Graduate School of Frontier Sciences, The University of Tokyo

Graduate Program in Sustainability Science

2008-2010

Master's Thesis

A Study on Effectiveness of Field Water Tube as a Practical Indicator to Irrigate SRI Rice Field in Alternate Wetting and Drying Irrigation Management Practice

August 2010

Adviser: Professor YAMAJI Eiji

47086865 MD. ABDUL LATIF

A Study on Effectiveness of Field Water Tube as a Practical Indicator to Irrigate SRI Rice Field in Alternate Wetting and Drying Irrigation Management Practice

By

MD. ABDUL LATIF

Supervisor
Professor YAMAJI Eiji
Co-Supervisor
Asso. Professor YARIME Masaru

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER`S OF SCIENCE IN
SUSTAINABILITY SCIENCE

Graduate Program in Sustainability Science
Graduate School of Frontier Sciences
The University of Tokyo

11 August, 2010

The thesis attached hereto entitled **"A Study on Effectiveness of Field Water Tube as a Practical Indicator to Irrigate SRI Rice Field in Alternate Wetting and Drying Irrigation Management Practice"** prepared and submitted by **MD. ABDUL LATIF** in partial fulfillment of the requirements for the master's degree in Sustainability Sciences is hereby accepted.

Prof. YAMAJI Eiji

山路永司

Principal Supervisor

Date: August 10, 2010

ACKNOWLEDGEMENTS

First, I heartily thank and convey my deep sense of gratitude and appreciation to my supervisor Dr. YAMAJI Eiji, Head and Professor of the Department of International Studies (DOIS) for his continuous support in my Master program and conduct this research successfully. He taught me how to run experiment, make research plan, ask questions and express my ideas. He showed me different ways to approach a research problem and the need to be persistent to accomplish any goal.

Special thanks goes to my co-supervisor, Dr. YARIME Masaru, Associate Professor of the Department of Sustainability Science (GPSS) who is most responsible for helping me to complete the writing of this dissertation as well as the challenging research that lies behind it. I am indebted to Dr. Onuki Motoharu Associate Professor of the Department of Sustainability Science (GPSS) for his valuable suggestions and creative remarks on my research and all necessary assistance through my two years life at Tokyo University. I wish to express my deepest thanks to Dr. Makoto Yokohari, Professor of the Department of Natural Environment Studies for his remarkable comments in the GPSS seminar. I am grateful to Dr. Mashahiko Kunushima, Professor of the Department of International Studies and Director of Kashiwa International Office (KIO) and in-charge of the Asian Development Bank-Japan Scholarship Program (ADB-JSP) for all sorts of cooperation to a foreign student like me. I greatly acknowledge Asian Development Bank-Japan Scholarships Program (ADB-JSP) for full financial support me to complete two year- long masters program.

I am extremely grateful to Dr. Psyche Fontanos, Research Assistant Professor of Integrated Research System for Sustainability Science (IR3S) Ms. Mari Matsuoka, the KIO officer, Ms. Ojima Yumi Secretary to the GPSS, Ms Miyuki Ohashi, Secretary to

the DOIS, for their assistance inspiration and moral support throughout this research work.

I am indebted to all the laboratory members of Agro-environmental Engineering (AEE) to friendly support me in my research specially I owe my deepest gratitude to Tejendra Chapagain who has made available his support in a number of ways to like a mentor to friend. Mr. Yukio Wakimoto and Mr. Jun Tsurui helped me to collect the meteorological data. I am thankful to Mr. Azuma Junji, Ms. Kako Inoue, Mr. Simon Ikenoue, Mr. Jose Cristhian Veizaga Mr. Morio Sato for their kind help. I am also grateful to all the member of 606 lab of sustainability science for their valuable comments, necessary suggestions and inspiration.

Last, but not least, I am thankful to my respected mother Mrs. Lutfunnessa, my beloved wife Mrs. Shamima Nasrin, my affectionate son Master Md. Sajeed Ishteaque who suffered a lot for me and kept patience throughout the study period. I dedicated my work to Late Mr. Ashraful Haque, my father and former senior teacher of Kushtia High School, Kushtia, Bangladesh and all the farmers of Bangladesh and Japan.

MD. ABDUL LATIF

11. August, 2010

Table of Contents

List of Figures

List of Tables

List of Appendices

ACRONYMS

ADB	Asian Development Bank
ASNS	Alternately Submerged and Nonsubmerged
AWDI	Alternate Wetting and Drying Irrigation
BADC	Bangladesh Agricultural Development Corporation
BD	Bangladesh
BRRI	Bangladesh Rice Research Institute
CIIFAD	Cornell International Institute for Food, Agriculture and Development
CS	Continuously Submerged
DAT	Days After Transplanting
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
SRI	System of Rice Intensification

Abstract

A roof-top Lysimeter scale experiment was conducted at the Kashiwa Campus, University of Tokyo to find out the effectiveness of Field Water Tube in terms of monitoring the depth of ponded water, determining the right timing of irrigation in Alternating Wetting and Drying Irrigation (AWDI) management regime of System of Rice Intensification (SRI) rice cultivation. The experimental layout was Demonstration Strip Design with replication where Diameter of Field Water tube was Treatment and it replicated twice. In the study 5 different diameter PVC Tube(viz. 5cm, 7.5cm, 10cm, 12.5cm and 15cm) which all were perforated used as treatment(5A, 5B, 7.5A, 7.5B, 10A, 10B, 12.5A, 12.5B, 15A and 15B respectively). When the water level went to 10cm below the soil surface level then irrigation was applied in the drying cycle of AWDI. Throughout the study period, Water level of different diameter Water Tube associated with prevailing moisture percentage, pressure, temperature were monitored to find out relationship among water level of Water Tube, moisture and pressure.

The study revealed that all the treatments measured the water level perfectly and determined the appropriate time of irrigation in AWDI management regime. The study disclosed that in measuring Water depth all the Water Tube exhibited close linked (in same diameter maximum r^2 value 0.9955 and minimum r^2 value 0.9876, in different diameter maximum r^2 value 0.995 and minimum r^2 value 0.965) to each other. The study also found out that there was variation in ponded depth measurement by different diameter Water Tube when water level went -5cm below soil surface where narrower diameter demonstrated maximum ponded depth and wider diameter exhibited minimum ponded depth. The treatment 5B reached maximum lowest depth -18.1cm followed by

-18.cm by 5A. On the other hand 12.5B reached minimum lowest depth -13.5cm followed by 14.0cm by 15A.The study also found that there was difference in decreasing rate in water level reduction in 24 hours where maximum is –15.4cm by 7B and minimum -11.5cm by 15B.

It is demonstrated that Water Tube measurement has strong relationship (r^2 value 0.9829) with Water Level sensor measurement (Hioki Meter). The study uncovered that there was significant relationship between ponded depth and pressure (maximum r^2 value is 0.5445 and minimum r^2 value is 0.4594) at 5cm depth Tensiometer. In the study no significant relationship was established between Water Tube measurement and Moisture sensor measurement.

The study unveiled that the AWDI practiced with Water Tube measurement formed huge crack (maximum3.5cm width) in the soil and remained up to 35 days from its initiation and after flowering stage again crack formed for AWDI practicing. Plant height, number of tiller, leaf number, height and color were found in good condition and no stress was found on plant in the experiment.

Key words: Field Water Tube, Ponded depth, Diameter of Water Tube, Alternate Wetting and Drying Irrigation, SRI, Soil crack.

1. Introduction

1.1. Background

Rice, the staple food of nearly half of the world's population (2.7 billion) mostly from Asian countries, provides 35-60 percent calories consumed (Guerra et al., 1998). Food security in Asia is depended largely on irrigated rice fields, where rice produces three quarters of all rice harvested using 79 million ha of irrigated land (Tuong et al, 2002) and irrigated rice, the prolific user of water uses 50% of all diverted freshwater (Barker et al., 1999). By 2025, the per capita available water resources in Asia are expected to decline by 15-54 percent compared with 1990 (Guerra et al., 1998) and already 12 million hectares of south Asia's irrigated rice are at risk of severe water shortage, with serious consequences for regional food security and social stability (IRRI, 2006). Specially dry season rice of Bangladesh, India, and Pakistan is in vulnerable condition due to lack of available irrigated water and hence the food security and livelihood of rice producers and consumers in that region. To cope with looming water crisis, we must sought water saving technologies to maintain and to increase rice production for meeting the world's food needs with less water. In other words, the efficiency of water use in irrigated rice production systems must be significantly increased.

But rice is very sensitive to water stress and any attempts to reduce water inputs through water saving technologies may result in yield reduction. The challenge is to develop novel technologies that will allow rice production to be maintained or increased in the face of declining water availability. Several strategies are being pursued to reduce rice water requirements, such as saturated soil culture ((Borrel et al, 1997), alternate wetting and drying Irrigation AWDI ((Li 2001, Tabbal et al 2002), ground cover systems (Lin Shan et al 2002) system of rice intensification (SRI, Stoop et al 2002), aerobic rice (Bouman et al 2002), and raised beds (Singh et al 2002) [Aswathanarayana, U, 2007].

Experimental research on individual technologies is ongoing, but no attempt has yet been made to take stock of where we are at the moment or to synthesize and compare the performance of the different technologies (IRRI, 2002). One new strategy proposed is the using of Field Water Tube in System of Rice Intensification (SRI) with Alternating Wetting and Drying Irrigation (AWDI) management regime as a more efficient, resource saving and productive way to practice rice farming. Field Water Tube is plastic/bamboo/ceramic made perforated Tube using for monitoring water depth and determination irrigation timing in AWDI regime. In AWDI management practice, rice fields are not kept continuously submerged but are allowed to dry intermittently during the rice-growing period (Van der Hoek et al. 2001) and rice grows under mostly aerobic soil conditions. On the other side SRI is a methodology for increasing the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients (http://ciifad.cornell.edu/sri/).

Rice cultivation in Alternate Wetting and Drying Irrigation management is generally practiced with 5days interval, 7 days interval, 10days interval irrigation etc. but the idea of predetermined days interval cannot be treated as the demand driven approach perfectly. Need based water management is required to ensure more sustainable way to use of valuable water resource. Moreover, success of AWDI depends largely on the irrigation the field at the right time when needs water for the rice plant. But determination of right irrigation timing during the dry Cycles of AWD is very hard due to different soil physical properties such as soil structure, soil texture, bulk density of soil; soil pore space etc and different soil have different hydraulic conductivity like movement of water, infiltration/percolation rate, and water retaining/holding capacity.

Farmers fail to decide the appropriate time for irrigation in different soil type like sandy, silty and clayey soil in drying regime of AWDI and farmers pay penalty as yield reduction for saving irrigated water. To solve the crucial problem of yield reduction, International Rice Research Institute (IRRI) recommended using Field Water Tube which is 15cm or more diameters; 40-cm long perforated Water Tube for monitoring water depth in AWDI management practices. They claimed that there will be no yield penalty where farmers re-irrigate when water level goes to 15cm below soil surface in AWDI practice. Philippine Rice Research Institute recommended using 12cm diameter Tube and suggested to re-irrigate when water level goes to 15cm below soil surface (http://www.philrice.gov.ph//index.php?option=com_content&task=view&id=913&Itemid=107) in controlled irrigation (CI) during dry season rice cultivation. Bangladesh Rice Research Institutes recommended to use 7-10cm diameter water Tube and suggested to re-irrigate when water level goes to 20cm below soil surface in AWDI regime. Therefore, more study is required on Field Water Tube and its diameter size to uncover the effectiveness, accuracy, durability of the instrument as a good practical indicator of irrigation in AWDI management regime.

1.2. Research Objective

To do the study on Field Observation Tube we have set the following distinct objective:-

- To identify the Water Tube usefulness to determine when to irrigate (Qualitative Measurement) SRI Rice field in Alternate Wetting and Drying Irrigation Management Practice.
- To identify the Water Tube usefulness to determine how much to irrigate (Quantitative Measurement) the rice field in Alternate Wetting and Drying Irrigation Management Practice.
- To identify the merits and demerits of water tube based on cost, simplicity, time-consumption, labor-intensive, accuracy.
- To suggest for improving the impediments to the improvement of the tool.

1.3. Research Hypothesis

Before going to study, it is assumed that Field Water Tube will be

-Low cost,

-Having High accuracy rate

-Durable,

-Portable,

-Simple to use (measure the water depth)

-Low labor-intensive and time consuming.

-Adapt with the tool

-Easily available in the market

The following hypotheses were formulated prior to the study:

- Field water tube will be a good practical indicator to monitor the depth of ponded water on the field to implement Alternate Wetting and Drying Irrigation (AWDI) Management Practice in SRI Rice field.
- The water tube will indicate successfully when to irrigate (Qualitative Measurement) in SRI Rice field of Alternate Wetting and Drying Irrigation (AWDI) Management regime.

2. Literature Review

2.1. Field water Tube

2.1.1. Evolution of Field Water Tube

In 2004, to implement Alternate Wetting and Drying Irrigation successfully, IRRI recommended making hole in the rice field to monitor the water depth and suggested to re-irrigate in the vegetative and post flowering stage of rice plant when water level goes to 15cm below the soil surface (Tuong, 2007).In 2007, IRRI suggested to use Field Observation Water Tube in lieu of Hole Observation technology to monitor the water depth and determination of irrigation timing.

2.1.2. Elements and Application

IRRI recommended the Field Observation Tube can be made of 25-40-cm long plastic pipe/ bamboo/ceramic, has a diameter of 15 cm or more, and perforated the tube with holes on all sides. To install the Water Tube in rice field, it is required to dig the tube in the soil so that 20 cm protrudes above the soil surface and then required removing the soil from the inside so that the bottom of the tube is visible. The tube should be placed in a flat part of the field close to a bund, so it is easy to monitor the ponded water depth easily (IRRI, 2009).

According to IRRI, Field Water Tube is a practical way to implement AWD by monitoring the depth of ponded water on the rice field. After irrigation, the depth of ponded water will gradually decrease. When the ponded water has dropped to 15 cm below the surface of the soil, irrigation should be applied to re-flood the field with 5 cm of ponded water. From one week before to one week after flowering, ponded water should always be kept at 5 cm depth. After flowering, during grain filling and ripening, the water level can drop again to 15 cm below the surface before re-irrigation (Rice fact

sheet IRRI, 2009). In 2007, IRRI scientist Dr. To Phuc Tuong conducted an experiment on application of Field Water Tube in AWDI management regime at BADC Farm, Modhupur, Tangail in Bangladesh and showed that Field Water Tube worked successfully to monitor the water depth and capable to indicate right timing of irrigation and save water, gasoline and electricity without any yield penalty. In 2008, M.M.H. Oliver and others used Field Water Tube in their research which was 4 cm in diameter and 40 cm in length and installed in the field keeping 7 cm above the soil and the remaining 33 cm (perforated) underneath to measure the depletion of soil water in the field (M.M.H. Oliver et. at, 2008). According to Knowledge Bank of Bangladesh Rice Research Institute (BRRI), Field Observation Tube can be made with 7-10cm perforated pipe which 10cm remains above soil surface and 20cm goes below soil surface and perforated hole 5cm apart.

According to Dr Hamid Miah, former DG of BRRI (Bangladesh Rice Research Institute), to apply AWD technology requires only a 10 cm diameter and 25 cm long PVC pipe or hollow bamboo pieces or even waste bottles of cold drinks like coco cola etc. Fifteen cm on one side of the pipe is perforated for easy horizontal movement of water and it is to be installed vertically with its perforated portion under the ground level when the soil within the pipe is to be scooped out so that soil at the lower end of the pipe is visible.
(http://bangladesheconomy.wordpress.com/2010/02/22/awd-irrigation-technology-can-benefit-bangladesh/).

2.1.3. Benefits of Field Water Tube

2.1.3.1. Direct Benefit -Water Saving

Filed Water Tube can reduce 5 number irrigations compared to farmers' practice, save irrigation water by 25 percent in the Boro season (dry season rice) of Bangladesh.

2.1.3.2. Indirect Benefits

There are many indirect benefits of using Water Tube in rice cultivation. Here are the followings

2.1.3.2.1. Reduction of Disease

Though the using of Water Tube, less water will be applied, plant adaptive capability will be high. Rice plant will be less affected by pest and disease incidence will be reduced.

2.1.3.2.2. Reduce cost of Production

By the applying this technology, water related cost (irrigation) will be decreased. Therefore, production cost of rice will be reduced

2.1.3.2.3. Diesel and electricity cost

Where pump irrigation is applied there diesel and electricity cost will be reduced. In case of Bangladesh, 30-40 liter/ha diesel and 1 thousand 300 BD ($20) currency will be saved for electricity purposes. In Bangladesh, diesel cost will decrease up to 7.420 Billion BD Currency if this technology can be applied throughout the country.

2.1.3.2.4. Reduction of ground water depletion and arsenic contamination

The country which use ground water for irrigation, they can be hugely benefitted from using Field water Tube through reducing ground water depletion and arsenic contamination in the food web.

2.1.3.2.5. More Production

500 kg more paddy per hectare can be produced through applying this technology. By applying this technology 2.4million ton of rice can be produced In Bangladesh.

2.1.3.2.6. Environment Friendly

Specially it is environment friendly technology. Soil ecology will be improved through ponded depth ups and down specifically microbial activity will be enhanced due to getting aeration when ponded depth will be under the soil surface. No radioactive materials are released from Water Tube.

2.2. SRI-System of Rice Intensification

2.2.1. Origin and Concept

SRI developed with farmers in Madagascar almost 20 years ago by Fr. Henri de Laulanie, is a system of production that through synergistic interactions can produce much higher grain yields than usually archived by the conventional practices with new varieties and inputs.SRI is a set of ideas and insights that emphasize the use of younger seedlings (< 15 days) planted singly or doubly and at wider spacing, together with the adoption of intermittent irrigation, organic fertilization and active soil aeration to the extent possible (Uphoff 2007; Stoop et al. 2002).

SRI is a methodology for increasing the productivity of irrigated rice cultivation by changing the management of plants, soil, water and nutrients. SRI management facilitates better growing conditions for rice plants, particularly in the root zone, than those for plants grown under traditional practices. SRI practices lead to healthier, more productive soil and plants by supporting greater root growth and by nurturing the abundance and diversity of soil organisms. SRI efficiently uses scarce land, labor,

capital and water resources, protects soil and groundwater from chemical pollution, and is accessible to poor farmers (Uphoff, 2006).By following SRI management practice, more can be achieved with less.

2.2.2. Elements

Followings are the set of practices that are considered key in SRI (stoop et al,2002; Uphoff,2007)

a) **Seedlings**-SRI prefers 8-12 days old seedlings with two small leaves and certainly less than 15 days to protect their growth potential. Seedlings are transplanted singly or doubly rather than 4-5 to avoid root competition and carefully and promptly to have minimum trauma to the roots.

b) **Spacing**- Wider spacing in a square grid pattern, 25x25 cm or wider -- 30x30 cm or 40x40 cm, even up to 50x50 cm with the best quality soil to encourage greater root and canopy growth.

c) **Soil-** Soil is kept moist but well-drained and aerated, with good structure and enough organic matter to support increased biological activity.

d) **Water-** In SRI Rice field, only a minimum of water is applied during the vegetative growth period, and then only a thin layer of water is maintained on the field during the flowering and grain filling stage. Alternatively, to save labor time, some farmers flood and drain (dry) their fields in 3-5 day cycles with good results. Best water management practices depend on soil type, labor availability and other factors, so farmers should experiment on how best to apply the principle of having moist but well-drained soil while their rice plants are growing. (http://ciifad.cornell.edu/sri/).

e) **Weeds** - weeds become a problem in SRI fields for not keeping flooded condition throughout the cultivation period. Weeding is necessary at least once or twice,

starting 10-12 days after transplanting, and preferably 3 or 4 times before the canopy closes.

2.2.3. Benefits of SRI

As application of water is very minimal so water requires very less to compare with conventional flooded condition. Water productivity is higher in all combinations of practices in the intermittent irrigation plots: 1.74 g/liter with SRI management and AWDI as compared to 1.23 g/liter from normal planting methods with ordinary water management (Chapagain, T., & Yamaji, E. 2010). Single/double transplanting with SRI can save 50-80% seedlings as compared to traditional rice cultivation.SRI rice have healthier roots, high tiller numbers, big panicles, early maturity and are resistant to disease, pest and lodging. SRI methods by inducing rice plants to grow much larger and deeper root systems give SRI plants more resistance to impact of drought. Better root systems also enable farmers to reduce their irrigation requirements.

2.3. AWDI

2.3.1. Innovation and concept

A Good water management in lowland rice focuses on practices that conserve water (by eliminating the unproductive water flows of seepage, percolation, and evaporation) while ensuring sufficient water for the crop. One method to save water in irrigated rice cultivation is the intermittent drying of the rice fields instead of keeping them continuously flooded. This method is referred to as alternate wet/dry irrigation (AWDI). Alternate Wetting and Drying (AWD) is a water-saving technology that lowland (paddy) rice farmers can apply to reduce their water use in irrigated fields. Many Researchers tried to use less water in rice cultivation and then build a concept of AWDI.

a) Qinghua Shi, et.al conducted three experiments in Jiangxi, China, aimed at understanding the performance of rice under different water management practices (flooded, intermittent irrigation, and dry cultivation) (IRRI, 2002).

b) G. Lu, et.al conducted a study to compare the effects of water-saving irrigation regimes on yield, irrigation water input, water balance components, and water productivity of aerobic and conventional rice varieties. The experiments were conducted in Huibei, near Kaifeng, in Henan Province (from June to October 2001) and in Tuanlin, near Jingmen, in Hubei Province (from May to September 2001), China. They found that Continuous flooding had the highest irrigation water inputs, followed by alternate wetting and drying irrigation, saturated soil culture in raised beds, flush irrigation in aerobic soil, and rainfed treatments. Rice yields did not differ significantly among water treatments.

c) A. Gani,et al conducted an experiment lowland rice area of Riau Province, Indonesia from July to November 2001 to assess the effects of different water management practices (continuously flooded and intermittent wetting and drying), seedling age, and nutrient management.

d) P. Belder,et al were conducted a field experiments at sites in irrigated lowland areas in China (Hubei) and the Philippines (Nueva Ecija) during the summer season (April-September) of 1999 and 2000 and (December- April) of 2000-01.to compare two water regimes: (1) continuously submerged (CS) and (2) alternately submerged and nonsubmerged (ASNS)

In alternate wetting and drying (AWD), irrigation water is applied to obtain flooded conditions after a certain number of days have passed after the disappearance of ponded

water. AWD is also called ‘intermittent irrigation’ or ‘controlled irrigation’. The number of days of nonflooded soil in AWD before irrigation is applied can vary from 1 day to more than 10 days.

The AWDI method of cultivating rice implies that rice fields are not kept continuously submerged but are intermittently dried during the rice growing stage (Rice growing Stage- 10 days after transplanting to panicle initiation R. Cabangon et al. 2003)

In AWD practice, irrigation water is applied to flood the field a certain number of days after the disappearance of ponded/flooded water. The number of days of non-flooded soil in AWD between irrigations can vary from 1 day to more than 10 days.

AWD can be started a few days after transplanting (or with a 10-cm tall crop in direct seeding). When many weeds are present, AWD can be postponed for 2-3 weeks until weeds have been suppressed by the ponded water.

2.3.2. Benefits and Limitations

2.3.2.1. Yield

Alternately wet and dry Irrigation did not affect grain yield (Choudhury et al 1991, De Dios et al 2000) or even led to an increase in yield if irrigation was carefully managed (Wu 1999, Mao et al 2000) [IRRI, 2002]. This yield benefit has been ascribed to better root vigor and depth (Mao et al 2000); a reduction in lodging, pests, and diseases (Yi 1999); and better soil oxygenation (Wang 1999). Other studies reported a yield decline when AWDI regimes were tested (Borell et al 1997, Lu et al 2000, Bouman and Tuong 2001) [IRRI, 2002].

2.3.2.2. Remove Toxic Chemicals

Cheng (1983) reported that aerobic soil conditions favored the removal of toxic chemicals in the rhizosphere.

2.3.2.3. Saving Water and Enhancing Water Productivity

AWDI can save a significant amount of irrigation water (28%) without reduced grain yield (7.4t/h compared with 7.37t/ha from normal planting with ordinary water management) (Chapagain, T., & Yamaji, E. 2010). Several AWDI trials were conducted in China and the Philippines, reported savings in water for AWD range from 13% to 30%, with no significant reduction in yield (Cabangon et al 2001, Belder et al 2002) and enhances Water Productivity in Irrigated Rice. AWDI minimizes pest and disease incidence, shortening the rice crop cycle, and also improving plant stand until harvest (Chapagain, T., & Yamaji, E. 2010). Parminder Virk, et al undertook a study to identify rice varieties, both inbreds and hybrids, suitable for alternate wetting-and-drying (AWD) irrigation during the vegetative phase, saving around 17% of water, without any significant reduction in yield(Parminder Virk, et al 2003).

2.3.2.4. Save Gasoline and electricity

According to Dr. Hamid Miah, IRRI's Liaison scientist in Bangladesh, by applying this technology 30-40 liter/ha diesel and 1 thousand 300 BD currency can be saved for electricity purposes (Bangla Daily "Naya Diganta-17th July", 2009).

2.3.2.5. Reduction of Disease

When rice fields are dried in AWDI, the mosquito larvae will die and less adult mosquitoes will be produced in the rice fields and help to reduce mosquito-borne diseases, especially malaria and Japanese encephalitis.

2.3.2.6. Problems of Weeds and More Labor

In AWDI management weed grows. So weeding is done more frequently than conventional flooding irrigation and more labor requires for weeding or herbicide has to be used which is costly.

3. Materials and Methods

3.1. Description of the Study Area

Fig.1.a Environmental Science Building | Fig.1.b Roof top Lysimeter

Fig.1 Study Area-Environmental Science Building Roof top Lysimeter, Kashiwa, Chiba

This study was conducted at the roof top Lysimeter of environmental building in Kashiwa Campus, University of Tokyo which is under in Kashiwa city, Chiba, Japan during the rice season of 2010 (April to August). The experimental site was situated at 35^0 54' North latitude and 139° 56' East longitude, and at an altitude of 55 m above mean sea level. The size of the Lysimeter was 500*160*60cm^3 and soil depth was 30cm. The soil of the experimental site was sandy loam and homogeneous with fairly good soil fertility. Mochigome cultivar, the second major rice variety (もち米-sticky rice) in Japan, was used and the experiment was carried out under natural environment.

3.2. Climatic Features of the Area

Japan is under temperate climatic region and the climate of the area was warm oceanic that is mild in winter and relatively cools in summer. Table 1 summarizes the climatic data in the experimental site during the rice –season (April to 10th August). Average daily mean temperature was 19.28°C, with the hottest days in July (up to 36.7), whereas the daily minimum temperature was 15.11°C. The average monthly sunshine hour was

recorded as 179.03hours during the cropping season, with maximum received in May (213.2 hours).The lowest was recorded in April (135.7hours).The rainy season started from April and continued up to whole experiment period. Total precipitation in the location during the period April to August was recorded as (496.0 mm), with April received the highest amount of rainfall (194.5mm).

Table 1 Meteorological data during April to August, 2010

Months	Rainfall (mm)		Temperature(hrs)			Sunshine (hrs)
	Total	Daily Max	Average	Daily Max	Daily Minimum	
April	194.5	48	10.9	16.3	6.4	135.7
May	109.5	24.5	17.6	22.7	13.0	213.2
June	109.5	26.5	22	27.0	18.1	167.3
July	77.0	21.5	26.6	31.7	22.9	199.9
Up to 10thAug.	5.5	4.5	28.5	35.0	22.6	89.3
Average	122.6	25.0	21.12	26.54	16.6	179.03

Source: Abiko Meteorological Station, Chiba (Average of Total Rainfall and Sunshine hours was counted up to July)

3.3. Experiment Details

3.3. 1. Apparatus

i) Different Sized (Diameter) Field Observation

Water Tube - 5cm, 7.5cm 10cm 12.5cm and 15cm Diameter Tube.

Height-25cm

Perforated holes space-2cm apart

Perforated holes diameter-3mm

The thickness is 0.5cm, 0.4cm, 0.3cm, 0.25cm and 0.2cm for 15cm, 12.5cm, 10cm, 7.5cm and 5cm diameter Tube respectively.

ii) A ruler,

iii) 4 ECH2O Soil Moisture Sensors,

iv) 4 Temperature Sensors

v) 4 Tensiometers (5cm, 10cm, 15cm and 20cm)

vi) 1 Hioki Meter (Water Level Sensor)

vii) 2 Data Logger,

viii) Lysimeter (Reinforce Cement Concrete-RCC)

Size-500*160cm^2

ix) Leaf Color Chart

Table 2 Use of Apparatus and their measurement

No	Apparatus	Measuring activity	Unit
1.	Water Tube	Water Level	cm
2.	Moisture Sensor	Soil Moisture	Millivolt
3.	Temperature Sensor	Soil Temperature	centigrade
4.	Tensiometer	Soil Pressure	KPa
5.	Hioki Meter	Water Level	0.1KPa
6.	Data Logger	Storage Data	-
7.	Leaf Color Chart	Leaf Color	Number

Apparatus, measurement activity and unit of measurement were described in Table 2.

3.3.2. Section

The experimentation was laid out in Demonstration Strip Design. In the experiment, 4 moisture sensors, 4 temperature sensors 4 Tensiometers (5cm, 10cm, 15cm, 20cm), 5 different diameter (5cm, 7.5cm, 10cm, 12.5cm and 15cm) Field Observation Water Tube were installed and rice plant were cultivated in the Lysimeter(Fig.2). Field Observation

Tubes used in the experiment as treatment. 4 moisture sensors and 4 temperature sensors were attached with 2 Data loggers which were placed just outside the Lysimeter. An under drain was connected with the Lysimeter.

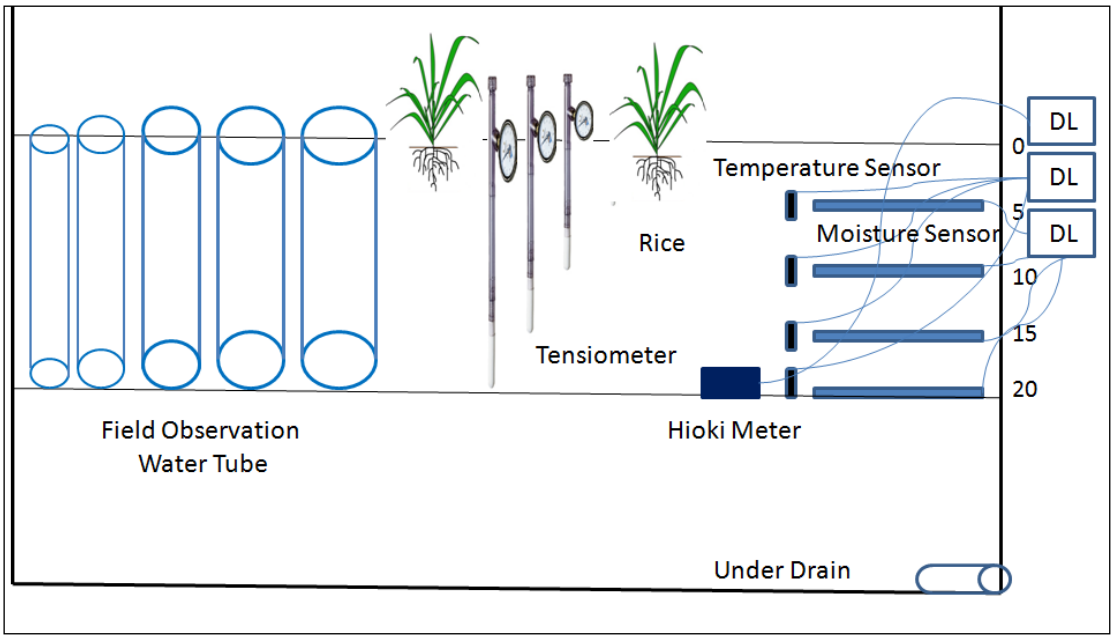


Fig.2 Section of Lysimeter Scale Experiment

a) Moisture Sensors-4 Moisture sensors were installed horizontally in 5cm, 10cm, 15cm and 20cm depth of the soil and all moisture sensors were connected with one data logger.

b) Temperature Sensors-4 Temperature sensors were installed horizontally in 5cm, 10cm, 15cm and 20cm depth of the soil and all temperature sensors were connected with one data logger.

c) Tensiometers-4 Tensiometers (5cm, 10cm, 15cm, 20cm) were installed vertically in 5cm, 10cm,15cm and 20cm depth of the soil respectively.

d) Hioki Meter-1 Hioki Meter (Water Level sensor) was installed horizontally in 20cm depth of the soil.

e) Field Water Tube-5 different diameters perforated Field Observation water Tube

(5cm, 7.5cm, 10cm, 12.5cm and 15cm) were installed vertically which all were 25cm in height. All the Filed Water Tube's 5cm remained above the soil and rest 20cm remained under the soil.

e) Rice plant – Rice plants were transplanted in the soil surface.

3.3.3. Detailed Area Plan

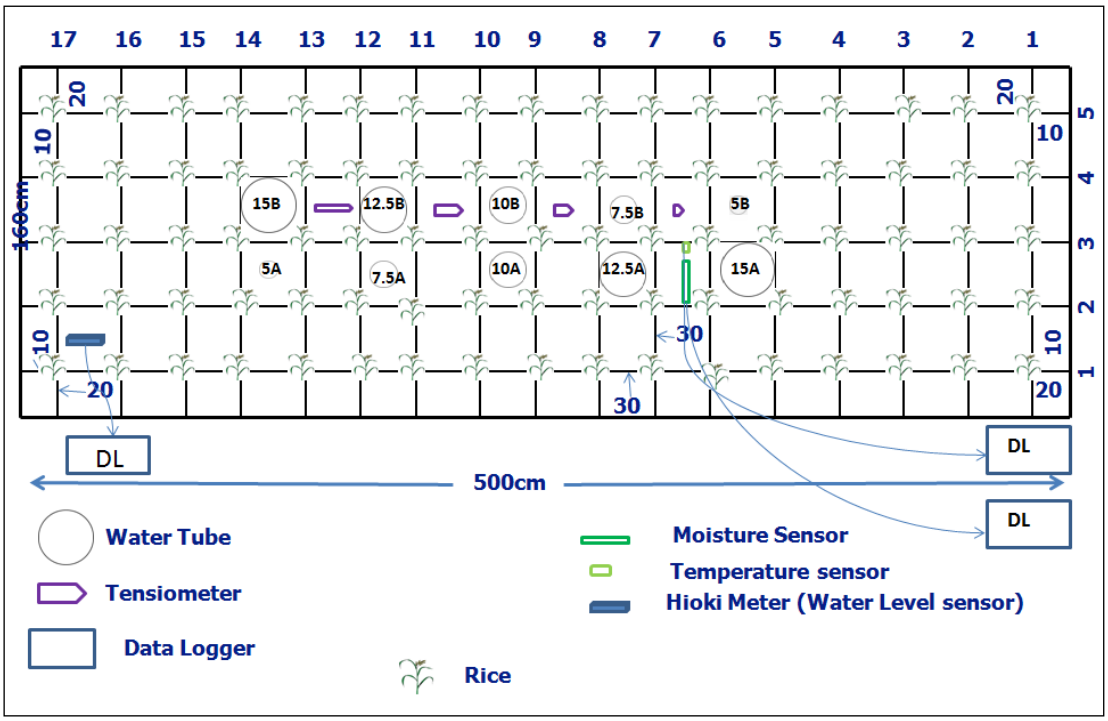


Fig.3 Detailed Area Plan of Lysimeter Scale Experiment

The Lysimeter of 500*160cm^2 or 8m^2 was divided in to 5 column and 17 rows (Fig.3). The distance between each column and row was 30cm (square shape).The distance from corner of Lysimeter to corner column and row were 20cm and 10 respectively. In the experiment, 5 different diameters Field Water Tube used as treatment and it replicated twice. 5 cm diameter was treated as 5A and 5B, 7.5cm treated as 7.5A and 7.5B, 10cm treated as 10A and 10B, 12.5cm treated as 12.5A and 12.5B, and 15cm treated as 15A and 15B. Tubes were installed between 3rd and 4th column in the following way 15A in between the 13th and 14th row, 12.5A in 12th and 11th row, 10A in 10th and 9th row, 7.5A

in 8th and 7th row, 5A in 6th and 5th row. Then again these field water Tube were replicated between 2nd and 3rd column in the following way-15B in between 6th and 5th row, 12.5B in 8th and 7th row, 10B in10th and 9th row, 7.5B in 12th and 11th row and 5B in 13th and 14th row. In longitudinal Line-A the distance between 15A and 12.5A was 46cm, 12.5.A to10A was 47cm, 10A to 7.5A was 51cm and 7.5A to 5A was 50cm.In the same way In longitudinal Line-B the distance between 15B and 12.5B was 46cm, 12.5.B to10B was 47cm, 10B to 7.5B was 51cm and 7.5B to 5B was 50cm.Onthe other hand the distance between opposite Line Tube was 21cm (between 15A and 5B),18.5cm (12.5 A and 7.5B), 19cm (10A and 10B), 20cm (7.5A and 12.5B) and 21cm (5A and 15B).

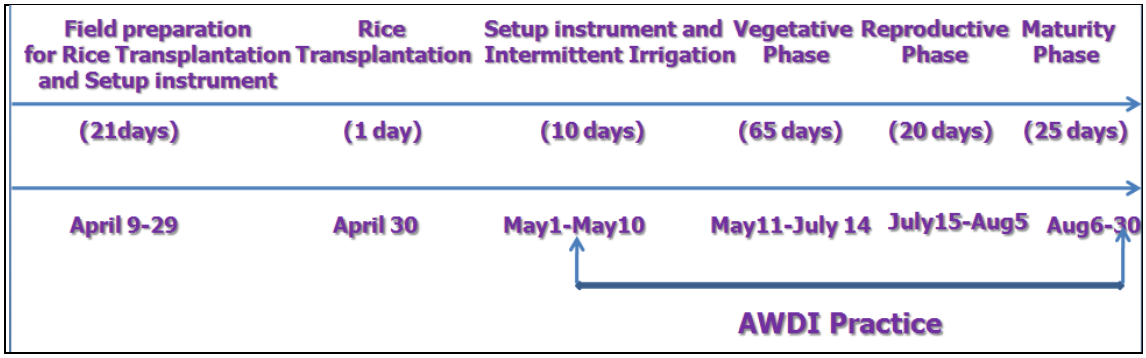
4 Moisture sensors and 4 Temperature sensors were installed at between column 2nd and 3rd as well as between row 7th and 6th. 4 Tensiometers were installed at between column 3rd and 4th in the following direction-20cm Tensiometer at 13th and 12th row, 15cm at 11th and 10th row, 10cm at 9th and 8th row, 5cm at 7th and 6th row. The distance between each Tensiometer was 60cm. 1 Hioki meter (water level sensor) was installed at between column 1st and 2nd 3rd as well as between row 16th and 17th in -20cm depth of soil surface. Hioki Meter was installed inside a Water Tube which inside's soil was taken away. At every joint of column and row 2 rice plants were planted or totally 170 rice plants were transplanted at 85points (17*5).

3.3.4. Schedule of Activities

In the experiment, total days were required 123 days from field preparation to rice reproductive phase (April 9 to August 10) (Table 3). The AWDI application was done in whole vegetative phase from May 1 to July 14 (DAT 1 to DAT 77) and after flowering stage at DAT 88 to DAT 102 and these days are the sources of all observed

data.

Table 3 Schedule of activities



3.3.5. Field Preparation, Setup Instrument and Transplanting

In the experiment, the level of the field was flat in the Lysimeter with very good provision of irrigation and under drainage facilities. The field was thoroughly ploughed and puddle with 4-5cm of standing water in the field. The soil was puddled up to 15cm below the soil surface and utmost tried to break the entire clog (Fig.4). The objective of that work was to make the experiment field in homogenous condition and to soften the soil and get a soft seedbed for the seedlings to establish themselves faster, to

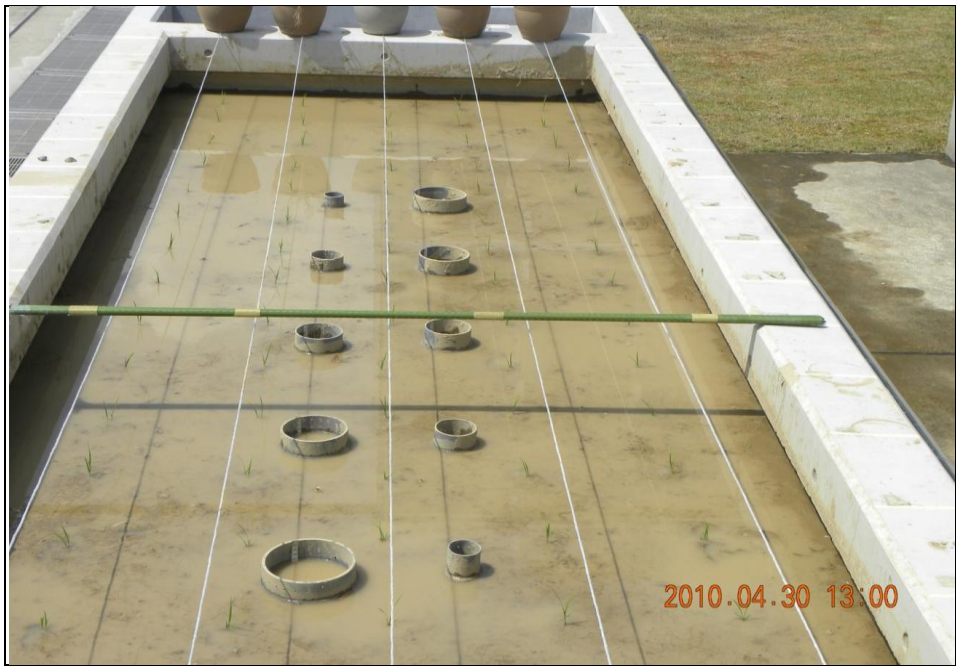


Fig.4 Field Preparation, Setup Instrument and Transplanting

reduce of weed growth and to minimize the leaching losses of nutrients with percolated water. Remaining rice roots (stubble) in the Lysimeter, weeds, were incorporated into the soil to obtain organic fertilizer from it. Puddling was done by hand shovels. The land was leveled after puddling to facilitate a uniform distribution of water to get right reading of apparatus used.

After completion of field preparation, installation of apparatus was started. The field space was marked with scale and several strings were hanged over it to specify the point of installation. Then all the apparatus was duly setup. After apparatus installation again leveled the field.

On 30th April, 14day-old, 2 phyllochorons, healthy and vigorous seedlings grown in the nursery under protective environment and with same level of management during middle to end of the April were transplanted doubly per hill. From setup apparatus to transplantation of rice were done from outside of the field for minimizing disturbance of soil in the Lysimeter.

3.3.6. Irrigation Management

This was one of the most important features of the experiment. When determining the irrigation schedule, major emphasis was laid on critical stages of water requirement in the given climatic situation. AWD irrigation was applied after 1 day of transplanting and continues up to whole experiment period (102 days). AWD Irrigation management was divided into two regimes

a. Irrigation for 10 days after Transplantation (1 Day Interval AWDI)
b. Irrigation for 11 days to 102 days after Transplantation (AWDI with Field Water Tube)

a) Irrigation for 10 days after Transplantation:

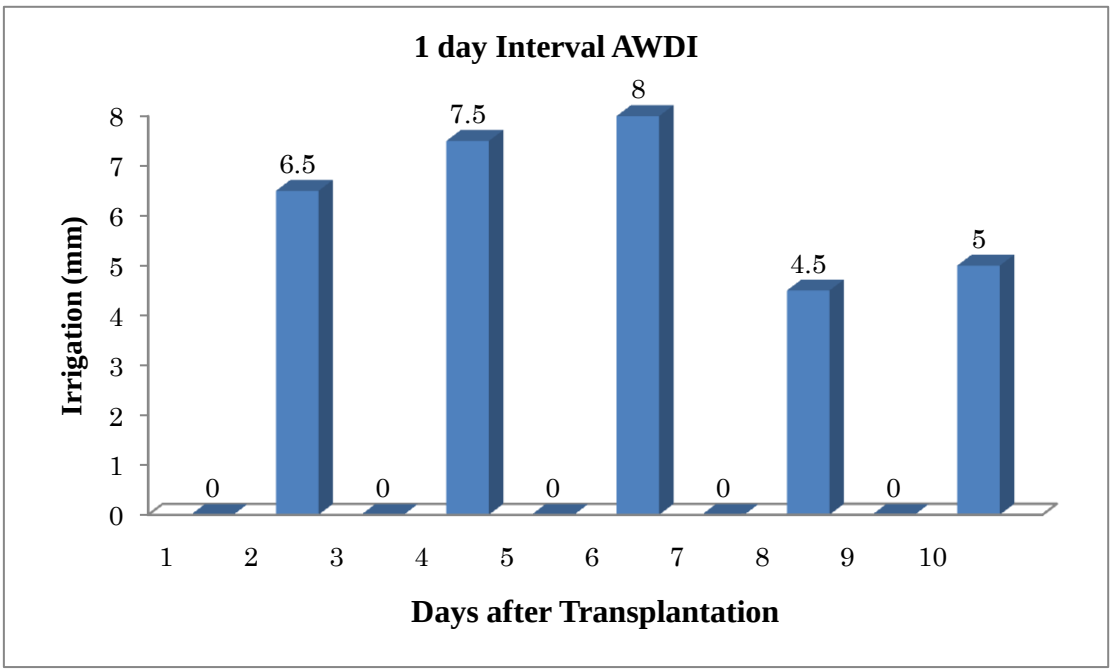


Fig.5 Irrigation for 10 days after Transplantation

AWD Irrigation was done in every alternative day in this regime (May1 to May 10). On 2nd May, irrigation was done in the field first time after rice transplantation. Then 2nd, 3rd, 4th and 5th Irrigation were done on 4th May, 6th May, 8th May and 10th May consequently and the amount of irrigation was 6.5mm, 7.5mm, 8mm, 4.5mm and 5mm respectively (Fig.5). Irrigation was done in the afternoon (5.30pm) in this schedule.

In these 10 days AWDI, Water Tube reading was also taken and special care was taken that the sufficient water (field capacity) remains in the soil for taking water easily from soil by the baby rice plant. To perform AWDI, SRI principle -a minimum of water was applied during the vegetative growth period

b) Irrigation for 11 days to 102 days after Transplantation:

From DAT 11, AWDI management started with Water Tube measurement and the methodology of irrigation was when water level would go to 15cm depth of 15-A Water Tube then re-irrigated the field up to DAT75 and again restarted at DAT 85(Fig.6).

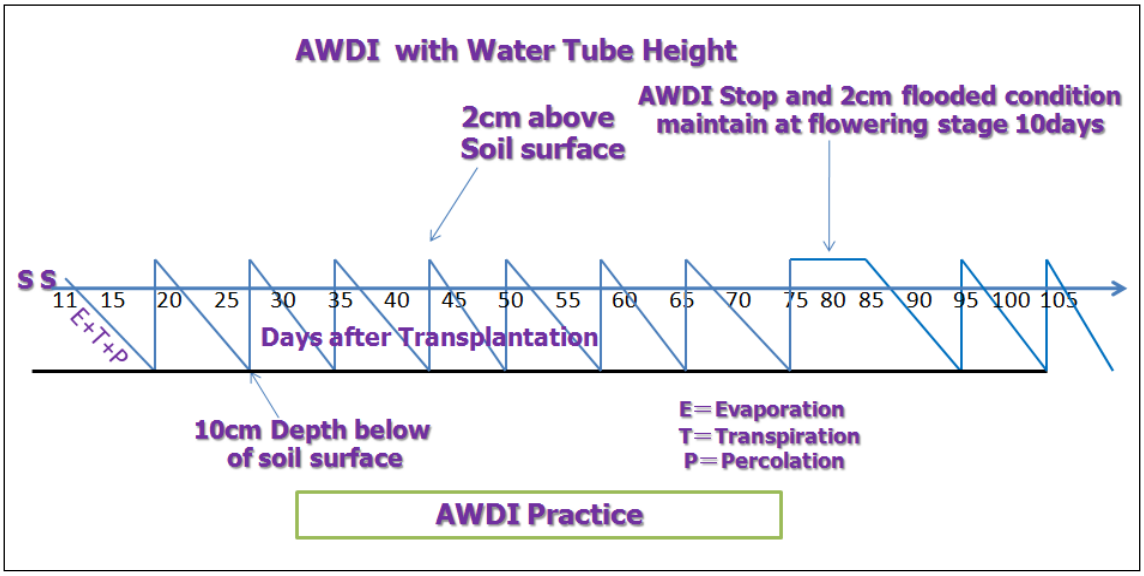


Fig6. Application of AWDI with Water Tube Measurement

But due to the climatic condition and to fulfill the main objective (Effectiveness of Field Water Tube) of the experiment the Fig.7 AWD irrigation was done. On DAT36, the maximum amount of water (60mm) was irrigated and continuous irrigation was done to flood the field from DAT76 to DAT86 for flowering (Fig.7). After flowering stage AWDI started on DAT88 and continue up to DAT102. The time of the irrigation was mainly in the afternoon and as per requirement of the irrigation it was done after 9.00am also.

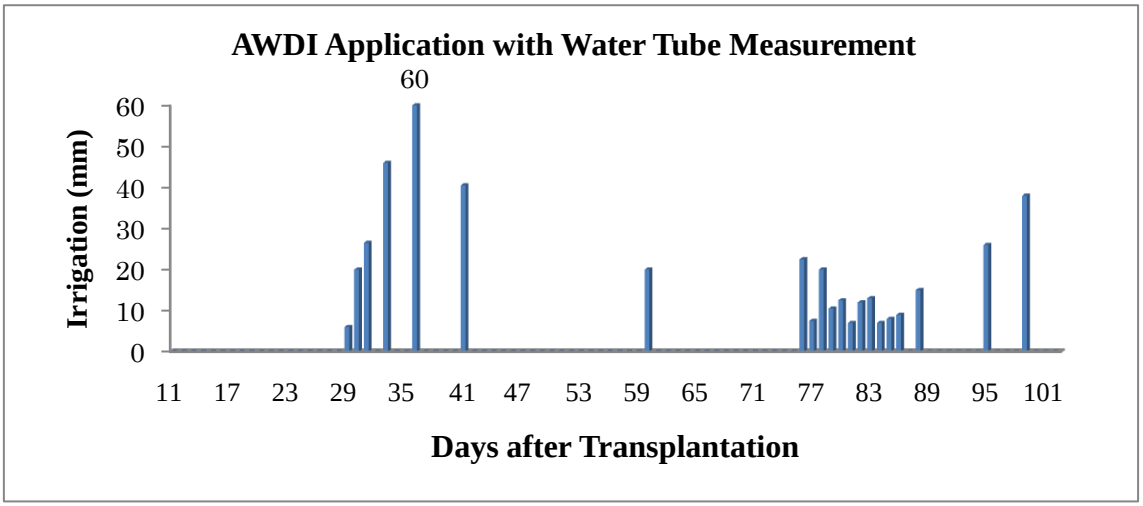


Fig.7 Irrigation for 11 to102 days after Transplantation

To find out the ponded water, ponded depth was measured in the certain point of the field with the help of a simple measuring scale (ruler) and a Field Water Tube which diameter was15cm. When the water was over the surface then ruler reading was taken and when water went to the under the soil surface then field Water Tube's water level reading was taken to know the water level. The ruler reading was compared with the field water tube's reading and both reading was adjusted also. Due to variation of sun shine hours, there was varied evapotranspiration rate and it put impact on the ponded depth.

The experimental site was equipped with a pipe irrigation system and flow rate was measured to find out the amount of water pour in the field.

3.3.7. Drainage

Under drain was open completely through the experiment period. Surface drainage was needed one time (DAT 69) and as done by siphoning process for midterm drainage before flowering stage.

3.3.8. Other Cultural Practices

As the main purpose of this study was to observe the effectiveness of Field Observation Water Tube. The work was measuring water level, ponded depth, irrigation, soil moisture, pressure, temperature etc. Due to clog and siltation, cleaning of Field Water Tube was done at 23 DAT. Plant height, leaf height, leaf number, leaf color, no of shoot was measured in every 7 days interval. Chemical fertilizer was applied in 2 steps (at 24 DAT and 61 DAT after transplanting) and rate of fertilizer application was N 8gm/m^2, P_2O5 8gm/m^2, K_2O 8gm/m^2 totally. Weeding was done in every 10 days interval by

hand. No herbicide and pesticide was applied in the experiment.

3.4. Parameter Observed

3.4.1. Apparatus Measurement

Field water Tube, Moisture sensor, Temperature sensor, Tensiometer was observed 12 hours intervals (9am and 9pm) and Plant growth observed 7 days interval throughout the experiment period.

3.4.1.1. Field Water Tube

The Water Tubes were installed vertically as its 5cm remain over the soil surface and 20cm remain under the soil.

3.4.1.1.1. Water Level

Each Field water Tube was attached with a ruler to measures the water Level in the field. The measurement of Water Tube was taken at 9am and 9pm and it was started at DAT1 and it continued up to DAT102.

The water level measurement was taken of the Tube where water level touched the ruler line horizontally. To take right measurement observed the Tube from various directions like over the Tube, right side of the Tube, and left side of the Tube. To avoid reflection in the sun light, measurement was taken under shadow of object. To observe Water Level at 9.00pm Torch was used to get the measurement.

3.4.1.1.2. Siltation

Observed the siltation affected Water Tube, No of Siltation occurrence, in which level of siltation in different Water Tube, The DAT of Siltation in the Water Tube were recorded duly.

3.4.1.2. Moisture Sensor Measurement and its Calibration

The Decagon ECH_2O sensor is an instrument that was used to easily measure soil

moisture in an accurate way but it did not measure soil moisture directly. In the experiment, 4 moisture sensors (5cm, 10cm, 15cm and 20cm depth) were used to measure soil moisture in 5cm, 10cm, 15cm and 20cm depth. The measurement unit of Moisture sensor is Millivolt which is dielectric constant of soil. Therefore, before installation of Moisture sensor calibration of soil sensor was required.

Calibration was needed for moisture sensor which measures Engine Coolant Temperature (ECT-measuring unit Millivolt) or the dielectric constant of the soil, which is a strong function of water content or volumetric water content of the soil.

For calibration of moisture sensor, several soil samples were taken and measured volumetric water content (weight of moisture/weight of moist soil) of that soil samples through oven drying method and calibrated that findings with moisture sensor reading.

Two moisture sensors were calibrated (Fig.8) and The Equations of calibration were,

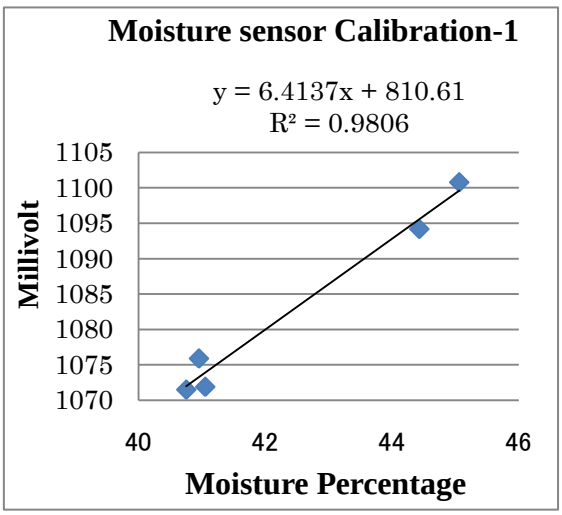


Fig.8a Moisture Sensor Calibration-1

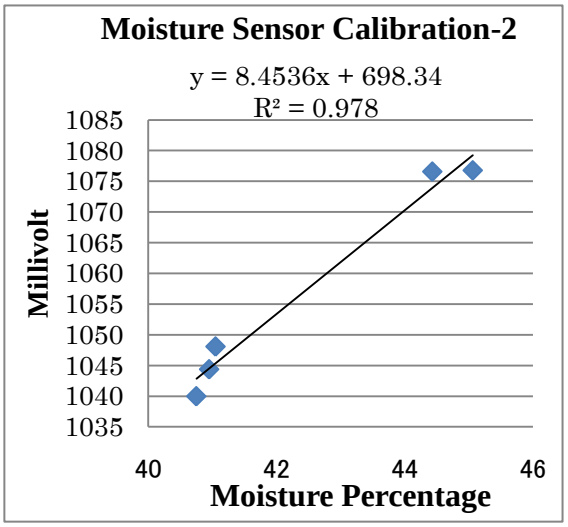


Fig.8b Moisture Sensor Calibration-2

Fig.8 Moisture Sensor Calibration

a) Y=6.4137x+810.61 and r^2=0.9806

b) Y=8.4536x+698.34 and r^2=0.978

[Where, Y=Moisture Sensor Reading in Millivolt, x = Moisture in volume]

To convert the Moistures Sensors Millivolt data in moisture percentage, calibration result of a) Y=6.4137x+810.61 had been used due to its r^2 value (0.9806) is closer to 1.

The data logger stored the soil sensors data of moisture sensor in Millivolt and it displayed the data through computer. Special software ECH_2O Utility was used to represent the data. Then Millivolt data was converted to moisture in volume (moisture weight/wet soil weight). The moisture sensor data was taken of moisture level of 9.00am and 9.00pm and the data was taken from DAT1 to DAT102.

3.4.1.3. Temperature Sensor

Temperature sensor measured the soil temperature and the unit was in Celsius scale. The data was collected through Data logger by using ECH_2O Utility software. In the experiment 4 Decagon Temperature sensors were used at 5cm, 10cm, 15cm and 20cm depth to measure the temperature at the aforesaid depth.

3.4.1.4. Tensiometer

A Pf meter measures the water retention and soil moisture tension of soil. It shows how easy it is to pull water from the soil. Through Tensiometer it is judged how much pressure is required of a plant to draw up water with their roots and how long water can be absorbed after the soil is moisturized.

In the experiment, 4 Hioki Pf meters (Tensiometer) were used which measured the soil tension of 5cm, 10cm, 15cm and 20cm depth. Its measuring unit was KPa ranges from 0KPa to -80KPa with three distinctive areas like 0-5KPa (Yellow color mark-saturation), 6KPa-20KPa (Green color mark-field capacity) and 21-KPa-80KPa (red color mark-wilting).

3.4.1.5. Hioki Meter

Hioki meter is an instrument to measure water level in the field. Hioki Meter measures

water level indirectly. It measures the Relative Humidity up to 80% and shows the pressure of water. When ponded depth or water level is high then it shows relative humidity is high by expressing in pressure and when water level is less then it shows relative humidity is less again by expressing in pressure. Hioki Meter measurement unit is 0.1KiloPascal.When data of pressure is recorded in Hioki Meter then the pressure data of water is converted to height of water level.

3.4.2. Soil Physical Condition- Crack

Soil Crack was observed like how many days after soil crack formed, when it was

Fig.9.a. Soil Crack on DAT6

Fig.9.b. Soil Crack on DAT18

Fig.9.c. Soil Crack on DAT25

Fig.9.d. Soil Crack on DAT31

	
Fig.9.e. Soil Crack on DAT38	Fig.9.f. Soil Crack on DAT44
	
Fig.9.g. Soil Crack on DAT52	Fig.9.h. Soil Crack on DAT59
	
Fig.9.i. Soil Crack on DAT66	Fig.9.j. Soil Crack on DAT92

	
Fig.9.k. Soil Crack on DAT95	Fig.9.l. Soil Crack on DAT102

Fig9. Soil Crack Formation in the Experiment Field

vanished and when it would reappear, width of the crack, the impact of soil crack on the plant etc (Fig.9).

3.4.3. Crop Measurements

Plant height-Plant height was measured at an interval of 7 days beginning on the DAT10 of transplantation and continued up to DAT101. 13 Plants were selected randomly out of 85 and then measured the plant height of each. Plant height was taken from the base to the top of the longest leaf of main tiller referred as plant height.

Leaf Height-Longest leaf height was measured and it was taken from the base of the leaf to the top of the leaf.

Number of leaves and Tillers-Number of leaves and tillers were counted from randomly selected sample at 7 days interval starting from DAT10 and continued to DAT101.

Effects on weed population, insect and pests, and disease occurrence-Weed populations, their species, and time required for weeding were taken into consideration. 10 days interval, species of weed grown in the field was identified. The height of the weed was also measured. Similarly, types, intensity and extent of damage by insect pests and diseases were also observed during the investigation.

3.4.4. Water measurement

Total amount of irrigation water and total amount of rain water applied in the experiment was measured and it was identified which percentage of irrigation can be fulfilled by rain water to performing AWDI irrigation with Field Water Tube.

3.5. Data Analysis

Field Observation data were recorded every day and the data were compiled by Microsoft Excel software. To record the moisture sensor and Temperature sensor Data ECH_20 Utility software had been used. MS-Excel software was also used for simple correlation, ascending/descending, average, mean, graphical presentation etc.

4. Results and Discussion

The application of AWDI in SRI Rice field with Water Tube treatment effects derived during the course of investigation are presented hereunder with the help of table and depicted with suitable figures, graphs wherever necessary. Hand in hand, an attempt is being made to evaluate the results so obtained and to offer explanation with available evidences wherever possible for the observed variations in the mentioned traits with an aim to establish the cause and effect relationship as far possible.

4.1. Comparison of Apparatus Measurement

The apparatus used in the experiment are compared to find the relationship of their measurements. Comparison is done between water Tube and Water Tube, Water Tube and Moisture Sensor, Water Tube and Tensiometer, Water Tube and Temperature Sensor, Moisture sensor and Tensiometer, moisture sensor and temperature sensor.

4.1.1. Water Tube and Water Tube

The differences of Water Tubes water level, siltation occurrence are compared in this section as well as tried to find relationship among the Water Tubes. Comparison is done among all Water Tube, between two same diameter Water Tube, two different diameters Water Tube, same longitudinal line Water Tubes and different longitudinal line Water Tubes.

4.1.1.1. All Water Tube

4.1.1.1.1. Ponded Depth and Lowest Point of Water Depth

Measurement of the water depth is the prime objective of this experiment. It is found that different water levels are shown by the all water Tube (Fig.10). It is observed that out of total 204 observations in 102 days experiment, in 117 observations water level is on soil surface level or over the soil surface and in 87 observations the water is under

the soil surface. The maximum ponded depth is 5.4cm above the soil surface and minimum depth is varied. It is notified that water depth of all Water Tube is similar with some small difference when water remains around soil surface (Fig.10).

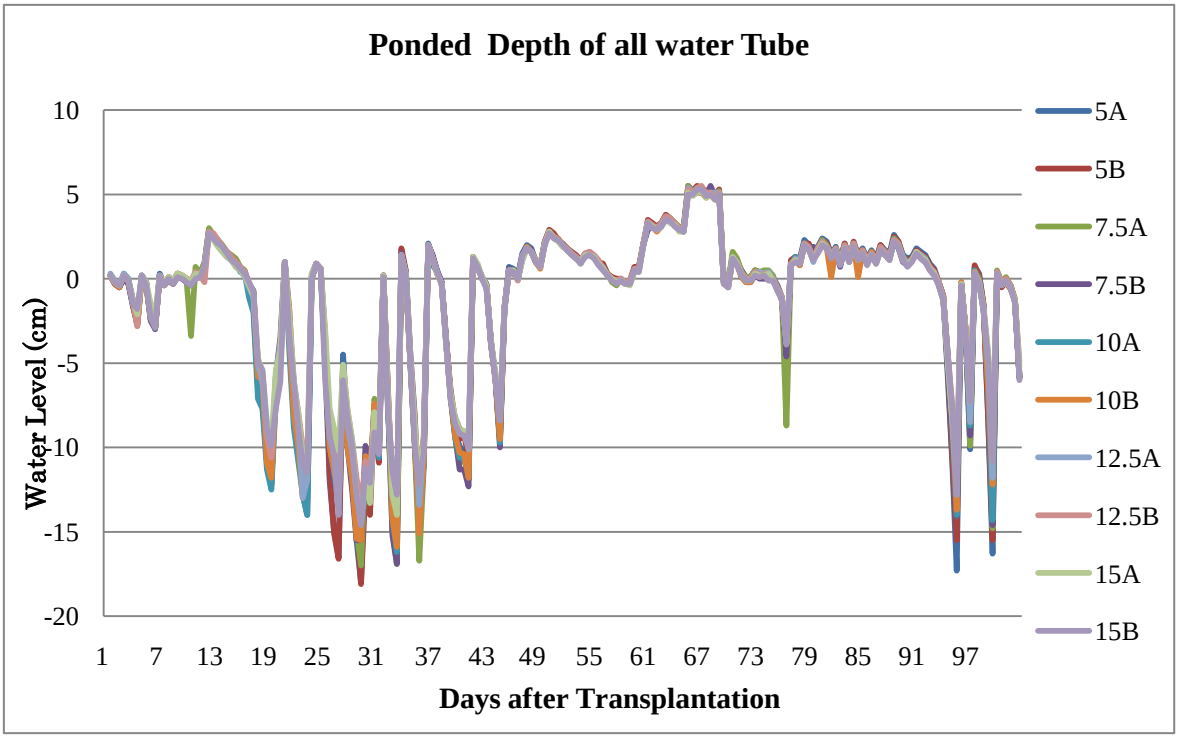


Fig.10 Ponded depth of all Water Tube in the experiment Period

But when water goes to the under the soil surface specially when water level goes to 10cm below the soil surface then water level difference among the water tube varies greatly (Fig.10).

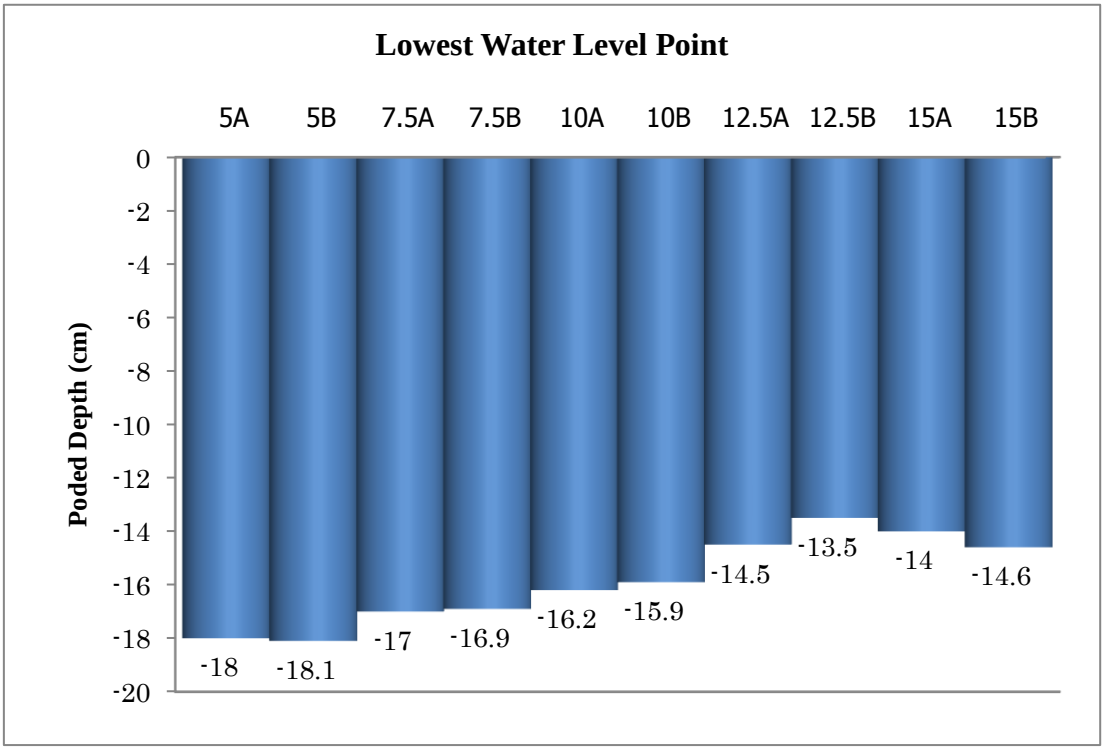


Fig.11 Lowest Water Level Point of all Water Tube

It is invented that among the 5 different diameter water tubes, the narrower diameter Water Tube shows lower ponded depth than the wider diameter Water Tube. It is scrutinized that the lowest or extreme ponded depth is shown by 5B and that is -18.1cm below the surface level and minimum lowest ponded depth is -13.5cm in 12.5B (Fig.11). The difference between two points is 4.6cm and it is very significant for AWD irrigation management in rice field. It implies that if a farmer use 5cm diameter Tube and another farmer use 12.5cm water tube then their management of AWD irrigation will be different due to using different diameter water tube and these Water Tubes can be shown around 4cm difference water level in the drying condition of AWDI specially when water level goes beyond 10cm depth under the soil surface. The average of lowest water depth point in 5 different diameters water tubes is -15.87cm and the difference from the average lowest point to maximum lowest point is -2.23cm in 5B and minimum lowest

point is 2.37cm in 12.5B which is also very important findings in applying water tube in Alternating wetting and Drying irrigation management regime. It is indicated that if a farmer use 5cm water tube and another farmer use 7.5cm or 10cm Water Tube then the average lowest water depth can be varied 2-3cm and if a farmer use 12.5cm or 15cm diameter Tube then the variation of average lowest water depth 2-3cm also in respect with 7.5cm or 10cm water tube.

It is also detected that the maximum mean lowest ponded depth (mean of maximum7 lowest ponded depth in 204 observations of each Water Tube) is shown by 5A and 5B Water Tube and that is -15.43cm and the minimum lowest ponded depth is 12.24cm in 12.5B (Fig.12).

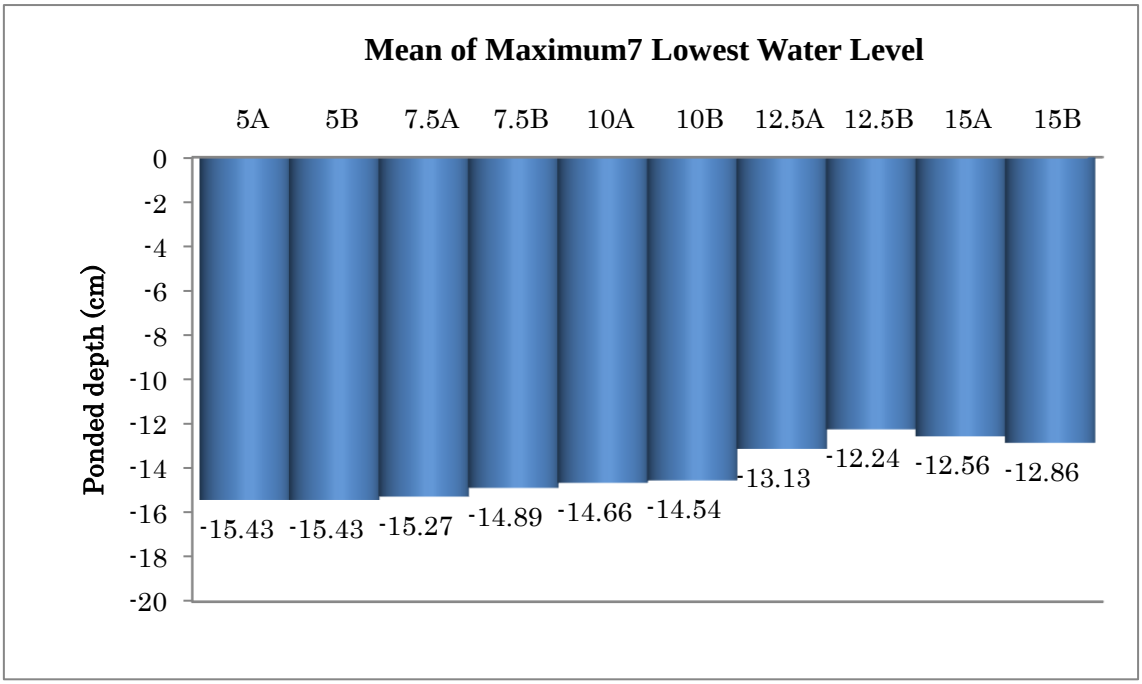


Fig.12 Mean of Maximum 7 lowest ponded depth in 150 observations of each Water Tube

The variation of these two points is 3.19cm which can put very significant impact on using water tube in AWDI management in Rice cultivation. From this finding it can be stated that averagely the water level difference can be 3.19cm when water level goes to

below 10cm of soil surface and if we use 12.5cm diameter water tube and 5cm diameter water tube. The average of mean lowest water level is -14.10cm and the difference from lowest point (-15.43cm) is -1.33cm and highest point is 1.86cm (Fig.12) which implies that when water level goes 10cm below soil surface then if a farmer use 11cm diameter Water Tube then ponded Water depth will be different -1.33cm in case of using 5cm diameter Water Tube by another farmer and 1.86cm in case of using 15cm diameter Water Tube.

Crossing the threshold of -5cm, 10cm and -15cm depth have been investigated. It is identified that maximum 26 observations, -5cm depth is crossed by15A Tube (Table 4). -10cm depth is crossed maximum 20 observations by 7.5B and 10A Tube.-15cm threshold is crossed maximum 7 observation crosses by Tube 5A.

Table 4 Number of observations to cross a certain depth by all Water Tube

Thre-shold	**5A**	**5B**	**7.5A**	**7.5B**	**10A**	**10B**	**12.5A**	**12.5B**	**15A**	**15B**
-5cm	18	18	22	17	19	18	25	24	26	24
-10cm	10	10	16	20	20	18	15	13	13	16
-15cm	7	6	4	4	2	4	0	0	0	0

4.1.1.1.2. Water Level Decreasing Trend

It is noticed that AWD irrigation after a long days, decreasing trend is very high. It is observed that when water remains in the surface area, then decreasing rate is slower. When water level cross the surface to the under the soil surface then water level decreasing rate is higher and when water goes to 5cm below to the soil surface there decreasing trend is very high. Water Level decreasing rate is Maximum in small diameter Water Tube than larger diameter Tube's Water Level decreasing rate (Fig.13).

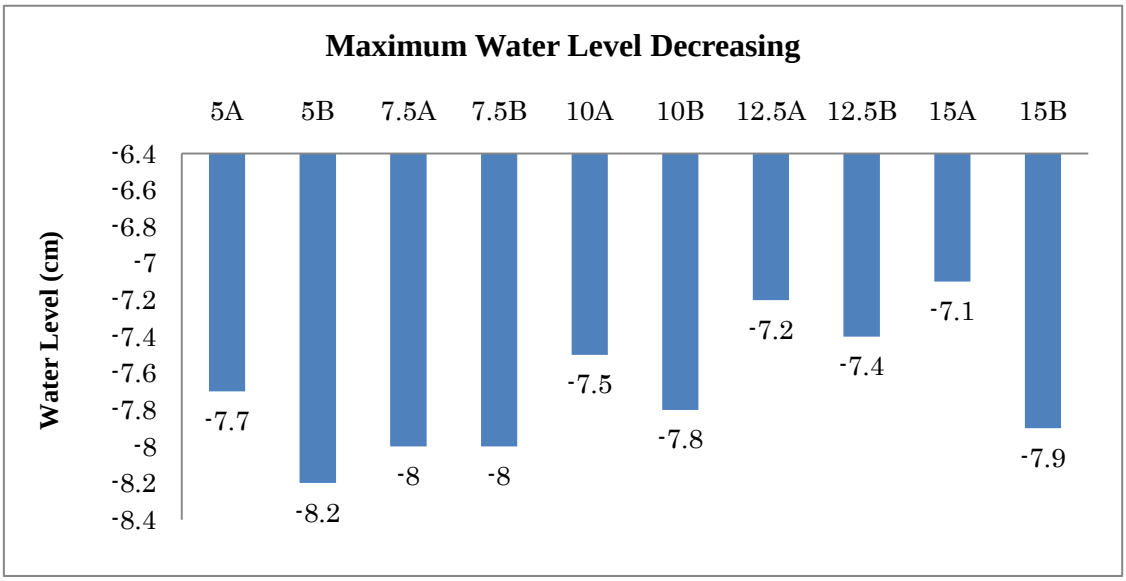


Fig.13 Maximum Water Level decreasing in 204 observations of each Water Tube

Highest water level reduction is happened in 5B Tube and that is -8.2cm and lowest reduction in 15A and that is 7.1cm. The difference between the two points is 1.1cm. There is another finding is that all the maximum reduction of water level have not come in one day. It has come in 3different days DAT 25 for 5B, DAT 31 for 5A, 10A, 12.5A, 12.5B, 15A, 15B and in DAT32 for 7.5A, 7.5B and 10B. On DAT 25 the highest and lowest decreasing was -8.2cm (5B) and -3.6cm (15A) and the difference was 4.6cm. The highest and lowest decreasing was -7.7cm (5A) and -7.1cm (15B) and the difference was 0.6cm On DAT 31. On DAT 32 the highest and lowest decreasing was -8.cm (7A and 7B) and -4.6cm (12.5B) and the difference was 3.4.cm.

It is also found that the average of Maximum water level reduction (data of 20 highest water level reduction of each Tube) is higher in small diameter water tube than larger diameter Water Tube (Fig14).

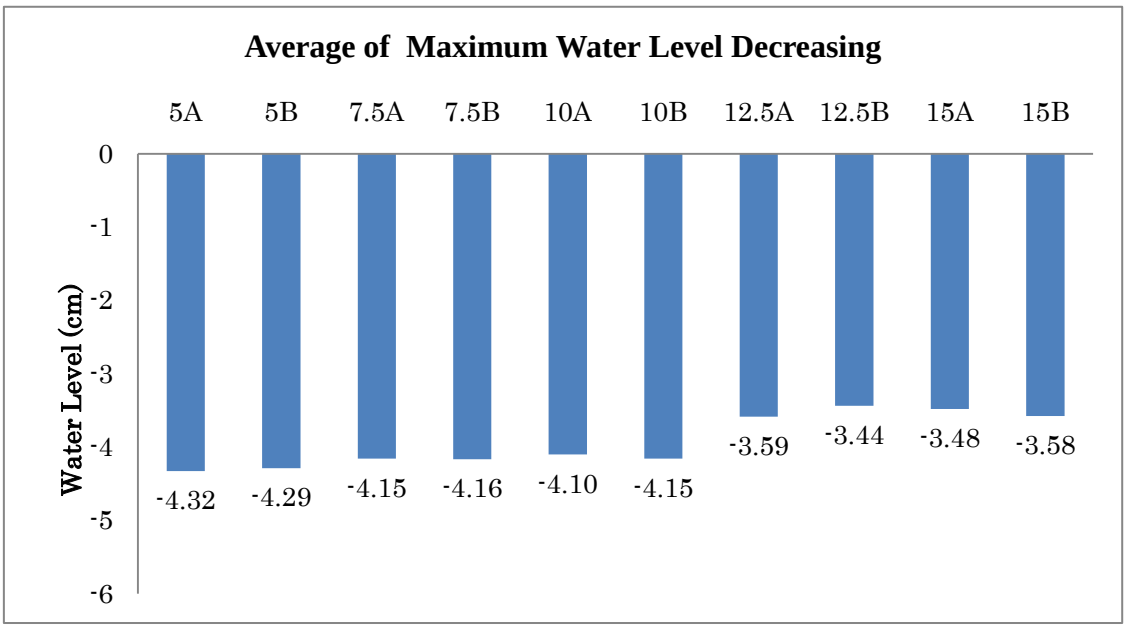


Fig.14 Average of 20 maximum Water Level decreasing incident of all Water Tube

It is found that the highest of average maximum water level reduction is -4.33cm in 5A and the less is -3.44cm in 12.5B and the difference is 0.89cm (Fig.14).

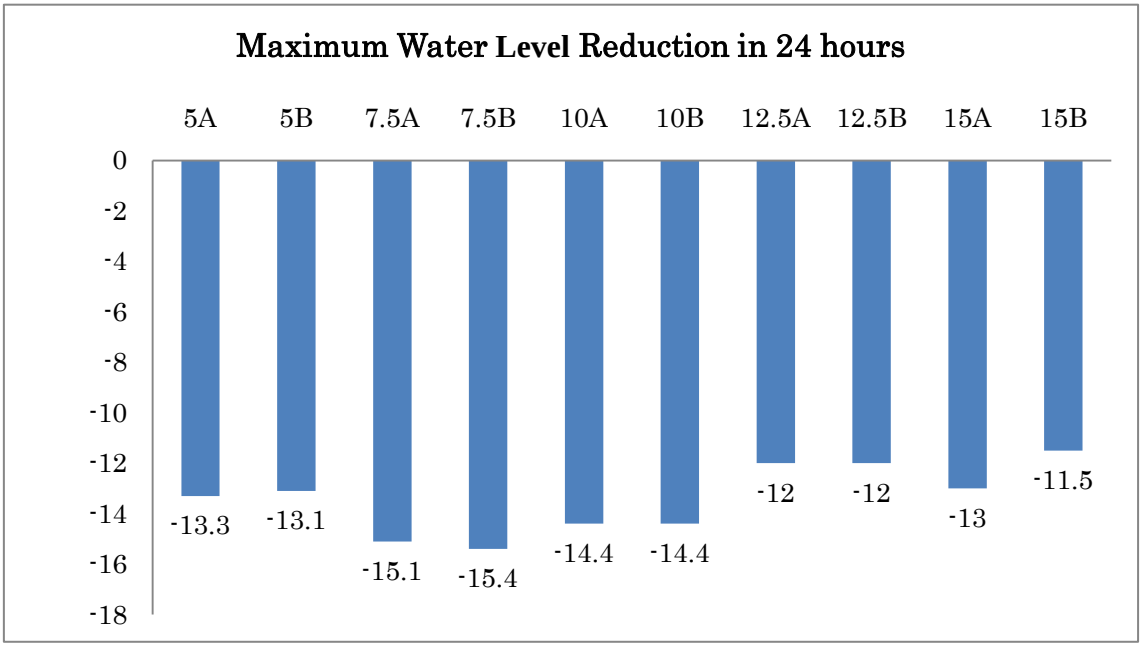


Fig.15 Maximum Water Level Reduction in 24 hours by all water Tube

It is observed that the highest maximum water level reduction in 24 hours is happened in 7.5B Water Tube (-15.4cm) and less maximum water level reduction in 15B Tube

(-11.5cm) (Fig.15).

4.1.1.1.3. Siltation

Siltation shows less performance ability of application Water Tube technology in the field. It is observed that comparatively narrower (6 Tubes -5A, 5B, 7.5A, 7.5B, 10A, 10B) tubes are troubled with siltation (Fig.16).

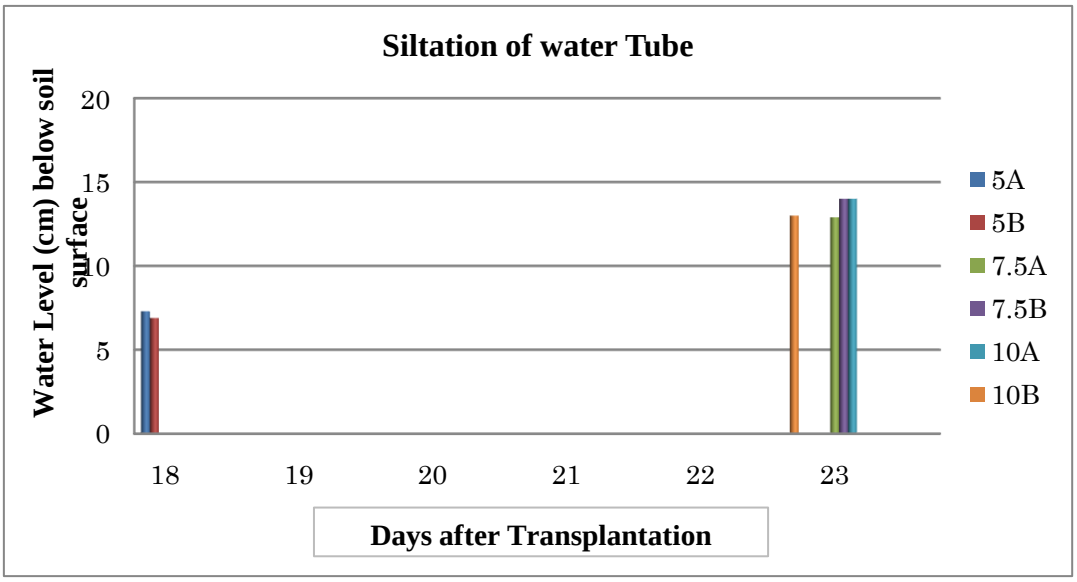


Fig.16 Siltation Incident and its affected Water Tube

First, Siltation has been identified on DAT 18 in 5cm- diameter Water Tubes. It is observed that the siltation height is -7.3cm and -6.9cm under the soil surface of 5cm-A and 5cm-B Tube respectively. On DAT 23, siltation is observed in 10B Tube and on DAT 24, siltation observed in 7.5A, 7.5B, 10A Tube. The siltation height was under the soil surface -14cm, -12.9cm, -13cm and -13cm respectively.

Being muddy/puddling condition at the initial stage of rice transplantation, soil is passed in Water Tube with water through the hole and after being settled down of sediment in the Water Tube, siltation is occurred. Due to plenty space at the inside of the larger diameter Water Tube, the sediment amount is not sufficient to cover Tube- bed to form huge siltation, therefore siltation incident have not been observed in the larger water

Tube. Moreover, it is experienced at the time of installation that to clean and remove the soil inside the Tube is not possible for 5cm diameter water Tube due to heavy muddy condition of the soil and as well as narrower diameter of the Tube.

4.1.1.1.4. Observation Difficulties

Hassle of taking water level measurement is very much related with the performance of the Water Tube. It is identified that to get water depth measurement reading from 5cm diameter Tube is very hard when water level goes -10cm depth of the soil.7.5cm water Tube has same problem when water level goes -15cm below the soil surface. 10cm diameter Tube shows few difficulties after water level goes -15cm depth. 12.5cm diameter Water Tube and 15cm diameter Water Tube shows no difficulty at the time of observation around -15cm depth.

It is observed that after DAT54 algae was formed in all Water Tube and it was difficult to take the water level measurement. It is identified that application of fertilizer and prolong ponded depth over the soil surface make darker in the inside of Water Tube specially the narrower diameter (5A and 5B) Water Tube was severely affected**.**

4.1.1.2. Same Diameter Water Tube

Here, is discussed about same diameter Water Tube on difference and relationship between 5A and 5B, 7.5A and 7.5B, 10A and 10B, 12.5A and 12.5B and 15A and 15B. Comparison is based on level of ponded water depth, and their difference, as well as finds relationship between them through their water level measurement.

4.1.1.2.1. 5cm Diameter Water Tubes

It is observed that Ponded depth of 5A and 5B Tube has gone hand in hand with some fluctuations (Fig.17). It is also observed that ponded depth difference between 5A and 5B Water Tube has happened when water level goes -5cm below the soil surface

(Fig.17). Due to siltation incidence on DAT 18, taking measurement has been postponed for 5A and 5B up to DAT23 to complete one cycle of irrigation. After clearing the sediment from inside the Tube on DAT23, Tubes are installed and there is no data of ponded water level from DAT 18 to DAT23.

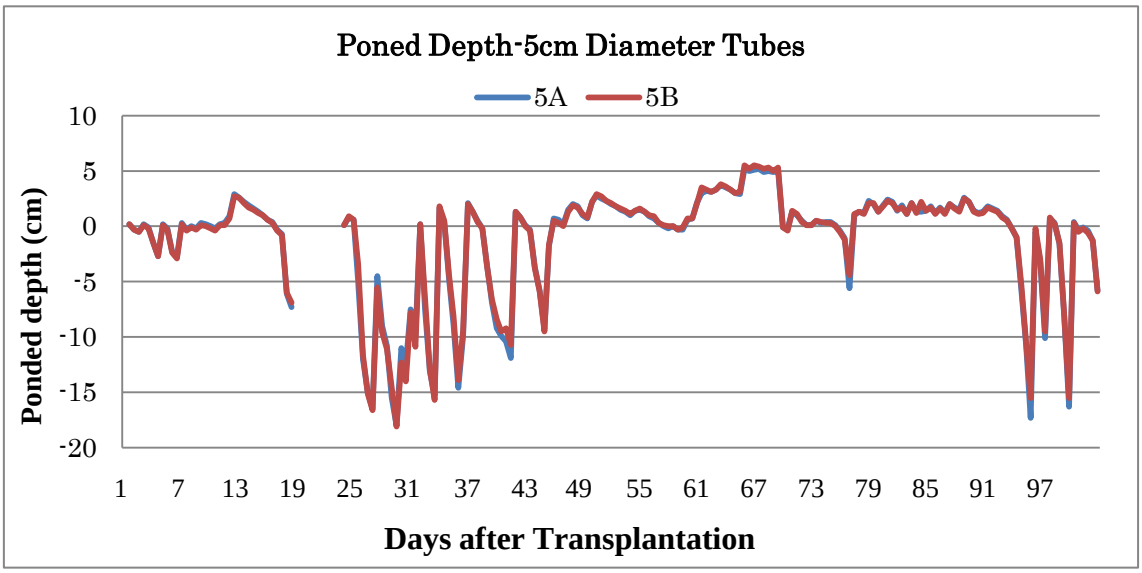


Fig.17 Ponded Depth of 5cm Diameter Tubes

It is perceived that in ponded depth difference, sometimes 5A water Tube shows lower level of water than 5B and vice versa 5B (Fig.18) and that is occurred for decreasing rate of water level is varied both of the Tubes.

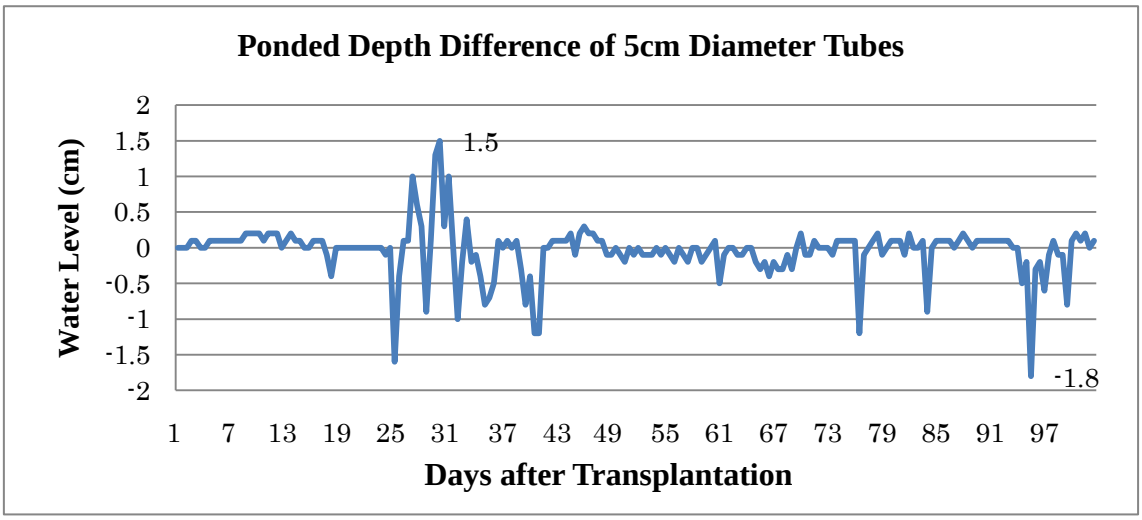


Fig.18 Ponded Depth Differences of 5cm Diameter Tubes

The maximum ponded depth difference of 5cm Tubes is found 1.8cm on DAT95 and then the water depth is -17.3cm in 5A and -15.5cm in 5B. It is investigated that most of the time the variation of water depth of 5A and 5B Tube is between 0-5mm (Fig.18).

The relationship between 5A and 5B water level measurement is found very strong and that was 0.9946(Fig.19)

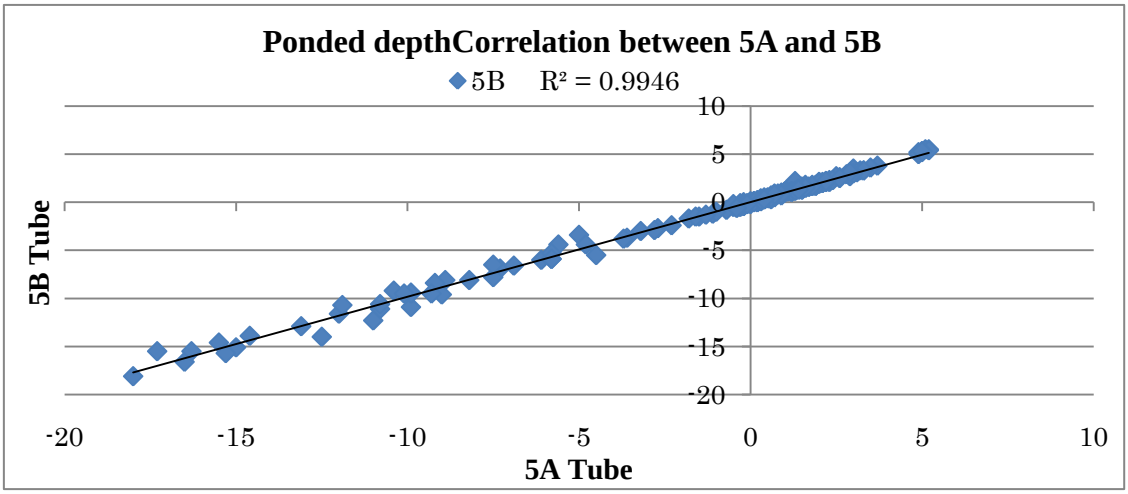


Fig.19 Correlation of 5cm Diameter Tubes

4.1.1.2.2. 7.5cm Diameter Water Tubes

In the case of 7.5cm diameter Water Tube, it is identified that Ponded depth of7.5A and 7.5B Tube has gone simultaneously with some variations (Fig.20). It is also observed that most of the time ponded depth has altered between 7.5A and 7.5B Water Tube when water level goes -7cm below the soil surface (Fig.20)

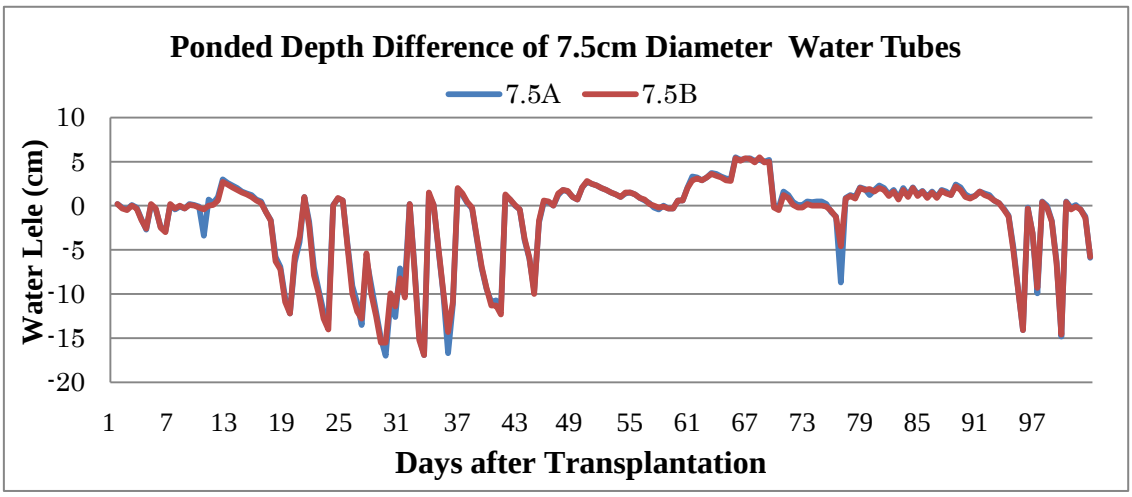


Fig.20 Ponded Depth of 7.5cm Diameter tubes

It is observed that the lowest water level is found at 7.5A and 7.5B on different days (Fig.20). On DAT29 the lowest water level is found at 7.5A Water Tube and that is17cm below the soil surface and the lowest water level was found at 7.5B Water Tube on DAT33 and that was -16.9cm below the soil surface. The difference of lowest water level is 0.1cm only.

In the case of ponded depth difference of 7.5cm diameter Water Tubes, sometimes 7.5A shows lesser water depth than 7.5B and vice versa (Fig.21).It is identified that

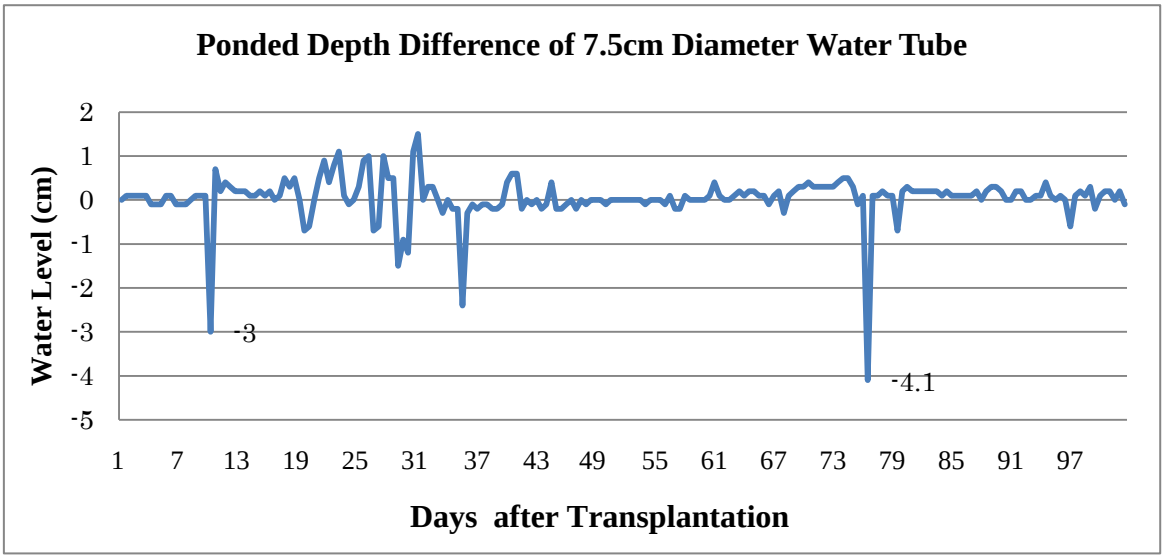


Fig.21 Ponded Depth Difference of 7.5cm Diameter Tubes

Maximum variation of water depth is 4.1cm and it is followed by 3cm. It is notified that 4.1cm difference is occurred on DAT76 and the water level is -8.7cm and -4.6cm in 7.5A and 7.5B respectively. On DAT10, the ponded depth difference is 3.0cm and the water level is -3.4cm and -0.4cm below the soil surface in 7.5A and 7.5B Water Tube respectively.

The relationship between 7.5A and 7.5B water level measurement has shown very strong relationship and that was 0.9891(Fig.22)

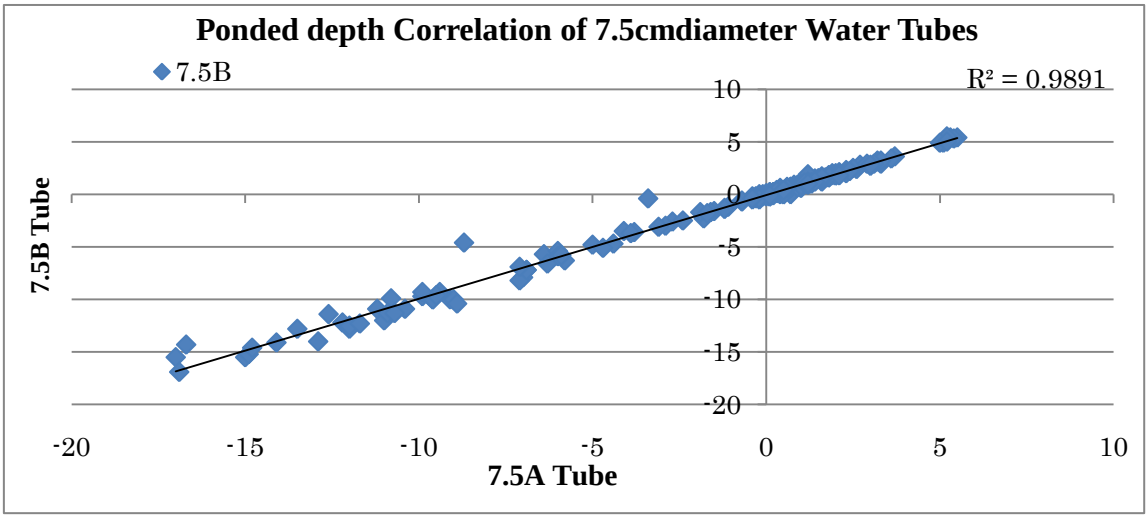


Fig.22 Correlation of Ponded Depth of 7.5cm Diameter Tubes

4.1.1.2.3. 10cm Diameter Water Tubes

It is identified that Ponded depth of 10A and 10B Tube has proceeded coinciding with little change (Fig.23). It is also observed that most of the time ponded depth difference between 10A and 10B Water Tube has happened when water level goes -5cm below the soil surface (Fig.23) Due to siltation incidence of 10B Water Tube on DAT 22 (9pm), taking measurement has been postponed on DAT23 (9am) to observe one irrigation cycle.

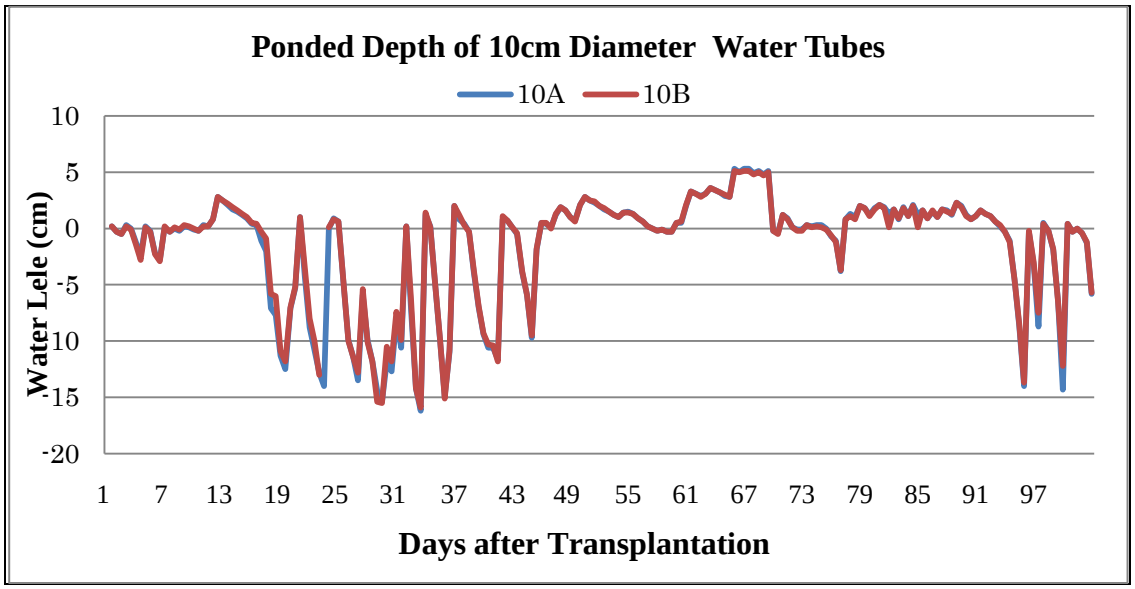


Fig.23 Ponded Depth of 10cm Diameter Tubes

Lowest ponded depth is observed in both Water Tubes on DAT 33. On that day the lowest ponded depth is -16.2cm in 10A Tube and -15.9cm in 10B Tube below the soil surface. Therefore the difference of lowest ponded depth is found 0.3cm.

It is identified that maximum ponded depth difference of 10A and 10B is 2.1cm at when the Tubes ponded depth is -14.3cm and – 12.2cm respectively on DAT99 (Fig.24).

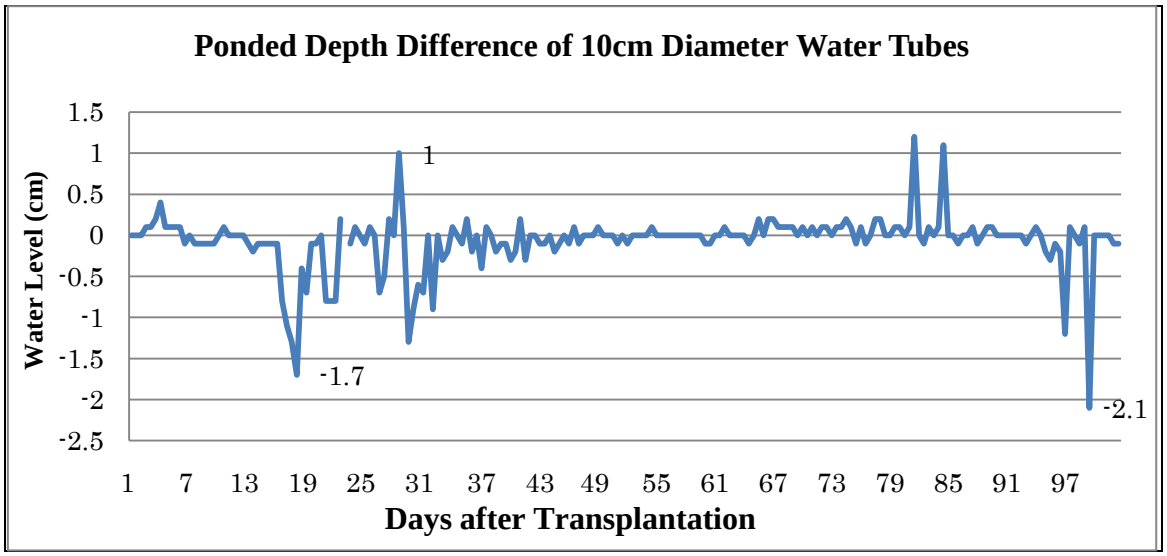


Fig.24 Ponded Depth Difference of 10cm Diameter Tubes

The second highest ponded depth difference is1.7cm at when the Tubes ponded depth is

-7.3cm and – 6.9cm respectively on DAT18.

The relationship of ponded depth of 10cm diameter Water Tube has been found very strong and that is 0.9955 (Fig.25).

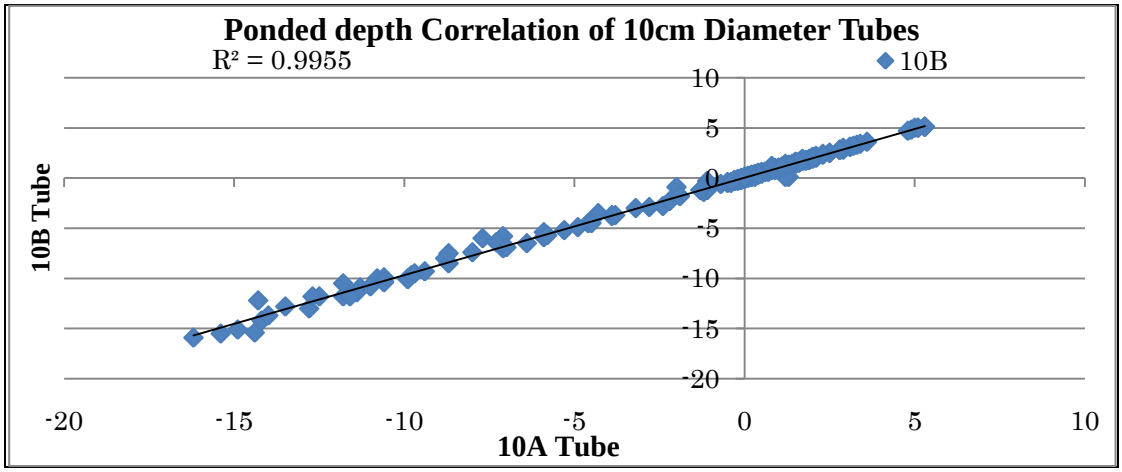


Fig.25 Correlation of Ponded Depth of 10cm Diameter Tubes

4.1.1.2.4. 12.5cm Diameter Water Tubes

In the case of 12.5cm diameter Water Tubes comparison, it is identified that Ponded depth of12.5A and 12.5B Tube has run simultaneously with some variations (Fig.26). It is also observed that lowest point is varied when the water depth crosses -5cm below the soil surface (Fig.26).The lowest point of water depth is-14.5cm (on DAT29) in 12.5A Tube and -13.5cm (on DAT29) is in 12.5B Tube (Fig.26).

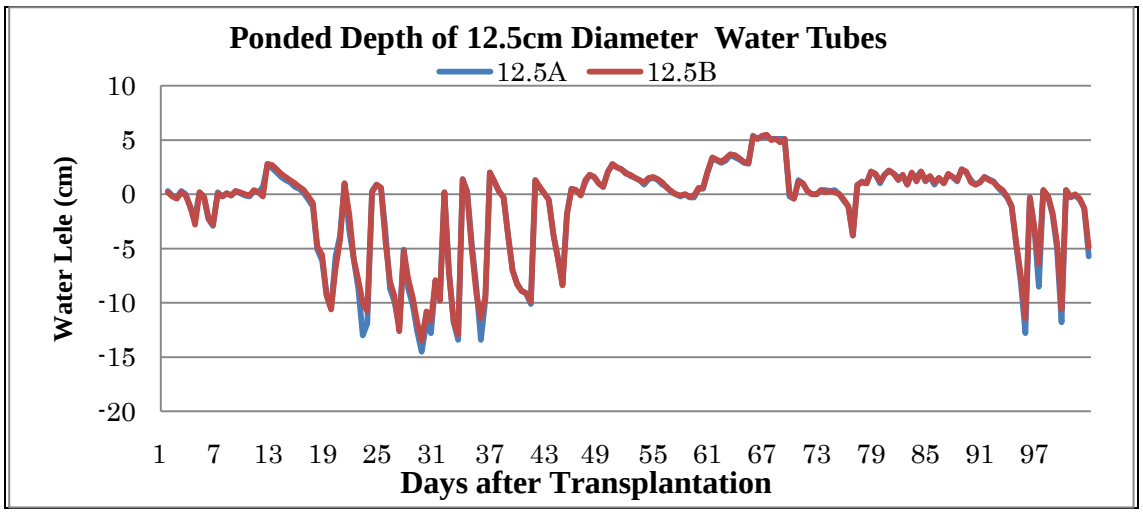


Fig.26 Ponded Depth of 12.5cm Diameter Tubes

It is scrutinized that maximum difference of water depth in 12.5cm water Tube is -3cm (Fig.27) and the water depth of 12.5A and 12.5 is -13cm and -10cm respectively (DAT22). The second highest difference of water depth 2.1cm is found on DAT97 at that time ponded depth is -8.5cm in 12.5A and-6.4cm in 12.5B (Fig.27).

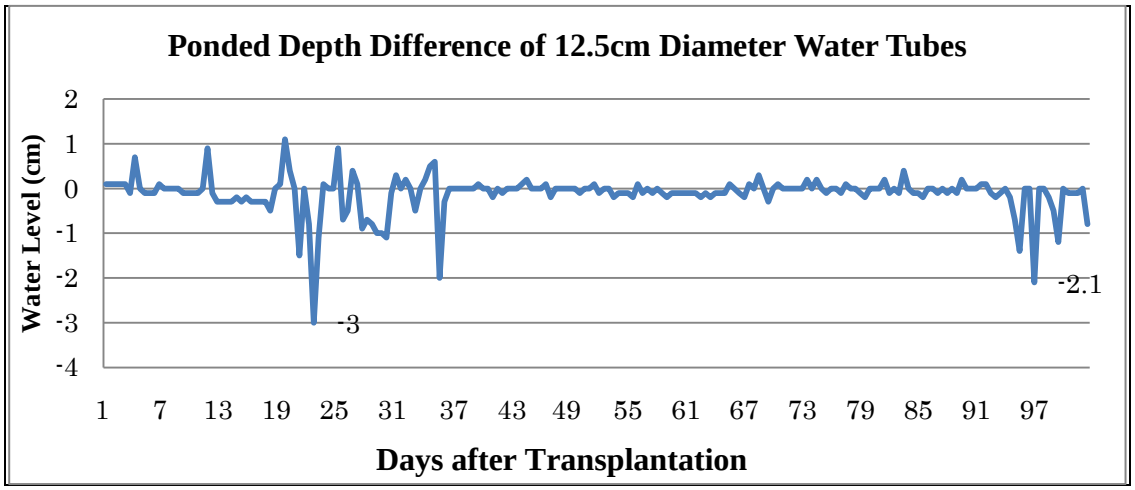


Fig.27 Ponded Depth Difference of 12.5cm Diameter Tubes

The relationship of ponded depth of 10cm diameter Water Tube has been found strong and that is 0.9923(Fig.28).

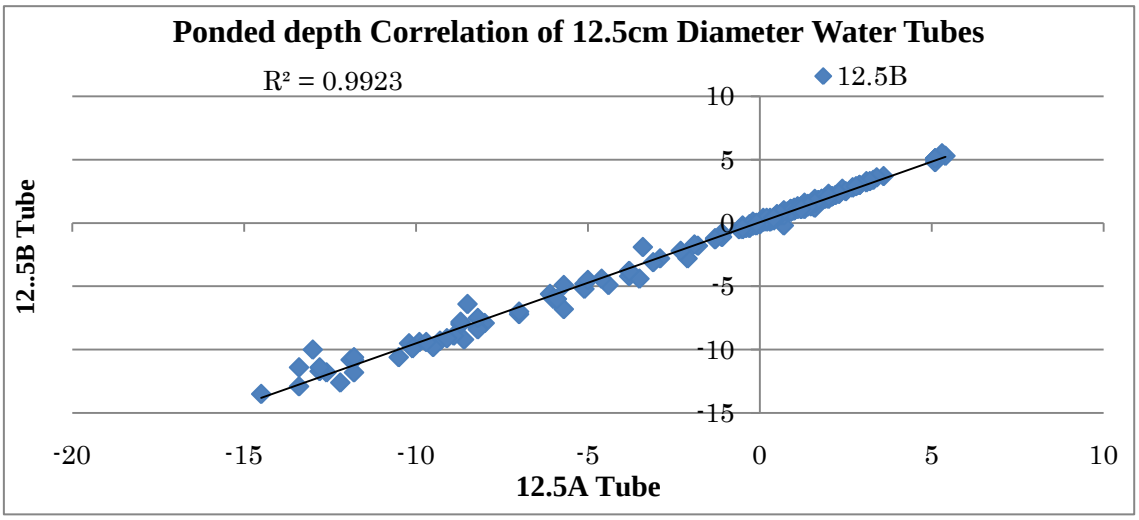


Fig.28 Correlation of Ponded Depth of 12.5cm Diameter Tubes

4.1.1.2.5. 15cm Diameter Water Tubes

It is identified that Ponded depth of 15A and 15B Tube has proceeded coinciding with some variations (Fig.29). The lowest point of 15A and 15B is observed in DAT 29 and the water depth is -14.6cm and 14.0cm and the difference of lowest depth point is 0.6cm. It is detected that 15A Tube has crossed the -10cm depth threshold in total 12 observations and 15B Tube has crossed the same threshold in 12 observations.

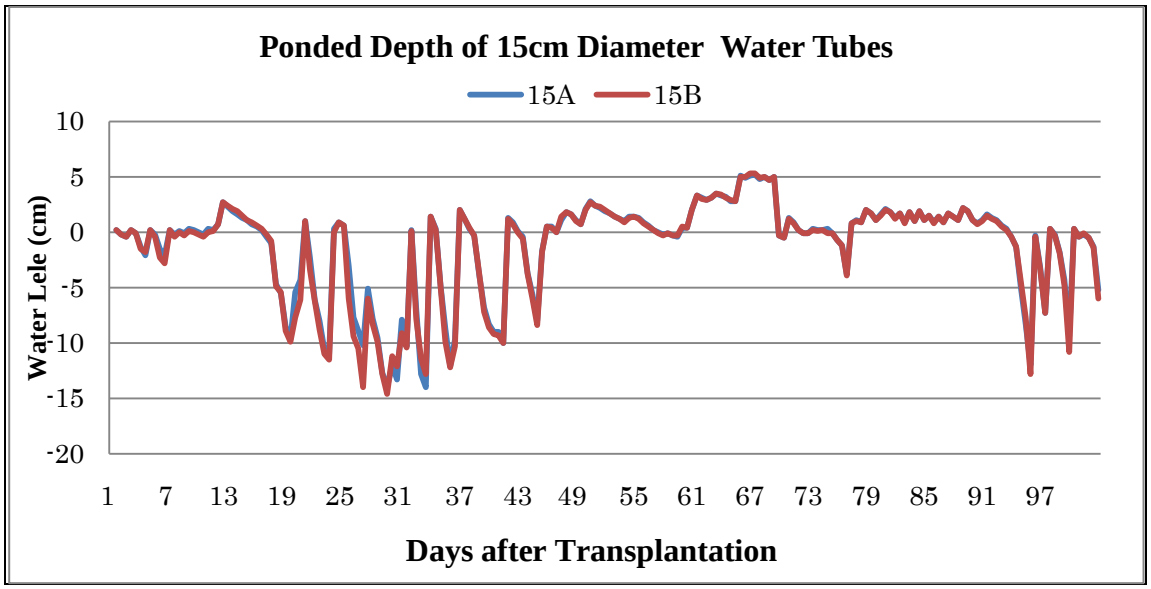


Fig.29 Ponded Depth of 15cm Diameter Tubes

It is identified that maximum ponded depth difference of 15A and 15B is 3.8cm at when the Tubes ponded depth is -10.2cm and - 14cm respectively on DAT27 (Fig.30). The second highest ponded depth difference is 3cm and is happened on DAT25 at when the water level of 15A and 15B indicates -3cm and -6cm respectively. Therefore, from this result it shows that 15B exhibits lower reading than 15A.

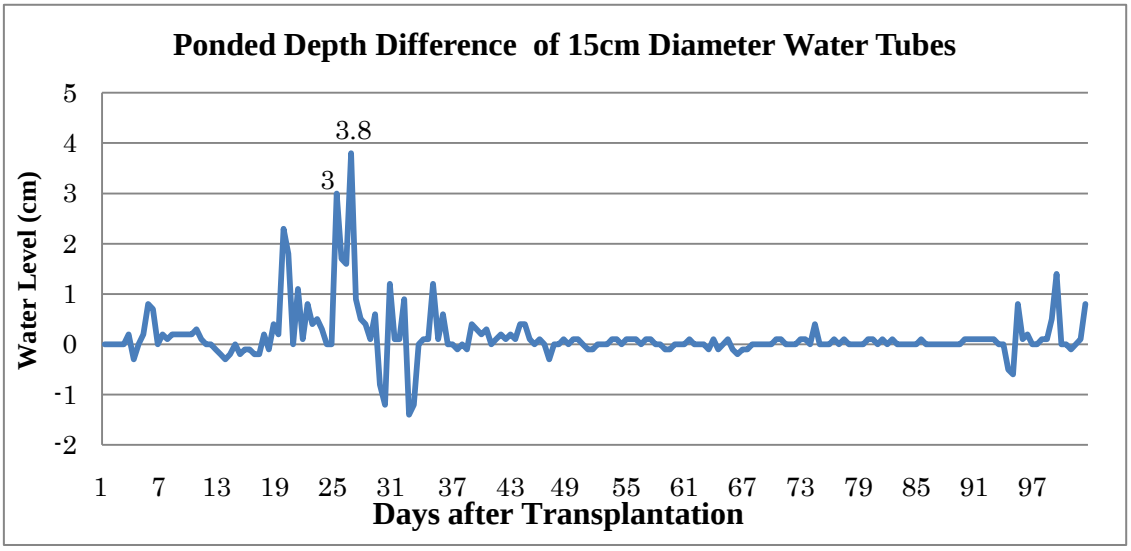


Fig.30 Ponded Depth Difference of 15cm Diameter Tubes

The relationship of ponded depth of 15cm diameter Water Tube has been found less strong (r^2=0.9876) than others (Fig.31).

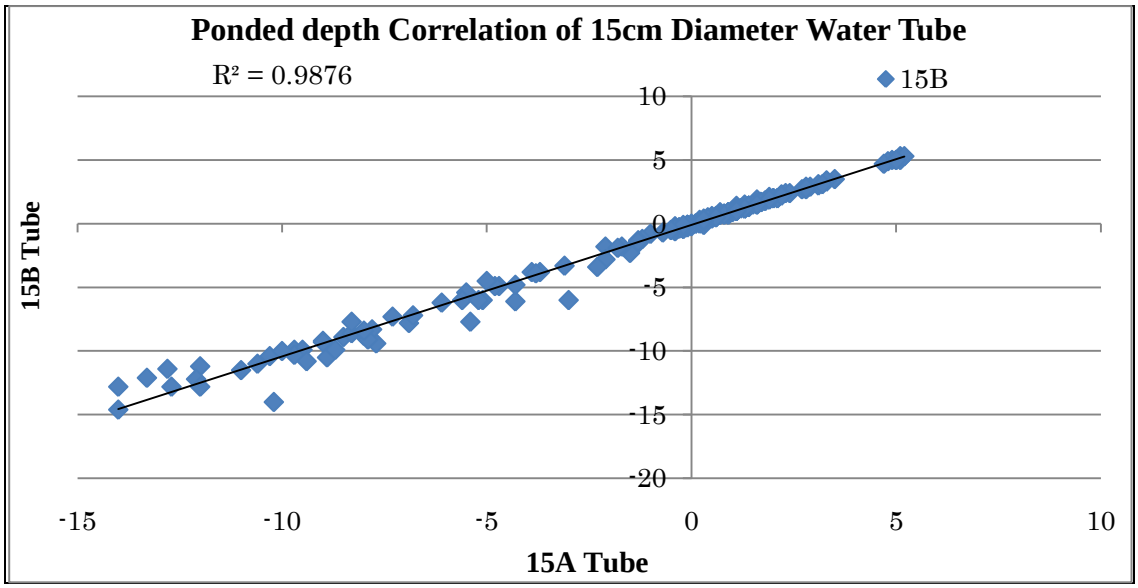


Fig.31 Correlation of Ponded Depth of 15cm Diameter Tubes

4.1.1.3. Different Diameter Water Tube

Here, the comparison has been done among same longitudinal line different diameter water tubes in respect of distance, maximum depth difference, depth at maximum difference, observations of crossing the threshold of -5cm -10cm and -15cm depth.

Correlation coefficient also discussed in this section to find relationship between two Tubes.

Here, same longitudinal line water tube like i) 5A, 7.5A, 10A, 12.5A, 15A, and ii) 5B, 7.5B,10B, 12.5B, 15B iii) Opposite Longitudinal Line-Line A with Line B have been compared and tried to find relationship between two Water Tubes. Comparison have been done 5A with 7.5B, 10B, 12.5B, 15B and 7.5A with 5B, 10B, 12.5B and 15B etc.

4.1.1.3.1. Longitudinal Line-A

In the longitudinal Line-A, 12.5A and 15A is placed in minimum distance (46cm) and 5A and 15A is placed in maximum distance (224cm) (Table5).

It is demonstrated that most of maximum depth difference has happened under -10cm below the soil surface. It is also observed that maximum depth difference is occurred between small and large diameter combination and minimum is between small-small and large-large diameter combination. It is identified that maximum ponded depth difference is 6.9cm in Longitudinal Line-A and it is between 5A and 15A and at the time of maximum difference; the ponded depth is -16.3cm in 5A and -9.4cm in 15A. In this Table it is shown that maximum depth difference is less in between 12.5A and 15A which is 2.4cm and at this difference is happened in two observations at -13.0cm and -11.8cm depth of 12.5A and -10.6cm and -9.4cm depth of 15A.

It is detected that maximum relationship remains between 10A and 12.5A & 12.5A and 15A (r^2 value is 0.993) and minimum relationship remains between 5A and 15A (r^2 value is 0.965).

Table 5 Comparison in Longitudinal Line –A

Comparison		**Distance (cm) of Tubes**	**Max Depth Diff. (cm)**	**Depth at Max diff. (cm)**		**R^2**
i	**ii**			**i**	**ii**	
5A	7.5A	50.0	4	-15.0	-11.0	0.979
7.5A	10A	51.0	-4.9	-8.7	-3.8	0.986
10A	12.5A	47.0	2.8	-8.8 -16.2	-6.0 -13.4	0.993
12.5A	15A	46.0	2.4	-13.0 -11.8	-10.6 -9.4	0.993
5A	10A	108.5	3.6	-15.0	11.4	0.984
5A	12.5A	165.5	5.1	-15.0	-9.9	0.981
5A	15A	224.0	6.9	-16.3	-9.4	0.965
7.5A	12.5A	108.0	4.9	-8.7	-3.8	0.984
7.5A	15A	166.5	5.4	-14.8	-9.4	0.979
10A	15A	105.5	4.9	-14.3	-9.4	0.986

4.1.1.3.2. Longitudinal Line-B

In the longitudinal Line-B, 12.5B and 15B is also placed in minimum distance (46cm) and 5B and 15B placed in maximum distance (224cm) (Table 6).

It is also identified that maximum depth difference is occurred between small and large diameter combination and minimum is between small-small and large-large diameter combination. It is found that maximum ponded depth difference is 5.7cm in Longitudinal Line-B and it is between 5B and 12.5B (Table 6). At the time of maximum difference, the ponded depth is -15.1cm in 5B and -9.4cm in 12.5B.

Table 6 Comparison in Longitudinal Line- B

Comparison		**Distance (cm) In Lysi.**	**Max Depth Diff. (cm)**	**Depth at Max diff. (cm)**		**R^2**
i	ii			i	ii	
5B	7.5B	50.0	3.8	-16.6	-12.8	0.981
7.5B	10B	51.0	2.4	-14.6	-12.2	0.994
10B	12.5B	47.0	3.7	-15.1	-11.4	0.987
12.5B	15B	46.0	1.9	-4.2	-6.1	0.995
5B	10B	108.5	3.8	-16.6	-12.8	0.981
5B	12.5B	165.5	5.7	-15.1	-9.4	0.977
5B	15B	224.0	4.7	-15.5	-10.8	0.979
7.5B	12.5B	108.0	4.0	-16.9 -14.6	-12.9 10.6	0.984
7.5B	15B	166.5	4.1	-16.9	-12.8	0.979
10B	15B	105.5	3.1	-15.9	-12.8	0.985

In this Table it is shown that maximum depth difference is less in between 7.5B and 10B which is 1.9cm and this difference is happened in -4.2cm depth of 12.5B and -6.1cm depth of 15B.

It is detected that maximum relationship remains between 12.5B and 15B (r^2 value is 0.995) and minimum relationship remains between 5B and 12.5B (r^2 value is 0.977).

4.1.1.3.3. Opposite Longitudinal Line

In the comparison of opposite longitudinal Line-A with Line-B, 5A and 7.5B & 5B and 7.5A are positioned in maximum distance (168cm) and 7.5A and 12.5B & 7.5B and12.5A

are placed in minimum distance (20cm) Table7.

Table7 Comparison in Opposite Longitudinal Line

Comparison		**Distance (cm) In Lysi.**	**Max Depth Diff. (cm)**	**Depth at Max diff. (cm)**		**R^2**
i	ii			i	ii	
5A	7.5B	168	3.7	-16.5	-12.8	0.984
5A	10B	107.5	4.1	-16.3	-12.2	0.981
5A	12.5B	50.5	5.9	-17.3	-11.4	0.973
5A	15B	21.0	5.5	-16.3	-10.8	0.976
5B	7.5A	168	4.1	-15.1	-11.0	0.976
7.5A	10B	51.0	5	-8.7	-3.7	0.986
7.5A	12.5B	20.0	5.3	-16.7	-11.4	0.980
7.5A	15B	50.0	4.8	-8.7	-3.9	0.974
5B	10A	107.5	3.7	-15.1	-11.4	0.985
7.5B	10A	51.0	2	-2.3	-4.3	0.994
10A	12.5B	50.5	3.7	-14.3	-10.6	0.989
10A	15B	107.0	3.5	-14.3	-10.8	0.986
5B	12.5A	50.5	5.2	-15.1	-9.9	0.985
7.5B	12.5A	20.0	3.5	-16.9	-13.4	0.988
10B	12.5A	50.5	2.8	-15.4	-12.6	0.990
12.5A	15B	167.5	2.5	-3.5	-6	0.991

5B	15A	21.0	6.4	-16.6	-10.2	0.972
7.5B	15A	50.0	-5.2	-14.6	-9.4	0.983
10B	15A	107.0	-3	-15.1	-12.1	0.986
12.5B	15A	167.5	-2.4	-12.6	-10.2	0.992

It is identified that maximum depth difference is occurred between small and large diameter combination and minimum is between small-small and large-large diameter combination. It is found that maximum ponded depth difference is 6.4cm and it is between 5B and 15A (Table 7) and at the time of maximum difference, the ponded depth is -16.6cm in 5B and -10.2cm in 15A. In this Table it is shown that maximum depth difference is less in between 7.5B and 10A which is 2.0cm and this difference is happened in -2.3cm depth of 7.5B and -4.3cm depth of 10A.

It is detected that maximum relationship remains between 7.5B and 15A (r^2 value is 0.994) and minimum relationship remains between 5B and 15A (r^2 value is 0.972).

4.1.2. Water Tube and Moisture Sensor

It is investigated that Moisture percentage measured by moisture sensor has increased throughout the experiment period with day night fluctuation (Fig31). It has identified from the moisture sensor measurement that moisture increases in, 10cm and 15cm depth throughout the experiment period except 5cm and 20cm depth moisture sensor which shows decreasing trend (Fig32). The increase of moisture percentage from starting to DAT 75 of experiment is 14.54%, 13.93%, 15.08%, in 5cm, 10cm 15cm depth respectively and decreases -6.28% in 20cm depth. After DAT75, 5cm depth moisture sensor shows to moisture decreasing the soil.

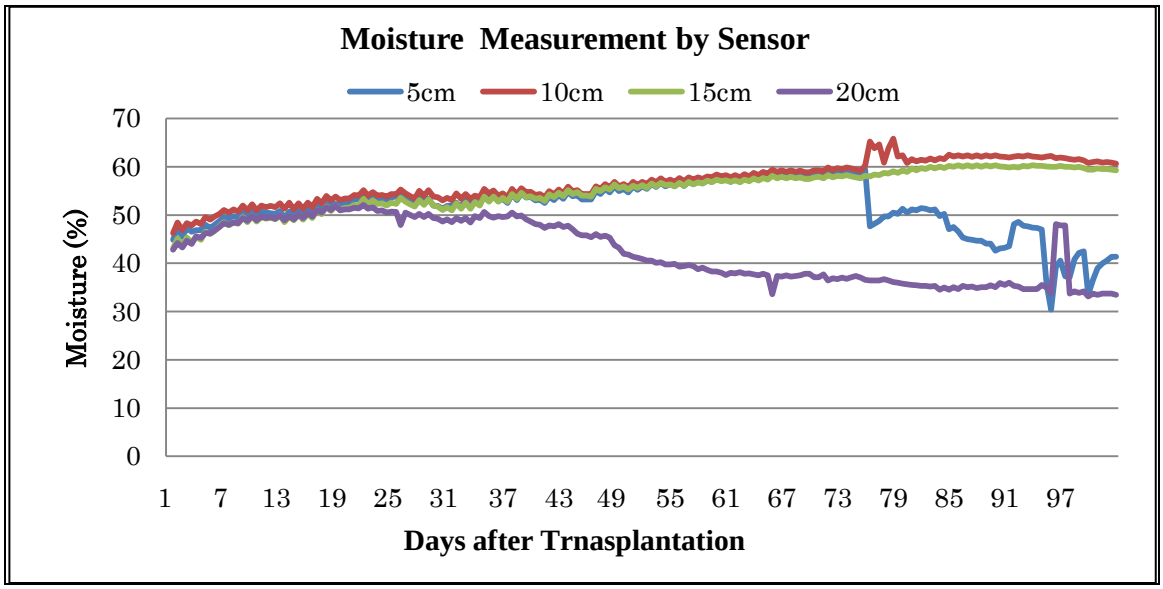


Fig.32 Moisture measurement by sensor

It is also observed that in10cm water depth moisture percentage is highest in all the time followed by 5cm depth moisture and moisture is the lowest in 20cm depth. In the starting period maximum moisture is found 46.27 (%) in 10cm depth and minimum is 42.84(%) in 20cm depth and the difference of moisture percentage is 3.43(%) between 10cm and 20cm depth. At the ending period the maximum moisture is 60.7(%) in 10cm depth and minimum is 33.5(%) in 20cm depth and the difference is 27.2(%).

It is detected that moisture percentage is higher in 9pm than 9am and moisture difference at am-pm is below 3% and at the ending experiment moisture change at am-pm is huge and it crosses 10% change at 4 times (Fig.33). Only 20cm and 5 cm depth moisture sensor shows that moisture at 9am is greater than 9pm in some days.

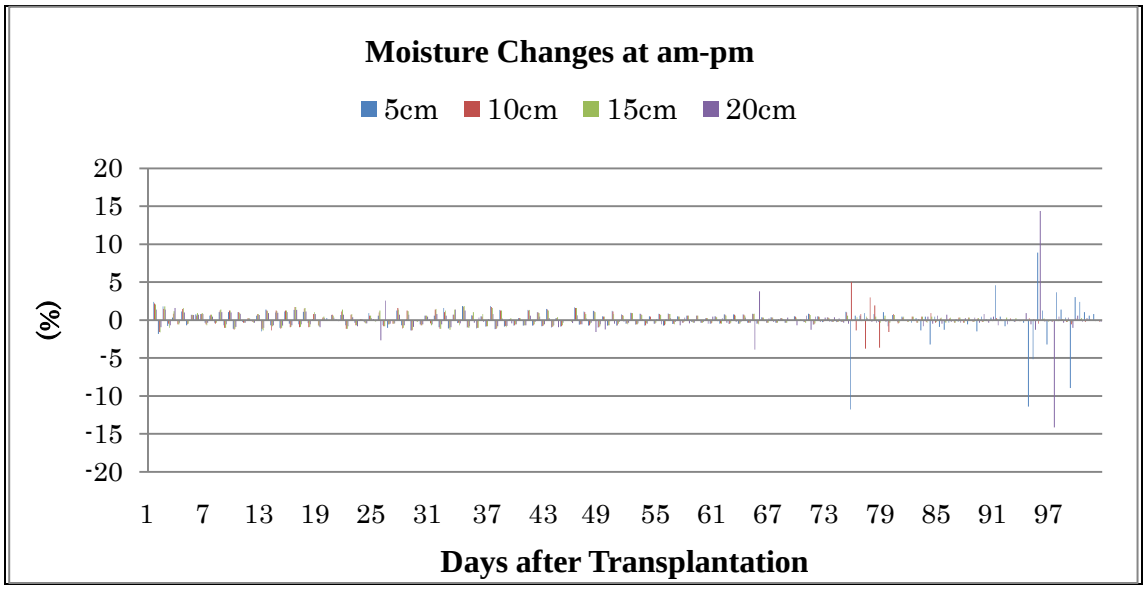


Fig.33 Moisture changes at am-pm

In the experiment, it is not found that moisture presence has relationship with Ponded water depth measured by Water Tube (Fig.34). Only 20cm depth Moisture sensor has shown 0.21 relationships with Water Tube measurement and others has shown very much insignificant result which is less than 0.1.

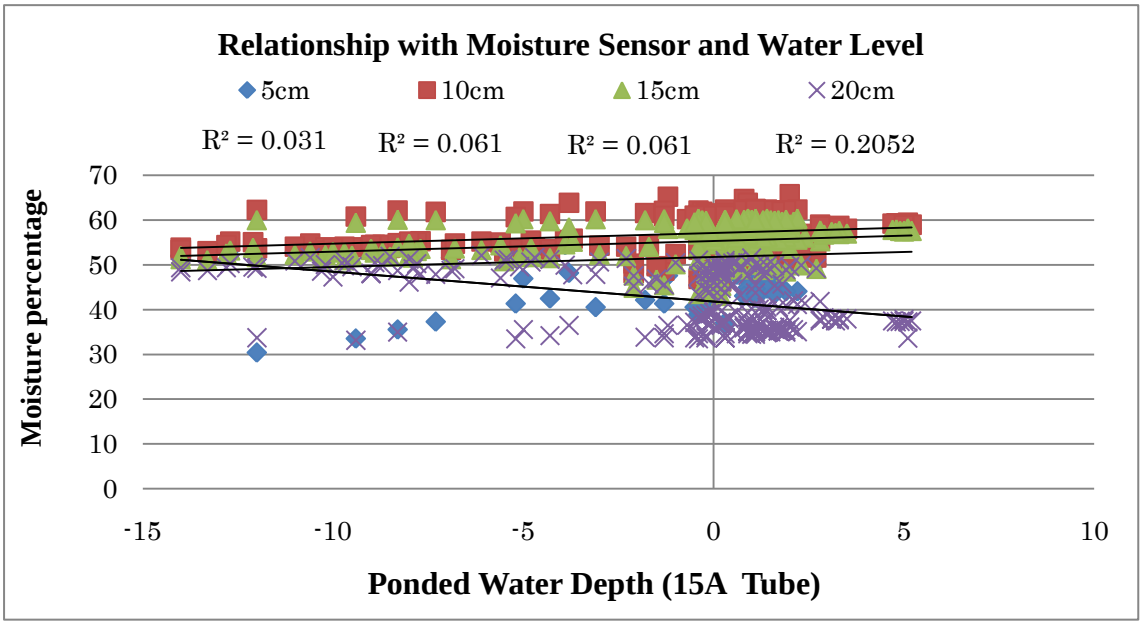


Fig.34 Relationship between ponded depth and Moisture

It is explored that moisture sensor measurement has few relationship (maximum r^2

value 0.0284 and r^2 value minimum 0.0023) between irrigation (Fig.35) and moisture percentage. Irrigation was done in the evening (mostly 5.30-6.30pm) and data of Moisture sensor has been taken 9.00am and 9.00pm on irrigation day but this irrigation has little impact on moisture increase at 9.00pm.

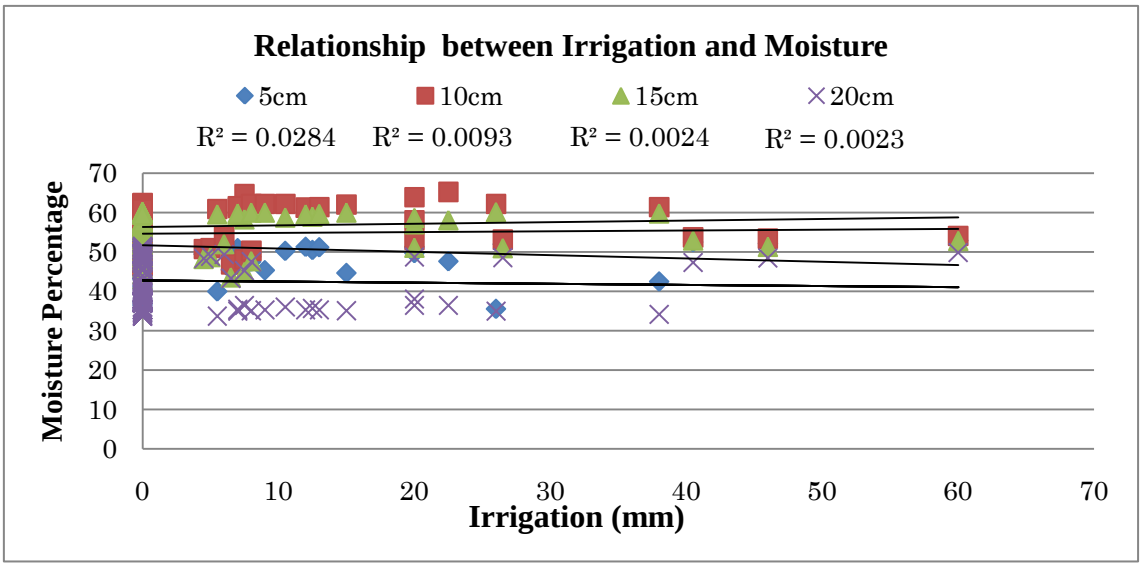


Fig.35 Relationship between Irrigation and Moisture

4.1.3. Water Tube and Tensiometer

In 102 days experiment, number of observation is 204 and out of 204 pressure observations in soil, 24 observations have detected pressure prevailing in 5cm soil depth, 15 observations in 10cm depth, 15 observations in 15cm depth and 6 observations in 20cm depth of soil (Fig.36).

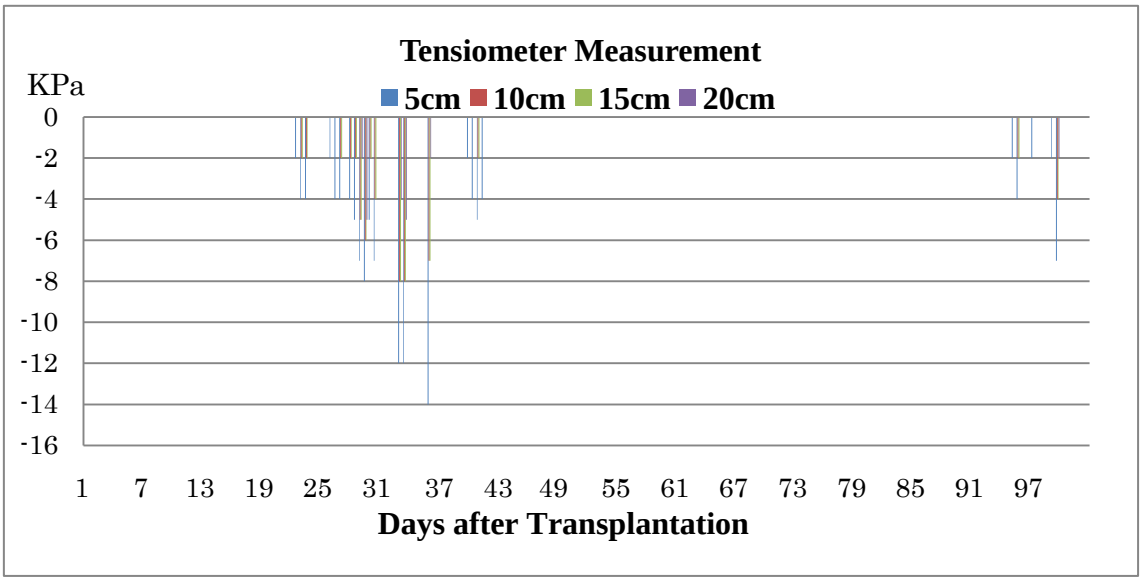


Fig.36 Soil Pressure measurement by Tensiometer

On DAT 22 first pressure is identified in 5cm depth Tensiometer. At that day maximum ponded depth is found -10. 8cm in Water Tube 10A and minimum water depth is -7.9cm in Water Tube 12B. Last pressure is found on DAT 99 where pressure is -7KPa,-4KPa, -4KPa and -2KPa in 5cm, 10cm, 15cm and 20cm depth Tensiometer respectively. 5cm depth Tensiometer shows pressure at minimum water level -4.3cm (15A Tube) depth below the soil surface.10cm, 15cm and 20cm depth Tensiometer shows pressure at minimum water level -9.4cm (15A Tube)depth below the soil surface. In Tensiometer measurement, maximum pressure (-14KPa) is found on DAT 35 by 5cm depth Tensiometer. At that pressure different diameter Water Tube shows different water level. Maximum Ponded depth (-16.7cm) is shown by 7.5A Tube and minimum ponded depth is shown by 12.5B Tube (Fig.37).At this time 10cm depth, 15cm depth and 20cm depth Tensiometer shows -7KPa,-7KPa and -2KPa pressure respectively.

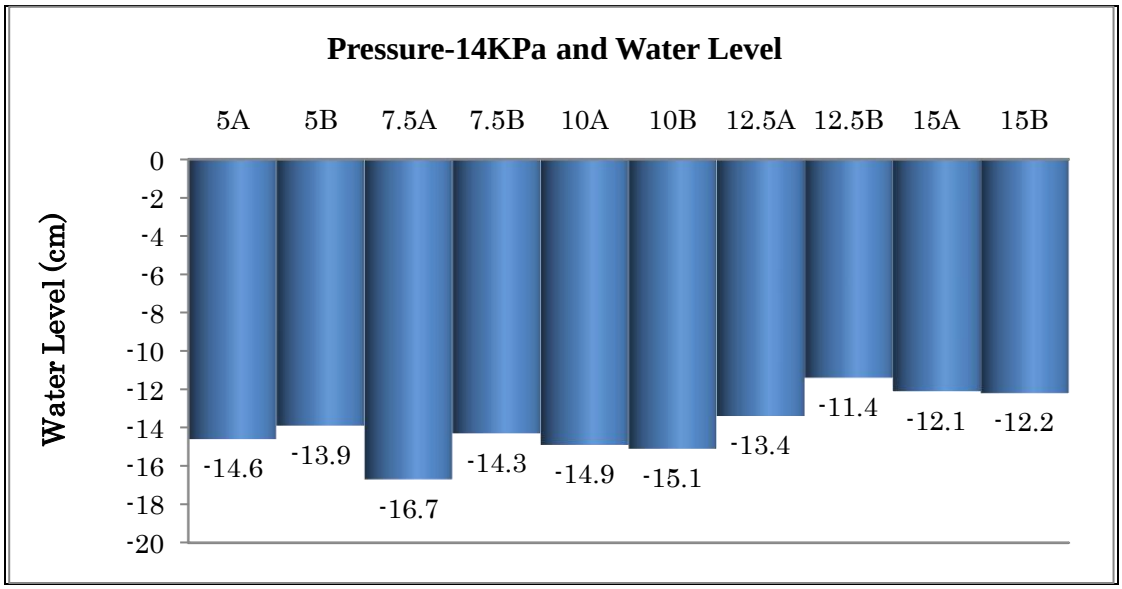


Fig.37 Maximum Pressure and Ponded Water Depth

10cm depth Tensiometer shows maximum soil pressure (-8KPa) on DAT 33 and at that time 5cm, 15cm and 20cm depth Tensiometer shows -12KPa, -8KPa,-5KPa respectively.

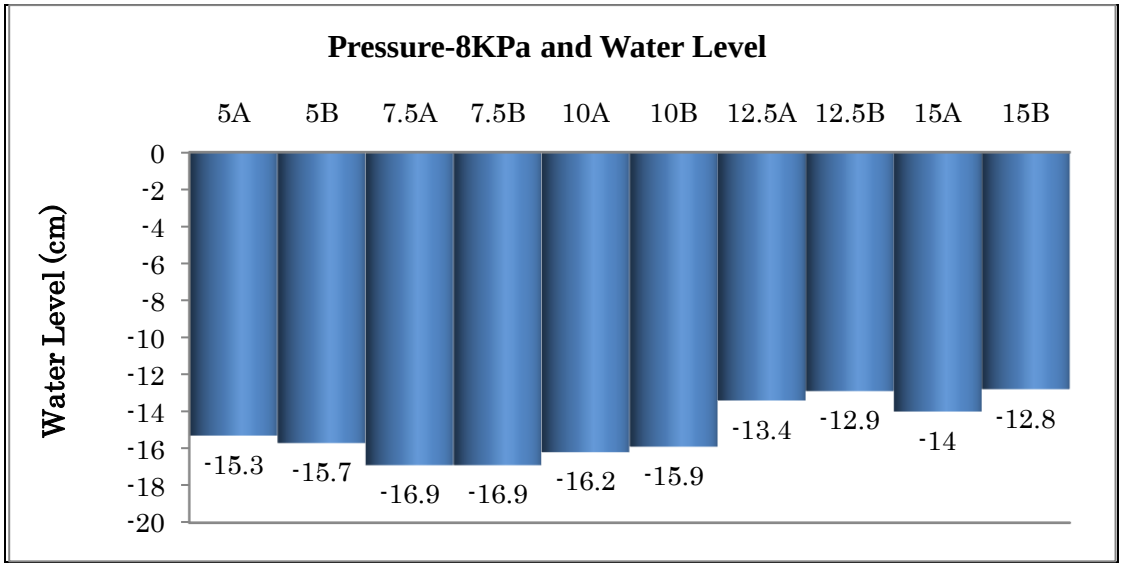


Fig.38 Maximum Pressure at 10cm depth Tensiometer and Ponded Water Depth

When -8KPa pressure prevails at 10cm depth Tensiometer, the maximum ponded depth (-16.9cm) is shown by 7.5A Tube and minimum water depth (-12.8cm) is shown by 15B Tube (Fig.38). IT is identified that 10cm and 15cm depth soil moisture all the time

shows same pressure reading.

On DAT 29, 20cm depth Tensiometer shows maximum (-5KPa) pressure at soil and maximum lowest depth is shown by Water Tube 5B (Fig.39). The maximum water depth is -18.1cm (5B) and minimum water depth is -13.5cm shown by 12.5B Tube. At this measurement point, 5cm, 10cm and 15cm depth Tensiometer shows -8KPa, -6KPa and -6KPa pressure respectively. On DAT 33 20cm depth Tensiometer shows maximum (-5KPa) pressure at soil when ponded water depth is maximum -16.9cm (7.5B)and minimum depth is -12.9cm (12.5B).

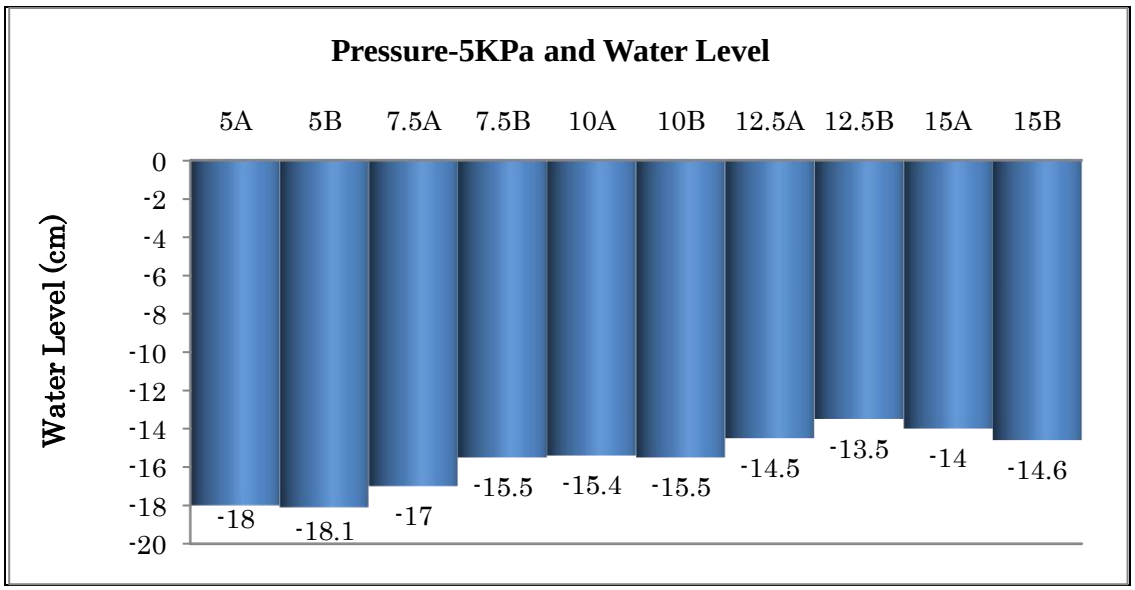


Fig.39 Maximum Pressure at 20cm depth Tensiometer and ponded Water depth

Relationship between soil pressure and different diameter Water Tube has been investigated and it is found that maximum relation (r^2＝0.547) prevails between soil pressure at 5cm depth Tensiometer and 5B Water Tube (Fig.40 and41) and minimum relation (r^2＝0.4594) is identified in 15B Water Tube.

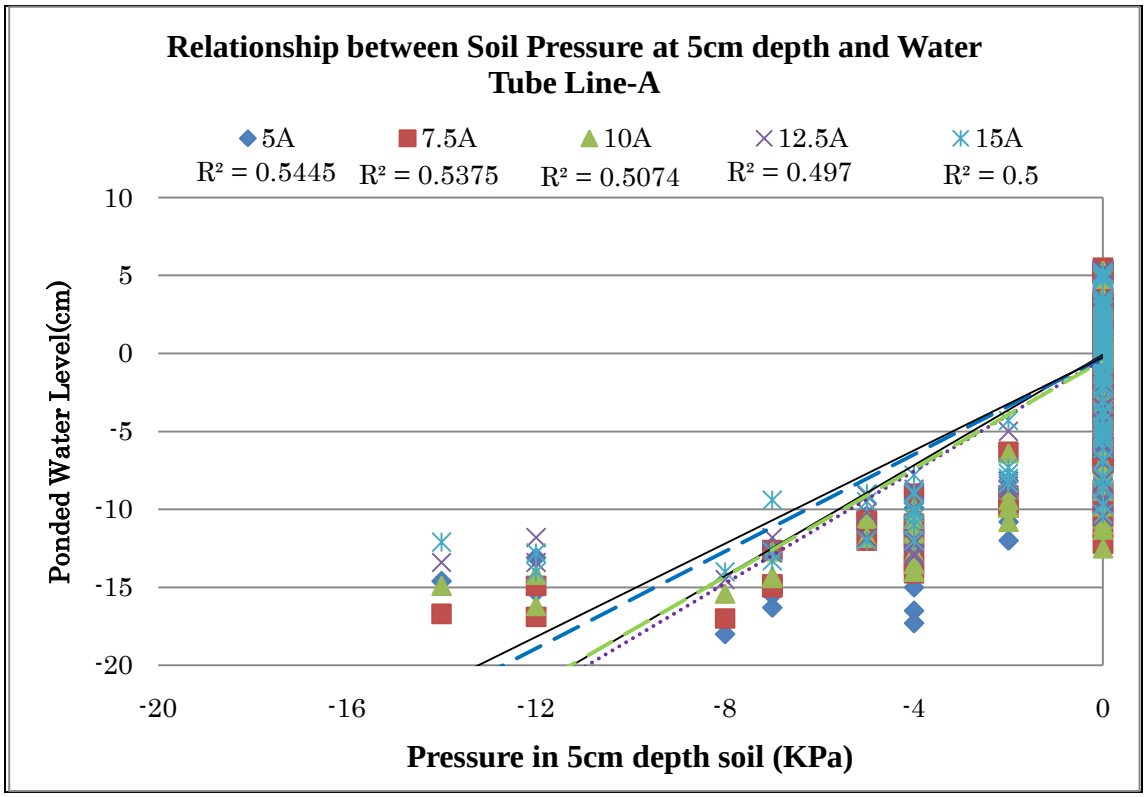


Fig.40 Relationship between soil pressure at 5cm depth and Line-A Water Tube

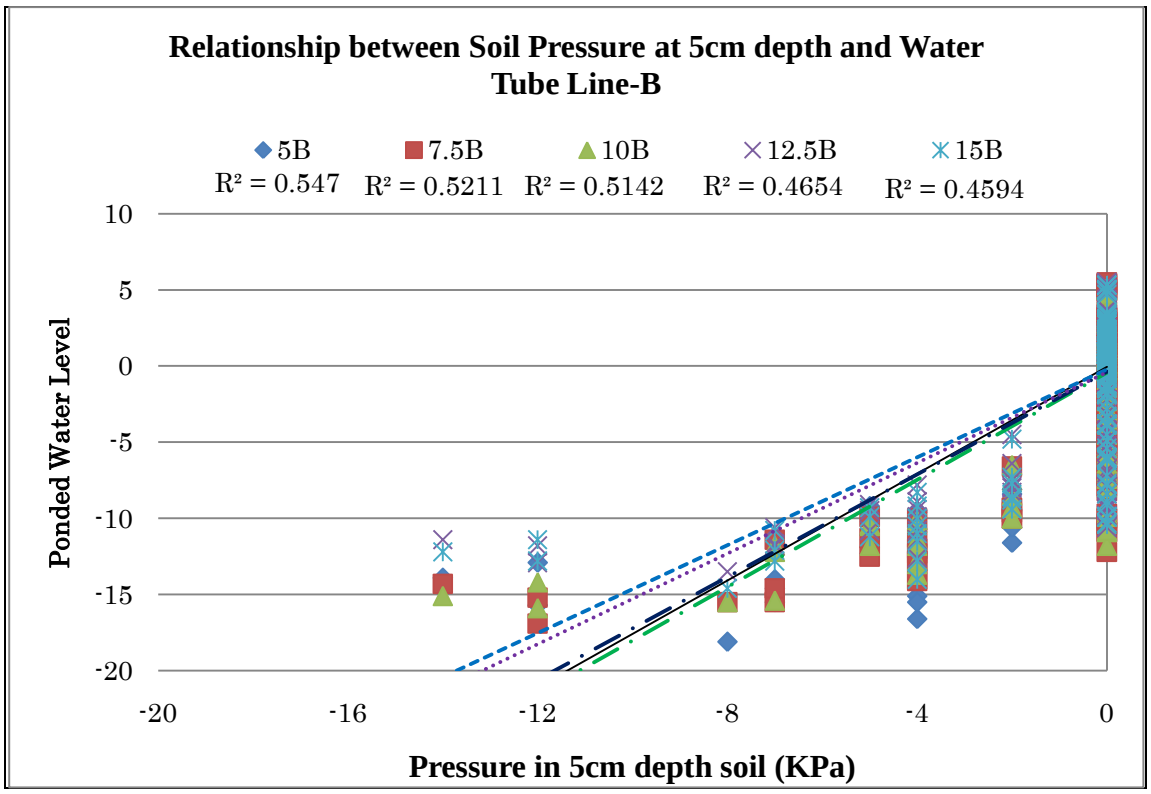


Fig.41 Relationship between soil pressure at 5cm depth and Line-B Water Tube

From the Fig.40 and 41, it is also observed that no pressure prevailed above -4.3cm (15A Tube) depth of the soil.

4.1.4. Water Tube and Hioki Meter

It is found that Hioki Meter (Water Level Sensor) measurement goes side by side with Water Tube Ponded depth measurement (Fig.42). Hioki Meter proves that Water Level measurement by Water Tube is very accurate.

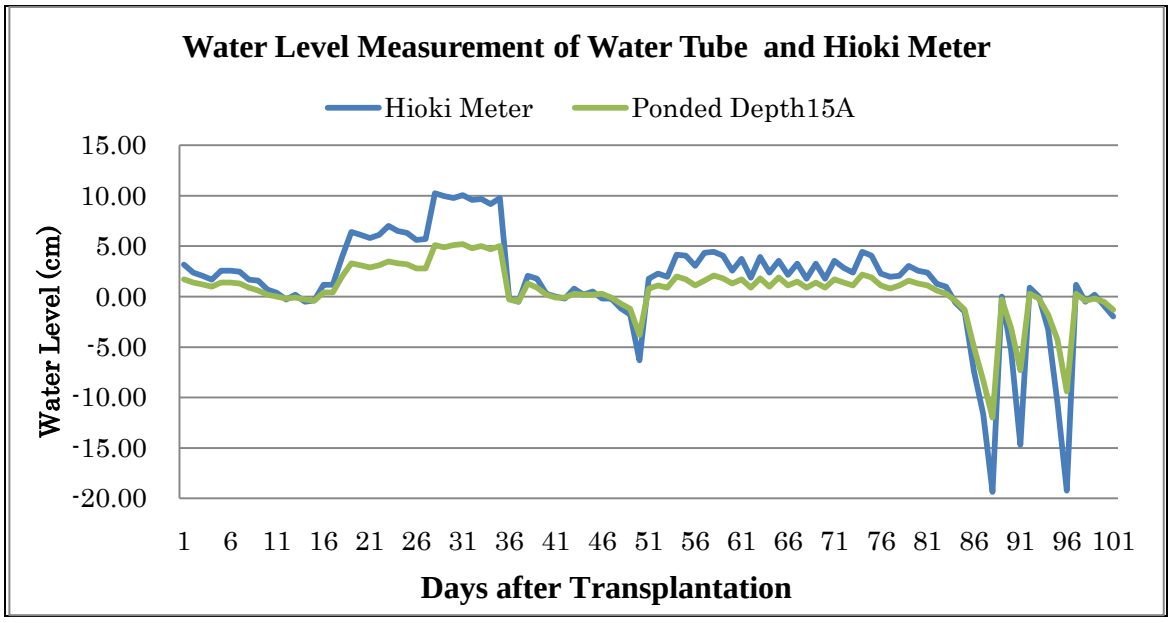


Fig.42 Water Level Measurement by Water Tube and Hioki Meter

It is found that Water Tube measurement has strong relationship with Hioki Meter measurement (Fig43.).It is identified also that larger diameter Water tube has better relationship with Hioki Meter (Fig.44). Maximum relationship between Water Tube and Hioki Meter is 0.9884 (r^2 value) by 12.5B Tube and minimum relationship is 0.9575 (r^2 value) by 5A Tube (Fig 43 and 44).

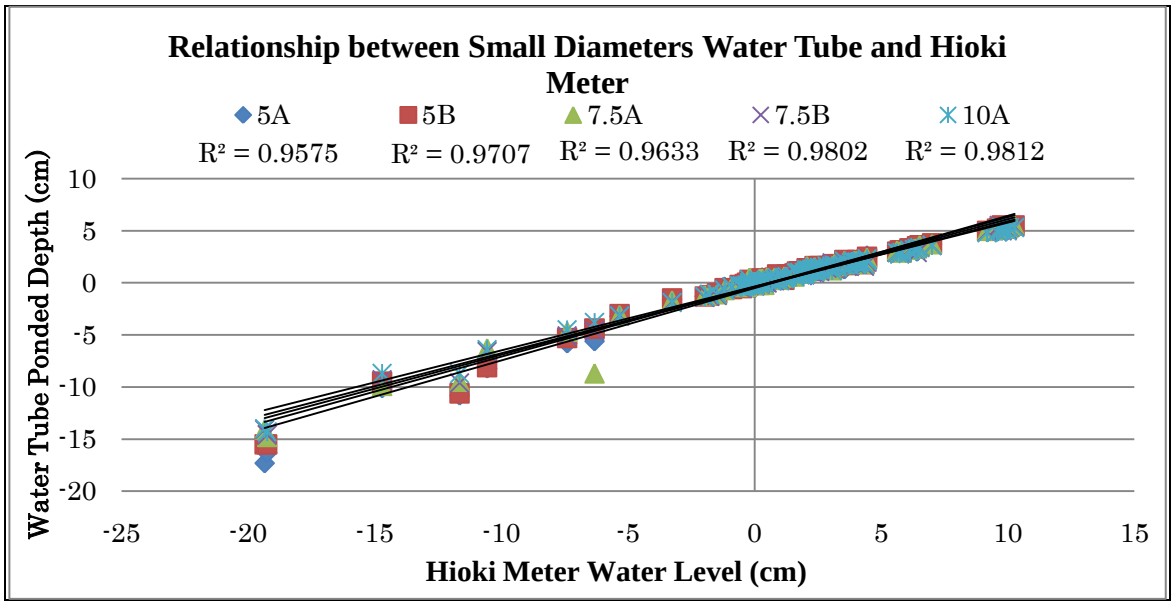


Fig.43 Relationship between Small Diameters Water Tube and Hioki Meter

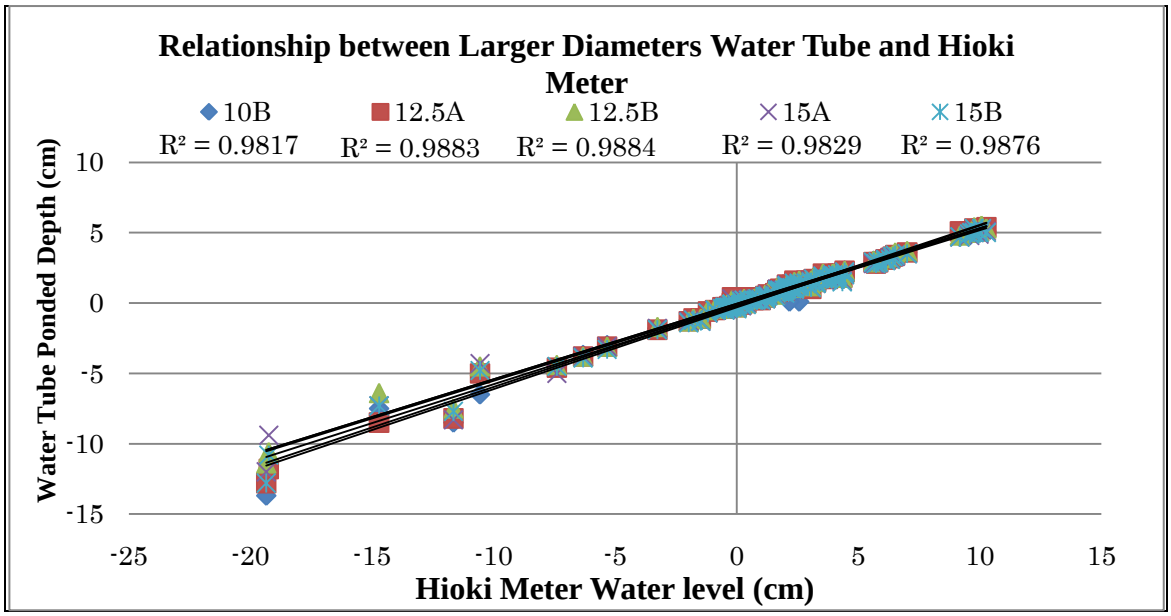


Fig. 44 Relationship between Larger Diameters Water Tube and Hioki Meter

4.1.5. Water Tube and Temperature sensor

Average air temperature is 21.12°c in the whole experiment period and it differs slightly with soil average temperature at 9 am and 9pm in 5cm, 10cm, 15cm and 20cm depth (Table.8). The maximum average temperature remains higher at night than day time. At 9pm in 10cm depth soil shows maximum 26.89°c and 20cm depth shows minimum

temperature 17.44°c.

Table 8 Air Temperature and Soil Temperature

Time	**Air Tem**	**5cm**	**10cm**	**15cm**	**20cm**
Average9am	21.12	20.64	25.48	20.91	17.44
9pm		22.30	26.89	22.22	18.69

(Average air temperature from April1 to 10th August)

It is identified that when water level is on soil surface then Temperature Sensor shows relationship with Water Tube measurement. Higher temperature in air and in soil with large sun shine hours increases evapotranspiration. But when water goes to under the soil then there is only transpiration (percolation rate counts as static here for flooded and drying cycle). It is investigated that there is very insignificant relationship between Temperature sensor and Water Tube by using water level decreasing data of drying cycle of AWDI and temperature data on that particular observation. 15 observations data on maximum decreasing of ponded depth has been counted and considers temperature on that time and find that there are less than 0.2 relationships between temperature and ponded depth (Fig.45 and 46). Therefore, from this investigation it is not found that higher temperature increases more transpiration and decreasing water level rapidly.

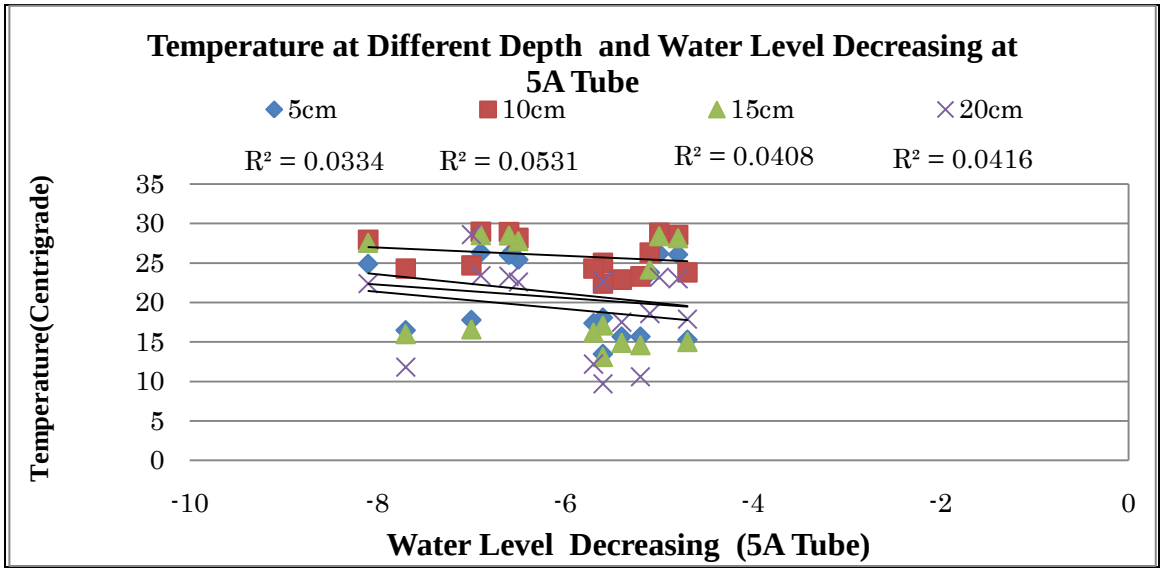


Fig.45 Relationship between 5A Tube Ponded depth and 10cm depth Temperature

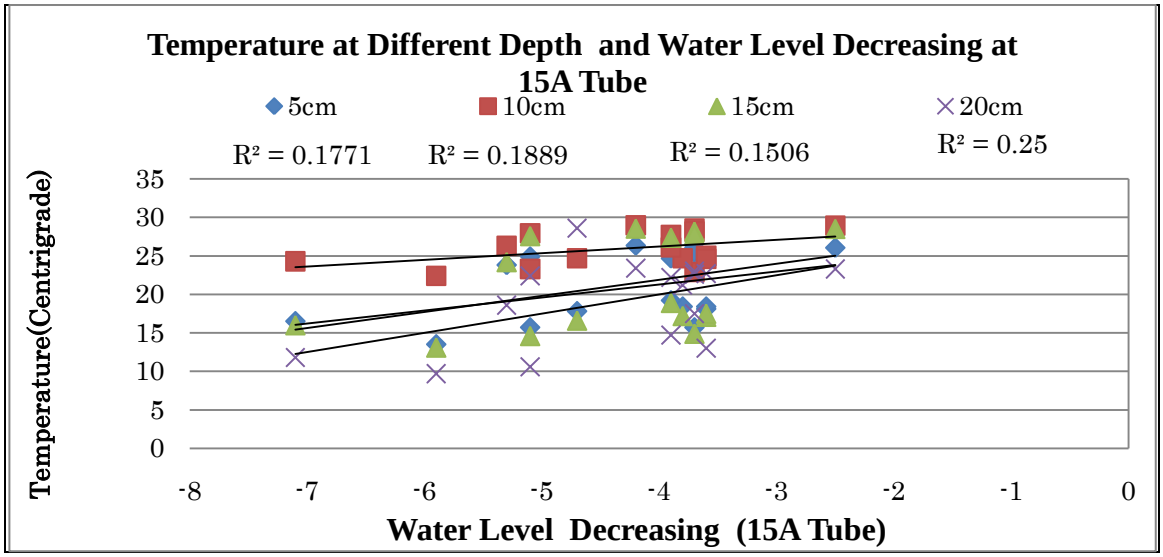


Fig.46 Relationship between 15B Tube Ponded depth and 10cm depth Temperature

From this searching, the finding is the transpiration of rice plant does not relate with temperature increase and decrease and Temperature sensor has less relationship with Water Tube measurement.

4.1.6. Moisture Sensor and Temperature sensor

It is identified that Moisture sensor and Temperature sensor measurement has significant relationship (Fig47). Throughout the experiment period temperature has increased and as

well as moisture also increased according to moisture sensor measurement.

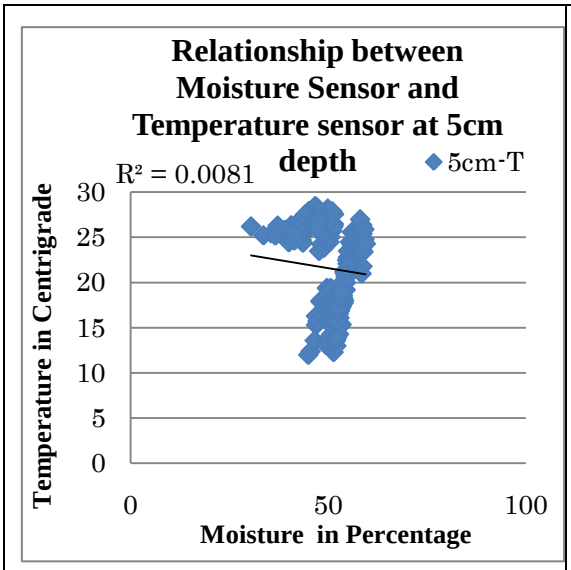


Fig.47a Relationship between Moisture Sensor and Temperature sensor at 5cm depth

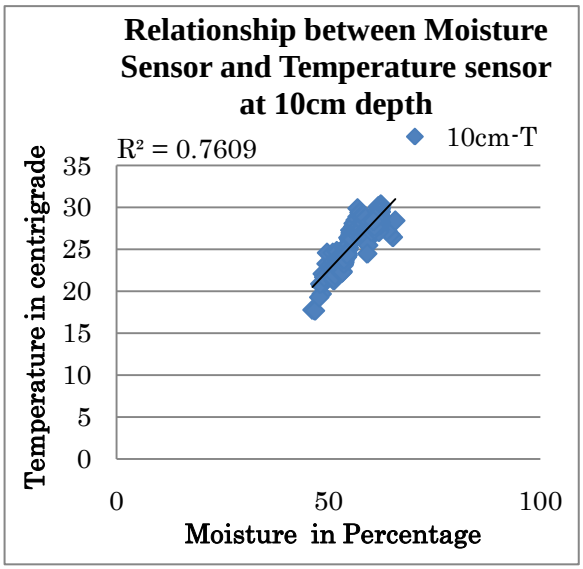


Fig.47b Relationship between Moisture Sensor and Temperature sensor at 10cm depth

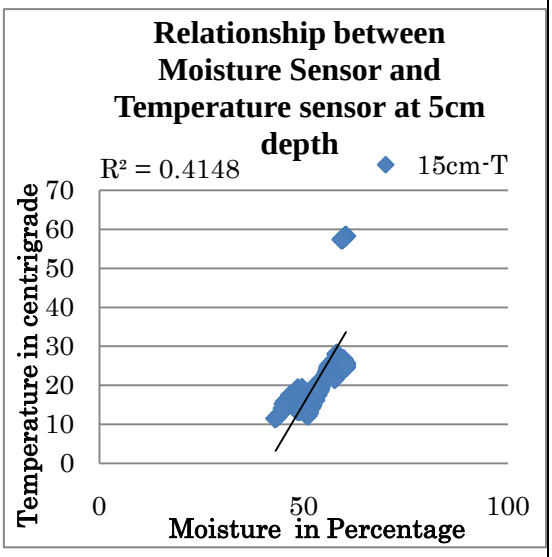


Fig.47c Relationship between Moisture Sensor and Temperature sensor at 15cm depth

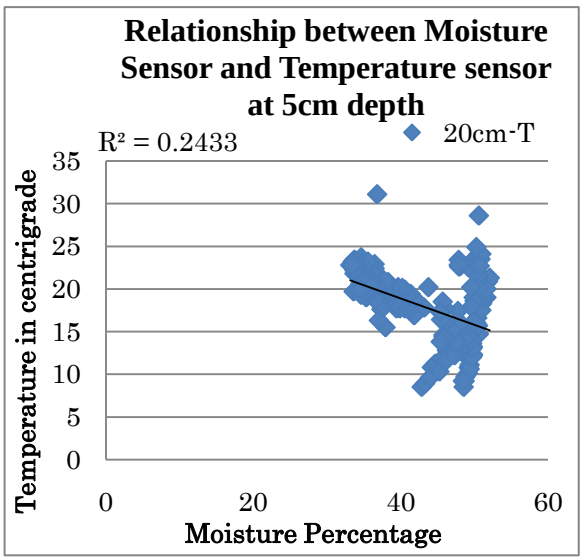


Fig.47d Relationship between Moisture Sensor and Temperature sensor at 20cm depth

Fig.47 Relationship between Moisture Sensor and Temperature Sensor

Actually 5cm, 10cm and 15cm depth moisture sensor and temperature sensor shows meaningful relationship with them. 10cm depth Moisture and Temperature sensor shows maximum relationship (r^2=0.7617).15cm depth and 5cm depth moisture sensor and temperature sensor shows also considerable relationship (r^2=0.7605 and r^2=0.7605 respectively) but 20cm depth Moisture and Temperature sensor shows very poor relationship(r^2=0.0884).

4.1.7. Moisture Sensor and Tensiometer

In the experiment, it is identified that there is no relationship between soil moisture sensor and Tensiometer. 5cm, 10cm and 15cm depth moisture sensor indicates that moisture increases throughout the experiment period (Fig.48). On the other hand, Tensiometer indicates soil pressure increase and deceases with irrigation application and without irrigation.

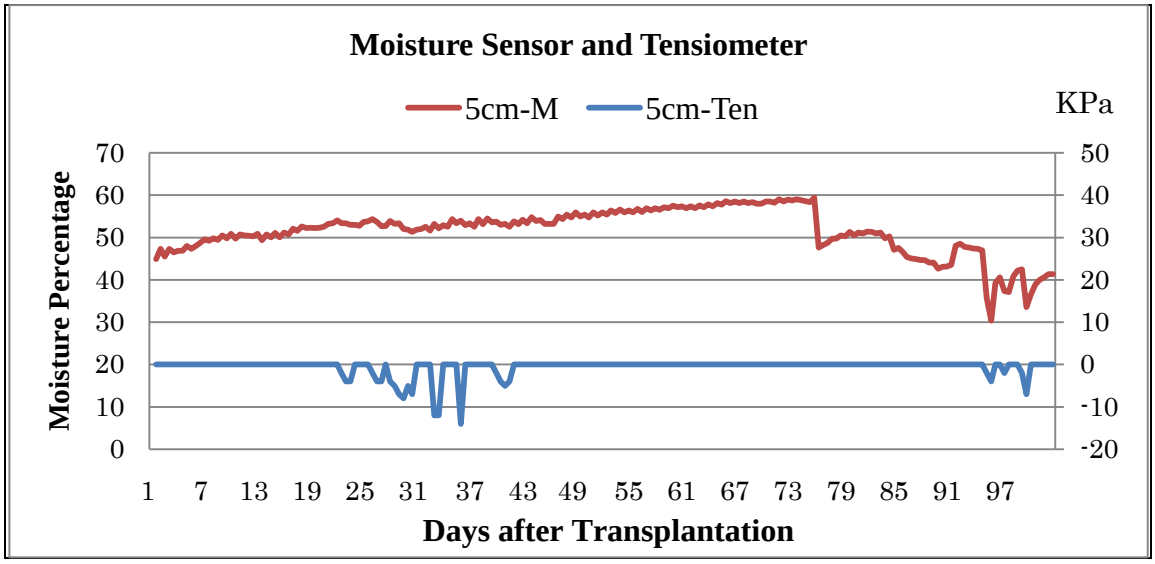


Fig.48 Comparison between Moisture sensor and Tensiometer

4.2. Soil Physical Condition

4.2.1. Soil Crack and Water Height

It is investigated that soil crack has relationship with water level. When water level goes to under the soil then soil crack shows maximum width. It is observed that first soil crack

is formed on DAT 6 and the maximum size of the crack is 5mm (Table9). Ponded water depth is -2.1cm below the soil surface at this crack formation. From DAT 7 to DAT 16, no

Table 9 Soil Crack and Ponded Depth

DAT	Time	Ponded Depth 15A (cm)	Max Width of the Crack(cm)
6	9am	-2.1	0.5
	9pm	0.2	
12	9am	2.7	0
	9pm	2.4	
18	9am	-5.5	1.5
	9pm	-8.5	
22	9am	-8.0	2.5
	9pm	-10.6	
26	9am	-8.9	3.0
	9pm	-10.2	
29	9am	-9.5	3.5
	9pm	-12.7	
32	9am	-6.9	3.5
	9pm	-12.8	
35	9am	-8.7	3.5
	9pm	-12.1	
39	9am	-6.8	3.5
	9pm	-8.3	
44	9am	-6.6	3.5
	9pm	-8.0	
52	9am	1.7	2.5
	9pm	1.5	
56	9am	0.6	(Concave) 2.0+
	9pm	0.3	
60	9am	0.5	(Concave)2.0+
	9pm	2.1	
66	9am	5.2	(Concave)1.5+
	9pm	5.4	
72	9am	0.1	(Concave)1.0+
	9pm	0.1	

78	9am	0.9	(Concave)1.0+
	9pm	2.0	
84	9am	1.9	(Concave)1.0+
	9pm	1.1	
90	9am	0.8	(Concave)1.0+
	9pm	1.1	
96	9am	-0.3	(Concave)1.5+
	9pm	-3.1	
102	9am	-1.3	(Concave)2.0+
	9pm	-5.2	

soil crack is observed and this period ponded Water depth is over the soil surface (maximum 2.7cm, minimum -0.4cm). Soil crack is reappeared on DAT 17, the ponded water depth is -1cm at 9am and -4.9cm at 9pm. the size of the crack is increased from DAT 18 and it continues to increase up to DAT29 and the water depth is -9.5cm(9am) and -12.7cm(9pm) depth of soil on that day. Then soil crack is stabled up to DAT44 (water depth-6.6cm at 9am and -8.0cm 9pm). After DAT 44 to DAT 75 water level is over the soil surface continuously and some small crack is disappeared and big crack is sedimented and depth reduced look like concave shape. It is observed that soil crack is formed around the Water Tube larger and around larger width crack is found the wider diameter Tube(Fig.9f).After flowering stage (DAT88), AWDI again restarted and the algae which was born inside the crack become dead as well as soil crack start to appear.

4.2.2. Soil Crack and Irrigation

As AWD irrigation started from DAT1, soil crack is appeared earlier. One day interval irrigation in 10 days after rice transplantation is done and the amount of irrigation water is less (minimum 35 Liter to maximum 64 Liter) and crack is formed on DAT6. For rain and irrigation the crack has been disappeared from DAT7 to DAT16. Again crack is

appeared on DAT17 and these cracks continue and increase up to DAT29. From DAT 11 to DAT29 there is no application of irrigation but rain comes on DAT12-13, DAT15, DAT20, DAT21, DAT24 and DAT25. Large crack is remained until DAT44 after that it reduces its width and formed it concave shaped on DAT56. It is investigated that soil crack is observed up to DAT52 and after initiation to disappear of crack days is 35 days. It is observed that when irrigation is done or rainfall occurs then sediment is accumulated in the bottom of the crack. If rainfall or irrigation is too high and after that soil remain under water for 12-14 days then soil becomes soft and crack is diminishes mostly. This concave shape of crack remains at the end of experiment period. After flowering stage when AWDI irrigation started at DAT88, soil crack appeared.

4.3. Crop Measurement

4.3.1. Effect on Crop Growth

It is identified that Plant growth curve is S-shaped in this experiment. On DAT10 the height of the plant is 10.34cm and leaf height is 7.5cm (Fig.49, average of 13 data). Plant and leaf height is slowly increased up to DAT46 and then time plant height is 32.25cm and longest leaf height is 20.21cm. On DAT 91 plant height is the maximum 111.3cm and leaf height is 46.5cm.It is found that Plant height is decreased due to longest leaf has been died or broken after DAT 91.It is observed that Leaf height retards its growth after DAT73.

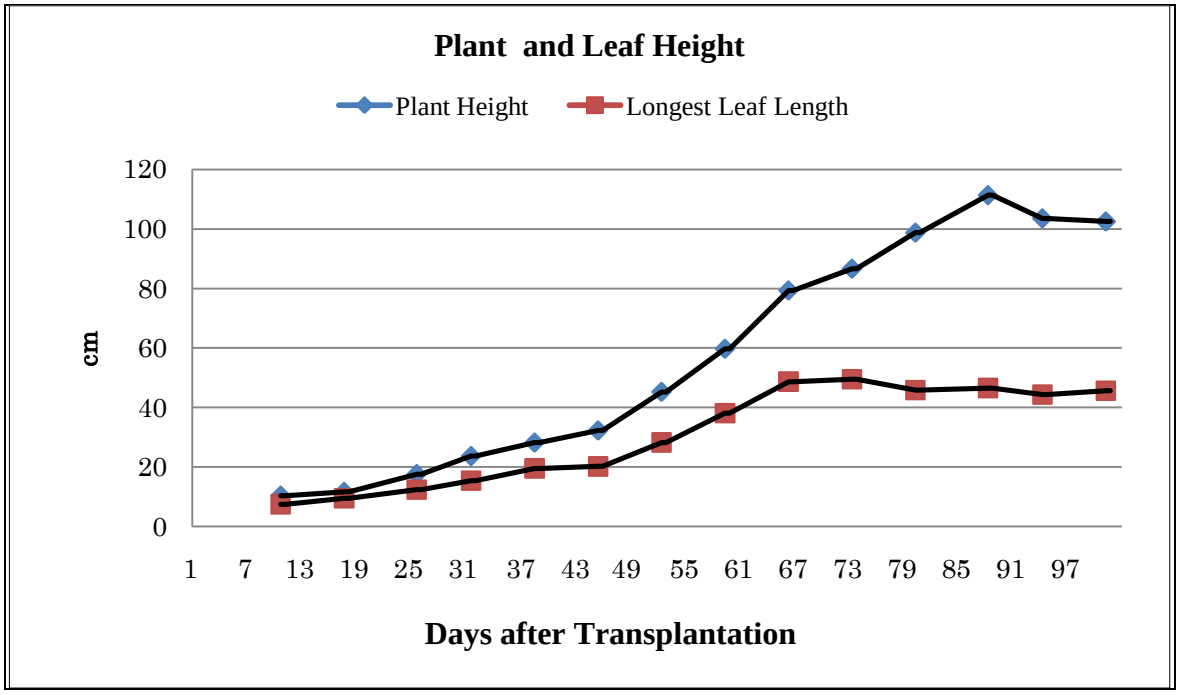


Fig. 49 Plant and Leaf Height

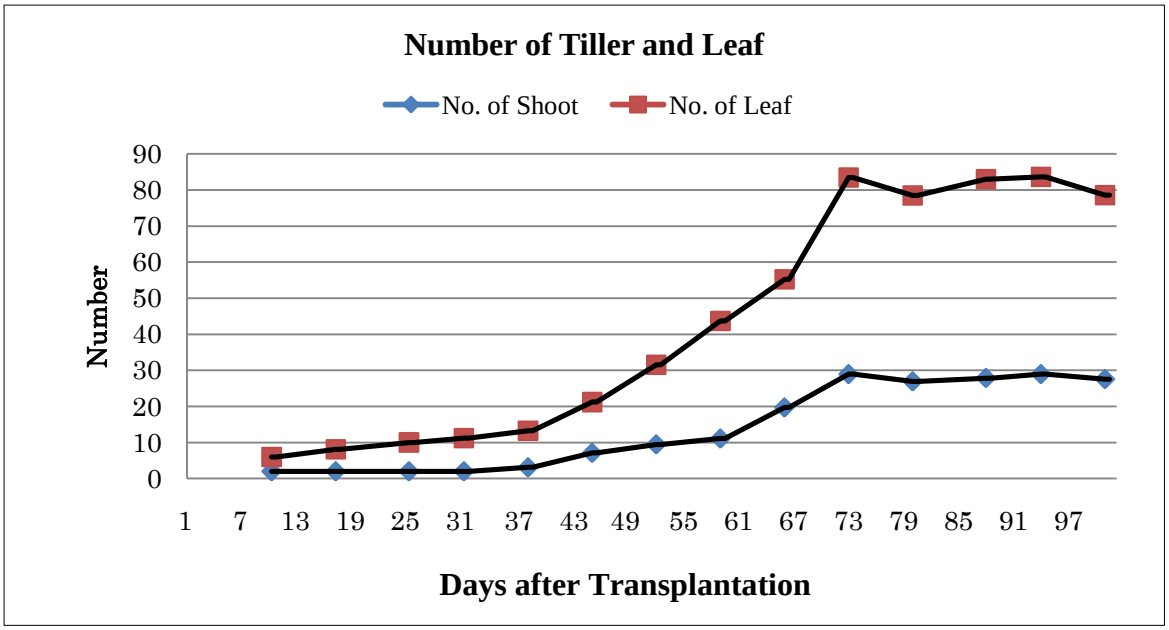


Fig. 50 Number of Shoot and Leaf

It is also observed that Number of Tiller/shoot growth and Leaf growth shows exponential growth curve. On DAT10 the number of the shoot and leaf of the plant is 2 and 6 (Fig.50, average of 13 data). Tiller/Shoot and leaf number is slowly increased up to

DAT38 and then time Shoot and leaf number is 3.09 and 19.55 respectively. It is investigated that maximum Tiller is observed On DAT 73 and then the number of shoot is 28.92 and leaf is 83.46.After DAT 73, the number of Tiller has slightly decreased. Therefore number of Effective Tiller is 27.54 which is very good phonological result for rice plant.

It is investigated that some plants fall in huge crack and face physical difficulties for harboring in the soil (Fig.51a) It is observed some roots appear over the soil on DAT 59 which indicates Vigorous root growth of plant(Fig.51b) .

	
Fig.51a Plant face difficulties in setting roots for huge soil crack on DAT44	**Fig.51b** Vigorous Root growth observe in soil surface on DAT59

Fig.51 Effect of soil crack on crop growth

This figure shows that a plant is fallen in large crack and is fighting to survive.

4.3.2. Effects on Weeds

It is observed that there is visible effect on weed growth in field. Weed is appeared after DAT18.Arrow head (*sagittaria* spp.) is commonly found in the experiment followed by *cyperus rotundus*, *Najas spp*. and some other narrow –leaves weeds. Weeding is done by

hand and weeds are left in the field to produce organic manure for the plant. Some algae are born in the concave part of the crack when water is over the soil surface for 12-14 days. First weeding is done on DAT21 and it is not hard labor. On DAT 53 weeding is maximum laborious task.

4.4. Water Requirement

Total water applied in the field is 77.8 cm of which 45.8cm comes from irrigation and 32cm water comes from rainfall which is 59% and 41% of total irrigation (Fig.52). Following the rianfall, irrigation can be minimized through application of water tube Technology in AWDI.Therefore it is identified that optimum use of rainfall water can be ensured by Water Tube.

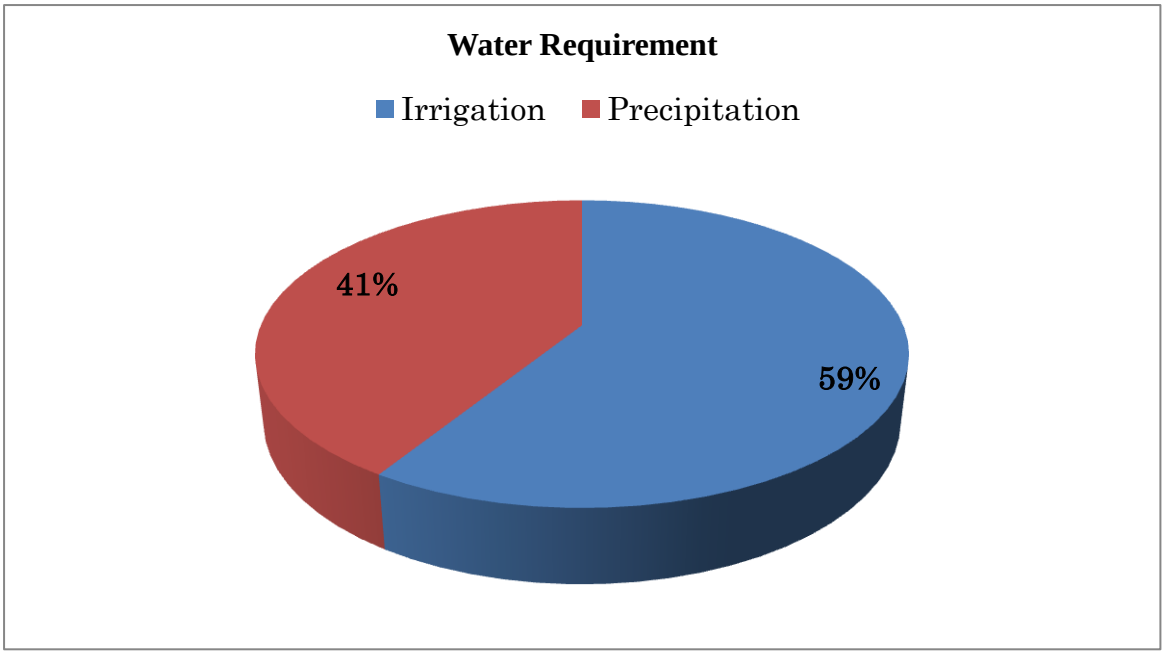


Fig52. Analyse of source of water in Rice cultivation with AWDI

4.5. Merits and Demerits of Water Tube

4.5.1. Accuracy

In the experiment, it is find out that all the Tubes are accurate to measure the water level and provides signal on water availability of the field and shows the irrigation timing. Simply, by the using of open eye, all the Tube is able to measure the ponded depth with 100% accuracy. There is no requirement of calibration of the Tube.

Some special time there are problems to take right measurement and creates problem of deciding irrigation timing. At the time of huge sedimentation and algae formation in the Tube, there is problem to measure the ponded depth. Smaller diameter Tube like 5cm and 7.5cm diameter Tube has problem at the time of taking measurement when water level goes -10cm and -15cm respectively below the soil surface. The inside of the Tube is very dark and there is chance to take misreading the water level. Wider diameter Tube like12.5cm and 15cm has no problem of taking accurate reading when water level goes -10cm depth of the soil. There is chance of miscalculation in the night time measurement. In the night when torch is used to take measurement then light is reflected on the water and hard to measure the right depth. This light reflection problem is also occurred due to sun shine at day time measurement.

4.5.2. Cost

It is investigated that the cost of the 25centimetr PVC Water Tube is comparatively cheap at local market in Japan (Table10). Making perforated hole by hand drilling or electric drilling machine on each side of Tube incurs very nominal cost. Farmers can make this Tube perforated easily in their spare time. There is no carrying, installation and maintenance cost.

Table 10 Price of Different Diameter PVC Water Tube

Tube Diameter(cm)	Size(m)	Price of Tube (¥)	Price of 25cm Length (¥)
5	4m	750	47
7.5	4m	1200	75
10	4m	1400	88
12.5	4m	3100	194
15	4m	4500	282

In assumption, in 1 hectare rectangular rice field 4 Water Tube is sufficient to measure the water level.4 Water Tube is required in this sense that taking average of the 4 Water Tube is better which reduces the risk of any chance of misreading.

4.5.3. Labor

Installation, observation, maintenance is not hard laborious job for using Water Tube and it does not consume time. The only task is installation of Water Tube and taking measurement of water level. The farmers who use Rice Transplanter they can install it after rice transplantation. They have to dig the soil and clear the soil from inside the Tube then installation of Water tube should be done. Additional Labor is not required for maintenance of the Water Tube. If the farmer use small diameter Water Tube there is problem of siltation and after clearing the sediment inside the Tube they can use it very effectively.

4.5.4. Durability and Portability

As PVC pipe is not perishable instrument and not affected by heavy rain fall, flooding, high sun shine, its durability is very high. There is no chance of damaging this instrument by other animal.

After one harvesting if it is washed properly then it can be used for another season and in

this way it can be used for several years. Anyone can carry this the field Water Tube very easily.

4.5.5. Availability

Water Tube is available in the local market. Any farmer can collect that instrument from home appliance market. Its chance of scarcity is very rare.

4.5.6. Environment Friendly

Water Tube is very environment friendly and it does not damage environment through emitting any radioactive matter. It does not impact on human and animal health and does not damage flora and fauna environment .At the production stage of PVC pipe gasoline is required but if bamboo made water Tube or brick built Water Tube is used then any mining resource is not required. In Japan, bamboo is available also and there is advantage to make this Water Tube by Bamboo plant.

4.5.7. Simplicity and Adaptability

The Water Tube is very simple technology to apply in SRI Rice field to follow Alternate Wetting and Drying Irrigation regime. As the technology is very simple, farmer can adopt it very easily. The water Tube Technology posses Rogers (1965) theory of "Diffusion of Innovations" which has many benefits such as relative advantage over Tensiometer and Moisture Sensor technology for measuring soil water availability. Saving water is prime priority in irrigated agriculture now and this technology is very compatible because by applying this technology farmer can save valuable water resource and as well as normal growth of rice will be ensured. This Water Tube Technology is very easy to trail in the farmers' field and farmers can observe its performance through demonstration very easily. Therefore its trial-ability and Observibility is very high.

5. Conclusion and Recommendation

5.1. Summary of the achievements

In the experiment, Water Tube proved that it is the technology which meets the need of performing AWDI rightly, where irrigation was done in based on water requirement of the field not by predetermined interval approach. Water Tube showed significant performance to measure the water availability as well as water requirement by the plant. It exhibited right timing of irrigation. All the Water Tube monitored the depth of the ponded Water very successfully in the drying period of AWDI and shows the requirement of water in field.

In the experiment 5 different diameter-5cm, 7.5m, 10cm, 12.5cm and 15cm diameter Water Tube measured the ponded water level and their relationship in measurement were very close in same diameter maximum r^2 value 0.9955 and minimum r^2 value 0.9876, in different diameter maximum r^2 value 0.995 and minimum r^2 value 0.965. Different diameter Water Tube showed variation in measurement when water level went to below the soil surface specially when water crossed -5cm depth threshold then variation in ponded depth measuring started. It is also identified that maximum depth difference is occurred between small and large diameter Water Tube and minimum is nearby diameter Water Tube.

The narrower diameter Water Tubes displayed maximum lowest ponding depth (-18.1cm by 5cm Water Tube) while wider diameter showed minimum lowest ponding depth (-13.5cm by 12.5cm water Tube). The difference of two different diameters is 4.6cm at measuring of water level. Mean of lowest water level varied 3.2cm where maximum was -15.43cm (5cm Water Tube) and minimum was -12.24cm(12.5cm Water Tube)

Again narrower diameter Water Tubes exhibited highest rate of water level decreasing (-8.2cm by 5cm water Tube) and wider diameter performed less in water level decreasing (-7.1cm by 15cm Water Tube) and the difference is decreasing rate is 1.1cm. Narrower Tubes (5cm, 7.5cm and 10cm) faced problem of siltation (one time) in the experiment and there was problem to take measurement 5cm Tube for severe observation difficulties.

But when we considered pricing of the Tube, narrower Tubes (5cm and 7.5cm) are less pricy than the Wider Tubes almost one third to one forth of 12.5cm and 15cm Tube.

Water Tubes shows very good relationship with Hioki Meter and all the Water Tubes measures water level with Hioki Meter very similar way. Larger diameter shows better performance (maximum r^2 value is 0.9884 by 12.5B) than smaller diameter Water Tube (r^2 value is 0.9575 by 5A) at the comparing with Hioki Meter.

All the Water Tubes showed positive relationship (maximum r^2 value is 0.5445 and minimum r^2 value is 0.4594) with Tensiometer. In the experiment when ponded water depth decreased Tensiometer showed pressure is increasing in the field. In the 102 days experiment period, there were 204 observations of which only 24 observations revealed that there is pressure in the soil. When ponded water depth crossed minimum -4.3cm depth below the soil surface -2KPa pressure was found in 5cm depth Tensiometer. Maximum pressure was found -14KPa in 5cm depth Tensiometer and at that time maximum ponded depth was -16.7cm and minimum depth was -11.4cm.Maximum pressure was found in -5KPa in 20cm depth Tensiometer and at that time maximum ponded depth was -18.1cm and minimum-12.9cm.

Water Tube revealed very poor relationship with moisture measurement by Moisture sensor (maximum r^2 value is 0.2052 and minimum r^2 value is 0.031).Moisture sensor also exhibited poor relationship with irrigation application (maximum r^2 value is 0.0284 and minimum r^2 value is 0.0093). Moisture Sensor at 5cm, 10cm and 20cm depth demonstrated its very poor relationship with Temperature Sensor (maximum r^2 value is 0.7609 and minimum 0.0081).

Water Tube measurement disclosed insignificant relationship (maximum r^2 value is 0.25 and minimum 0.0334) with Temperature sensor measurement at the drying cycle of AWDI when water went under the soil surface. This finding revealed that when water goes to under the soil surface, there is only transpiration of plant for decreasing water level and transpiration of plant has no relationship with increase and decrease of temperature.

In the experiment, huge soil crack was formed (maximum 3.5cm width) and crack was continued up to 52 DAT. The huge crack remained total 35days.Soil crack was again observed after flowering stage when AWDI start again.

At the end of the experiment, Plant growth was 102.5cm in height; leaf number 78.56, leaf height 45.65cm, number of shoot /tiller per hill 27.54 and it color was 3 in leaf chart which was regarded as good health condition of the plant. Specially The Number of tiller which is shown Effective Tiller per plant shows very promising.

5.2. Limitations and Future Need

The study exhibited that Water Tube technology is promising one but the experiment was done in very small scale and large scale experiment in the farmers' field would be better to get more out come from the experiment. In the experiment rainfall was a good

source of water but the study did not show how much irrigation should be done after little or medium rainfall when water level goes to -15cm or -10cm depth. More study is required on how much irrigation is required at certain depth of ponded water specially when crosses the surface of soil and goes below the surface. There is huge scope to study on irrigation by the Water Tube in rice zone. The experiment only identified diameter size of Water Tube as the reason for variation of water level and its decreasing rate. But what other causes related with ponded depth difference was not identified like is there any impact on diameter of perforated hole of the tube. More Study is required on water Tube made with PVC, bamboo and brick to compare its performance. More rigorous study is required on rice root growth, how much it grows in the Water Tube irrigation management. Other SRI component like 7 days seedlings, single seedling per hill, organic manure application can be a good study with AWDI management by Water

At last, based on the Lysimeter scale experiment at Kashiwa, Japan it can be concluded that Water Tube technology expressed itself as a complete demand driven approach which superseded 5days interval, 7 days interval, and 10days interval irrigation approach of AWDI. To increase productivity and to produce rice in water-wise way, Water Tube technology can be very good option for sustainable rice farming which can save valuable water resource and reduce production cost. Farmers can choose their Water Tube according to their preference and ability. But they should consider that when they will use larger diameter (12.5cm and above) then will re-irrigate when Water level goes -10cm depth below the soil surface. The farmer who choose smaller diameter (5cm to 10cm) then they will irrigate when water level goes-15cm depth below the soil surface.

References

1. ADB, (2005). ADB Technical Assistance Report -Project Number: 38522 Technical Assistance Development and Dissemination of Water-Saving Rice Technologies in South Asia pp1-3
2. Aswathanarayana,U (2007). Food and Water Security Chapter-12 : Aerobic Rice-an efficient Water management Strategy for Rice Production`
3. B. A. M. Bouman,(2002).Water Wise Rice Production Google Book pp52
4. Barker R, Dawe D, Tuong TP, Bhuiyan SI, Guerra LC (1999). The outlook for water resources in the year 2020: challenges for research on water management in rice production. In "Assessment and orientation towards the 21st century", Proceedings of 19th session of the International Rice Commission, Cairo, Egypt, 7-9 September 1998. FAO. pp 96 – 109.
5. Belder, P. B. A. M. Bouman, R. Cabangon, Lu Guoan, E. J. P. Quilang, Li Yuanhua, J. H. J. Spiertz and T. P. Tuong (2004) Effect of water-saving irrigation on rice yield And water use in typical lowland conditions in Asia Agricultural Water Management Volume 65, Issue 3, 15 March 2004, Pages 193-210
6. Chapagain, T., & Yamaji, E. (2010). The effects of irrigation method, age of seedling and spacing on crop performance, productivity and water-wise rice production in Japan. Paddy and Water Environment, 8 (1), 81-90.
7. Cobos, R. Douglas (2009) Calibrating ECH2O Soil Moisture Sensors –Application Note Decagon Devices pp1-7
8. Guerra LC, bhuiyan SI, Tuong TP, barker R (1998). Producing More Rice with Less Water from Irrigated System. SWIM Paper5: International Irrigation Management Institute, Colombo pp1.

9. IRRI, (2002). Potentials Of Water-Saving Technologies In Rice production: An Inventory And Synthesis Of Options At The Farm Level (DPPC Ref. No.: 2002-26)pp1-2
10. IRRI, (2002). Water –Wise Rice Production pp3-129
11. IRRI, (2004). Poster on Control your Irrigation- save water and get high yield!
12. IRRI, (2009). Rice science for better World Rice Fact Sheets-Saving Water: Alternate Wetting Drying (AWD)
13. Oliver, M.M.H. M.S.U. Talukder and M. Ahmed (2008). J. Bangladesh Agril. Univ. 6(2): 409–414, 2008 Alternate wetting and drying irrigation for rice cultivation
14. Stoop WA, Uphoff N, Kassam A (2002). A review of agricultural research raised by the system of rice intensification (SRI) from Madagascar: Opportunities for improving farming systems for resource-poor farmers. Agricultural Systems 71:249-274
15. Tuong,T (2007). Alternate Wetting and Drying Irrigation (AWD): a technology for water saving in rice production [Paper presented at the Crop Cutting Ceremony, BADC Farm, Modhupur, Tangail, May 14,2007
16. Tuong TP, Bouman BAM (2002). Rice production in water scarce environments. In: Kijne JW, Barker R, Molden D (eds), Water Productivity in Agriculture : Limits and Opportunities for Improvement. The Comprehensive Assessment of Water Management in Agriculture Series, Volume 1, CABI Publishing, Wallingford, UK. p.13-42.
17. Uphoff N (2006). The system of Rice Intensification (SRI) as a methodology for reducing water requirements in irrigated rice production. Paper for International Dialogue on Rice and water: Exploring Options for Food Security and sustainable

Environments, held at IRRI, Los Banos, Philipines, March7-8, 2006.

18. Van der Hoek et al. (2001) research report-47 Alternate Wet/ Dry Irrigation in Rice Cultivation : Apractical Way to save water and control malaria and Japanese encephalitis pp1-4
19. Virk, P Sant S. Virmani, V. Lopena and R. Cabangon (2004) Enhancing Water Productivity in Irrigated Rice Crop science- Proceedings of the 4th International Crop Science Congress Brisbane, Australia, 26 Sep – 1 Oct 2004
20. Ali, Ashraf (2009) By applying water saving Irrigation Technology 7.4 billion Bangladesh currency can be saved-Production of dry season rice will be increased 2.4 million ton- Bangla Daily "Naya Diganta-17th July", 2009 http://www.dailynayadiganta.com/2009/07/17/fullnews.asp?News_ID=156598&sec=2
21. Bangladesh Economic News February 22, 2010 .AWD irrigation technology can benefit Bangladesh (http://bangladesheconomy.wordpress.com/2010/02/22/awd-irrigation-technology-can-benefit-bangladesh/).
22. Bangladesh Rice Research Institute (BRRI) online Knowledge Bank- http://www.knowledgebank-brri.org/awd.php
23. Home Page- SRI-(http://ciifad.cornell.edu/sri/).
24. PhilRice(http://www.philrice.gov.ph//index.php?option=com_content&task=view&id=913&Itemid=107)

APPENDICES

Appendix1. Monthly Meteorological Data at Abiko Meteorological Station, Chiba during 2010

Month	Rainfall (mm)				Temperature (℃)					Wind (m / s)					Sunshine
	Total	Daily max	Maximum		Average			Max	Least	Ave.	Max		Maximum instantaneous		Time
			1 Hour	10 min	Daily mean	Daily max	Daily min			Wind speed	Wind speed	Wind direct	Wind speed	Wind direct	(H)
Jan	11.5	9	2.5	1.5	4.9	10.6	-0.2	18.7	-3.6	1.2	4.8	SSW	12.3	SSW	202.9
Feb	112	34	8	2	4.9	9.7	0.8	21	-3.9	1.3	6.2	SSW	15.2	SSW	110.3
Mar	99.5	31.0	15.0	4.5	8.2	13.5	3.0	21.7	-1.4	2.5	15.1	SSW	26.2	SSW	97.1
Apr	194.5	48	17	5.5	10.9	16.3	6.4	24.6	0.5	2.3	10.4	SSW	20.9	S	135.7
May	109.5	24.5	7	3.5	17.6	22.7	13.1	30	7.6	2.5	8.3	SSW	17.5	SSW	213.2
June	109.5	26.5	14	10	22	27.1	18.1	31.9	9.7	2.1	8.8	SSW	16	SSW	167.3
July	77	21.5	15.5	6.5	26.5	31.7	22.9	36.7	18.6	2.6	9.3	SW	18.5	SW	199.9
Up to 10th Aug.	5.5	5.5	4.5	2.5	28.5	35.0	22.6	-	-	2.6	4.7	SSW	8.75	SSW	89.3

Source: Abiko Meteorological Station, Chiba, 2010

Appendix2 Ponded Depth Data (in cm)

Data	DAT	Date	Time	Water Tube									
				5A	5B	7.5A	7.5B	10A	10B	12.5A	12.5B	15A	15B
1	1	5 月 1 日	9am	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2
2			9pm	-0.3	-0.3	-0.2	-0.3	-0.3	-0.3	-0.1	-0.2	-0.2	-0.2
3	2	5 月 2 日	9am	-0.5	-0.5	-0.4	-0.5	-0.5	-0.5	-0.3	-0.4	-0.4	-0.4
4			9pm	0.2	0.1	0.1	0	0.3	0.2	0.3	0.2	0.2	0.2
5	3	5 月 3 日	9am	-0.1	-0.2	-0.2	-0.3	0	-0.1	0	-0.1	-0.1	-0.1
6			9pm	-1.5	-1.5	-1.5	-1.6	-1.2	-1.4	-1.3	-1.2	-1.3	-1.5
7	4	5 月 4 日	9am	-2.7	-2.7	-2.7	-2.6	-2.4	-2.8	-2.1	-2.8	-2.1	-1.8
8			9pm	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.2
9	5	5 月 5 日	9am	-0.2	-0.3	-0.4	-0.3	-0.2	-0.3	-0.3	-0.2	-0.2	-0.4
10			9pm	-2.3	-2.4	-2.4	-2.5	-2.2	-2.3	-2.3	-2.2	-1.5	-2.3
11	6	5 月 6 日	9am	-2.8	-2.9	-2.9	-3	-2.8	-2.9	-2.9	-2.8	-2.1	-2.8
12			9pm	0.3	0.2	0.1	0.2	0.1	0.2	0.2	0.1	0.2	0.2
13	7	5 月 7 日	9am	-0.3	-0.4	-0.4	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.4
14			9pm	0	-0.1	-0.1	0	0	0.1	0.1	0.1	0.1	0
15	8	5 月 8 日	9am	-0.2	-0.3	-0.3	-0.3	-0.2	-0.1	-0.1	-0.1	-0.1	-0.3
16			9pm	0.3	0.1	0.2	0.1	0.2	0.3	0.3	0.3	0.3	0.1
17	9	5 月 9 日	9am	0.2	0	0.1	0	0.1	0.2	0.1	0.2	0.2	0
18			9pm	0	-0.2	-0.1	-0.2	-0.1	0	-0.1	0	0	-0.2
19	10	5 月 10 日	9am	-0.2	-0.4	-3.4	-0.4	-0.2	-0.2	-0.2	-0.1	-0.2	-0.4

20			9pm	0.2	0.1	0.7	0	0.3	0.2	0.3	0.4	0.3	0
21	11	5 月 11 日	9am	0.3	0.1	0.3	0.1	0.2	0.2	0.2	0.2	0.2	0.1
22			9pm	0.9	0.7	1	0.6	0.8	0.8	0.7	-0.2	0.7	0.7
23	12	5 月 12 日	9am	2.9	2.7	3	2.7	2.8	2.8	2.7	2.8	2.7	2.7
24			9pm	2.6	2.6	2.6	2.4	2.5	2.5	2.4	2.7	2.3	2.4
25	13	5 月 13 日	9am	2.2	2.1	2.3	2.1	2.1	2.2	2	2.3	1.9	2.1
26			9pm	1.9	1.7	2	1.8	1.7	1.9	1.6	1.9	1.6	1.9
27	14	5 月 14 日	9am	1.6	1.5	1.6	1.5	1.5	1.6	1.3	1.6	1.3	1.5
28			9pm	1.3	1.2	1.4	1.3	1.2	1.3	1.1	1.3	1.1	1.1
29	15	5 月 15 日	9am	1	1	1.2	1	0.9	1	0.7	1	0.7	0.9
30			9pm	0.6	0.6	0.7	0.6	0.4	0.5	0.5	0.7	0.5	0.6
31	16	5 月 16 日	9am	0.4	0.3	0.5	0.3	0.3	0.4	0.1	0.4	0.2	0.3
32			9pm	-0.3	-0.4	-0.7	-0.7	-1.1	-0.3	-0.5	-0.2	-0.4	-0.2
33	17	5 月 17 日	9am	-0.7	-0.8	-1.6	-1.7	-2	-0.9	-1.1	-0.8	-1	-0.8
34			9pm	-6.1	-6	-5.8	-6.3	-7.1	-5.8	-5.1	-4.8	-4.7	-4.9
35	18	5 月 18 日	9am	-7.3	-6.9	-6.9	-7.2	-7.7	-6	-6.1	-5.6	-5.5	-5.4
36			9pm	Siltation	Siltation	-10.4	-10.9	-11.3	-10.9	-9.3	-9.3	-8.5	-8.9
37	19	5 月 19 日	9am	Siltation	Siltation	-12.2	-12.2	-12.5	-11.8	-10.5	-10.6	-9.7	-9.9
38			9pm	Siltation	Siltation	-6.4	-5.7	-7.1	-7	-5.7	-6.8	-5.4	-7.7
39	20	5 月 20 日	9am	Siltation	Siltation	-4.1	-3.5	-5.3	-5.2	-3.8	-4.2	-4.3	-6.1
40			9pm	Siltation	Siltation	1	1	1	1	1	1	1	1
41	21	5 月 21 日	9am	Siltation	Siltation	-1.8	-2.3	-4.3	-3.5	-3.4	-1.9	-2.3	-3.4

42			9pm	Siltation	Siltation	-7	-7.9	-8.8	-8	-6	-6	-6.1	-6.2
43	22	5 月 22 日	9am	Siltation	Siltation	-9.6	-10	-10.8	-10	-8.7	-7.9	-8	-8.8
44			9pm	Siltation	Siltation	-12	-12.8	-12.8	-13	-13	-10	-10.6	-11
45	23	5 月 23 日	9am	Siltation	Siltation	-12.9	-14	-14	Siltation	-11.9	-10.8	-11	-11.5
46			9pm	0.1	0.1	0.1	0	0	0.1	0.3	0.2	0.3	0
47	24	5 月 24 日	9am	0.8	0.9	0.8	0.9	0.9	0.8	0.9	0.9	0.9	0.9
48			9pm	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
49	25	5 月 25 日	9am	-5	-3.4	-4.4	-4.7	-4.6	-4.5	-3.5	-4.4	-3	-6
50			9pm	-12	-11.6	-9.1	-10	-9.9	-10	-8.7	-8	-7.7	-9.4
51	26	5 月 26 日	9am	-15	-15.1	-11	-12	-11.4	-11.4	-9.9	-9.4	-8.9	-10.5
52			9pm	-16.5	-16.6	-13.5	-12.8	-13.5	-12.8	-12.2	-12.6	-10.2	-14
53	27	5 月 27 日	9am	-4.5	-5.5	-6	-5.4	-5.9	-5.4	-5.1	-5.2	-5.1	-6
54			9pm	-9	-9.6	-9	-10	-9.9	-10.1	-8.7	-7.8	-7.8	-8.3
55	28	5 月 28 日	9am	-10.8	-11.1	-12	-12.5	-11.8	-11.8	-10.2	-9.5	-9.5	-9.9
56			9pm	-15.5	-14.6	-15	-15.5	-14.4	-15.4	-12.6	-11.8	-12.7	-12.8
57	29	5 月 29 日	9am	-18	-18.1	-17	-15.5	-15.4	-15.5	-14.5	-13.5	-14	-14.6
58			9pm	-11	-12.3	-10.8	-9.9	-11.8	-10.5	-11.8	-10.8	-12	-11.2
59	30	5 月 30 日	9am	-12.5	-14	-12.6	-11.4	-12.7	-11.8	-12.8	-11.7	-13.3	-12.1
60			9pm	-7.5	-7.8	-7.1	-8.2	-8	-7.4	-8	-7.9	-7.9	-9.1
61	31	5 月 31 日	9am	-9.9	-10.9	-8.9	-10.4	-10.6	-9.9	-9.5	-9.8	-10.3	-10.4
62			9pm	0.2	0.6	0.6	0.3	0.2	1	0.2	0.2	0.2	0.1
63	32	6 月 1 日	9am	-7.5	-6.5	-6.9	-7.2	-7.3	-6.4	-7	-7.2	-6.9	-7.8

64			9pm	-13.1	-12.9	-14.9	-15.2	-14.2	-14.2	-11.8	-11.8	-12.8	-11.4
65	33	6 月 2 日	9am	-15.3	-15.7	-16.9	-16.9	-16.2	-15.9	-13.4	-12.9	-14	-12.8
66			9pm	1.6	1.8	1.2	1.5	1.2	1.4	1.4	1.4	1.4	1.4
67	34	6 月 3 日	9am	0.4	0.5	0.1	0.1	0.2	0.1	0.3	0.1	0.3	0.2
68			9pm	-4.8	-4.4	-5	-4.8	-4.9	-4.9	-4.4	-4.9	-4.8	-4.9
69	35	6 月 4 日	9am	-8.9	-8.1	-9.9	-9.7	-9.8	-9.7	-8.6	-9.2	-8.7	-9.9
70			9pm	-14.6	-13.9	-16.7	-14.3	-14.9	-15.1	-13.4	-11.4	-12.1	-12.2
71	36	6 月 5 日	9am	-9.9	-9.4	-11.2	-10.9	-11	-10.8	-9.7	-9.4	-9.7	-10.3
72			9pm	2.1	2	1.9	2	2	2	2	2	2	2
73	37	6 月 6 日	9am	1.3	1.3	1.2	1.4	0.8	1.2	1.2	1.2	1.2	1.2
74			9pm	0.5	0.4	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.4
75	38	6 月 7 日	9am	-0.2	-0.2	-0.3	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
76			9pm	-3.6	-3.7	-3.8	-3.6	-3.9	-3.7	-3.8	-3.8	-3.9	-3.8
77	39	6 月 8 日	9am	-6.9	-6.6	-7.1	-6.9	-7	-6.9	-7	-7	-6.8	-7.2
78			9pm	-9.2	-8.4	-9.4	-9.3	-9.4	-9.3	-8.2	-8.3	-8.3	-8.6
79	40	6 月 9 日	9am	-9.9	-9.5	-10.9	-11.3	-10.6	-10.3	-8.9	-8.9	-9	-9.2
80			9pm	-10.4	-9.2	-10.7	-11.3	-10.6	-10.4	-9.1	-9.1	-9	-9.3
81	41	6 月 10 日	9am	-11.9	-10.7	-11.7	-12.3	-11.6	-11.8	-10.1	-9.9	-10	-10
82			9pm	1.3	1.3	1.1	1.3	0.8	1.1	1.3	1.3	1.3	1.2
83	42	6 月 11 日	9am	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.7	0.9	0.7
84			9pm	0.1	0	0	0.1	0.1	0.1	0.1	0.1	0.1	0
85	43	6 月 12 日	9am	-0.3	-0.4	-0.4	-0.4	-0.5	-0.4	-0.5	-0.5	-0.4	-0.6

86			9pm	-3.7	-3.8	-3.9	-3.7	-3.9	-3.8	-3.8	-3.8	-3.7	-3.8
87	44	6 月 13 日	9am	-5.8	-5.9	-6	-5.9	-5.9	-5.9	-5.9	-6	-5.6	-6
88			9pm	-9.3	-9.5	-9.6	-10	-9.7	-9.5	-8.2	-8.4	-8	-8.4
89	45	6 月 14 日	9am	-1.8	-1.7	-1.9	-1.7	-1.9	-1.8	-1.8	-1.8	-1.7	-1.8
90			9pm	0.7	0.5	0.4	0.6	0.5	0.5	0.5	0.5	0.5	0.5
91	46	6 月 15 日	9am	0.6	0.3	0.4	0.5	0.4	0.5	0.4	0.4	0.5	0.4
92			9pm	0.2	0	0	0	0.1	0	0	-0.1	0	0
93	47	6 月 16 日	9am	1.5	1.3	1.2	1.4	1.2	1.3	1.1	1.3	1.1	1.1
94			9pm	2	1.9	1.8	1.8	1.9	1.9	1.8	1.8	1.8	1.8
95	48	6 月 17 日	9am	1.8	1.7	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.6
96			9pm	1	1.1	1	1	1	1	1	1	1	1
97	49	6 月 18 日	9am	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
98			9pm	2.1	2	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2
99	50	6 月 19 日	9am	2.8	2.7	2.7	2.8	2.8	2.8	2.7	2.8	2.8	2.9
100			9pm	2.4	2.4	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.7
101	51	6 月 20 日	9am	2.2	2.3	2.3	2.3	2.4	2.4	2.3	2.3	2.3	2.3
102			9pm	1.9	2	2	2	2	2	2	2	2	2.1
103	52	6 月 21 日	9am	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8
104			9pm	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6
105	53	6 月 22 日	9am	1.5	1.2	1.3	1.3	1.2	1.2	1.3	1.3	1.3	1.4
106			9pm	1	0.9	0.9	1.1	1	1	1	1	1	1.1
107	54	6 月 23 日	9am	1.4	1.3	1.4	1.5	1.4	1.4	1.4	1.5	1.4	1.4

108			9pm	1.4	1.4	1.5	1.6	1.5	1.4	1.5	1.5	1.5	1.6
109	55	6 月 24 日	9am	1.3	1.2	1.3	1.4	1.3	1.3	1.3	1.3	1.3	1.3
110			9pm	0.9	0.8	0.9	1.1	0.9	0.9	0.9	0.9	0.9	1
111	56	6 月 25 日	9am	0.6	0.5	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.9
112			9pm	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.3	0.3
113	57	6 月 26 日	9am	0	-0.1	0	0	0	0	-0.2	0	0	0.1
114			9pm	-0.2	-0.3	-0.2	-0.1	-0.2	-0.2	-0.4	-0.2	-0.2	0
115	58	6 月 27 日	9am	-0.1	-0.1	0	0	-0.1	-0.1	0	-0.1	0	0
116			9pm	-0.3	-0.3	-0.3	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
117	59	6 月 28 日	9am	-0.4	-0.3	-0.3	-0.1	-0.3	-0.3	-0.3	-0.3	-0.3	-0.1
118			9pm	0.4	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.6	0.7
119	60	6 月 29 日	9am	0.4	0.4	0.5	0.6	0.5	0.6	0.6	0.6	0.7	0.7
120			9pm	2	2	2	2.1	2	2.1	2.1	2	2.1	2
121	61	6 月 30 日	9am	3.3	3.3	3.3	3.4	3.3	3.3	3.3	2.9	3	3.5
122			9pm	3.1	3	3.1	3.2	3.1	3.1	3.2	3.1	3.2	3.3
123	62	7 月 1 日	9am	2.9	2.9	2.9	3	2.9	2.8	2.9	2.9	3.1	3.1
124			9pm	3.1	3.1	3.1	3.3	3.1	3.1	3.2	3.2	3.3	3.3
125	63	7 月 2 日	9am	3.5	3.5	3.6	3.7	3.6	3.6	3.7	3.6	3.7	3.8
126			9pm	3.3	3.4	3.4	3.6	3.4	3.4	3.6	3.4	3.5	3.6
127	64	7 月 3 日	9am	3.2	3.1	3.2	3.3	3.2	3.2	3.3	3.2	3.3	3.3
128			9pm	2.8	2.9	2.9	3	2.9	3	3.1	2.9	3	3
129	65	7 月 4 日	9am	2.8	2.8	2.8	2.9	2.8	2.8	3	2.8	2.9	3.1

130			9pm	5.1	5	5.4	5.3	5.3	5.1	5.5	5.4	5.2	5.5
131	66	7 月 5 日	9am	4.9	5	5.1	5.1	5	5	5.2	5.1	5	5.2
132			9pm	5.1	5.3	5.3	5.4	5.3	5.1	5.3	5.4	5.1	5.5
133	67	7 月 6 日	9am	5.2	5.3	5.3	5.5	5.3	5.1	5.4	5.3	5.2	5.4
134			9pm	4.8	4.9	5.1	5	4.9	4.8	5.1	4.9	4.9	5.2
135	68	7 月 7 日	9am	5	5	5.1	5.1	5.1	5	5.2	5.5	5	5.3
136			9pm	4.7	4.7	5.1	4.8	4.8	4.7	5	4.9	4.9	5
137	69	7 月 8 日	9am	5	5	5.1	5.1	5.1	5	5.2	5	5	5.3
138			9pm	-0.3	-0.3	-0.2	0.1	-0.2	-0.2	0.1	-0.2	-0.1	-0.1
139	70	7 月 9 日	9am	-0.5	-0.5	-0.4	-0.4	-0.4	-0.5	-0.2	-0.5	-0.2	-0.4
140			9pm	1.3	1.2	1.3	1.2	1.2	1.2	1.6	1.2	1.3	1.4
141	71	7 月 10 日	9am	0.9	0.8	1	1	0.9	0.8	1.2	0.9	1	1.1
142			9pm	0.2	0.2	0.3	0.3	0.1	0.1	0.4	0.1	0.5	0.4
143	72	7 月 11 日	9am	0.1	-0.1	0	0	-0.1	-0.2	0.1	-0.2	0.1	0.1
144			9pm	0.1	-0.1	0	0	-0.1	-0.2	0.1	-0.2	0.1	0.1
145	73	7 月 12 日	9am	0.5	0.2	0.4	0.4	0.3	0.3	0.5	0.2	0.5	0.5
146			9pm	0.4	0.1	0.4	0.2	0.2	0.1	0.4	0	0.3	0.4
147	74	7 月 13 日	9am	0.3	0.2	0.3	0.3	0.3	0.2	0.5	0	0.4	0.3
148			9pm	0.3	-0.1	0.4	0.2	0.3	0.1	0.5	0	0.4	0.3
149	75	7 月 14 日	9am	0	-0.1	0	0	0	-0.1	0.2	-0.1	0.1	0
150			9pm	-0.5	-0.7	-0.6	-0.5	-0.7	-0.6	-0.7	-0.6	-0.4	-0.5
151	76	7 月 15 日	9am	-1.1	-1.2	-1.2	-1.3	-1.1	-1.2	-1.1	-1.1	-1.2	-1.2

152			9pm	-5.6	-4.4	-8.7	-4.6	-3.8	-3.7	-3.8	-3.8	-3.8	-3.9
153	77	7 月 16 日	9am	1	1.1	0.9	0.8	0.8	0.8	0.8	0.9	0.8	0.8
154			9pm	1.3	1.3	1.2	1.1	1.3	1.1	1.2	1.1	1.1	1
155	78	7 月 17 日	9am	1.2	1.1	1	0.8	1	0.8	1	1	0.9	0.9
156			9pm	2.3	2.1	2.1	2	2	2	2.1	2.1	2	2
157	79	7 月 18 日	9am	2	2.1	1.9	1.8	1.8	1.8	1.8	1.9	1.7	1.7
158			9pm	1.3	1.3	1.2	1.9	1.2	1.1	1	1.2	1.1	1.1
159	80	7 月 19 日	9am	1.9	1.8	1.8	1.6	1.8	1.7	1.8	1.8	1.6	1.5
160			9pm	2.4	2.3	2.3	2	2.1	2.1	2.2	2.2	2.1	2
161	81	7 月 20 日	9am	2.2	2.1	2	1.8	1.9	1.8	1.9	1.9	1.8	1.8
162			9pm	1.4	1.5	1.3	1.1	1.3	0.1	1.5	1.3	1.3	1.2
163	82	7 月 21 日	9am	1.9	1.7	1.8	1.6	1.7	1.7	1.7	1.8	1.7	1.7
164			9pm	1.1	1.1	0.9	0.7	0.8	0.9	0.9	0.9	0.9	0.8
165	83	7 月 22 日	9am	2.1	2.1	2	1.8	1.9	1.8	1.9	2	1.8	1.8
166			9pm	1.3	1.2	1.2	1	1.1	1.1	1.6	1.2	1	1
167	84	7 月 23 日	9am	1.3	2.2	2.1	2	2.1	2	2.1	2.1	1.9	1.9
168			9pm	1.4	1.4	1.3	1.1	1.2	0.1	1.2	1.3	1.1	1.1
169	85	7 月 24 日	9am	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.5	1.5
170			9pm	1.2	1.1	1	0.9	0.9	0.9	0.9	1.1	0.9	0.8
171	86	7 月 25 日	9am	1.7	1.6	1.6	1.5	1.5	1.6	1.5	1.5	1.4	1.4
172			9pm	1.2	1.1	1	0.9	1	1	1	1	0.9	0.9
173	87	7 月 26 日	9am	2	2	1.8	1.7	1.7	1.7	1.8	1.9	1.7	1.7

174			9pm	1.7	1.6	1.6	1.4	1.6	1.5	1.6	1.6	1.4	1.4
175	88	7 月 27 日	9am	1.5	1.3	1.2	1.2	1.2	1.3	1.2	1.3	1.1	1.1
176			9pm	2.6	2.5	2.4	2.2	2.3	2.3	2.3	2.3	2.2	2.2
177	89	7 月 28 日	9am	2.2	2.2	2.1	1.8	2	1.9	2	2.1	1.9	1.9
178			9pm	1.4	1.3	1.3	1	1.2	1.1	1.3	1.1	1.1	1.1
179	90	7 月 29 日	9am	1.2	1.1	1	0.8	0.8	0.8	0.9	0.9	0.8	0.7
180			9pm	1.3	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1
181	91	7 月 30 日	9am	1.8	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5
182			9pm	1.6	1.5	1.4	1.2	1.3	1.3	1.4	1.3	1.3	1.2
183	92	7 月 31 日	9am	1.4	1.3	1.2	1	1.1	1.1	1.2	1.1	1.1	1
184			9pm	0.9	0.8	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.5
185	93	8 月 1 日	9am	0.6	0.5	0.3	0.3	0.2	0.3	0.2	0.4	0.3	0.2
186			9pm	-0.2	-0.2	-0.3	-0.4	-0.3	-0.3	-0.3	-0.2	-0.4	-0.4
187	94	8 月 2 日	9am	-1	-1	-1.1	-1.2	-1.1	-1.2	-1.1	-1.1	-1.3	-1.3
188			9pm	-5.8	-5.3	-4.7	-5.1	-4.5	-4.5	-4.6	-4.4	-5	-4.5
189	95	8 月 3 日	9am	-10.8	-10.6	-9.5	-9.6	-8.7	-8.5	-8.2	-7.5	-8.3	-7.7
190			9pm	-17.3	-15.5	-14.1	-14.1	-14	-13.7	-12.8	-11.4	-12	-12.8
191	96	8 月 4 日	9am	-0.5	-0.2	-0.2	-0.3	-0.3	-0.2	-0.3	-0.3	-0.3	-0.4
192			9pm	-3.2	-3	-3.1	-3.1	-3.2	-3	-3.1	-3.1	-3.1	-3.3
193	97	8 月 5 日	9am	-10.1	-9.5	-9.9	-9.3	-8.7	-7.5	-8.5	-6.4	-7.3	-7.3
194			9pm	0.7	0.8	0.5	0.4	0.5	0.4	0.4	0.4	0.3	0.3
195	98	8 月 6 日	9am	0.3	0.2	0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3

196			9pm	-1.6	-1.5	-1.7	-1.8	-1.9	-1.8	-1.9	-1.7	-1.8	-1.9
197	99	8 月 7 日	9am	-8.2	-8.1	-6.3	-6.6	-6.4	-6.5	-5	-4.5	-4.3	-4.8
198			9pm	-16.3	-15.5	-14.8	-14.6	-14.3	-12.2	-11.8	-10.6	-9.4	-10.8
199	100	8 月 8 日	9am	0.4	0.3	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3
200			9pm	-0.3	-0.5	-0.2	-0.4	-0.3	-0.3	-0.3	-0.2	-0.4	-0.4
201	101	8 月 9 日	9am	-0.1	-0.2	0.1	-0.1	0	0	-0.1	0	-0.2	-0.1
202			9pm	-0.4	-0.6	-0.4	-0.4	-0.4	-0.4	-0.5	-0.4	-0.5	-0.5
203	102	8 月 10 日	9am	-1.3	-1.3	-1.2	-1.4	-1.3	-1.2	-1.3	-1.3	-1.3	-1.4
204			9pm	-5.8	-5.9	-5.9	-5.8	-5.8	-5.7	-5.7	-4.9	-5.2	-6

Appendix3 Moisture Sensor Data (in percentage)

Data	DAT	Date	Time	5cm	10cm	15cm	20cm
1	1	5 月 1 日	9am	44.9	46.27	43.08	42.84
2			9pm	47.3	48.44	45.14	44.22
3	2	5 月 2 日	9am	45.48	46.85	43.53	43.3
4			9pm	47.3	48.33	45.35	44.67
5	3	5 月 3 日	9am	46.51	47.86	44.33	43.98
6			9pm	46.85	48.68	45.48	45.59
7	4	5 月 4 日	9am	46.85	48.1	44.9	45.25
8			9pm	47.99	49.58	46.51	46.27
9	5	5 月 5 日	9am	47.3	49.02	46.04	46.17
10			9pm	48.02	49.69	46.73	46.82
11	6	5 月 6 日	9am	48.78	50.27	47.65	47.52
12			9pm	49.58	51.06	48.55	48.33
13	7	5 月 7 日	9am	49.24	50.5	47.86	47.99
14			9pm	49.81	51.19	48.55	48.44
15	8	5 月 8 日	9am	49.47	50.73	48.21	48.33
16			9pm	50.5	51.98	49.58	49.36
17	9	5 月 9 日	9am	49.81	50.95	48.55	48.78
18			9pm	50.84	52.21	49.81	49.77
19	10	5 月 10 日	9am	49.7	50.95	48.68	48.89
20			9pm	50.73	51.98	49.58	49.7
21	11	5 月 11 日	9am	50.5	51.64	49.24	49.36
22			9pm	50.39	51.87	49.47	49.58
23	12	5 月 12 日	9am	50.27	51.64	49.13	49.24
24			9pm	50.84	52.43	49.92	49.91
25	13	5 月 13 日	9am	49.36	51.29	48.55	48.89
26			9pm	50.73	52.56	49.7	49.81
27	14	5 月 14 日	9am	50.05	51.19	48.89	49.13
28			9pm	51.06	52.43	50.05	50.09
29	15	5 月 15 日	9am	50.05	51.29	49.02	49.36
30			9pm	51.19	52.56	50.27	50.39
31	16	5 月 16 日	9am	50.73	51.64	49.36	49.7
32			9pm	52.09	53.35	51.06	51.06

33	17	5 月 17 日	9am	51.53	52.43	50.16	50.5
34			9pm	52.6	53.93	51.75	51.64
35	18	5 月 18 日	9am	52.21	53.01	50.84	51.06
36			9pm	52.32	53.81	51.87	51.87
37	19	5 月 19 日	9am	52.21	53.12	51.06	50.95
38			9pm	52.32	53.45	51.53	51.19
39	20	5 月 20 日	9am	52.56	53.46	51.53	51.19
40			9pm	53.24	54.15	52.09	51.53
41	21	5 月 21 日	9am	53.35	54.04	51.98	51.4
42			9pm	54.02	55.18	53.35	52.09
43	22	5 月 22 日	9am	53.35	54.04	52.21	51.29
44			9pm	53.35	54.73	53.01	51.64
45	23	5 月 23 日	9am	53.01	54.04	52.32	50.84
46			9pm	53.01	54.15	52.43	50.95
47	24	5 月 24 日	9am	52.78	53.81	51.98	50.5
48			9pm	53.7	54.38	52.56	50.73
49	25	5 月 25 日	9am	53.81	54.27	52.32	50.61
50			9pm	54.38	55.29	53.59	47.94
51	26	5 月 26 日	9am	53.7	54.48	52.76	50.5
52			9pm	52.67	53.93	52.21	50.03
53	27	5 月 27 日	9am	52.67	53.46	51.75	49.58
54			9pm	53.93	55.05	53.12	50.27
55	28	5 月 28 日	9am	53.24	53.93	52.09	49.58
56			9pm	53.35	55.18	53.24	50.27
57	29	5 月 29 日	9am	51.98	53.81	51.98	49.36
58			9pm	51.87	53.68	51.75	49.24
59	30	5 月 30 日	9am	51.29	53.01	51.06	48.68
60			9pm	51.87	53.57	51.64	49.13
61	31	5 月 31 日	9am	51.98	53.12	50.95	48.55
62			9pm	52.56	54.49	52.43	49.36
63	32	6 月 1 日	9am	51.64	53.35	51.29	48.78
64			9pm	53.25	54.38	52.56	49.36
65	33	6 月 2 日	9am	52.16	53.35	51.29	48.44
66			9pm	52.88	54.04	52.67	49.81
67	34	6 月 3 日	9am	52.5	53.68	51.98	49.36

68			9pm	54.34	55.41	53.81	50.61
69	35	6 月 4 日	9am	53.37	54.49	52.78	49.8
70			9pm	53.98	55.07	53.81	49.47
71	36	6 月 5 日	9am	52.89	54.04	52.78	49.81
72			9pm	53.37	54.49	53.59	49.58
73	37	6 月 6 日	9am	52.5	53.68	52.78	49.7
74			9pm	54.33	55.4	54.38	50.5
75	38	6 月 7 日	9am	53.12	54.26	53.35	49.7
76			9pm	54.46	55.52	54.6	49.92
77	39	6 月 8 日	9am	53.61	54.73	53.68	49.13
78			9pm	53.73	54.83	53.91	48.68
79	40	6 月 9 日	9am	53	54.15	53.35	48.1
80			9pm	53.25	54.38	53.59	47.99
81	41	6 月 10 日	9am	52.5	53.68	52.9	47.3
82			9pm	53.85	54.94	54.26	47.86
83	42	6 月 11 日	9am	53.12	54.26	53.68	47.65
84			9pm	54.18	55.26	54.6	48.1
85	43	6 月 12 日	9am	53.35	54.48	53.91	47.52
86			9pm	54.83	55.86	55.18	47.76
87	44	6 月 13 日	9am	53.86	54.95	54.38	47.07
88			9pm	54.1	55.18	54.73	46.15
89	45	6 月 14 日	9am	53.25	54.38	54.04	45.81
90			9pm	53.25	54.38	54.04	45.81
91	46	6 月 15 日	9am	53.25	54.38	53.81	45.43
92			9pm	54.94	55.97	55.4	46.04
93	47	6 月 16 日	9am	54.33	55.4	54.94	45.48
94			9pm	55.44	56.44	55.75	45.7
95	48	6 月 17 日	9am	54.71	55.75	55.29	45.35
96			9pm	55.92	56.89	56.32	43.76
97	49	6 月 18 日	9am	54.94	55.97	55.52	43.19
98			9pm	55.44	56.44	55.97	41.94
99	50	6 月 19 日	9am	54.71	55.75	55.29	41.82
100			9pm	55.92	56.89	56.1	41.36
101	51	6 月 20 日	9am	55.19	56.21	55.64	41.13
102			9pm	55.92	56.89	56.21	40.91

103	52	6 月 21 日	9am	55.44	56.44	55.64	40.56
104			9pm	56.41	57.35	56.55	40.56
105	53	6 月 22 日	9am	55.8	56.78	55.98	40.11
106			9pm	56.65	57.58	56.66	40.22
107	54	6 月 23 日	9am	55.92	56.89	56.21	39.76
108			9pm	56.41	57.35	56.32	39.76
109	55	6 月 24 日	9am	55.92	56.89	55.98	39.88
110			9pm	56.77	57.69	56.66	39.31
111	56	6 月 25 日	9am	56.04	57.01	56.09	39.42
112			9pm	56.9	57.81	56.89	39.65
113	57	6 月 26 日	9am	56.4	57.34	56.32	39.41
114			9pm	56.9	57.81	56.78	38.74
115	58	6 月 27 日	9am	56.54	57.47	56.55	39.07
116			9pm	57.13	58.03	57.13	38.62
117	59	6 月 28 日	9am	56.9	57.81	56.78	38.28
118			9pm	57.5	58.37	57.34	38.28
119	60	6 月 29 日	9am	57.13	58.03	57	38.06
120			9pm	57.38	58.26	57.24	37.59
121	61	6 月 30 日	9am	56.9	57.81	56.89	38.06
122			9pm	57.38	58.26	57.24	37.93
123	62	7 月 1 日	9am	56.9	57.81	56.78	38.17
124			9pm	57.63	58.5	57.34	37.82
125	63	7 月 2 日	9am	57.13	58.03	57	37.93
126			9pm	57.86	58.72	57.58	37.71
127	64	7 月 3 日	9am	57.38	58.26	57.13	37.48
128			9pm	58.11	58.95	57.69	37.82
129	65	7 月 4 日	9am	57.75	58.61	57.34	37.48
130			9pm	58.59	59.4	58.16	33.6
131	66	7 月 5 日	9am	58.11	58.95	57.58	37.37
132			9pm	58.48	59.29	57.92	37.25
133	67	7 月 6 日	9am	58.11	58.95	57.58	37.48
134			9pm	58.48	59.29	57.92	37.25
135	68	7 月 7 日	9am	58.11	58.95	57.58	37.37
136			9pm	58.36	59.18	57.81	37.48
137	69	7 月 8 日	9am	58	58.84	57.47	37.82

138			9pm	58	58.84	57.47	37.82
139	70	7 月 9 日	9am	58.48	59.29	57.81	37.14
140			9pm	58.48	59.29	57.92	37.14
141	71	7 月 10 日	9am	58.23	59.06	57.58	37.71
142			9pm	59.07	59.85	58.26	36.45
143	72	7 月 11 日	9am	58.48	59.29	57.81	36.9
144			9pm	58.96	59.75	58.16	36.69
145	73	7 月 12 日	9am	58.71	59.51	58.03	37.03
146			9pm	59.07	59.85	58.26	36.79
147	74	7 月 13 日	9am	58.84	59.64	58.03	37.14
148			9pm	58.59	59.4	57.81	37.37
149	75	7 月 14 日	9am	58.36	59.18	57.58	37.03
150			9pm	59.44	60.2	58.16	36.56
151	76	7 月 15 日	9am	47.64	65.23	58.03	36.45
152			9pm	48.21	63.86	58.38	36.45
153	77	7 月 16 日	9am	48.78	64.66	58.26	36.45
154			9pm	49.7	60.89	58.72	36.68
155	78	7 月 17 日	9am	49.7	63.86	58.61	36.45
156			9pm	50.5	65.8	59.06	36.11
157	79	7 月 18 日	9am	50.27	62.15	58.72	36
158			9pm	51.3	62.37	59.29	35.77
159	80	7 月 19 日	9am	50.5	60.78	58.95	35.65
160			9pm	51.18	61.57	59.63	35.54
161	81	7 月 20 日	9am	50.95	61.12	59.29	35.42
162			9pm	51.41	61.46	59.75	35.31
163	82	7 月 21 日	9am	51.3	61.23	59.52	35.31
164			9pm	50.95	61.69	59.98	35.2
165	83	7 月 22 日	9am	51.18	61.35	59.63	35.31
166			9pm	49.81	61.8	60.09	34.51
167	84	7 月 23 日	9am	50.27	61.57	59.75	34.97
168			9pm	47.07	62.49	60.2	34.51
169	85	7 月 24 日	9am	47.53	62.15	59.98	35.08
170			9pm	46.62	62.37	60.32	34.62
171	86	7 月 25 日	9am	45.36	62.15	59.98	35.31
172			9pm	45.02	62.37	60.32	35.08

173	87	7 月 26 日	9am	44.9	62.03	59.98	35.2
174			9pm	44.67	62.37	60.32	34.85
175	88	7 月 27 日	9am	44.67	62.03	59.98	35.08
176			9pm	44.1	62.37	60.32	35.08
177	89	7 月 28 日	9am	44.1	62.15	60.09	35.42
178			9pm	42.62	62.37	60.32	35.08
179	90	7 月 29 日	9am	43.08	62.15	60.09	35.88
180			9pm	43.19	62.03	59.98	35.54
181	91	7 月 30 日	9am	43.53	61.92	59.86	36
182			9pm	48.1	62.15	59.98	35.31
183	92	7 月 31 日	9am	48.56	62.26	59.86	35.2
184			9pm	47.76	62.15	60.2	34.62
185	93	8 月 1 日	9am	47.64	62.37	60.09	34.62
186			9pm	47.41	62.15	60.32	34.62
187	94	8 月 2 日	9am	47.3	62.03	60.2	34.62
188			9pm	46.96	61.92	60.2	35.54
189	95	8 月 3 日	9am	35.57	62.15	60.09	34.97
190			9pm	30.42	62.26	59.98	33.71
191	96	8 月 4 日	9am	39.31	61.8	59.98	48.1
192			9pm	40.56	61.92	60.2	47.87
193	97	8 月 5 日	9am	37.32	61.8	59.98	47.87
194			9pm	37.14	61.57	59.98	33.71
195	98	8 月 6 日	9am	40.79	61.46	59.86	34.17
196			9pm	42.16	61.57	59.98	33.83
197	99	8 月 7 日	9am	42.5	61.35	59.75	34.17
198			9pm	33.55	60.78	59.4	33.14
199	100	8 月 8 日	9am	36.57	61	59.4	33.71
200			9pm	38.96	61.12	59.63	33.48
201	101	8 月 9 日	9am	39.99	60.89	59.52	33.71
202			9pm	40.56	61	59.52	33.71
203	102	8 月 10 日	9am	41.36	60.89	59.4	33.71
204			9pm	41.36	60.66	59.29	33.48

Appendix4 Tensiometer Data (Kilo Pascal)

Data	DAT	Date	Time	5cm	10cm	15cm	20cm
1	1	5 月 1 日	9am	0	0	0	0
2			9pm	0	0	0	0
3	2	5 月 2 日	9am	0	0	0	0
4			9pm	0	0	0	0
5	3	5 月 3 日	9am	0	0	0	0
6			9pm	0	0	0	0
7	4	5 月 4 日	9am	0	0	0	0
8			9pm	0	0	0	0
9	5	5 月 5 日	9am	0	0	0	0
10			9pm	0	0	0	0
11	6	5 月 6 日	9am	0	0	0	0
12			9pm	0	0	0	0
13	7	5 月 7 日	9am	0	0	0	0
14			9pm	0	0	0	0
15	8	5 月 8 日	9am	0	0	0	0
16			9pm	0	0	0	0
17	9	5 月 9 日	9am	0	0	0	0
18			9pm	0	0	0	0
19	10	5 月 10 日	9am	0	0	0	0
20			9pm	0	0	0	0
21	11	5 月 11 日	9am	0	0	0	0
22			9pm	0	0	0	0
23	12	5 月 12 日	9am	0	0	0	0
24			9pm	0	0	0	0
25	13	5 月 13 日	9am	0	0	0	0
26			9pm	0	0	0	0
27	14	5 月 14 日	9am	0	0	0	0
28			9pm	0	0	0	0
29	15	5 月 15 日	9am	0	0	0	0
30			9pm	0	0	0	0
31	16	5 月 16 日	9am	0	0	0	0
32			9pm	0	0	0	0

33	17	5 月 17 日	9am	0	0	0	0
34			9pm	0	0	0	0
35	18	5 月 18 日	9am	0	0	0	0
36			9pm	0	0	0	0
37	19	5 月 19 日	9am	0	0	0	0
38			9pm	0	0	0	0
39	20	5 月 20 日	9am	0	0	0	0
40			9pm	0	0	0	0
41	21	5 月 21 日	9am	0	0	0	0
42			9pm	0	0	0	0
43	22	5 月 22 日	9am	-2	0	0	0
44			9pm	-4	-2	-2	0
45	23	5 月 23 日	9am	-4	-2	-2	0
46			9pm	0	0	0	0
47	24	5 月 24 日	9am	0	0	0	0
48			9pm	0	0	0	0
49	25	5 月 25 日	9am	0	0	0	0
50			9pm	-2	0	0	0
51	26	5 月 26 日	9am	-4	0	0	0
52			9pm	-4	-2	-2	0
53	27	5 月 27 日	9am	0	0	0	0
54			9pm	-4	-2	-2	0
55	28	5 月 28 日	9am	-5	-2	-2	0
56			9pm	-7	-5	-5	-2
57	29	5 月 29 日	9am	-8	-6	-6	-5
58			9pm	-5	-2	-2	0
59	30	5 月 30 日	9am	-7	-4	-4	0
60			9pm	0	0	0	0
61	31	5 月 31 日	9am	0	0	0	0
62			9pm	0	0	0	0
63	32	6 月 1 日	9am	0	0	0	0
64			9pm	-12	-8	-8	-4
65	33	6 月 2 日	9am	-12	-8	-8	-5
66			9pm	0	0	0	0
67	34	6 月 3 日	9am	0	0	0	0

68			9pm	0	0	0	0
69	35	6 月 4 日	9am	0	0	0	0
70			9pm	-14	-7	-7	-2
71	36	6 月 5 日	9am	0	0	0	0
72			9pm	0	0	0	0
73	37	6 月 6 日	9am	0	0	0	0
74			9pm	0	0	0	0
75	38	6 月 7 日	9am	0	0	0	0
76			9pm	0	0	0	0
77	39	6 月 8 日	9am	0	0	0	0
78			9pm	-2	0	0	0
79	40	6 月 9 日	9am	-4	0	0	0
80			9pm	-5	-2	-2	0
81	41	6 月 10 日	9am	-4	0	0	0
82			9pm	0	0	0	0
83	42	6 月 11 日	9am	0	0	0	0
84			9pm	0	0	0	0
85	43	6 月 12 日	9am	0	0	0	0
86			9pm	0	0	0	0
87	44	6 月 13 日	9am	0	0	0	0
88			9pm	0	0	0	0
89	45	6 月 14 日	9am	0	0	0	0
90			9pm	0	0	0	0
91	46	6 月 15 日	9am	0	0	0	0
92			9pm	0	0	0	0
93	47	6 月 16 日	9am	0	0	0	0
94			9pm	0	0	0	0
95	48	6 月 17 日	9am	0	0	0	0
96			9pm	0	0	0	0
97	49	6 月 18 日	9am	0	0	0	0
98			9pm	0	0	0	0
99	50	6 月 19 日	9am	0	0	0	0
100			9pm	0	0	0	0
101	51	6 月 20 日	9am	0	0	0	0
102			9pm	0	0	0	0

103	52	6 月 21 日	9am	0	0	0	0
104			9pm	0	0	0	0
105	53	6 月 22 日	9am	0	0	0	0
106			9pm	0	0	0	0
107	54	6 月 23 日	9am	0	0	0	0
108			9pm	0	0	0	0
109	55	6 月 24 日	9am	0	0	0	0
110			9pm	0	0	0	0
111	56	6 月 25 日	9am	0	0	0	0
112			9pm	0	0	0	0
113	57	6 月 26 日	9am	0	0	0	0
114			9pm	0	0	0	0
115	58	6 月 27 日	9am	0	0	0	0
116			9pm	0	0	0	0
117	59	6 月 28 日	9am	0	0	0	0
118			9pm	0	0	0	0
119	60	6 月 29 日	9am	0	0	0	0
120			9pm	0	0	0	0
121	61	6 月 30 日	9am	0	0	0	0
122			9pm	0	0	0	0
123	62	7 月 1 日	9am	0	0	0	0
124			9pm	0	0	0	0
125	63	7 月 2 日	9am	0	0	0	0
126			9pm	0	0	0	0
127	64	7 月 3 日	9am	0	0	0	0
128			9pm	0	0	0	0
129	65	7 月 4 日	9am	0	0	0	0
130			9pm	0	0	0	0
131	66	7 月 5 日	9am	0	0	0	0
132			9pm	0	0	0	0
133	67	7 月 6 日	9am	0	0	0	0
134			9pm	0	0	0	0
135	68	7 月 7 日	9am	0	0	0	0
136			9pm	0	0	0	0
137	69	7 月 8 日	9am	0	0	0	0

138			9pm	0	0	0	0
139	70	7 月 9 日	9am	0	0	0	0
140			9pm	0	0	0	0
141	71	7 月 10 日	9am	0	0	0	0
142			9pm	0	0	0	0
143	72	7 月 11 日	9am	0	0	0	0
144			9pm	0	0	0	0
145	73	7 月 12 日	9am	0	0	0	0
146			9pm	0	0	0	0
147	74	7 月 13 日	9am	0	0	0	0
148			9pm	0	0	0	0
149	75	7 月 14 日	9am	0	0	0	0
150			9pm	0	0	0	0
151	76	7 月 15 日	9am	0	0	0	0
152			9pm	0	0	0	0
153	77	7 月 16 日	9am	0	0	0	0
154			9pm	0	0	0	0
155	78	7 月 17 日	9am	0	0	0	0
156			9pm	0	0	0	0
157	79	7 月 18 日	9am	0	0	0	0
158			9pm	0	0	0	0
159	80	7 月 19 日	9am	0	0	0	0
160			9pm	0	0	0	0
161	81	7 月 20 日	9am	0	0	0	0
162			9pm	0	0	0	0
163	82	7 月 21 日	9am	0	0	0	0
164			9pm	0	0	0	0
165	83	7 月 22 日	9am	0	0	0	0
166			9pm	0	0	0	0
167	84	7 月 23 日	9am	0	0	0	0
168			9pm	0	0	0	0
169	85	7 月 24 日	9am	0	0	0	0
170			9pm	0	0	0	0
171	86	7 月 25 日	9am	0	0	0	0
172			9pm	0	0	0	0

173	87	7 月 26 日	9am	0	0	0	0
174			9pm	0	0	0	0
175	88	7 月 27 日	9am	0	0	0	0
176			9pm	0	0	0	0
177	89	7 月 28 日	9am	0	0	0	0
178			9pm	0	0	0	0
179	90	7 月 29 日	9am	0	0	0	0
180			9pm	0	0	0	0
181	91	7 月 30 日	9am	0	0	0	0
182			9pm	0	0	0	0
183	92	7 月 31 日	9am	0	0	0	0
184			9pm	0	0	0	0
185	93	8 月 1 日	9am	0	0	0	0
186			9pm	0	0	0	0
187	94	8 月 2 日	9am	0	0	0	0
188			9pm	0	0	0	0
189	95	8 月 3 日	9am	-2	0	0	0
190			9pm	-4	-2	-2	0
191	96	8 月 4 日	9am	0	0	0	0
192			9pm	0	0	0	0
193	97	8 月 5 日	9am	-2	0	0	0
194			9pm	0	0	0	0
195	98	8 月 6 日	9am	0	0	0	0
196			9pm	0	0	0	0
197	99	8 月 7 日	9am	-2	0	0	0
198			9pm	-7	-4	-4	-2
199	100	8 月 8 日	9am	0	0	0	0
200			9pm	0	0	0	0
201	101	8 月 9 日	9am	0	0	0	0
202			9pm	0	0	0	0
203	102	8 月 10 日	9am	0	0	0	0
204			9pm	0	0	0	0

Appendix5 Hioki Meter Data (in cm)

Data	DAT	Date	Time	Hioki Meter
1	1	5 月 1 日	9am	0.460249
2			9pm	-0.28449
3	2	5 月 2 日	9am	-0.65686
4			9pm	0.460249
5	3	5 月 3 日	9am	-0.09831
6			9pm	-2.14634
7	4	5 月 4 日	9am	-5.1253
8			9pm	0.460249
9	5	5 月 5 日	9am	-0.28449
10			9pm	-4.00819
11	6	5 月 6 日	9am	-5.1253
12			9pm	0.274064
13	7	5 月 7 日	9am	-0.28449
14			9pm	0.274064
15	8	5 月 8 日	9am	-0.09831
16			9pm	0.646435
17	9	5 月 9 日	9am	0.460249
18			9pm	0.087879
19	10	5 月 10 日	9am	-0.09831
20			9pm	0.83262
21	11	5 月 11 日	9am	0.460249
22			9pm	-0.28449
23	12	5 月 12 日	9am	5.301061
24			9pm	5.114876
25	13	5 月 13 日	9am	4.370136
26			9pm	3.625396
27	14	5 月 14 日	9am	3.06684
28			9pm	2.508285
29	15	5 月 15 日	9am	1.94973
30			9pm	1.391175
31	16	5 月 16 日	9am	0.83262
32			9pm	-0.28449

33	17	5 月 17 日	9am	-1.4016
34			9pm	-8.849
35	18	5 月 18 日	9am	-10.3385
36			9pm	-17.2273
37	19	5 月 19 日	9am	-19.6477
38			9pm	-12.5727
39	20	5 月 20 日	9am	-7.73189
40			9pm	1.94973
41	21	5 月 21 日	9am	-3.44964
42			9pm	-11.0832
43	22	5 月 22 日	9am	-14.6207
44			9pm	-18.5306
45	23	5 月 23 日	9am	-20.0201
46			9pm	0.460249
47	24	5 月 24 日	9am	1.763545
48			9pm	1.20499
49	25	5 月 25 日	9am	-8.10426
50			9pm	-14.8069
51	26	5 月 26 日	9am	-17.4135
52			9pm	-23.3714
53	27	5 月 27 日	9am	-9.59374
54			9pm	-14.4346
55	28	5 月 28 日	9am	-17.5997
56			9pm	-21.882
57	29	5 月 29 日	9am	-25.0471
58			9pm	-20.0201
59	30	5 月 30 日	9am	-21.6958
60			9pm	-14.6207
61	31	5 月 31 日	9am	-18.1583
62			9pm	0.460249
63	32	6 月 1 日	9am	-13.3174
64			9pm	-21.882
65	33	6 月 2 日	9am	-23.93
66			9pm	2.69447
67	34	6 月 3 日	9am	0.274064

68			9pm	-9.03519
69	35	6 月 4 日	9am	-17.0411
70			9pm	-21.1372
71	36	6 月 5 日	9am	-17.4135
72			9pm	3.811581
73	37	6 月 6 日	9am	2.3221
74			9pm	0.646435
75	38	6 月 7 日	9am	-0.47068
76			9pm	-6.98715
77	39	6 月 8 日	9am	-12.9451
78			9pm	-15.3655
79	40	6 月 9 日	9am	-16.4826
80			9pm	-16.855
81	41	6 月 10 日	9am	-18.3444
82			9pm	2.508285
83	42	6 月 11 日	9am	1.391175
84			9pm	0.274064
85	43	6 月 12 日	9am	-0.84305
86			9pm	-6.98715
87	44	6 月 13 日	9am	-11.0832
88			9pm	-15.5517
89	45	6 月 14 日	9am	-3.26345
90			9pm	1.018805
91	46	6 月 15 日	9am	0.83262
92			9pm	-0.09831
93	47	6 月 16 日	9am	2.508285
94			9pm	3.439211
95	48	6 月 17 日	9am	3.06684
96			9pm	1.94973
97	49	6 月 18 日	9am	1.391175
98			9pm	3.997766
99	50	6 月 19 日	9am	5.301061
100			9pm	4.742506
101	51	6 月 20 日	9am	4.370136
102			9pm	3.625396

103	52	6 月 21 日	9am	3.439211
104			9pm	2.880655
105	53	6 月 22 日	9am	2.508285
106			9pm	2.135915
107	54	6 月 23 日	9am	2.880655
108			9pm	3.06684
109	55	6 月 24 日	9am	2.69447
110			9pm	2.135915
111	56	6 月 25 日	9am	1.20499
112			9pm	0.646435
113	57	6 月 26 日	9am	0.087879
114			9pm	-0.09831
115	58	6 月 27 日	9am	0.087879
116			9pm	-0.28449
117	59	6 月 28 日	9am	-0.09831
118			9pm	1.20499
119	60	6 月 29 日	9am	1.20499
120			9pm	3.997766
121	61	6 月 30 日	9am	6.418172
122			9pm	6.045802
123	62	7 月 1 日	9am	5.673431
124			9pm	6.231987
125	63	7 月 2 日	9am	6.976727
126			9pm	6.790542
127	64	7 月 3 日	9am	6.231987
128			9pm	5.673431
129	65	7 月 4 日	9am	5.487246
130			9pm	9.955688
131	66	7 月 5 日	9am	9.583318
132			9pm	10.14187
133	67	7 月 6 日	9am	10.32806
134			9pm	9.397133
135	68	7 月 7 日	9am	9.583318
136			9pm	9.024763
137	69	7 月 8 日	9am	9.583318

138			9pm	0.274064
139	70	7 月 9 日	9am	-0.65686
140			9pm	2.3221
141	71	7 月 10 日	9am	1.94973
142			9pm	0.646435
143	72	7 月 11 日	9am	0.087879
144			9pm	0.087879
145	73	7 月 12 日	9am	0.83262
146			9pm	0.460249
147	74	7 月 13 日	9am	0.646435
148			9pm	0.460249
149	75	7 月 14 日	9am	0.087879
150			9pm	-0.84305
151	76	7 月 15 日	9am	-1.96016
152			9pm	-6.98715
153	77	7 月 16 日	9am	1.763545
154			9pm	2.135915
155	78	7 月 17 日	9am	1.94973
156			9pm	3.997766
157	79	7 月 18 日	9am	3.625396
158			9pm	2.3221
159	80	7 月 19 日	9am	3.439211
160			9pm	4.183951
161	81	7 月 20 日	9am	3.625396
162			9pm	2.508285
163	82	7 月 21 日	9am	3.439211
164			9pm	1.763545
165	83	7 月 22 日	9am	3.811581
166			9pm	2.3221
167	84	7 月 23 日	9am	3.997766
168			9pm	2.508285
169	85	7 月 24 日	9am	3.253026
170			9pm	2.135915
171	86	7 月 25 日	9am	2.880655
172			9pm	1.94973

173	87	7 月 26 日	9am	3.625396
174			9pm	3.06684
175	88	7 月 27 日	9am	2.508285
176			9pm	4.370136
177	89	7 月 28 日	9am	3.997766
178			9pm	2.135915
179	90	7 月 29 日	9am	1.763545
180			9pm	2.135915
181	91	7 月 30 日	9am	3.06684
182			9pm	2.508285
183	92	7 月 31 日	9am	2.135915
184			9pm	1.391175
185	93	8 月 1 日	9am	0.83262
186			9pm	-0.28449
187	94	8 月 2 日	9am	-1.96016
188			9pm	-8.10426
189	95	8 月 3 日	9am	-13.876
190			9pm	-21.1372
191	96	8 月 4 日	9am	-0.47068
192			9pm	-5.68386
193	97	8 月 5 日	9am	-11.828
194			9pm	0.83262
195	98	8 月 6 日	9am	-0.28449
196			9pm	-3.07727
197	99	8 月 7 日	9am	-8.29045
198			9pm	-19.6477
199	100	8 月 8 日	9am	0.83262
200			9pm	-0.28449
201	101	8 月 9 日	9am	0.087879
202			9pm	-0.65686
203	102	8 月 10 日	9am	-2.33253
204			9pm	-9.03519

Appendix6 Temperature Sensor Data (in centrigrade)

Data	DAT	Date	Time	5cm	10cm	15cm	20cm
1	1	5 月 1 日	9am	12	17.8	11.5	8.5
2			9pm	15.8	19.7	15.2	10.8
3	2	5 月 2 日	9am	12.4	17.7	11.9	8.9
4			9pm	16.3	20.7	15.5	11.2
5	3	5 月 3 日	9am	13.6	19.3	12.8	9.6
6			9pm	16.3	22.1	15.9	11.8
7	4	5 月 4 日	9am	15.3	20.9	14.1	10.3
8			9pm	17.9	23.3	16.9	12.8
9	5	5 月 5 日	9am	15.7	21.7	15.5	11.6
10			9pm	18	24.6	17.5	13.9
11	6	5 月 6 日	9am	17.6	22.9	17.4	12.9
12			9pm	19.4	24.6	19.2	15
13	7	5 月 7 日	9am	17.9	23.1	17.1	13.2
14			9pm	18.7	23.6	18	13.8
15	8	5 月 8 日	9am	17.4	22.8	16.7	12.9
16			9pm	19.4	24.8	19.3	15.1
17	9	5 月 9 日	9am	17.1	22.7	16.5	12.7
18			9pm	19.3	24.7	19	14.8
19	10	5 月 10 日	9am	15.7	22.1	15.8	12.1
20			9pm	18.1	23.8	17.7	13.6
21	11	5 月 11 日	9am	17	22.9	16.5	12.6
22			9pm	16.5	22.7	16.4	23.2
23	12	5 月 12 日	9am	15.7	22.2	15.2	22.5
24			9pm	17.1	23.8	16.8	19
25	13	5 月 13 日	9am	13.1	21.3	13.4	14.3
26			9pm	16.2	23.2	15.9	18
27	14	5 月 14 日	9am	13.9	21.6	13.6	15.4
28			9pm	16.3	23.4	16	17.5
29	15	5 月 15 日	9am	13.5	21.5	13.4	14.8
30			9pm	16.1	23.4	16.1	16.6
31	16	5 月 16 日	9am	14.3	21.9	13.6	15.9
32			9pm	18	24.5	17.2	19.9

33	17	5 月 17 日	9am	15.7	22.9	14.9	17.5
34			9pm	18.7	25.3	18.2	19
35	18	5 月 18 日	9am	17.2	23.8	15.9	18.3
36			9pm	18.1	25.1	18.2	20.9
37	19	5 月 19 日	9am	17.1	23.9	16.1	17.5
38			9pm	17.4	24.3	16.9	19
39	20	5 月 20 日	9am	17.4	24.1	16.5	19
40			9pm	18.9	25.1	17.9	20.6
41	21	5 月 21 日	9am	18.4	24.7	17.2	21.2
42			9pm	21.2	27.3	20.5	21.3
43	22	5 月 22 日	9am	18	25	17.3	19.9
44			9pm	19.4	26.4	19.5	20
45	23	5 月 23 日	9am	17.4	24.9	17.3	23.5
46			9pm	17.2	24.8	17.3	24.1
47	24	5 月 24 日	9am	16.1	24	16	21.5
48			9pm	18.1	25	17.1	22.7
49	25	5 月 25 日	9am	17.8	24.7	16.6	28.6
50			9pm	20	27	19.6	22.6
51	26	5 月 26 日	9am	17.7	25.4	17.4	20.1
52			9pm	15.1	24.1	15.9	18.6
53	27	5 月 27 日	9am	14.3	23.2	14.3	20.2
54			9pm	18	25.7	17.8	24.9
55	28	5 月 28 日	9am	15.3	23.8	15	17.9
56			9pm	18	25.9	18.1	16
57	29	5 月 29 日	9am	14.2	23.5	14.8	11.1
58			9pm	13.8	23.3	14.5	10.8
59	30	5 月 30 日	9am	12.3	22.3	12.8	9.2
60			9pm	13.6	23.1	14	10.1
61	31	5 月 31 日	9am	13	22.2	12.2	8.5
62			9pm	16.5	24.3	16	11.8
63	32	6 月 1 日	9am	13.5	22.4	13.1	9.7
64			9pm	15.4	24.1	16	11.9
65	33	6 月 2 日	9am	13.9	22.3	12.9	9.2
66			9pm	16.9	24.9	17.1	13.2
67	34	6 月 3 日	9am	15.7	23.3	14.6	10.6

68			9pm	19.2	26.1	18.9	14.7
69	35	6 月 4 日	9am	17.4	24.3	16.2	12.2
70			9pm	19.3	26.3	19.3	14.6
71	36	6 月 5 日	9am	16.9	24.1	16.6	12.3
72			9pm	18.1	25.3	18.6	14
73	37	6 月 6 日	9am	16.7	23.8	16.2	12
74			9pm	20.7	26.8	20.3	15.7
75	38	6 月 7 日	9am	18.4	24.6	17.5	13
76			9pm	20.6	26.9	20.8	16.1
77	39	6 月 8 日	9am	18.6	25	18.3	13.7
78			9pm	18.3	25.2	18.7	14.1
79	40	6 月 9 日	9am	17.2	24.3	17.9	12.9
80			9pm	17.8	24.8	18.7	13.5
81	41	6 月 10 日	9am	17.2	23.8	17.3	12.2
82			9pm	20.1	26.2	20.2	15.2
83	42	6 月 11 日	9am	18.5	24.7	18.8	13.6
84			9pm	21	26.8	21.1	16
85	43	6 月 12 日	9am	19.7	25.2	19.3	13.9
86			9pm	22.1	27.7	22.3	17.4
87	44	6 月 13 日	9am	19.9	25.6	20.2	15.1
88			9pm	20.3	26.5	21.4	16.2
89	45	6 月 14 日	9am	18.4	24.7	19.6	14.6
90			9pm	18.4	24.5	19.4	14.4
91	46	6 月 15 日	9am	19.1	24.4	18.8	13.8
92			9pm	23.5	28.1	22.6	17.7
93	47	6 月 16 日	9am	21.4	26.2	21.1	16.4
94			9pm	24.5	28.5	23.6	18.5
95	48	6 月 17 日	9am	22.5	27.1	21.8	17.3
96			9pm	25.6	29.9	25.2	20.2
97	49	6 月 18 日	9am	22.8	27.4	22.9	17.8
98			9pm	23.3	28.1	24.3	18.8
99	50	6 月 19 日	9am	21.3	26.2	22.2	16.9
100			9pm	24.6	28.9	24.8	19.4
101	51	6 月 20 日	9am	22.5	27.1	22.8	17.6
102			9pm	24.2	28.6	24.6	19.3

103	52	6 月 21 日	9am	22.4	27.1	22.9	17.7
104			9pm	25.4	29.4	25.3	19.9
105	53	6 月 22 日	9am	23	27.4	23.4	18.2
106			9pm	25.5	29.4	25.6	20.1
107	54	6 月 23 日	9am	22.8	27.1	23.6	18.2
108			9pm	23.7	27.8	24	18.6
109	55	6 月 24 日	9am	22.3	26.8	22.9	17.7
110			9pm	24.8	28.9	25.2	19.9
111	56	6 月 25 日	9am	22.3	26.7	22.8	17.7
112			9pm	24.9	29	25.5	20.2
113	57	6 月 26 日	9am	23.3	27.3	23.5	18.2
114			9pm	24.2	28.2	24.7	19.4
115	58	6 月 27 日	9am	23.3	27	23.7	18.4
116			9pm	25.3	28.8	25.5	20.1
117	59	6 月 28 日	9am	24.2	27.5	24.4	19
118			9pm	26.1	29.1	26.3	20.8
119	60	6 月 29 日	9am	24.3	27.5	24.8	19.3
120			9pm	25	28.2	25.5	20.1
121	61	6 月 30 日	9am	23.2	26.6	24	18.7
122			9pm	25.1	28.2	25.1	19.7
123	62	7 月 1 日	9am	23.2	26.8	23.8	18.5
124			9pm	25.5	28.1	25.4	19.9
125	63	7 月 2 日	9am	23.6	26.5	24.1	15.5
126			9pm	26.1	28.6	26.1	20.4
127	64	7 月 3 日	9am	24	27.1	24.5	19.1
128			9pm	26.2	28.8	26.3	20.7
129	65	7 月 4 日	9am	24.4	27.2	24.9	19.2
130			9pm	25.4	28.4	24.3	19.7
131	66	7 月 5 日	9am	24.1	27.2	25.4	19.9
132			9pm	26.3	28.5	26.4	20.7
133	67	7 月 6 日	9am	24.4	26.9	25	19.3
134			9pm	26.4	28.5	26.1	20.4
135	68	7 月 7 日	9am	24.4	26.8	25.1	19.4
136			9pm	25	27.3	25.3	19.6
137	69	7 月 8 日	9am	23.8	26.3	24.2	18.6

138			9pm	27	28.8	26.6	20.9
139	70	7 月 9 日	9am	24.7	27.1	24.9	19.3
140			9pm	24.2	26.8	24.9	19.4
141	71	7 月 10 日	9am	23.3	26.3	23.6	18.4
142			9pm	25.9	28.3	26	20.4
143	72	7 月 11 日	9am	23.6	26.6	24.1	18.7
144			9pm	24.7	27.1	25	19.4
145	73	7 月 12 日	9am	24	26.7	24.2	18.8
146			9pm	24.8	27.3	24.9	31.1
147	74	7 月 13 日	9am	23.4	26.3	24.1	18.5
148			9pm	21.8	25.5	22.9	17.6
149	75	7 月 14 日	9am	21	24.5	21.6	16.3
150			9pm	24.3	27.1	24.1	18.7
151	76	7 月 15 日	9am	23.5	26.5	28.1	22.9
152			9pm	24.3	27.2	26.2	21
153	77	7 月 16 日	9am	23.8	26.8	27.6	22.4
154			9pm	25.4	28.0	25.6	20.4
155	78	7 月 17 日	9am	24.5	27.3	27.3	22.1
156			9pm	25.7	28.4	25.8	20.6
157	79	7 月 18 日	9am	24.5	27.4	27.2	22
158			9pm	26.5	28.9	26	20.8
159	80	7 月 19 日	9am	25.1	27.8	26.5	21.3
160			9pm	27.5	29.5	25.1	19.9
161	81	7 月 20 日	9am	25.7	28.2	24.5	19.3
162			9pm	27.6	29.6	24.2	19
163	82	7 月 21 日	9am	26.4	28.7	25.4	20.2
164			9pm	27.9	30.0	25.1	19.9
165	83	7 月 22 日	9am	26.2	28.6	26.5	21.3
166			9pm	28.2	30.1	25.6	20.4
167	84	7 月 23 日	9am	26.8	29.0	26.7	21.5
168			9pm	28.3	30.3	25.8	20.6
169	85	7 月 24 日	9am	26.9	29.2	25.9	20.7
170			9pm	28.5	30.4	25.2	20
171	86	7 月 25 日	9am	26.5	28.9	25.9	20.7
172			9pm	27.9	30.0	25.4	20.2

173	87	7 月 26 日	9am	25.9	28.6	26.1	20.9
174			9pm	27.6	29.5	25.6	20.4
175	88	7 月 27 日	9am	26.0	28.6	26	20.8
176			9pm	27.5	29.8	25.5	20.3
177	89	7 月 28 日	9am	26.3	28.8	25.8	20.6
178			9pm	26.8	29.5	24.7	19.5
179	90	7 月 29 日	9am	25.3	28.2	25	19.8
180			9pm	24.7	27.8	25	19.8
181	91	7 月 30 日	9am	24.4	27.1	25.6	20.4
182			9pm	25.6	28.2	24.3	19.1
183	92	7 月 31 日	9am	25.3	27.9	24.8	19.6
184			9pm	26.8	29.0	24.5	19.3
185	93	8 月 1 日	9am	25.8	28.2	25.1	19.9
186			9pm	27.0	29.4	28.9	23.7
187	94	8 月 2 日	9am	26.1	28.6	28.2	23
188			9pm	26.2	28.8	28.4	23.2
189	95	8 月 3 日	9am	25.4	28.2	27.8	22.6
190			9pm	26.2	29.0	28.6	23.4
191	96	8 月 4 日	9am	25.7	28.2	27.9	22.7
192			9pm	26.3	29.0	28.6	23.4
193	97	8 月 5 日	9am	25.8	28.4	28.0	22.8
194			9pm	26.3	29.0	28.6	23.4
195	98	8 月 6 日	9am	25.7	28.3	27.9	22.7
196			9pm	26.0	28.9	28.5	23.3
197	99	8 月 7 日	9am	24.9	27.9	27.6	22.4
198			9pm	25.2	28.4	28.0	22.8
199	100	8 月 8 日	9am	25.2	28.1	27.8	22.6
200			9pm	25.8	28.8	28.4	23.2
201	101	8 月 9 日	9am	24.5	27.4	27.0	21.8
202			9pm	25.0	28.1	27.7	22.5
203	102	8 月 10 日	9am	24.7	27.7	27.4	22.2
204			9pm	25.3	28.4	28.0	22.8

Appendix7 7 Lowest Point of water Tube (in cm)

No. obser	5A	5B	7.5A	7.5B	10A	10B	12.5A	12.5B	15A	15B
1	-18	-18.1	-17	-16.9	-16.2	-15.9	-14.5	-13.5	-14	-14.6
2	-17.3	-16.6	-16.9	-15.5	-15.4	-15.5	-13.4	-12.9	-14	-14
3	-16.5	-15.7	-16.7	-15.5	-14.9	-15.4	-13.4	-12.6	-13.3	-12.8
4	-16.3	-15.5	-15	-15.2	-14.4	-15.1	-13	-11.8	-12.8	-12.8
5	-15.5	-15.5	-14.9	-14.6	-14.3	-14.2	-12.8	-11.8	-12.7	-12.8
6	-15.3	-15.1	-14.8	-14.3	-14.2	-13.7	-12.8	-11.7	-12.1	-12.2
7	-15	-14.6	-14.1	-14.1	-14	-13	-12.6	-11.4	-12	-12.1
Mean	-16.27	-15.87	-15.63	-15.16	-14.77	-14.69	-13.21	-12.24	-12.99	-13.04

Appendix 8 Plant Growth Data (Random sampling of 13 plants)

Data No	DAT	Date	Plant Observation				
			Plant Height (cm)	No. of Tiller/ Shoot	Longest Leaf (cm)	No of Leaf	Leaf Color
1	10	10.05. 2010	10.34	2	7.5	6	3
2	17	17.05.2010	11.59	2	9.5	8.08	3
3	25	25.05.2010	17.58	2	12.37	10	3
4	31	31.05.2010	23.64	2	15.39	11.2	4
5	38	07.06.2010	28.18	3.09	19.55	13.27	4
6	45	14.06.2010	32.25	7.1	20.21	21.2	4
7	52	21.06.2010	45.23	9.46	28.26	31.54	5
8	59	28.06.2010	59.71	11.08	38.12	43.7	4
9	66	05.07.2010	79.31	19.69	48.69	55.23	5
10	73	12.07.2010	86.62	28.92	49.54	83.46	5
11	80	19.07.2010	98.73	26.92	45.85	78.46	5
12	87	26.07.2010	111.35	27.85	46.54	83	5
13	94	02.08.2010	103.54	28.92	44.38	83.62	4
14	101	09.08.2010	102.5	27.54	45.6538	78.56	3