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Effect of different water depths on growth and yield of rice crop

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This study was conducted to evaluate the effect of different water depths on the growth and yield of rice crop. Experiment was carried out in containers having an area of 0.64 m^2 and the volume of 0.57 m^3 at laboratory. Four water depths of 5, 10, 15 and 20 cm were taken in account; each water depth was replicated three times. This study was conducted in controlled condition to avoid the impact of rain. Result indicated that 5 cm is optimum water depth for vegetative and mid stage (transplanting to mid drainage) of the rice crop growth, while 10 cm water depth is appropriate for mid drainage till late stage (mid drainage to harvesting) of the rice crop and the same (10 cm) is found suitable for maximum yield.

Key words: Water depth, rice crop, containers, plant growth, yield.

INTRODUCTION

Rice is an aquatic crop and mostly grown under submergence or variable ponding conditions. Variations in water depth due to irregularity of leveling, especially in large size paddy fields, often affect rice growth and yield (Anbumozhi et al., 1998). Recently, effects of deeper ponding water depth on plant growth have received renewed attention because of the subsurface irrigation and water table conditions in large sized paddy fields (Murugaboopathi et al., 1991; Anbumozhi et al., 1994).

Water depth is an important parameter for the prediction of rice growth. The simulation growth model without inclusion of water depth tends to over predict rice shoot dry mass production (Caton et al., 1999). The morphological cause of yield reductions in rice crop under partial submergence has been attributed to impaired tillering (Yoshida, 1981).

Anbumozhi et al. (1998) observed that rice crop growth and yield were affected by the ponding water depth. The grain loss, due to the excessive ponding was more than that of the deficient ponding. This indicates that rice plants have the ability to survive better at shallow water depth than deeper ponding water depths. Among the three water regimes of continuous, intermittent and variable ponding; the variable water regime produced higher grain yield. Maximum crop production occur around 9 cm ponding water depth in all the water regimes.

In large sized low land paddy fields, a controlled amount of water is applied to precision-leveled soil surface surrounded by bunds (ridge), through surface or subsurface methods. High uniformity and water use efficiency can be obtained with these methods if the water is distributed uniformly over the entire field.

To identify the optimal water environment for improving crop yield, De Datta (1981) reported that extremely deep water resulted in poor crop growth and yield. The deep water tended to increase plant length. This tendency was directly related to the increasing inter-node length at

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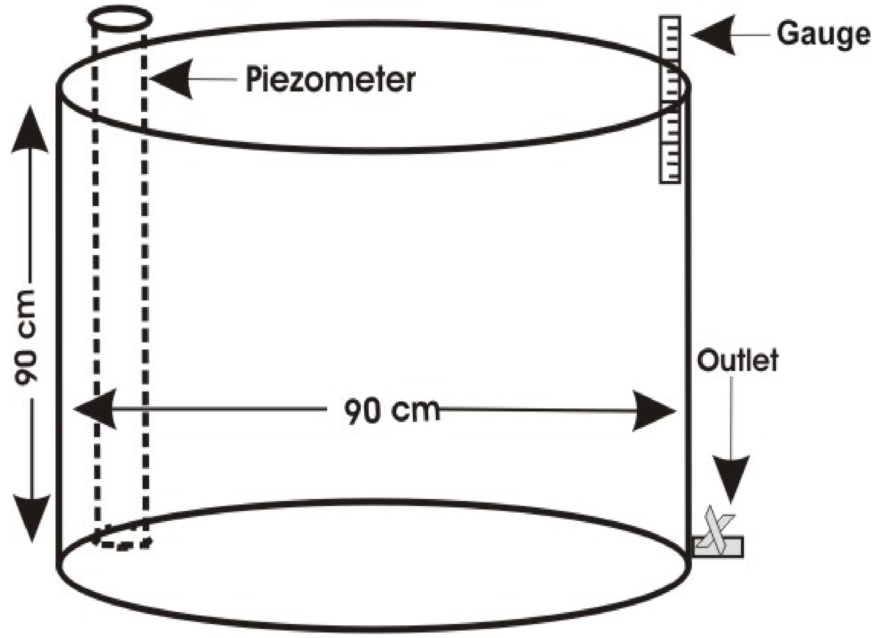

Figure 1. Schematic design of experimental container at laboratory.

the upper part of the culm and by deep-water stress and high air temperature there. Similar findings were reported by Quayyum et al. (1981). Purba (1993), Sugai et al. (1998) and Gun (1999) emphasized that increase of culm length is positively correlated with deep water. Deep water tended to inhibit tillering due to the submerged conditions and reduced leaf area during early rooting stages. It was found true by Ohe and Mimoto (1999).

However, literature is repleted with evidence that crops do respond to differential applications of water (Khatri and Smith, 2007; Sander and Bastiaanssen, 2004; Yinqiao et al., 2007). Irrigation as an input into the production process must be measured in terms of timing and quantity of water used by crops rather than by classifying whether or not a piece of land is irrigated. A large part of the variation in annual yield may be merely due to variations in timing and the quantity of irrigation water applied (Bertolacci et al., 2006; Ghinassi, 2007; Ghinassi et al., 2007; Prasad et al., 2006; Stewart et al., 1975). An optimal ponding water depth for the rice crop may cause a non-significant yield response to ponding water under given climatic and agronomic conditions.

This study is focused on the range of ponding water depths, from the shallowest (5 cm) to the deepest (20 cm) during the entire crop growth stages to determine the optimal water depth for rice crop at the labortary during 2011 growing season at Engineering College, Nanjing Agricultural University, Jiangsu province, P. R. China.

June to November is rice growing period at Nanjing, Jiangsu; climatically Nanjing area (1951 to 2007) shows average temperature maximum 28.04°C in July, and 10.07°C minimum in November, whereas in June 24.57°C, August 27.63°C, September 22.94°C and October 17.13°C. Humidity varies from 76.16% in October to 81.00% in July, while maximum rainfall occurs 172.77 mm in July.

MATERIALS AND METHODS

Twelve containers 0.9 × 0.9 m in size were prepared; piezometer, gauge and a controlled drainage outlet were installed in each container (Figure 1). Paddy soil was filled up to 0.7 m height in each container and water was applied. The soil used contained, 58% Sand, 32% Silt and 10% Clay; whereas it showed pH 6.05, organic matter 8.40 g/kg, TN 0.66 g/kg, total phosphorus 44.81 mg/kg, effective Fe 30.39 mg/kg, effective Cu 2.32 mg/kg, effective Mn 21.56 mg/kg and effective Zn 2.32 mg/kg. Each container was developed as per four different water depths of 5, 10, 15 and 20 cm with three replications of each water depth. These watering were started 2 weeks after transplanting (Figure 3).

An evaporation pan was installed at laboratory to observe the rate of evaporation. Fluctuation in water depth at each container and evaporation was observed on daily basis during the whole experimental period. However, the experimental containers were covered by shelters from rainfall (Figure 2).

Rice variety of Wuyungen No. 23 seed was transplanted in the field. The seed was first grown in nursery for 48 days that took 150 mm water (30 mm for 5 times). All other inputs were kept same for all containers. At the mid season drainage was also applied for 2 weeks time period.

Growth stages of rice plant

A 120-day variety, when planted in a tropical environment, spends about 60 days in the vegetative stage, 30 days in the reproductive stage, and 30 days in the ripening period.

Many scientists divide it in different stages but most of them just use four of their stages, that is, nursery, vegetative, mid season and late season stage.

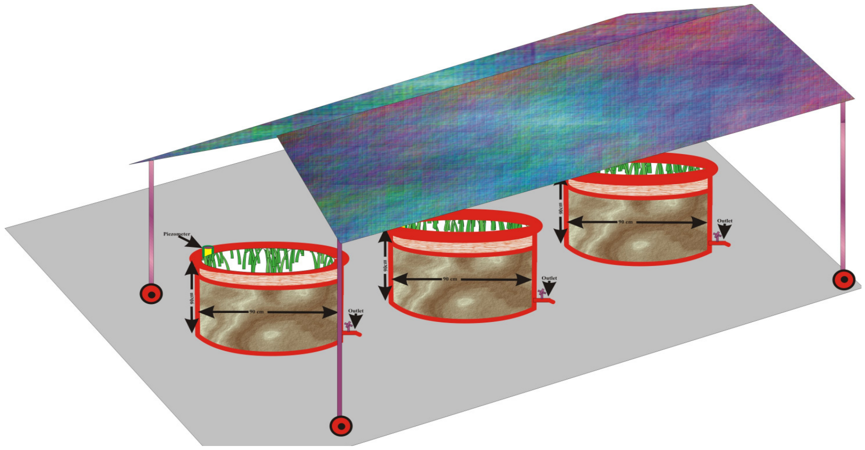

Figure 2. Schematic diagram of containers under shelter.

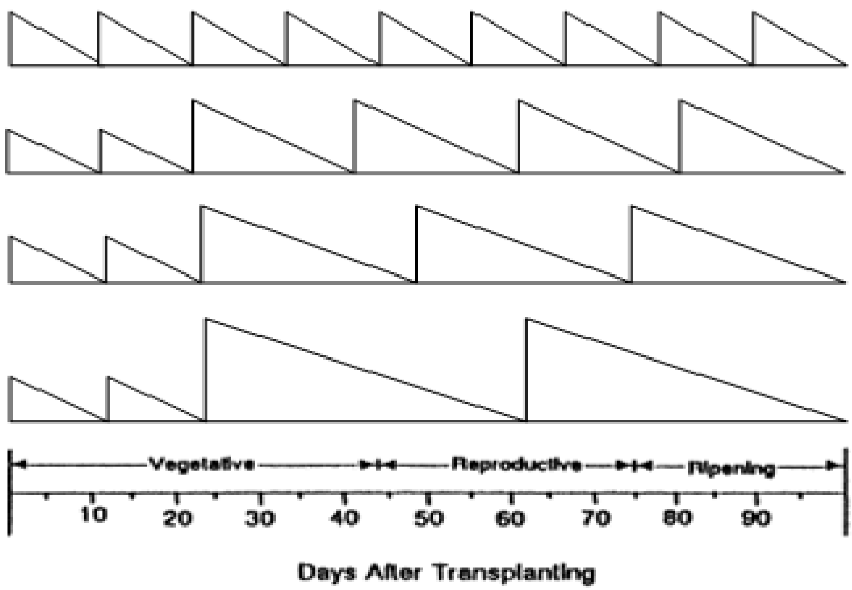

Figure 3. Schematic diagram of different water depths.

Nursery

It is the period from sowing to transplanting; duration ranges from 25 to 40 days.

Vegetative

It is a period from transplanting to panicle initiation; duration varies from 45 to 90 days.

Mid stage

It is the period from panicle initiation to flowering, which includes stem elongation, panicle initiation to flowering; duration is about 30 days.

Late stage

It is the period from flowering to full maturity; duration is about 30 days. Counce et al. (2000) introduced the cumulative leave number (CCLN) to express rice growth. In this method the rice growth stage has been divided in to three phases: seedling, vegetative and reproductive. Goswami et al. (2003) expressed the growth stage of rice and wheat in growing degree days for Ludhiana region India.

RESULTS AND DISCUSSION

During this study, the variation of water depths showed effective impact on the growth as well as productivity of the rice crop. At the initial stage of crop there was no significant difference ($p > 0.05$) in the height of plants as

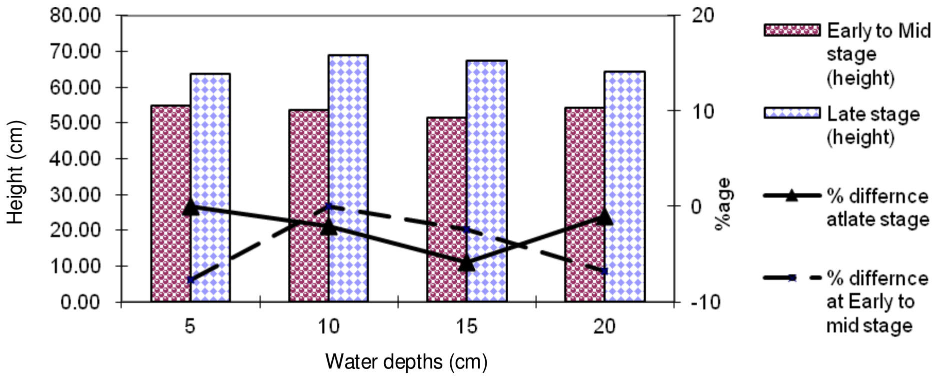

Figure 4. Impact of different depths on growth of plants.

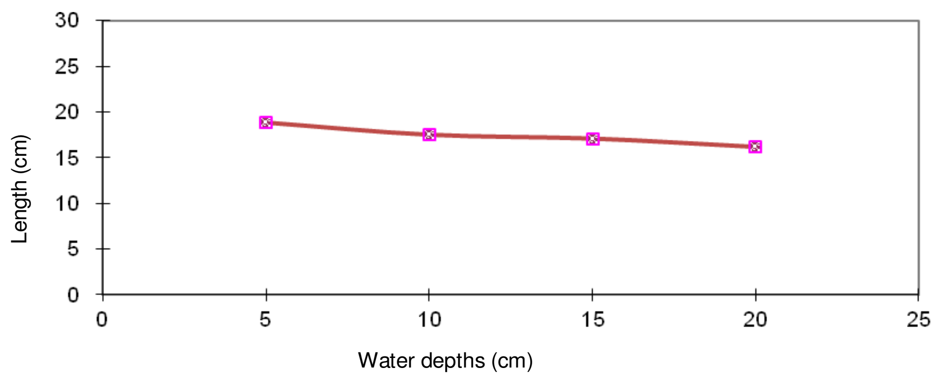

Figure 5. Impact of different water depths on root length.

the similar water depth was applied in all the containers for first 2 weeks to avoid the damage of transplanted plants, whereas significant difference ($p < 0.05$) was observed in height of plants at the mid stage. Maximum height of plants (54.81 cm) was measured in 5 cm water depths. Compared to that in 5 cm depth, the plant height was smaller by 2.08, 5.81 and 1.0% in 10, 15 and 20 cm depths, respectively. On the other hand at late stage, maximum height of plants was observed as 69 cm in 10 cm water depth which was smaller by 2.42, 6.77 and 7.72% in 15, 5 and 20 cm, respectively (Figure 4).

Concurrent with height, the plants servival, grown in 5 cm water depths showed minimum damage with only 3.35% and the plants damage was increase by 5, 15 and 10% for 10, 15 and 20 cm depths, respectively.

The length of plant roots showed significant difference ($P < 0.05$) and an inverse association was observed with the water depths used in this study. The longest length of root averaging 18.83 cm was measured in 5 cm water depth followed by smallar by 7.06, 9.29 and 14.13% in 10, 15 and 20 cm, respectively (Figure 5). This is agreed by De Datta (1981), that excessive water hampers rooting and decreases tiller productions.

Application of various water depths in rice showed significant impact on spike characteristics and grain weight. The maximum spike length (12 cm) was achieved in 10 cm water depth which was reduced by 20.83, 22.25 and 25%, in 15, 20 and 5 cm depths, respectively (Figure 6). Concurrent with length, the spike of rice plants grown at 10 cm depth weighed higher (2.07 g) compared to other water depths in which the spike weight was reduced by 2.9, 7.73 and 23.09% for 15, 5 and 20 cm depths, respectively (Figure 7).

Weight of 1000 grains was measured as 24.85 g at 10 cm depth, followed by 1.46, 7.85 and 10.96% reduction at 15, 20 and 5 cm, respectively (Figure 8). This shows that deeper water depth has adverse effects on spike characteristics and weight of grains than that of shallower water depth. On the other hand, the total yield shows opposite impact in those deeper and shallower water depths corresponding to 10 cm. Anbumozhi et al. (1998) reported that shallower ponding depths have relatively lesser yield reductions, compared to deeper ponding water depths with reference to the optimum ponding water depth of 9 cm. De Datta (1981) emphasized that extremely deep water resulted poor growth and yield. Panda et al. (1997) also reported that higher yields were obtained by subjecting the crop to submergence of 5 ± 2 cm during tillering and reproductive stages with 7 cm irrigation a day after disappearance of ponded water

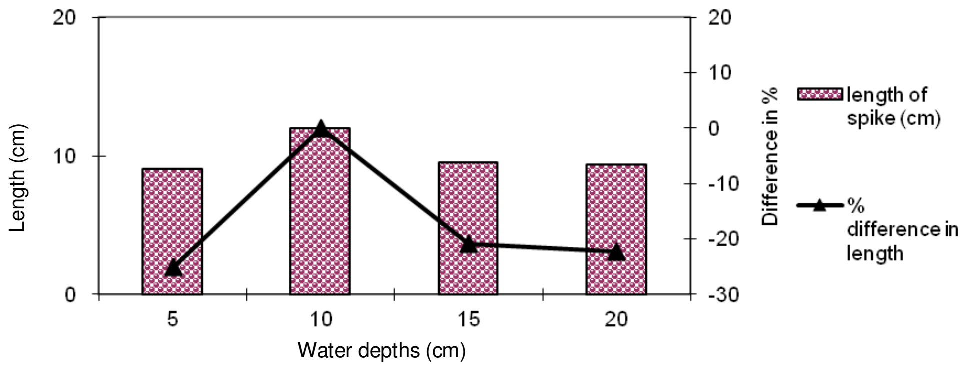

Figure 6. Comparision of length of spike.

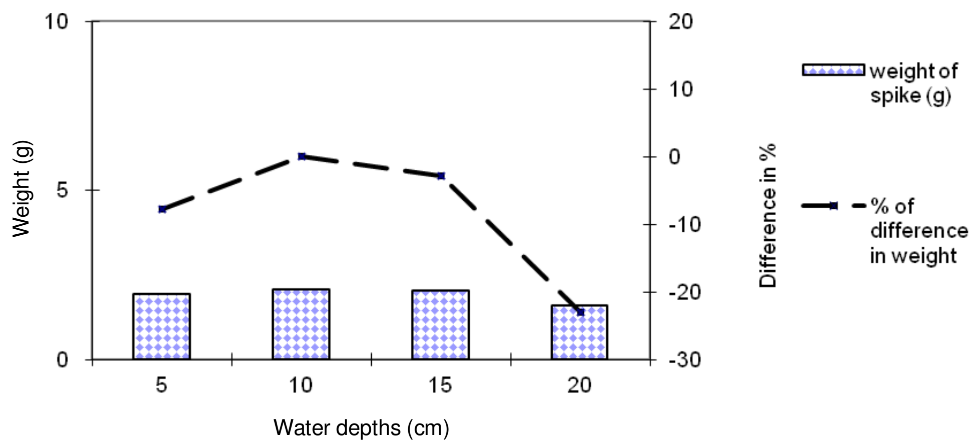

Figure 7. Comparison of weight of spike.

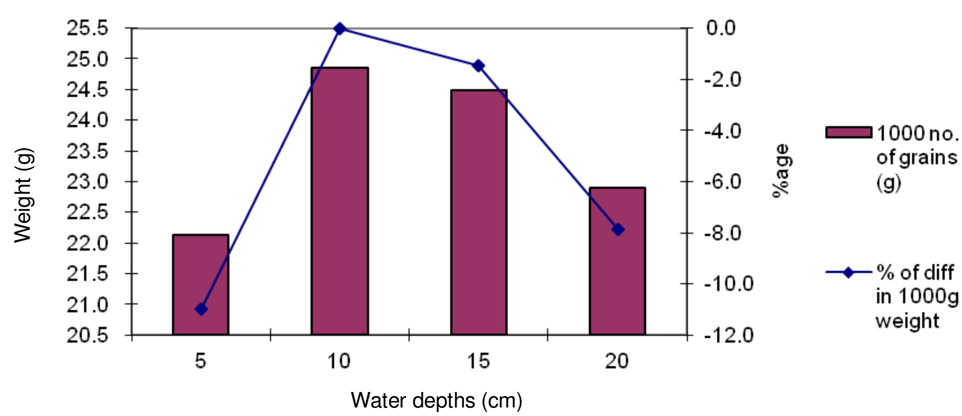

Figure 8. Weight of 1000 grains and their difference in percent age.

during the rest of the period.

The degree of crop susceptibility depends on plant species, plant development stage, soil and air temperature and duration of water logging (Matsushima, 1962; Murakami, 1968; Yamada, 1968; Sugimoto, 1971; Goor, 1974; Furuki, 1983; Nishio, 1983; Tabuchui, 1992).

Different water depths produced different water productivity (WP), at the 10 cm depth the WP of crop was found maximum at 0.43 kg m^{-3} followed by 0.33, 0.28 and 0.25 kg m^{-3} for 5, 15 and 20 cm, respectively. Cai and Rosegrant (2003) reported that the WP of rice ranged from 0.15 to 0.60 kg m^{-3}, while that of the other cereals ranged from 0.2 to 2.4 kg m^{-3} in 1995.

Conclusion

It is concluded from this study that the maximum plant survival and tallest average plant height were recorded in 5 cm water depth from cultivation till to mid stage of growth. The maximum water depth of 20 cm produced shortest root, while 5 cm produce longest root. The weight of 1000 grains has more affected by a deeper water depth as compared to shallower water depth but the total yield were opposite of these. It was observed that the number of grains loss due to excessive water depth has an adverse impact as compared to deficient water depths.

During laboratory experiment it was observed that 5 cm is optimum water level for vegetative and mid stage (transplanting to mid drainage) of the plant growth, while 10 cm water level is appropriate for late mid and late stage (mid drainage to harvesting) of the rice crop and the same is found suitable for maximum yield. So, it is recommended that a study should be conducted in the open field by limiting water depths and observes its impact on growth and yield of rice crop.

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