the growth of weeds, thus seedling with vigorous growth after transplant is essential to compete with weed growth. Study on performance of seedlings raised with different methods under AWD is required to determine which will produces the highest yield while reducing water use.

1.4 Objectives

The objectives of this study are:

1. To compare the growth and yield performance of rice single seedling using different seedling raising methods
2. To compare the growth and yield performance of rice single seedling under different irrigation method

1.5 Hypothesis:

Hypothesis 1:

H_0: There is no significant difference on growth and yield performance of rice between single seedlings used.

H_1: There is significant difference growth and yield performance of rice between single seedlings used.

Hypothesis 2:

H_0: There is no significant difference on growth and yield performance of rice under different irrigation method.

H_1: There is significant difference on growth and yield performance of rice under different irrigation method.

Hypothesis 3:

H_0: There is no interaction effect between seedling used and irrigation method on growth and yield performance of rice.

H_1: There is interaction effect between seedling used and irrigation method on growth and yield performance of rice.

Chapter 2

Literature Review

2.1 The Rice Plant

Rice crop has the unique ability to survive under flooded condition and it is able to produce new tillers after harvest. However, common agriculture practices do not practice ratooning of rice crop but instead it is cultivated as a semi-aquatic annual grass (GRiSP, 2013). Upon maturity, the plant begins to produce more stems from the main stem, each of them are referred as tiller. Tiller which bears a terminal flowering head or panicle is referred as productive tiller. The plant height can range from 0.4 meter to more than 5m (some varieties of floating rice) based on the variety and environmental conditions (GRiSP, 2013). There morphology of rice is divided into the vegetative phase and reproduction phase. Vegetative phase includes germination, seedling and tillering stage, while the reproductive phase consists of panicle initiation and heading stage.

2.1.1 Rice Growth Phases

Rice growth can be separated into 3 stages, which are vegetative and reproductive (Yoshida, 1981; GRiSP, 2013). Active tillering, gradual increase in plant height and leaf emergence at regular intervals were described as vegetative stages; culm elongation, decline in tiller number, emergence of flag leaf, booting heading and flowering were described as reproductive stages (Yoshida, 1981).

In general, rice crop is an annual crop which requires 3-6 of growth period before harvesting; the exact time differs under different environmental condition and variety (GRiSP, 2013). There are many varieties of rice but they are grouped into short-duration (105-120 days) varieties and long duration (150 days) varieties. Growth duration is mainly affected my length of vegetative growth stage, reproductive and ripening stage as mostly similar for most of the varieties (Yoshida, 1981). Under tropic condition, a cultivated short variety undergoes 60 days of vegetative phase, while both reproductive and ripening phase require 30 days.

Figure 2.1 is a schematic diagram illustrating the growth stages of rice plant based on a 120-day variety rice model. The vegetative phase consists half of the lifespan (60 days) of the crop while the other half is the reproductive phase. Gradual increase of plant height can be observed from 0-60 days after germination, tillering begin on day 20 and maximum increased of tiller number was followed until it reaches maximum at day 60, maximum number of tiller produced at the late vegetative phase. As the plant enters reproductive phase decline of tiller number occurred until it become

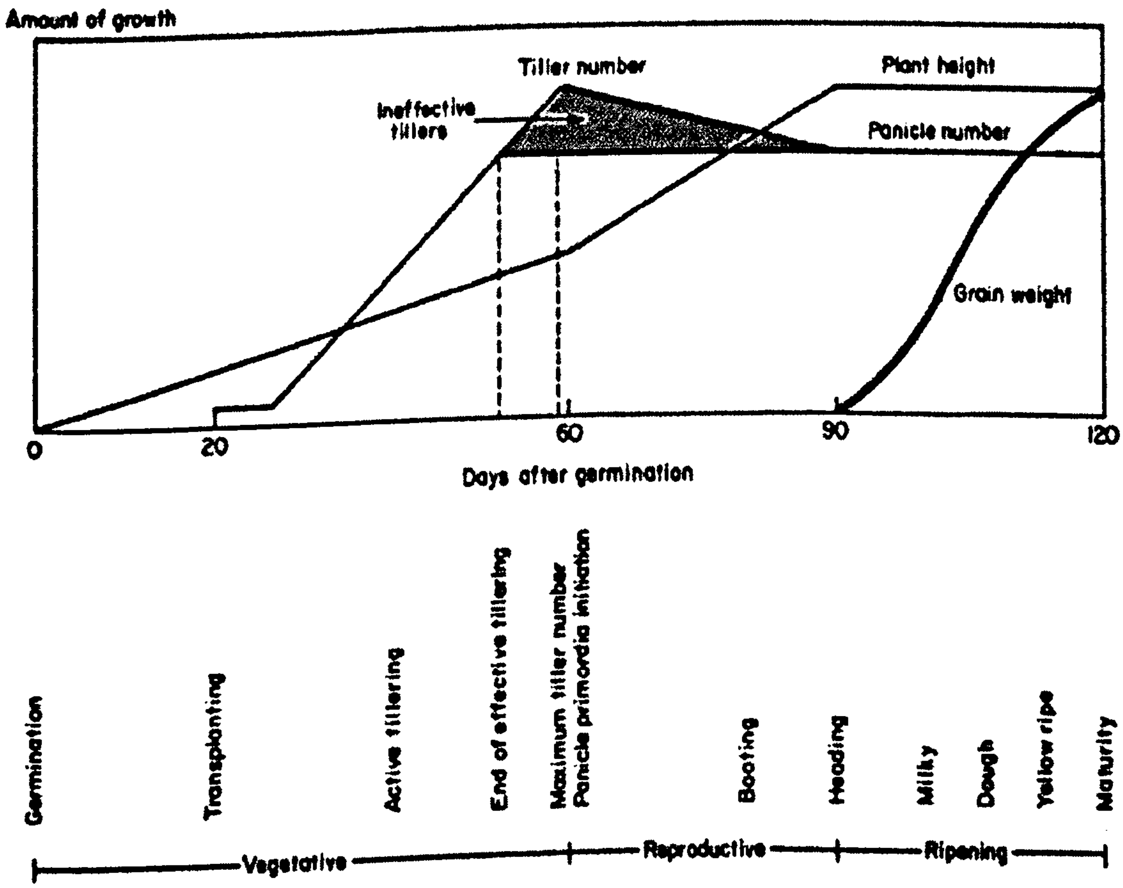

Figure 2.1 Life history of a 120-day variety grown in the tropics under the transplanting cultivation system (schematic).

Source: Yoshida (1981)

numerically equal to panicle number at the ripening stage. Then the plant enters booting and ripening phase on day 90 as the grain weight increases towards to end of crop cycle.

2.1.2 Plant Age and Leaf Number

The rice plant age is commonly expressed in calendar days after germination or sowing or seeding, it is often referred as days after sowing (DAS). Yoshida (1981) mentioned that reference is convenient when a same variety is cultivated under same condition; however, it is not suitable as reference when comparing growth under different environments due to different rate of development. In a nutshell, the physiological age of the plant is strongly affected by environment condition.

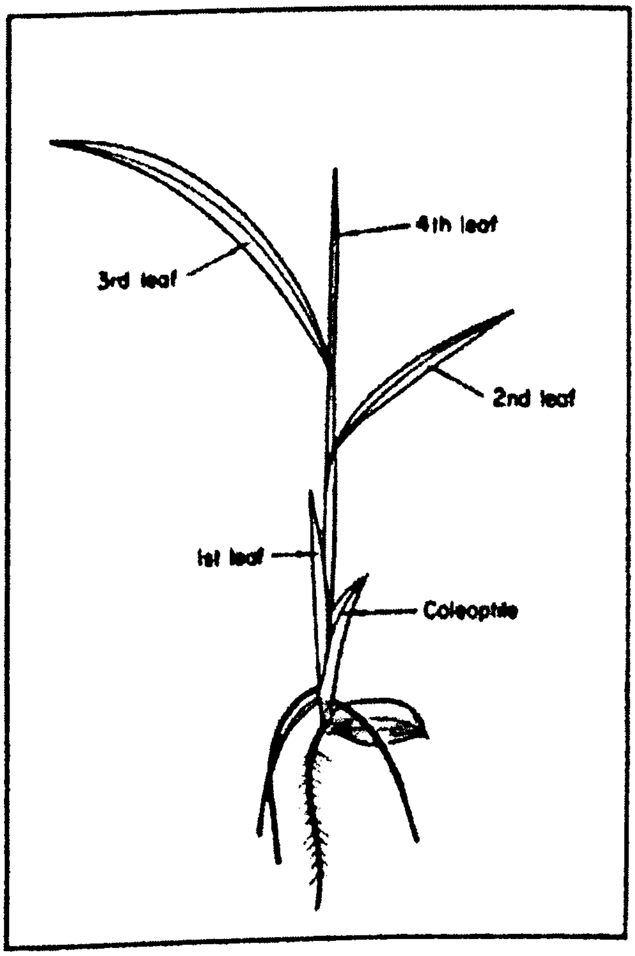

Figure 2.2 Counting leaf number of rice plant.
Source: Yoshida (1981)

According to Yoshida (1981), leaves number on the main culm is the best reference for physiological age of rice plant. Coleoptiles emerges and grows about 1cm at germination, first leaf begins to emerge right after that. The first leaf of rice plant shapes differently and does not resemble a leaf blade like others, it grows about 2cm long. The second leaf emerges before the first leaf is fully developed, it has well developed leaf blade unlike the first. The third and the succeeding leaves behave similarly, they emerge after each preceding leaf has fully elongated. A leaf is considered to have fully developed when the tip of the succeeding leaf emerges. The first leaf is more often referred as prophyll or incomplete leaf as it appears differently than others without leaf blade. Thus, the second leaf (Figure 2.2) is counted as the first.

2.1.3 The Rice Root System

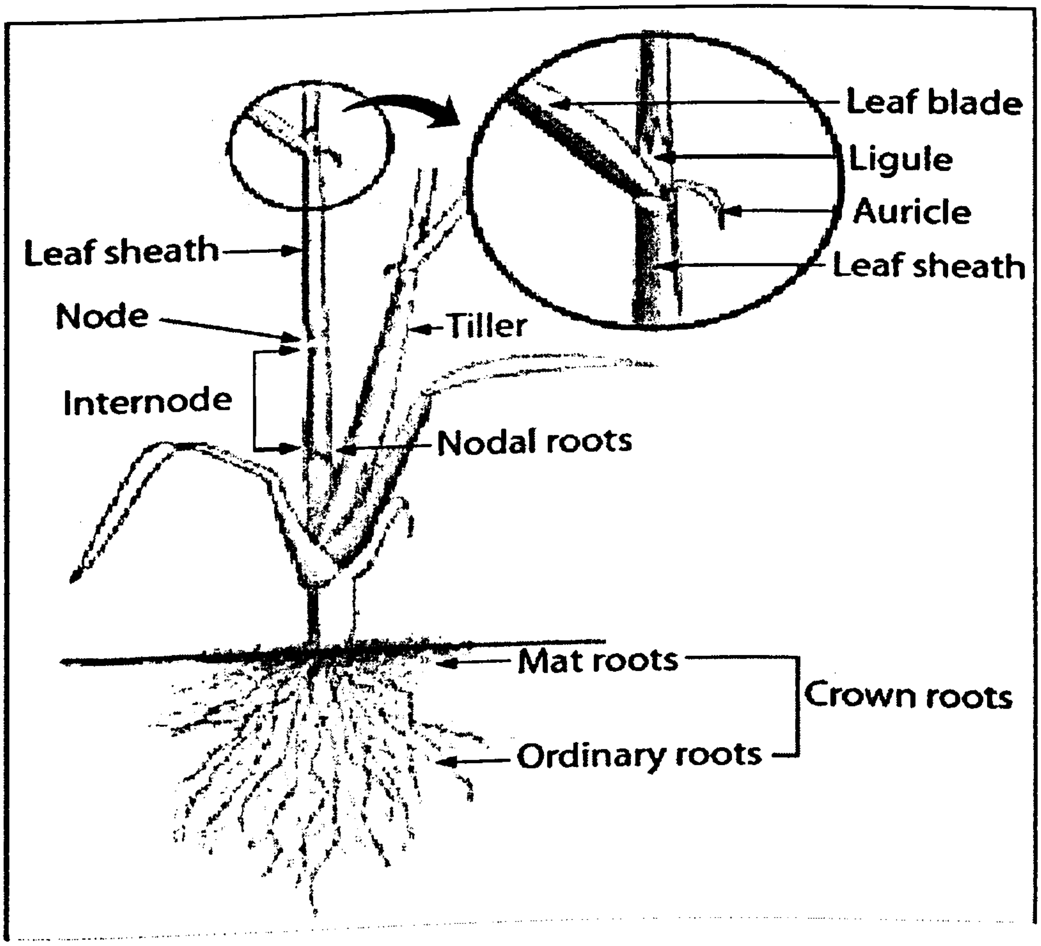

Figure 2.3 Parts of rice plants.
Source: GRiSP, 2013

Two major root systems are found on the rice plant which is crown roots (including mat roots) and nodal roots which is shown on Figure 2.3 (GRiSP, 2013). Rice root system is mainly consisting of nodal roots according to Yoshida (1981), primary roots are developed directly from the culm nodal region as shown in Figure 2.3. Primary roots develop branched secondary roots which in turn develop tertiary root as the root growth proceeds, rice roots are known to develop sixth-order branched root under lowland conditions (Yoshida, 1981). Root hairs development is governed by genetic and also affected by environmental condition, upland soils provide aerobic condition which favors root hair development (Kawata and Ishihara 1959, 1961, Kawata *et al.*, 1964). Continuous flooding creates an anaerobic environment which limits the root growth and the root growth seldom exceeds 40cm depth (Yoshida, 1981).

2.1.4 Seed Germination

Germination begins with water uptake by the seed (imbibitions) and ends with the emergence of the embryonic axis, usually the radicle, through the structures surrounding it (Bewley *et al.*, 2012). Similar to any other seeds, rice seed germination is affected by moisture, seed dormancy, aeration, and temperature. The seed germination occurs in a triphasic pattern (Takahashi, 1984) and it begins at 15% moisture content and achieved full germination at 25% moisture content (Hosikawa, 1989).

The three phases of seed germination (Bewley *et al.*, 2012)

1. Phase 1: imbibitions
2. Phase 2: metabolic activation (respiration and carbohydrate metabolism)
3. Phase 3: growth and emergence of root and shoot primordia from the hull

Similar to any other plants, rice germination take place with the emergence of the first shoots and roots from the seed. Rice seed is light neutral whereby its germination is not affected by any factor of light. In order to break the seed dormancy, adequate water supply and temperature range of 10-40°C is required. Rice seed is able to germinate in both flooded and non-flooded condition, but the seed behave differently under both conditions (GRiSP, 2013). Shoot emerge at first under flooded condition while root emerge first when sow in non-flooded soil.

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