Capillary-based Subsurface Irrigation System for Water-saving Agriculture

2014.3

Agricultural and Environmental Engineering
United Graduate School of Agricultural Science
Tokyo University of Agriculture and Technology

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学位論文要旨

Capillary-based Subsurface Irrigation System for Water-saving Agriculture
毛管現象を利用した節水地下灌漑システム

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Fresh water deficit will become crucial and the world will face the crisis in the next 10 years when the world population exceeds 8 billion. Agricultural activities which consume more than 70% of the available water are in great threat from competition with industrial and domestic use. However least efforts have been done to reduce water usage and practice water-saving in agriculture compared to the industrial and domestic because of the abundant available of this resource in many arable land. The irrigation management practices however are still advancing with newer technologies with higher efficiency. The aim of this study is to investigate the feasibility of the fibrous-capillary system for water-saving irrigation system. Capillary irrigation has a great potential to save water in agriculture because water is supplied directly into the rooting zone by the gradient of soil water potential caused by plant water uptake. An advancement of the capillary irrigation system is being introduced in this study in which a fibrous material is used as an interface to transport water from reservoir into the rooting zone. Water that flow in this system is managed by capillary action. A nonwoven fibrous sheet or a geo-textile system with high capillarity is used as the interface material. Water can be transported easily within the soil area using the fibrous system by the capillary flow. Infiltration into the soil from the fibrous system is at the soil natural absorption rate, thus creating a uniform wetting pattern by matching the soil capillary absorption properties. This allows the soil to absorb water as needed at a slower and more effective rate. On the other hand, plant uptake water freely from the wetted soil for transpiration. As the potential gradient increases, the water flow continues from the reservoir through the fibrous to replenish the deficit. The continuous water supply will sustain the soil-plant evapotranspiration at very minimum stress. This process is regarded as a plant-based irrigation system, which is being emphasized in this study in a new irrigation system. The control of the fibrous-capillary system is done by manipulating

the distance between the interface of the soil-fibrous to the water in the reservoir known as water supply depth. Manipulation of the depth will affect the capillary flow through the fibrous thus changing the irrigation volume rate. As the result the plant evapotranspiration will be affected. An optimal water supply depth will ensure sufficient water supply to the plant for healthy growth while minimizing the evaporation from the soil.

Experiments were conducted, by using the fibrous-capillary system apparatus built in a cylindrical and a rectangular container. A small reservoir with an adjustable water level controller was located under the container. A vertical fibrous sheet used to transfer the water was position on the container floor and buried in the soil. The other end of the vertical fibrous was immersed in the reservoir. A closed-climate chamber and a phytotron were used to conduct experiments related to water flow and plant water uptake. The results revealed the dynamics of water flow and soil moisture condition in the fibrous-capillary system which was largely affected by the climatic change and the plant growth stages. Moreover the dynamics were also affected by the change of water supply depth where the advancement of wetting front, soil water content and the cumulative infiltration were almost proportional to the decreased of the depth. This phenomenon was modeled by using a soil-plant-atmosphere-continuum (SPAC) approach and a modified version of the SPAC model was introduced. The time-space variation of water flow and wetting pattern in the fibrous-capillary system was successfully simulated and visualized based on Richard equation using HYDRUS.   An adaptive strategy is proposed to control this irrigation system in order to adapt the dynamic need of water by the plant at various growth stages has shown very substantial results in water-saving strategy.

This study has contributed to a new cultivation management strategy by water-saving irrigation system in which the system will significantly reduce the input cost and increase the profit. Proper utilization of the system and management assures better plant quality with less water by maintaining near perfect air/water content in the soil. All chemicals that may go through the system directly into the rooting zone shall result in excellence plant health with substantially less fertilizers by eliminating surface exposure which reducing harmful and wasteful run-off. The system offers a great technology for industry to develop a new water-saving irrigation system. The originalities of this study lies on the mechanism to transport water directly into the rooting zone by using the fibrous-capillary system and the measuring-control method for detecting plant water demand and supplying the accurate amount based on the detected demand.

Acknowledgement

All praise to ALLAH Most Gracious, Most Merciful, Who, Alone, brings forgiveness and light and new life to those who call upon Him. Praise to Allah for His great loving kindness which has encourages and brought me along to this stage and to Him is the ultimate dedication of this thesis.

The most significant thanks must go to my supervisor, Professor Sakae Shibusawa. I am very grateful for all his advice and insightful ideas, for many fruitful conversations during the development of my research, and I could have not completed this thesis without his kind support and general encouragement. His understanding, encouragement and personal guidance have provided not only an important fundament for this thesis, but also a good base for the enjoyable life in Japan.

I equally thank to my other two co-supervisors Prof. Tojo Seishu and Prof Saito Takahiro for their support during my study. I would also like to express my gratitude to Prof. Motoyoshi Ohaba for helping me with the research work throughout this period. He has been so kind and generous, gave me the opportunity to study and work in this research.

I also like to give many thanks to all my laboratory members for their company in my three years study and for their cooperation in my research. Especially I would like to give my thanks to Mrs. Terauchi, Mr. Masakazu Kodaira, Mr. Qichen Li, Mr. Rou Kanda, Mr. Hosaka Shun, Mrs Bintang and Mrs. Aliah for their kind support in my experiments and life. Great and many a thanks to the JST for their funding for this study.

Last but not perhaps, my special thanks go to my family members: my dearest wife, Sulasterie Waty binti Othman who has give continuous support and love, and massage on my shoulder during the long processes of study, experiments and thesis writing, and my sons Nasrullah and Naeemullah, my daughters Nazurah and Nabilah who always support my experiments and sometimes collect the ‘delicious’ data. You all made me happy and confident person to face the challenge every day. I am greatly indebted to my father Mr. Zainal Abidin bin

Abdul Manaf, and my dearest late mother Mrs. Siti Zalihar binti Ngah. And also to my parent in law Mr. Othman bin Ismail and Mrs. Samsiah binti Abdul Manan for taking care of my family in many ways for all these years.

Finally my sincere acknowledgement to University of Technology Malaysia for providing me the scholarship to support my study, and living in Japan.

Mohamad Shukri Bin Zainal Abidin
Tokyo, Japan, 2014

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Chapter 1

Introduction

1.1Background

1.1.1 Water crisis

Recent droughts and severe floods around the world have led to the increase concerns about water shortages for our daily life, industrial operations and agricultural activities. The increase in the world's population and social-economic development will somehow worsen the problem in the near future. Fresh water availability in easily used forms on the earth's surface such as lake and river, however, is extremely limited. Thus these limited resources must be used in a sustainable manner as we continue to conserve the water circulation. Water crisis will become apparently critical in the next 10 years (Roger, 2008). In has been estimated that in 2025 the water scarcity will cover almost 85% of the world surface when climate change and human population increase (Roger, 2008).

In Japan, water shortage is becoming a social concern due to excessive use and increasing demand of pure water for human use, industrial and agricultural activity. Number of water shortage problems has been reported by Japan Water Resources Department of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT, 2008), for the past 20 years. Water shortage is also a very serious problem in disaster affected area such as during The Great East Japan Earthquake on March, 11, 2011 where pure water supply became very limited and people concerned on contaminated water resources.

Even the water shortage problem is rare, the modern society in Japan requires comfortable lifestyles and high quality services based on stable water supply. Therefore, suspended or reduced water supply would have a serious impact on everyday home life and social activities as it disables people from doing their routine. Shortage of industrial water supply will result in immediate damage such as reduction or suspension of operations. While in agricultural, when shortages of water occur, farmers save water by means of "water-sharing” (method of distributing water in accordance with designated times and turns), intensification of repeated use and so on, though this requires a lot of labour and cost. For example, at the time of water shortage in 1994, the agricultural production cost was about three times as much as that in an average year (MLIT, 2008). As the consequence, when the amount of water available becomes insufficient, crop growth is reduced or completely hindered.

While the world's population is tripled in the 20th century, the use of renewable water resources has grown tremendously. Within the next fifty years, the world population is estimated to increase by another 40 to 50% (Shiklomanov, 1999). This population growth coupled with industrialization and urbanization will result in an increasing demand in water and will have serious consequences on the environment. Despite the increasing population the problem of water crisis reported by World Water Resources in 2000 is not originated mainly from having too little water but a very inefficient of management process of this resource (Cosgrove and Rijsberman, 2000).

With the current policies, correcting measures still can be taken to avoid the crisis to be worsening. There is an increasing awareness that the freshwater resources are limited and need to be protected both in terms of quantity and quality by every human being. "*Water is everybody's business*" was one of the key messages of the 2nd World Water Forum in 2000 (Orange and Rijsberman, 2000).

1.1.2 Agricultural water consumption

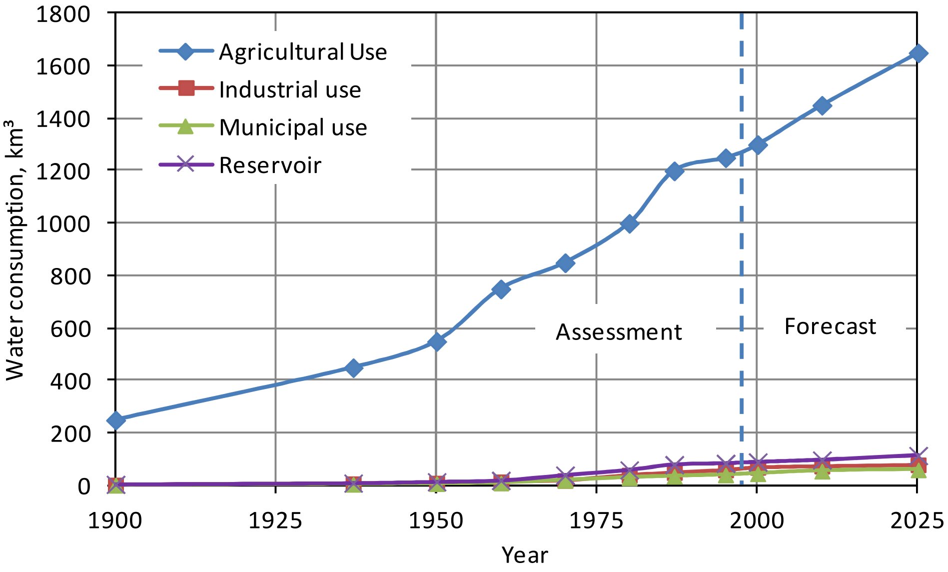

Fig. 1.1 Increasing water consumption for agricultural activity.

Agricultural production in Asia has been significantly increased in the past fifty years along with the increasing demand from the vast growth of population and urbanization as shown in Fig. 1.1 (Shiklomanov, 1999). The challenge for food security is also becoming the main agenda for all nations in every region. As a result, in agricultural production the withdrawals of fresh water for crop irrigation represent 66% of the total water withdrawals and up to 90% in arid regions. The other 34% of fresh water withdrawal, 10% is being used by domestic households, 20% by industry and 4% evaporated from reservoirs (Shiklomanov, 1999). It has been reported by the

Department of Water Resources that the largest fresh water used in Japan was from agricultural activity that consume approximately 66% of pure water resources, followed by human at 19% and industrial at 15% (MLIT, 2008).

Agricultural production provides multifunctional roles such as land conservation, recharge of water resources and conservation of the natural environment. Despite the fact that agricultural water forms one part of the water circulation cycle, and is an indispensable factor for producing food, arguments are also being made that most of world's total volume of fresh water use is consumed by agriculture, this sector should reduce its water requirement so that more water can be diverted to other uses. As the per capital use increases due to changes in lifestyle and as population increases as well, the proportion of water for human use is increasing. This, coupled with spatial and temporal variations in water availability, means that the water to produce food for human consumption, industrial processes and all the other uses is becoming scarce.

1.1.3 Water conservation and water saving

Whatever the use of freshwater (agriculture, industry, domestic use), huge saving of water and improving of water management is possible. A new paradigm of virtual water use and consumption in lifestyle or food habits, for example, may reduce the problem (Zimmer and Renault, 2002). Awareness on water saving and not to own unnecessary item has successfully reduce the domestic water consumption the past 10 years in Japan (MLIT, 2008). On the other hand the use of freshwater in industrial operation has also decline significantly in the past few years with the wastewater recycling process (MLIT, 2008). Despite the entire success story on industrial and domestic use on water saving, agricultural sectors are still struggling for an effective irrigation method to minimize water consumption while at the same time increasing its production to meet with the high demand.

The advancement of cultivation technology however in many ways has increases agriculture productivity while improving the water use efficiency (WUE). The irrigation system which plays a very important role in cultivation is being developed with various methods to transfer water to the plant from surface and subsurface of the soil. A traditional method of surface and subsurface irrigation such as furrow, flood, pitcher and pot are still being used in some areas. Because of their inefficiency these methods are becoming less popular except flood irrigation that is being used for paddy cultivation (Bouman and Toung, 2001). Most traditional methods are being replaced by a conventional irrigation method such as sub-irrigation, sprinklers and drip irrigation system. These systems are used commonly in arid and semi-arid irrigation area and have been used for many years (James, 1988). The challenge for high water saving and high WUE in the cultivation process now lies in the advancement of the irrigation management and the strategy to adapt the dynamic water demand by the crop (Jones, 2004; Prasad et al., 2006). Deficit irrigation for example offers one of the strategies for high water-saving mainly in arid and semi-arid land (Mahajan and Singh, 2006; Dodd, 2009; Jensen et al. 2010)

Drip irrigation system offers key advantages for meeting the water and nutrient standards. The system enables the application of small amount of water to the plant through the drippers which placed above or below the soil surface with a certain range of discharge rates to meet plant water demands. Subsurface drip irrigation (SDI), in which water is applied below the soil surface offers many advantages over the surface drip irrigation. It helps to conserve water by reducing evaporative water losses in agricultural systems since it applies water directly to the rooting zone. It also minimises deep percolation losses and elimination of runoff (Camp, 1998; Mahanjan 2006; Patel and Rajput, 2008).

Capillary irrigation, which uses a slight pressure difference of soil water, has brought new interest based on the traditional phenomenon of pitcher irrigation. The pitcher which filled with water is buried in the soil. Water seeps out to the root zone due to pressure head gradient across the wall of the pitcher at the soil's absorption rate naturally. A uniform wetting area is created around the pitcher by matching the soil capillary properties (Siyal et al., 2009; Setiawan et al., 1998). This method is cheap, simple and has high water saving potential. However, in the pitcher irrigation system the plants become dependent on the pitcher for water source and do not develop deep root system.

An improvement on the pitcher irrigation method is to use porous clay pipe, in which both conveyance and seepage of the water can be carried out instantaneously. This approach was experimented by Lipiec et al. (1988), Iwama et al. (1991) and Ohaba et al. (1998, 2010) using a negative pressure system to transfer water to a micro porous ceramic pipe. A similar capillary irrigation system using porous membrane with different negative pressures was developed and produced better yield and quality of hot pepper (Nalliah and Ranjan, 2010).

1.1.4 Research issues

Water crisis will become apparently a disaster in many regions on this earth in the next 10 years. Agricultural production which consumes largest portion of the available freshwater is the biggest competition to the increasing human population due to the limited water resources. A trade by water-saving management in agricultural production is a key technology not only for arid and drought-prone areas but also will expand to other areas when the water crisis expands. Precision Agriculture (PA) which relies on site specific technologies happens to allow comprehensive data on spatial and temporal variability and fine scale of plant water demand to be gathered (Shibusawa et al., 2006, 2007). This was the motivation to develop a site-specific irrigation system to meet the water demand for plant growth by applying precise control.

Drip irrigation has long been proven to generate high and quality yield. Subsurface drip irrigation increases the irrigation efficiency and improves management strategy by reducing evaporative water losses since it apply water directly to the root zone area (Camp, 1998). A negative pressure capillary irrigation has also shown a significant result in yield and water saving (Lipiec et al., 1988; Iwama et al., 1991; Ohaba et al., 1998, 2010; Nalliah and Ranjan, 2010). A combine method between subsurface drip irrigation and capillary irrigation by using negative pressure may lead to a new irrigation strategy and very beneficial to this study. Advancement of this method will allow precise measurement of individual crop-water characteristics and new strategies for efficient management of irrigation supply. Nevertheless, further advancement of irrigation management strategy along this new paradigm is required. This study was developed based on the phytotechnology platform (Shibusawa, 1989, 1995) for a site-specific irrigation system to meet the plant-water demand by applying precise control.

1.2 Literature review

Irrigation is a process to supply water for an agricultural purpose which is not satisfied by precipitation or underground water source under controlled circumstance. The process encompasses methods and technologies to transport water to the root zone of plant with various efficiency (James, 1988; Brouwer and Prins, 1989; Dukes et al., 2012). These technologies and their management strategy will be discussed in this section.

1.2.1 Conventional irrigation method

Flood irrigation is where the water is applied to the entire surface of the soil until it is covered by a ponded water. A partial flooding however is where the water is applied only in rows thus is called furrow irrigation. In this irrigation the concept is to supply water up to the saturated regime and to fill the soil reservoir to the maximum field capacity. Usually the irrigation is followed by a prolonged period of depletion to nearly the permanent wilting point before irrigation was applied to replenish the ‘deficit’ to the filed capacity. The disadvantage of flood or furrow irrigation is the root was subjected to alternating period of excessive wetness with consequent disruption of soil aeration and then the excessive desiccation to the detriment of root especially in the surface area.

Sprinkler irrigation is where the water is sprayed from overhead by using perforated pipes or nozzles under pressure so as to form the spray pattern. This system is more tolerant of variable soil textures since the rate of application can be more adequately controlled. Sprinkler systems that move over the landscapes such as central pivot, giving a large circular pattern of irrigated area. The disadvantage of sprinkler irrigation is quiet similar to flood or furrow in addition to high evaporation and run off.

Sub-irrigation provides water to plant from beneath the rooting zone. This irrigation is also called "seepage irrigation," and it is often used to grow field crops. The irrigation is managed by controlling the water table using buried perforated or porous pipe system. This method is usually use for organic soils where the water table is raised to moisten the soil and then lowered after the soil is at field capacity. Since plants naturally absorb water from the roots upwards, this method of irrigation makes a lot of sense.

Drip irrigation is where the water is applied directly into the root zone by means of applicators which operated under low pressure. Drip irrigation relies on the concept of irrigating only the root zone of a crop while maintaining the soil moisture at the optimum level (James, 1988). The applicator is being placed either on or under the surface of the ground. Water is continually added to the soil-one drop at a time. This keeps the soil at, or just below, field capacity, but only in the immediate area of the root zone of the crop. Higher water-use efficiency can easily be achieved by manipulating the irrigation frequency and emitter arrangement. Drip irrigation has been proven to generate a higher yield and quality of crops grown in either open fields or greenhouse farms (Camp, 1998).

Capillary irrigation uses porous material as an interface to disperse water into the soil at below the root zone. The porous material is made from ceramic or clay and has very low permeability to regulate infiltration into soil (Siyal et al., 2009; Setiawan et al., 1998). The advancement on textile technology allowed a geo-textile material to be used in capillary irrigation. The geo-textile fabric has higher permeability, maintains moisture uniformity along its area and allows soil to absorb water as needed at a slower and more effective rate. Due to high permeability in many cases water is transported through the fabric from a negative pressurized system. The irrigation substantially reduces water consumption and energy inputs compared to conventional sprinkler and drip system. A recent trial using capillary irrigation resulted in higher quality and water-use efficiency of greenhouse peppers (Nalliah and Ranjan 2010).

1.2.2 Fibrous based capillary irrigation

A key point of fibrous-capillary irrigation method is a potential gradient. A slight gradient of potential between soil, fibrous and water source will initiate the capillary flow. Further reduction of the matric potential in the root zone is caused by plant water absorption. A non-permeable material backing on the fibrous prevents water loss from downward percolation. The water flow characteristic in a fibrous medium has been modelled by Markicevic et al. (2012) and Landeryou et al. (2005). Research has been done on the feasibility of this approach and the results showed the capillary water supply method can adjust the soil moisture more efficiently and prevent the loss of water due to evaporation and drainage (M. Shukri, et al., 2011a). A field test has proven that the capillary irrigation using a fabric water mat can save water without reduction in yield for Japanese pear (Oya et al., 2011).

1.2.3 Crop based irrigation

A new measurement paradigm in irrigation management uses a crop-based method that enables the system to adapt to the variability in crop-water demand according to the individual crop-water response (Jones 2004; Raine et al. 2005; Smith and Baillie, 2009). Progress has been made by applying leaf temperature and sap flow measurement methods (Giorio and Giorio, 2003; Jones and Leinonen, 2003). However, these methods for sensing plant water-stress involve complex measuring systems and provide minimum information on irrigation volume and timing; thus they can only be used on an experimental scale (Jones, 2004).

The fibrous-capillary irrigation system combines both the irrigation system and the water flow sensor. The system provides continuous water supply to the root zone and the plant can uptake water from the soil freely based on their dynamic demand. At the same time, the flow sensor which embedded in the fibrous-capillary system indicates the actual plant water demand. The measurement which used the crop-based method enables the system to be managed effectively.

1.2.4 Irrigation management

Irrigation management involves a systematic approach to determine the irrigation requirement and scheduling. Irrigation requirement is the amount of water that must be supplied by irrigation to a crop. The requirement includes water used for crop consumptive use, maintaining a suitable salt balance, the root zone and overcoming the non uniformity and inefficiency of the irrigation system (James, 1988). The irrigation requirement does not include water from natural sources (such as precipitation) that crop can effectively use. Generally the requirement is based on the soil moisture deficit determined by using a soil-water balance model or the crop-water requirement estimated using the energy balance method (Ayars et al. 1999; Zhang et al. 2002; Hanks and Cardon, 2003; Jones 2004; Bonacheles et al. 2006). Irrigation scheduling is the process of determining when to irrigate and how much of water to apply per irrigation. Proper scheduling is essential for the efficient use of water, energy and other cultivation input such as fertilizer. The scheduling is usually coordinated with other farming activities including cultivation and chemical application. Benefits of proper scheduling are, improve yield and quality, water-energy conservation and lower production cost that will be evaluated in this study. The irrigation scheduling process can be determined based on plant or soil moisture condition.

a) Plant indicators

Plant indicator is the direct method to determine when to irrigate since the primary objective is to supply plant with the water they need and when it is needed. The visual appearance of wilting shoot and leaf or low growth rate of stem diameter and height may indicate the irrigation requirement (Brouwer and Pins, 1989, Lee and Shin, 1998). The rises of leaf temperature are associated with low transpiration due to closure of stomata (Boonen et al., 2000). Accumulation of the temperature increase beyond a critical limit indicates the irrigation time (Wagner, 1992; Mannini and Anconelli, 1993).

b) Soil indicators

The soil moisture indicates the current water content in the soil. Irrigation is required to maintain this moisture within the field capacity. The soil moisture deficit provides the estimation amount of water to irrigate (James, 1988). The soil water content also can be judged based on appearance and feel of the soil which require experience from the irrigators. The most accurate indicator is by sampling the soil; weighing and oven dry. This destructive method however cannot provide the result immediately on site. Methods such as soil water potential or the electrical conductivity enable the in-situ measurement by using tension meter, porous block and neutron scattering.

c) Amount to apply irrigation

The common way to determine the irrigation amount is to fill the root zone to field capacity by using water budget technique (James 1988). It is not necessary to fill up to the filed capacity to allow precipitation or during limited water supply. Irrigation can be applied to the crop at a full irrigation or deficit irrigation depending on the cropping situation. In full irrigation water is supplied at the entire irrigation requirement to gain a maximum production result. However exceeding full irrigation may reduce crop yield due to reducing soil aeration and restriction gas exchange between the soil and atmosphere (James 1988). In deficit irrigation water is supplied partially from the irrigation requirement. However it will reduce yield as smaller amounts of water, energy and other input production are used for cultivation.

Deficit irrigation is effectively used when the water supply system limits the water availability or the economic return is low (English, 2002; Prasad, 2006; Mahajan and Singh, 2006; Dodd, 2009; Jensen et al. 2010). This is accomplished by allowing planned plant stress during one or more period of the growing season. Water is supplied adequately during critical growth stage to maximize water use efficiency. This method focused on partial replacement and depleting of water below field capacity to maximize production per unit water or energy instead of maximizes production per unit land.

1.2.5 Precision irrigation approach

With the development of information technology, precision irrigation comes out and become a main agenda for the optimal irrigation management. Precision irrigation is defined as the accurate and precious application of water to meet the specific water requirements of individual plants or management units and minimize adverse environmental impact (Raine et al., 2005, 2007). Hence, an important characteristic of precision irrigation system is that the timing, placement and volume of water applied should match the plant water demand resulting in reduced non-transpiration losses and optimized crop production responses (Raine et al., 2005, 2007). A five years project to develop super water-saving system for agriculture has been started since 2011 under the Core Research Evolutionary for Science and Technology (CREST) funded by Japan Science and Technology (JST) entitled Water Saving System for Precision Agriculture (WSSPA). The advance system comprises three important elements of water circulation in soil-plant system as follows.

i. Underground capillary irrigation technique to meet the small reduction in water potential around the rooting zone during water uptake.
ii. Instrumentation technique of soil water capacity and water stresses of plant.
iii. Energy-reduced and high-efficient air–conditioning/environmental–control system in greenhouse with a water-purification and water recycle technique.

This study only focused on the first element to develop new irrigation technique based on water potential gradient for the plant uptake. Water needs for plants are affected by many physical parameters such as temperature, humidity, wind, cloud cover, size/age/condition of plants, and time of year. Thus the determination of the water need is not easy which require specific device and accurate measurements of various physical parameters. A subsurface irrigation method using fibrous-capillary system was developed (Ohaba et al., 2010; M. Shukri et al., 2011a) where the irrigation is driven only by capillary water flow, and which is characterized by the precious adaptation to requirements of water by plants, the real time measurement of evapotranspiration, and non-percolation of water and nutrients, and little evaporation from soil. This method has much great potential to fulfil the water requirements to meet the plant water need.

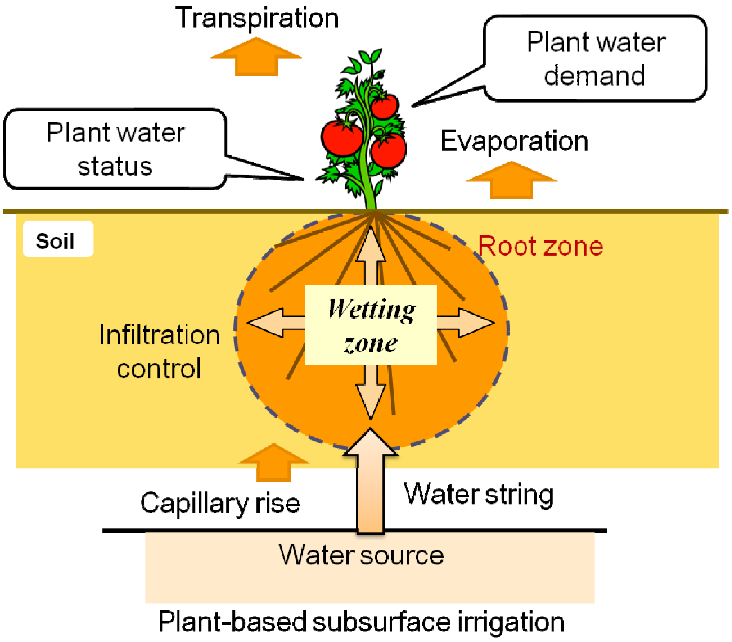

Fig.1.2 Model of the proposed capillary-based subsurface irrigation.

Figure 1.2 shows the model for the proposed capillary-based subsurface irrigation system. A high capillarity fibrous is used as a string to transport water from the reservoir directly into the rooting zone. Water that flows into the fibrous is driven by capillary force against gravity. Water continues to flow upward and forms a wetting zone inside the dry soil. The wetting zone diffuses gradually due to infiltration and redistribution process until the potential gradient between the fibrous and soil is balanced. At the same time, the moisture within the wetting zone decreased due to evaporation and root water uptake. The wetting zone thus become smaller and increases the gradient again and resumes the water flow.

The dynamics of the water distribution is pre-requisite for the design and operation of the capillary-based irrigation system. The distribution is varied continuously correspond to the soil properties, irrigation rate, evaporation and root uptake. Therefore, a precise control of the water level in the reservoir can produce an adaptive wetting zone for plant growth. The theoretical and experimental studies are required to elucidate the dynamics of the capillary-based subsurface irrigation.

Preceding research for subsurface irrigations can be seen as references such as related infiltration analyses (Green and Ampt, 1911; Moltz et al, 1968; Philip 1972; Al-Jabri et al., 2002) and irrigation system practices (Bresler et al., 1971; Vellids et al., 1990). Further studies suggest the mutual interaction between soil and water uptake by plants (Feddes et al., 1976; Malik et al., 1988). However, the irrigation technique developed by Ohaba et al. (2010) and M. Shukri et al. (2011a) is different from those in conventional irrigations. Thus, further studies were planned to determine the fundamental characteristics of the water flow and distribution in the fibrous-capillary irrigation system and the management strategy of this system to adapt the dynamic need of water by plant. Figure 1.3 shows the model for field application of the capillary-based subsurface irrigation.

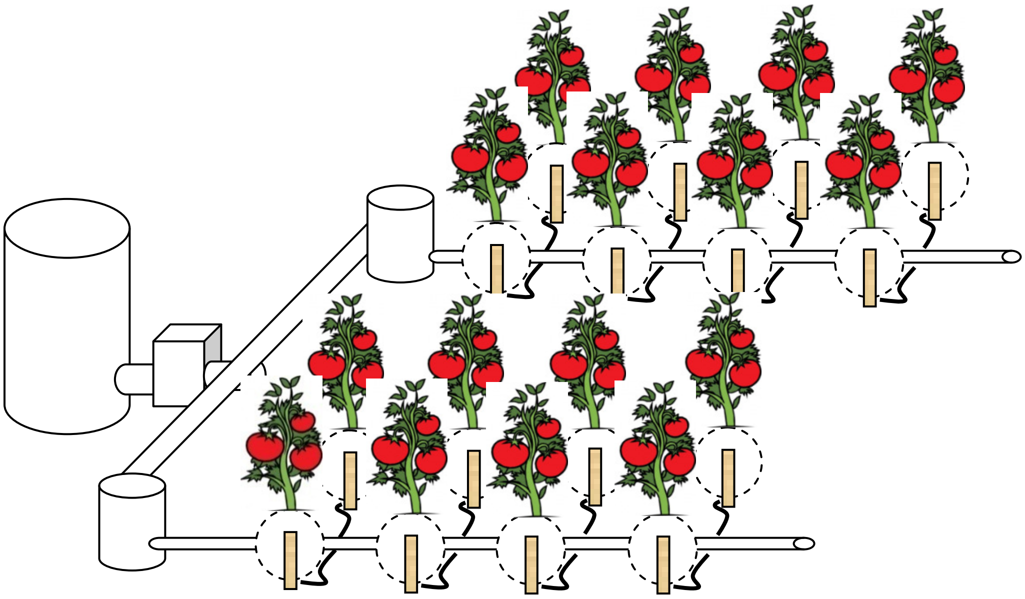

Fig. 1.3 Model for the field application of the capillary-based subsurface irrigation.

1.3 Aim and Objectives

Abundant irrigation supply cannot ensure high agricultural production. Thus, new irrigation management is required to maximize the profit. Hence, in light of preceding background and literature reviews, the ultimate aim of this study is to develop a new irrigation management strategy by using a water-saving system that will improve overall efficiencies in agricultural operation. The precision irrigation approach can implement this goal and the capillary-based system is chosen and to be investigated. The yield of greenhouse tomato production (Stanghellini et al., 2003) will be used as guideline to evaluate the proposed water-saving system. Specifically, this study intended to achieve the following objectives;

1. To establish a reliable technique based on capillary phenomena to transport irrigation water directly into the rooting zone.
2. To control the irrigation water supply based on the established technique to adapt the dynamic need of water by the plant.

3. To establish a quantification model for the water flow by using a SPAC system based on the established technique.

1.4 Thesis structure

This thesis is divided into six chapters. The first chapter is the Introduction which described the background issues, motivation and objective of this study. This chapter also includes literature review which discussed the technology in irrigation, advantage and disadvantages and their performance. The second chapter is on the establishment of capillary-based irrigation system. The third chapter discussed on the mechanism and control of water flow in the capillary-based system. The fourth chapter discussed along the SPAC modeling approach for the fibrous system. The fifth chapter discussed on the field application of the fibrous-capillary system. And the last chapter is summary and conclusion.

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