American Journal of

# Plant Nutrition and Fertilization Technology

ISSN 1793-9445

Academic
Journals Inc.

www.academicjournals.com

American Journal of Plant Nutrition and Fertilization Technology 3 (2): 33-42, 2013
ISSN 1793-9445 / DOI: 10.3923/ajpnft.2013.33.42


# Effect of Mid-season Drainage (MSD) on Growth and Yield of Rice in North East Japan

[1]Shah Moinur Rahman, [2]Ken-ichi Kakuda, [3]Yuka Sasaki and [2]Ho Ando
[1]United Graduate School of Agricultural Sciences, Iwate University, Morioka, 020-8550, Japan
[2]Faculty of Agriculture, Division of Safe and Reliable Agricultural Production, Yamagata University, Tsuruoka, 997-8555, Japan
[3]Field Science Centre, University Farm, Yamagata University, Tsuruoka, 997-0369, Japan

*Corresponding Author: Shah Moinur Rahman, United Graduate School of Agricultural Sciences, Iwate University, Morioka, 020-8550, Japan*

## ABSTRACT

Continuous flooding causes the soil to become increasingly anaerobic with low redox potential. For minimizing those adverse effects of continuous flooding on rice and for increasing the yield various kinds of water management methods have been practiced by farmers and investigated by researchers, including mid-season drainage, delayed flooding, shallow water management, intermittent irrigation, Alternate Wetting and Drying systems (AWD) etc. Two years field experiments were conducted to evaluate the effect of water management on plant growth, N uptake and yield of rice. The experiment consisted of three treatments with three replications mentioned as flooding from transplanting to 20 days before harvest (Flooded), Early Mid-Season Drainage (EMSD) and Mid-Season Drainage (MSD). Tiller number per $m^2$ and plant height (cm) was similar among the treatments during growing period. There was no significant different in leaf area index among the treatments. In the year 2009 and 2010, the trend of dry matter accumulation among the treatments were almost same but in 2010 year the value of dry matter production was bigger in MSD treatment than other treatments but statistically had no significant. Nitrogen uptake in plant was larger in MSD treatment during the drainage period and had no statistically significant differences. The trend of the brown rice yield of MSD treatment was larger than Flooded in the year 2010. Drained field conditions (MSD) did not decrease growth; N uptake and yield of rice despite induce higher root activity.

**Key words:** EMSD, MSD, LAI, N uptake, yield

## INTRODUCTION

The world needs more grain for food. This has to be achieved even with diminishing arable lands, water scarcity and rising costs of cultivation. In addition, climate change is adding further complexity (FAO, 2006).

Generally rice was cultivated with water i.e., continuous flooding during the most growing periods. We know, there is a relationship between effects of pH on nutrient availability under flooded condition and slightly acidic soils (pH = 6.5) are considered most favourable for overall nutrient uptake. Continuous flooding of rice field develops a reductive or reduced plow soil layer (Patrick and Reddy, 1976). However, the strict reductive conditions cause $CH_4$ production by methanogens. The $N_2O$ emission from a paddy field is caused by nitrification in the oxidative soil and denitrificaion in the semi-reductive soil.

However, the quality of irrigation water is being reduced by chemical pollution and salinization and the water resources itself is being depleted by falling ground water tables, silting of resources and increased competition from urban and industrial uses (Guerra *et al.*, 2008). Tuong and Bouman (2003) mentioned that raising beds, Swallow Water Depth with wetting and drying (SWD), Mid-season Drainage (MSD), Alternate Wetting and Drying systems (AWD), System of Rice Intensification (SRI) etc., are the common field techniques to save irrigation water.

MSD is a conventional cultural practice in Japan involves of surface water from the crop for about 7 or more than 7 days towards the end of tillering. Under these conditions, effect of MSD on growth and yield was not understood.

Rice plants grown in mostly aerated soil develop larger root systems than rice grown under flooded conditions, where roots die back due to lack of oxygen. Further, soil microorganisms beneficial for plant development will be more abundant and diverse when soil is kept aerated. Water management enhanced growth analysis and lodging resistant of rice and therefore enhanced root development which affect higher filled spikelets and higher 1000-grain weight.

During vegetative stage, water stress usually affects the growth and consequently decrease yield (Kamoshita *et al.*, 2004; Acuna *et al.*, 2008) and also agree with Mori and Fuji (2007).

Therefore, this study was conducted to know the combined effect of water management such as MSD on rice growth and yield in the year 2009 and 2010.

## MATERIALS AND METHODS

**General information:** Field experiments were conducted in Yamagata University Experimental Farm, Tsuruoka, Japan in 2009 and 2010. The soil properties were as follows: Sandy loam with a pH of 5.1, CEC of 15.1 cmoL (+) $kg^{-1}$, total-N content of 2.4 of g $kg^{-1}$, organic-C content of 25.7 g $kg^{-1}$, available $P_2O_5$ and exchangeable $K_2O$ of 0.17 and 0.13 g $kg^{-1}$ soil, respectively.

**Cultural practices:** One rice variety was used; Sasanisiki, which are cultivated in the Yamagata Prefecture. Chemical fertilizer was applied as N, P, K @ 6 g $m^{-2}$ and top-dressing application as N and K @ 2 g $m^{-2}$ at panicle initiation stage. The planting density was the same as in control with 22.2 hills $m^{-2}$. Each treatment had a plot size of 224 $m^2$. Seedlings at about three and half leaf stage were transplanted on May 14 in 2009 and May 17 in 2010. Four seedlings were planted on each hill.

**Treatments:** The experiment consisted of three treatments with three replications mentioned as flooding from transplanting to 20 days before harvest (Flooded), Early Mid-Season Drainage (EMSD) and Mid-Season Drainage (MSD). In Flooded treatment, the water level was kept at depth of 5-6 cm in both years. Drainage from June 15-25 (33 Days After Transplanting (DAT) to 43 DAT was carried out in EMSD in the year 2009 and drainage from June 14-24 (29-39 DAT) was carried out in EMSD in the year 2010. In MSD drainage from June 25 to July 5 (42-52 DAT) and June 21 to July 1 (36-46 DAT) were carried out in the year 2009 and 2010, respectively.

All the plots were arranged in Latin Square (LS) design with 3 replications. The dimensions of the plot were 28 m length and 8 m width.

**General sampling and measurement:** Number of tillers per hill were counted from the ten hills from fixed growth setting place of each plot at 34, 39, 44, 50, 57, 64, 75, 89, 95 DAT and mean values were calculated. The main stem was also included to calculate the total number tillers per hill and converted into per unit area basis.

The plant height was measured from growth checking 10 hills. Measurement was taken at 34, 39, 44, 50, 57, 64, 75, 89, 95 DAT. The measurement was started from early tillering and ended at harvestable maturity. It was measured from base of tip of the longest leaf of the main tiller.

Leaf area ($cm^2$) of the functional leaves was obtained at 64 and 85 DAT from three hills which were selected on average basis from randomly selected 4 hills×3 set i.e., 12 hills from each plot. These sample hills were selected from the samples for dry matter accumulation and nitrogen uptake by plant. Leaves were detached, kept in bowl containing water to minimize the leaf rolling and leaf area was then measured by automatic leaf area meter model AAM-7, Hayashi Denkoh Co. Ltd. Tokyo, Japan. Total leaf area per hill was recorded to find leaf area index by the following equation:

$$\text{Leaf Area Index (LAI)} = \frac{\text{Leaf area}}{\text{Ground area}} = \frac{\text{Leaf area cm}^2}{\text{Plant Spacing cm}^2}$$

Plant samples were taken from randomly selected 4 hills×3 set i.e., 12 hills from each plot of sampling area at 31, 41, 63, 88 and 105 DAT. Sampling was done from an area of 0.54 $m^2$. Plant samples were washed properly; roots were removed, separated into leaves, shoots and panicles. These samples were dried at a temperature of 80°C in an oven for 72 h to reach constant weight. Then, samples were weighed and calculated on area basis.

Nitrogen uptake by plant was determined by Kjeldahl method (Keeney and Nelson, 1982). The same plant samples were used for the determination of nitrogen uptake that was taken for dry matter accumulation.

Number of the effective tillers or panicles $m^{-2}$ was counted from each plot from the randomly selected yield place just before harvesting the crop. Sixty sample hills from 2.7 $m^2$ area were counted. The average values per hill were then converted to get the number of panicles per square meter.

Number of spikelets $m^{-2}$ and panicle$^{-1}$ were counted from the sample hills used for yield components i.e., 10 hills from each plot just before harvesting. All the spikelets from 10 hills were counted by automatic seed counting machine. The total number of spikelets was then divided by total number of panicles from 10 hills to obtain the number of spikelets per panicle.

All the spikelets were separated into filled and unfilled spikelets by using $(NH_4)_2SO_4$ solution having specific gravity of 1.06. The unfilled spikelets were again counted and used to calculate unfilled spikelets percentage.

Thousand-grains with 3 replications were counted from the grain obtained after separation .These grains were kept at 80°C for 72 h until constant weight for obtaining uniformity in moisture content and were weighed with the help of an electronic balance. Moisture percentage of the grain was measured by kent moisture meter. Finally the weight was adjusted to 14% moisture content.

Grain yield was measured at harvesting stage of crop growth from each plot consisting of 60 hills. They were measured on both yield components and yield examination basis.

The harvested hills were dried for 7 days in glass house, threshed with the help of mini threshing machine winnowed, cleaned and final weight was measured. Moisture percentage of the grain was measured at least 3 times by kent moisture meter and values were averaged. The grain weight from each replication was measured, mean values were calculated and computed on hectare basis. Final grain yield in yield examination was adjusted to 14% moisture content.

Milling percentage was calculated from the grains of hills selected for yield examination. After measuring paddy yield, it was milled for three times and brown rice yield was obtained.

Thousand brown rice grains were counted manually after milling of paddy from yield component. Grains obtained after milling were sieved in 1.9 mm diameter mesh. The grains having less than 1.9 mm diameter were discarded. These grains were kept at 80°C for 48 h until constant weight for obtaining uniformity in moisture content and were weighed in electronic balance. Moisture percentage of the grain was measured by Kent moisture meter. Grain weight was adjusted to 15% moisture content.

Brown rice yield was also measured at harvesting stage of crop growth from each plot consisting of 60 hills. They were measured on both yield components and yield examination basis. After taking the weight of paddy, grains were milled immediately. The milling process was repeated 3 times to ensure no rough paddy was remained in the brown rice. Moisture percentage of the brown rice was measured for 3 times by kent moisture meter and values were averaged. The grain weight from each replication was measured, mean values were calculated.

Finally brown rice yield in yield examination was adjusted to 15% moisture content.

**Data analysis:** Data were analyzed by STATCEL-2 software, Tukey-Kramer method. Excel programs were used for correlation and other statistical functions.

## RESULTS

**Number of tillers m$^{-2}$:** The mean value of the number of tillers m$^{-2}$ in the experiment for all treatments (Fig. 1) indicated that the number of tillers m$^{-2}$ increased up to 57 DAT and

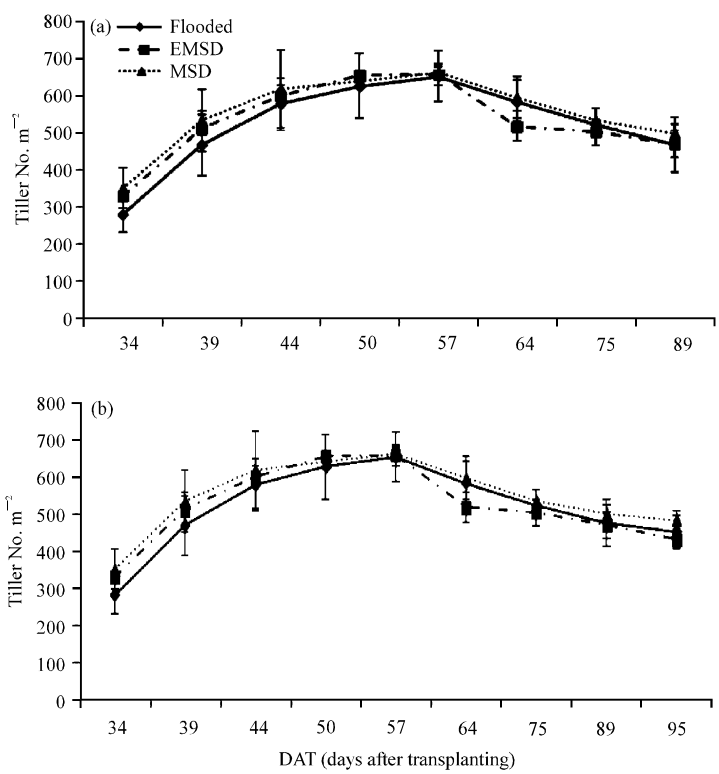


Fig. 1(a-b): Tiller number m$^{-2}$ at 28, 35, 38, 39, 44, 45, 50, 57, 64, 75, 89 and 95 DAT in Flooded, EMSD and MSD treatments in (a) 2009 and (b) 2010 and vertical bar represents standard error, Flooded: Continuous flooding, EMSD: Early mid-season drainage, MSD: Mid-season drainage

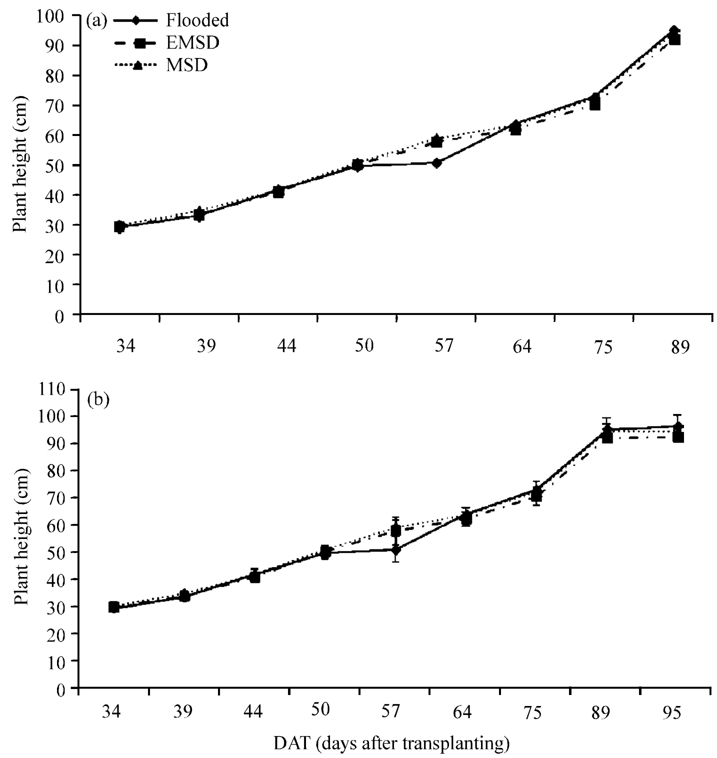


Fig. 2(a-b): Plant height at 28, 35, 38, 39, 44, 45, 50, 57, 64, 75, 89 and 95 DAT in flooded, EMSD and MSD treatments in (a) 2009 and (b) 2010, vertical bar represents standard error, Flooded: Continuous flooding, EMSD: Early mid-season drainage, MSD: Mid-season drainage

thereafter gradually declined. The decrease in the number of tillers per plant was attributed to death of some of the last tillers as a result of their failure in competition for light and nutrients (Fageria *et al.*, 1997). The increase in number of tillers $m^{-2}$ was recorded 39 and 57 DAT was remarkable (50%). The highest average number of tillers $m^{-2}$ was at 50 DAT and among the treatments there was no difference. During the growth stage the trend of tillers $m^{-2}$ was slightly higher in MSD than Flooded and EMSD treatments.

**Plant height (cm):** Plant height increased up to 89 DAT and its value ranged from 30-100 cm, respectively (Fig. 2). The increment in plant height was most intensive (80%) between 89-95 DAT. Among the three treatments the plant height was almost same among the treatments and had no significance differences.

**Leaf area index (LAI):** LAI ranged from 2.85-3.18 in 2009 and where in 2010, ranged from 3.18-4.11 and under MSD treatment, the increment in the leaf area index was more prominent (about 4.11) during the growth periods of heading stage (Fig. 3). In 2009, LAI value was shorter than 2010 as because could be different sampling method and human error and statistically had no significant different among the treatments. This was also supported by Yoshida (1983) that LAI of rice increased as crop growth advanced and reached a maximum at heading or flowering stage. There was no significant different in leaf area index among the three treatments.

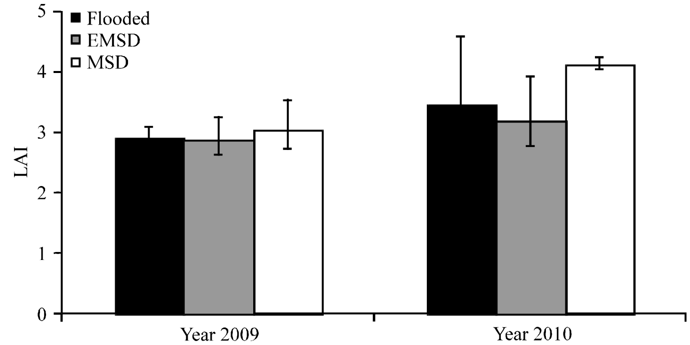


Fig. 3: Leaf area index at heading stage in flooded, EMSD and MSD treatments in 2009 and 2010, vertical bar indicates standard error, Flooded: Continuous flooding, EMSD: Early mid-season drainage, MSD: Mid-season drainage

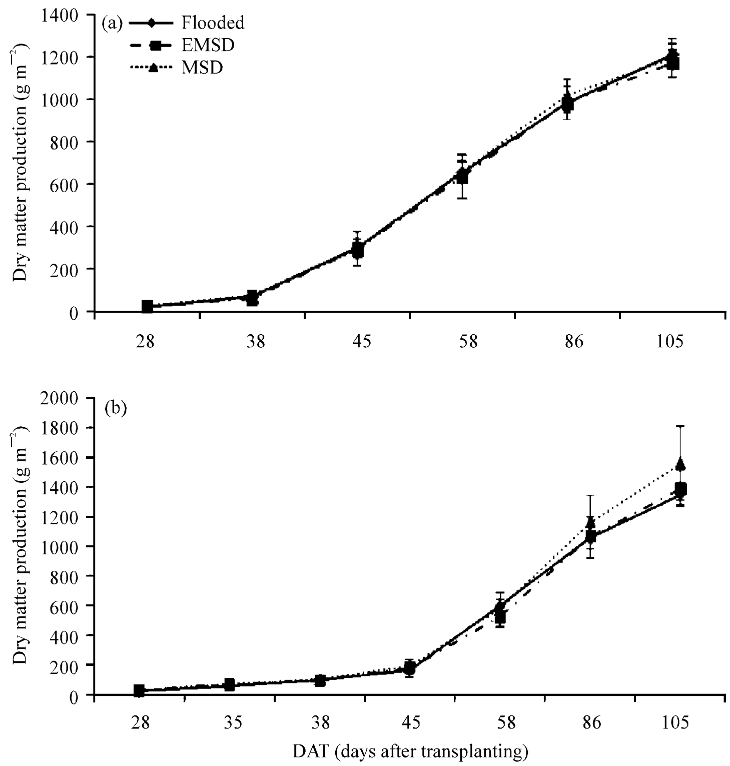


Fig. 4(a-b): Dry matter production at early tillering, mid-tillering, tillering, PI, heading and maturity stages in flooded, EMSD and MSD treatments in (a) 2009 and (b) 2010, vertical bar represents standard error, Flooded: Continuous flooding, EMSD: Early mid-season drainage, MSD: Mid-season drainage

**Dry matter production:** On an average, the total dry matter produced 0.045 $m^{-2}$ by the plant was increasing from 41-105 DAT (Fig. 4). In the year 2009 and 2010, the trend of dry matter accumulation among the three treatments were almost same but in 2010 year the value of dry matter production was bigger in MSD treatment than other treatments but statistically had no significant.

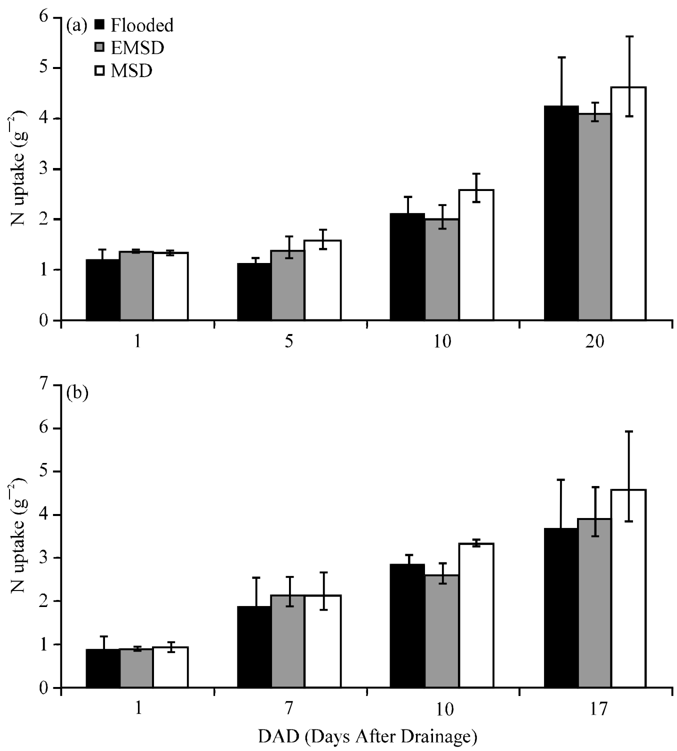


Fig. 5(a-b): Nitrogen uptake in plant at Days After Drainage (DAD) in Flooded, EMSD and MSD treatments in (a) 2009 and (b) 2010, vertical represents standard error, Flooded: Continuous flooding, EMSD: Early mid-season drainage, MSD: Mid-season drainage

**N uptake in plant:** Figure 5 showed that, in the year 2009 during the drainage period the nitrogen uptake in plant was almost same among the three treatments but MSD treatment showed little bigger value than other treatments and had no significant difference. In the year 2010, nitrogen uptake in plant was larger in MSD treatment during the drainage period than other treatments specially DAD 17 showed the greater value than other treatments and had no statistically significant differences among the treatments.

**Yield and yield components:** There was no significant difference in brown rice yield among the three treatments in the year of 2009 and 2010 (Table 1). In the year 2009, the brown rice yield of MSD treatment was very low because of lodging immediately after the flowering stage (Table 1). The grain yields in the same experiment were 664 and 594 g $m^{-2}$ for Flooded (control) and EMSD, respectively (Table 1). In the year 2010, the brown rice yield of MSD treatment was larger than flooded (635 g $m^{-2}$) and EMSD (623 g $m^{-2}$) treatments. The number of spikelets $m^{-2}$ tended to be larger in Flooded treatment than MSD and EMSD treatment in the 2009 but in the 2010 the opposite trend was observed (Table 1). The number of panicles $m^{-2}$ in EMSD smaller than Flooded and MSD treatments respectively in 2009 where in 2010, the number of panicles $m^{-2}$ showed the opposite trend. The number of spikelets $m^{-2}$ in Flooded was 36,000 and 35,000 which was 75% and 102% of that in MSD in 2009 and 2010 (Table 1). The number of spikelets $m^{-2}$ of EMSD and MSD treatment was significantly smaller than control in 2009 but in 2010 the treatments did not show

Table 1: Brown rice yield and yield components

| Year | Treatment | Brown rice yield (g $m^{-2}$) | Panicle No. ($m^{-2}$) | Spikelet No. ($panicle^{-1}$) | Spikelet No. ($\times 10^3$ $m^{-2}$) | Ripened grains (%) | 1000-grain wt. (g) |
|---|---|---|---|---|---|---|---|
| 2009 | Flooded | 664±59 | 475±19 | 76±0.9 | 36a±1 | 76±5 | 23.6±0.1 |
| | EMSD | 594±12 | 391±30 | 72±5 | 28b±1 | 87±3 | 24.1±0.1 |
| | MSD | 534±15 | 433±19 | 62±2 | 27b±0.2 | 82±1 | 23.8±0.1 |
| | p-value | 0.112 | 0.113 | 0.077 | 0.003 | 0.211 | 0.083 |
| 2010 | Flooded | 635±19 | 495±19 | 67±5 | 35±2 | 79±2 | 22.7±0.6 |
| | EMSD | 623±12 | 510±12 | 62±2 | 32±1 | 86±3 | 22.8±0.1 |
| | MSD | 653±51 | 481±32 | 70±5 | 34±5 | 84±4 | 22.9±0.6 |
| | p-value | 0.813 | 0.692 | 0.516 | 0.747 | 0.425 | 0.967 |

Values represent mean of three replications±standard error, Same letter in the same column are not significantly different, Flooded: Continuous flooding, EMSD: Early mid-season drainage and MSD: Mid-season drainage

any significant differences. The difference in 1000-grain weight among the treatments was negligible. On the other hand, in the 2009 and 2010, the spikelet filling and 1000-grain weight of among the treatments tended to be greater than that of 2010 (Table 1).

## DISCUSSION

With water management (MSD) individual plants with more favourable growing conditions have shorter phyllochrons. Despite that our result revealed that rice growth specially tiller number and plant height was not affected by drainage during growing season.

The trend of LAI in MSD was larger than Flooded and EMSD treatments at heading stage. This was also supported by Yoshida (1983) that LAI of rice increased as crop growth advanced and reached a maximum at heading or flowering stage.

N uptake was larger in MSD than Flooded and EMSD at 17 DAD though statistically had no significant. In this study suggest that the timing of N uptake should be taken into account, because N absorbed at different growth stages affects to biological and economic yield differently (Osaki *et al*., 1997; Yao *et al*., 2000).

Root respiration was higher in MSD than Flooded treatment at neck node differentiation stage only (data not shown). MSD might be due to better aeration during neck node differentiation stage and root system associated with higher mobility and absorption of inorganic N in soil solution which increased the uptake of nutrient and contributed to favourable growth attributes which in turn had resulted on higher yield attributes (Palachamy *et al*., 1989).

In addition, our expectation was MSD water management could enhanced field more drier and supported that the drained field conditions could induce higher root activity by enhancing root respiration and root revitalization, resulting in greater leaf area, higher photosynthesis activity, resulting in higher yield (Tsuno and Wang, 1988; Osaki *et al*., 1997) and the growth of shoots is very much dependent on root growth (Nikolaos *et al*., 2000). Such information argued that if the rice field was dried severely.

EMSD and MSD treatments the yield and yield components were not statistically significant; it means prolonged drained field condition of had no adverse effect on yield and yield components under unfertile soil. Mori and Fuji (2007) mentioned that EMSD reduces the grain number than MSD under fertile soil in Shonai area. Fertile and unfertile soil under different water management might be not same. Therefore, this study should be required further research for understanding the mechanism.

## CONCLUSION

This research indicates that the drained field conditions (MSD) did not decrease growth, N uptake and yield of rice despite induce higher root activity. However, their effects on growth and yield differ, depending on soil, nutritional and environmental conditions. Related studies on water management data should be needed for more confirmation.

## ACKNOWLEDGMENTS

We wish to thank Ministry of Education, Culture, Sports, Science and Technology-JAPAN (MONBUKAGAKUSHO: MEXT) for its financial support.

## REFERENCES

Acuna, T.L.B., H.R. Lafitte and L.J. Wade, 2008. Genotype and environment interactions for grain yield of upland rice backcross lines in diverse hydrological environments. Field Crops Res., 108: 117-125.

FAO, 2006. World agriculture towards 2030/2050 Prospects for food, nutrition, agriculture and major commodity groups. Interim Report, Global Perspectives studies unit, Food and Agriculture Organization of the United Nations, Rome.

Fageria, N.K., A.B. Santos and V.C. Baligar, 1997. Phosphorus soil test calibration for lowland rice on an Inceptisol. Agron. J., 89: 737-742.

Guerra, L.C., S.I. Bhuiyan, T.P. Tuong and R. Barker, 2008. Producing more rice with less water from irrigated system. SWIM Paper 5, IWMI/IRRI, Colombo.

Kamoshita, A., A. Rodriguez, Yamauchi and L. Wade, 2004. Genotypic variation in response of rain fed lowland to prolonged drought and rewatering. Plant Prod. Sci., 7: 406-420.

Keeney, D.R. and W.D. Nelson, 1982. Nitrogen-Inorganic Formsm, Methods of Soil Analysis Part 2: Chemical and Microbiological Properties. 2nd Edn., Am. Society of Agronomy, Inc., Madison, Wisconsin USA., pp: 643-698.

Mori, S. and H. Fujii, 2007. Effect of different starting time of midsummer drainage on the number of spikelets in rice plant. East Southeast Asia Federation Soil Sci. Societies, 8: 223-223.

Nikolaos, N., M.A. Koukou and N. karagiannidis, 2000. Effect of various root stock on xylem exudates cytokinin content, nutrient uptake and growth patterns of grape vines *Vitis vinifera* L. cv. Thompson seedless. Agronomist, 20: 363-373.

Osaki, M., T. Shimono, M. Matsumoto, T. Zheng and T. Tadano, 1997. A root-shoot interaction hypothesis of high productivity of field crops. Soil Sci. Plant Nutr., 43: 1079-1084.

Palachamy, A., S.D. Sundar Sing., A. Rajagopal, S. Ramiah and P. Paramasivam, 1989. Effect of irrigation regimes and nitrogen levels on rice varieties under transplanted condition. Madras Agric. J., 76: 498-806.

Patrick, W.H. Jr. and K.R. Reddy, 1976. Nitrification-denitrification reactions in flooded soils and water bottoms dependence on oxygen supply and ammonium diffusion. J. Environ. Qual., 5: 409-472.

Tsuno, Y. and Y.L. Wang, 1988. Analysis on factors causing cultivar differences in the ripening process of rice cultivars. Jpn. J. Crop Sci., 57: 119-131.

Tuong, T.P. and B.A.M. Bouman, 2003. Rice Production in Water-Scarce Environments. In: Water Productivity in Agriculture: Limits and Opportunities for Improvement, Kijne, J.W., R. Barker and D. Molden (Eds.). CABI Publishing, Wallingford, UK. pp: 53-67.

Yao, Y., Y. Yamamoto, Y. Wang, T. Yoshida, A. Miyazaki, Y. Nitta and J. Cai, 2000. Role of nitrogen regulation in sink and source formation of high-yielding rice cultivars. Soil Sci. Plant Nutr., 46: 825-834.

Yoshida, S., 1983. Rice. In: Potential Productivity of Field Crops under Different Environments, Banta, S.J. (Ed.). International Rice Research Institute, Philippines, pp: 103-127.