PJN
ISSN 1680-5194

Pakistan Journal of Nutrition

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
Mob: +92 300 3008585, Fax: +92 41 8815544
E-mail: editorpjn@gmail.com

OPEN ACCESS Pakistan Journal of Nutrition
ISSN 1680-5194
DOI: 10.3923/pjn.2017.638.644

Research Article
Effects of Ditch Distance in Rice Fields on the Growth and Production of Rice (*Oryza sativa* L.)

[1]Arman Effendi AR, [2]Aswaldi Anwar and [2]Reni Mayerni

[1]Faculty of Agriculture, Universitas Riau, Pekanbaru, 28293, Indonesia
[2]Faculty of Agriculture, Universitas Andalas, Padang, 25163, Indonesia

Abstract
Background and Objective: The System of Rice Intensification (SRI) is one of the techniques of planting rice that can increase rice productivity. However, in field application, there is still some questions as to which technique is the best for soil water conditions. By providing precise soil water conditions in ditch distances, it is expected that rice productivity could be increased and the use of water could be decreased. The aim of this study was to determine the effects of ditch distance on the growth and productivity of rice using SRI. **Materials and Methdos:** The rice variety used was Batang Piaman. This study was conducted using a Randomized Block Design (RBD) with five treatments of ditch distance, i.e., 1, 2, 3, 4 and 5 m and each treatment was given three replications. Data were analysed with the F-test ($p \leq 0.05$). **Results:** Ditch distance significantly affected the maximum number of tillers, plant growth rate, net assimilation rate, number of productive tillers and seed weight per clump, but the number of seeds per panicle and the weight of 1000 seeds were not significantly affected. The best ditch distance for optimum growth and production of rice was 2 m. Using a planting range of 25×25 cm, there were 160,000 rice clumps that produced 8.288 t of dried seeds per hectare. This yield was higher than the described yield of the same variety of 6 t ha^{-1}. **Conclusion:** The optimal ditch distance in planting rice using the SRI method was 2 m, resulting in an increase in rice yield of 38.13%.

Key words: System of rice intensification, ditch, soil aeration, productivity, *Oryza sativa* L.

Received: April 13, 2017 Accepted: June 12, 2017 Published: July 15, 2017

Citation: Arman Effendi AR, Aswaldi Anwar and Reni Mayerni, 2017. Effects of ditch distance in rice fields on the growth and production of rice (*Oryza sativa* L.). Pak. J. Nutr., 16: 638-644.

Corresponding Author: Arman Effendi AR, Faculty of Agriculture, Universitas Riau, Pekanbaru, 28293, Indonesia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice is a very important commodity in Indonesia because it is a staple food. Food sustainability in Indonesia depends on rice production. Generally, rice productivity is still low. The average productivity of rice in Indonesia is approximately 5.14 t ha^{-1}. The low productivity is mainly caused by a condition of anaerobic cultivation of rice done conventionally. This condition means that (1) Energy is used largely for ethylene synthesis and the development of aerenchyma tissue, which supplies oxygen to roots in the soil, (2) The development of rice roots is not optimal and (3) The development of aerobic bacteria is inhibited. According to Venkateswarlu and Visperas[2], the cultivation technique was not done optimally by farmers and therefore, the plant has not been able to express its genetic potential optimally.

There are some problems with a very thick layer of reduction soil in the conventional culture of rice that cause the productivity to be less than optimum. The problems are the following: (1) N is very labile resulting in a loss of approximately 70%[3], (2) Fe^{2+} accumulates to high concentrations poisoning the rice plants, (3) The formation of H_2S also causes poisoning of micro-organisms and rice plants; and (4) The use of energy for aerenchyma tissue formation results in less efficient absorption of nutrients and water[4]. For these reasons, it is necessary to improve rice cultivation by reducing the reduction soil layer using the System of Rice Intensification (SRI) and its modifications. The SRI is one of the intensification methods to explore optimal genetic potential. The SRI method has been applied in Indonesia to increase rice yield but still needs improvement to reach optimal yield.

Generally, farmers plant rice by flooding the rice field during nearly the entire period of planting. This technique has some weaknesses. It causes soil aeration to decrease such that the growth and development of roots are inhibited because of the disturbance in plant respiration. The flooding condition of the soil fills the soil pores with water disturbing oxygen circulation in the root zone and anaerobic, microscopic decomposers often produce compounds that are toxic to plant roots. To overcome this problem, good soil aeration is needed either at the vegetative or generative stage of the plants so there can be an optimum environment for root growth.

Preliminary research conducted in pots[5] studying the effects of various high water levels on the growth of aerenchyma and rice plants indicated that providing a 10 cm height of water under the soil surface showed the best rice growth characteristics. Further field study is needed to assess the effects of different distances of ditches in rice fields. Different distances cause different conditions of soil humidity. This research was done with the objective of determining the best ditch distance to provide optimum growth and productivity of rice.

MATERIALS AND METHODS

Study area: The study was conducted in the rice fields of BBI Pantai Marpoyan, Pekanbaru, Riau Province from June-December, 2012.

Design: The field design can be seen in Fig. 1-3. The experiment was arranged using a Randomized Block Design with five treatments and three replications. The treatments were distance between ditches (B1 = 1 m, B2 = 2 m, B3 = 3 m, B4 = 4 m and B5 = 5 m). There was a total of 15 experimental plots.

Research procedure

Land preparation: Plots for trial were ploughed semi-mechanically using hand tractor and man power and created in a muddy condition. While ploughing, the land was flooded for ±21 days and weeds were removed.

Preparation of nursery and seeds: A nursery was prepared near the trial plots in damp conditions with a size of 1×5 m = 5 m^2 and provided 0.5 kg compost (1 t ha^{-1}). Seeds were soaked for 2 days and those floating were discarded. Then, the seeds were washed, dried and sowed evenly in the nursery.

Planting: The seedlings were planted after 12 days in the nursery to a depth of ±2 cm. In each hole there was only one seedling. The planting range was 25×25 cm. For different ditch distances, there were a different number of individual plants. The number of individuals for the 1 m ditch distance (plot size 1×1 m) was 16 plants, for the 2 m ditch distance (plot size 2×1 m) was 32 plants, for the 3 m ditch distance (plot size 3×1 m) was 48 plants, for the 4 m ditch distance (plot size 4×1 m) was 64 plants and for the 5 m ditch distance (plot size 5×1 m) was 80 plants.

Irrigation: Water was managed based on soil condition. The height of the water surface was 10 cm under the soil surface. Water management was designed in such a way that the height of water surface remained at 10 cm under the soil. The height of the water under the surface of ditch remained stable

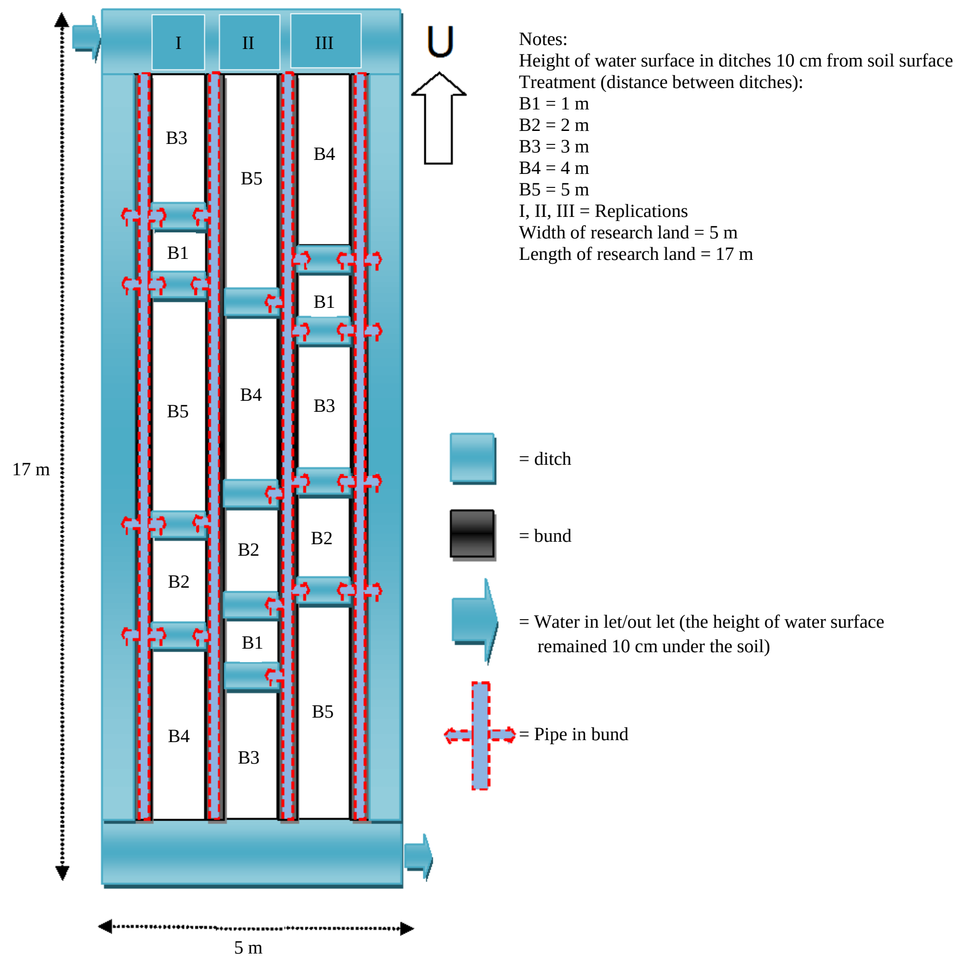

Fig. 1: Lay out of rice field

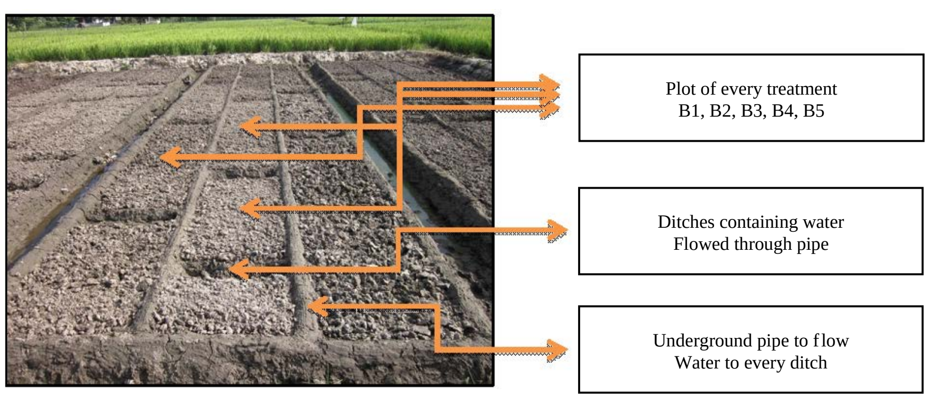

Fig. 2: Condition of rice field, plots and ditches before planting

because water flowed through pipes designed in a certain way (Fig. 1-3). Water that flowed to the rice field came from the ditches so that in different treatments the condition of water in the soil was different. At the time the rice was in its maturity, the land was completely dry.

Fertilizing: The fertilizers used were 200 kg Urea+100 kg SP-36+100 kg KCl for 1 ha or for each plant 1.25 g Urea, 0.625 g SP-36 and 0.625 g KCl. One-half of the Urea and all the SP-36 and KCl were given at the time of planting. The other half of the Urea was divided into two and each was given

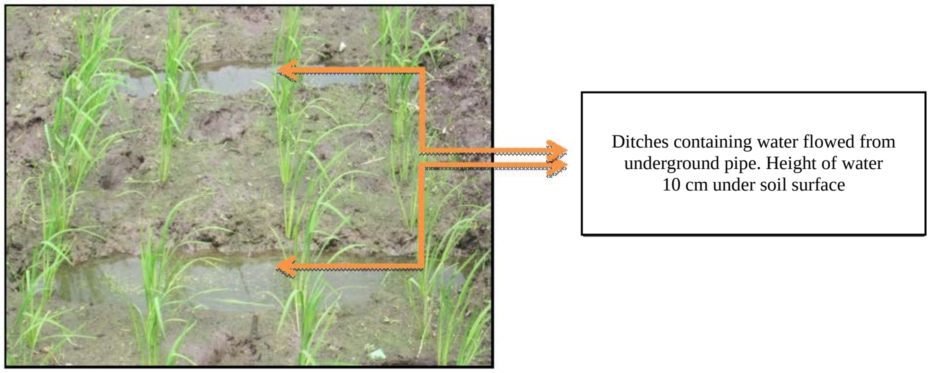

Fig. 3: Ditches with 1 m distance and 2 week old plants

at 21 and 42 days after planting. In addition to synthetic fertilizers, the plants were also given 10 t ha^{-1} of compost. Mutakin[6] stated that plants first need organic fertilizers at 10 t ha^{-1} and that this amount can be utilized to two planting seasons.

Plant protection: Weeding was done twice, at 20 and 40 days after planting. All plots were treated with Curater 3-G for pest control, which was applied at the time of planting using a dose of 17 kg ha^{-1}.

Harvesting: Rice was harvested when all panicles were 80% yellow. After being harvested, seeds were dried for 3 days to a water content of 14-16%. Then, the seeds were observed and scaled.

Parameters measured
Characteristics of plant growth:

- Total number of tillers. In every sample, the number of tillers was counted
- Plant Growth Rate (PGR) (g m^{-2} hari^{-1}). The increase in weight gained was compared with land width per time unit
- Net Assimilation Rate (NAR) (mg cm^{-2} hari^{-1})
- Characteristics of yield components and yield of rice
- Number of productive tillers. All tillers producing panicles were counted at harvesting time for each sample
- Number of seeds per panicle. The number of tillers was counted in every sample
- Weight of 1000 seeds (g). This was conducted at the same time of measuring production
- Weight of seeds per clump

Statistical analysis: Based on the environmental design and treatments, the linear model was as follows:

$$Y_{ij} = \mu+\delta_i+B_j+\epsilon_{ij}$$

Where:

Y_{ij} = Result from effects of distances between ditches
μ = Average general value
δ_i = Effect of block ith
B_j = Effect of distances between ditches jth
ϵ_{ij} = Error term

RESULTS AND DISCUSSION

Plant growth: The different distance between ditches resulted in a significant effect on the growth of the rice plants. This was seen in the parameters of total number of tillers, Plant Growth Rate (PGR) and Net Assimilation Rate (NAR).

The total number of tillers with a 2 m ditch distance (33.67 individuals) was significantly higher than that at 4 and 5 m but was not significantly different from the ditch distances at 1 and 3 m. Conditions of the 2 m ditch distance provided good aeration and increased micro-organism activity that resulted in an increase in the organic decomposition process and provided enough water to affect the growth media. This condition made the development of tillers optimum. Gardner *et al.*[7] stated that the number of tillers would be at a maximum level when plants had good genetic characteristics and a good environment favourable for the plants.

The plant growth rate tended to improve at the 2 and 1 m ditch distances (9.40 and 9.30 g m^{-2} day^{-1}, respectively). However, these growth rates were not significantly different from those at 3, 4 and 5 m ditch distances. In general, plant

Table 1: Total number of tillers, Plant Growth Rate (PGR) and Net Assimilation Rate (NAR) in different ditches distances

Ditches distance (m)	Total number of tillers (individuals)	Plant growth rate (g m^{-2} $days^{-1}$)	Net assimilation rate (mg cm^{-2} $days^{-1}$)
1	31.33^{ab}	9.30^{a}	0.47^{a}
2	33.67^{a}	9.40^{a}	0.49^{a}
3	29.33^{abc}	6.93^{b}	0.39^{b}
4	25.33^{bc}	5.63^{b}	0.35^{b}
5	23.33^{c}	3.97 c	0.34^{b}

Numbers followed by the same lower case in the same column were not significantly different based on DNMRT at 5% confidence level

Table 2: Number of productive tillers, number of seeds per panicle, weight of 1000 seeds and weight of seeds per clump

Ditch distance (m)	Number productive tillers (batang)	No. of seeds per panicle	Weight 1000 seeds (g)	Weight seeds per clump (g)
1	25.33^{ab}	64.33^{a}	27.67^{a}	49.38^{a}
2	27.67^{a}	64.67^{a}	27.33^{a}	51.80^{a}
3	24.67^{b}	63.33^{a}	27.33^{a}	46.45^{b}
4	17.67 c	62.33^{a}	28.33^{a}	34.67^{c}
5	13.33 d	60.33^{a}	27.67^{a}	26.05^{d}

Numbers followed by the same lower case in the same column were not significantly different based on DNMRT at 5% confidence level

growth rate is considered as an increase in the rate of total plant dried weight. If only one plant in a pot is measured, the yield is in grams per plant per day. The pattern of plant growth rate is often in the form of a cubic curve, where the plant growth rate produces more than one peak. Plant growth rate is very much affected by environmental conditions, mainly the quality of light and other growth-supporting factors such as water, nutrient and oxygen availability around roots. Gardner *et al.*[7] stated that the net assimilation rate was directly affected by the capability of leaves to absorb light radiation. Growth rate was measured based on the increase in weight of the plant canopy such that low weight was shown by the low weight of the canopy. This could occur because of a low rate of net photosynthesis[8].

The best net assimilation rate was found at ditch distances of 2 and 1 m producing net assimilation rates (0.49 and 0.47 mg cm^{-2} day^{-1}, respectively). These values were significantly different from those of ditch distances 3, 4 and 5 m. This was a result of higher soil humidity and an increase in micro-organism activities, which speed up the C-organic decomposition process to form assimilates and enough water was available to affect the growth media. Water in ditches moved horizontally through the trough soil pores and the flow made those areas passed more humid. Pascual and Wang[9] reported that root development would be optimum in soil conditions which were not too dry or too wet. They proved that irrigation at 3 day intervals provided optimum humidity which was shown by longer and heavier roots compared to those plants irrigated at 7 day intervals and continuous irrigation. Soil humidity is related to water content and soil aeration. Water in rice field plots moves. According to Hidayat[10], water in rice fields penetrated below the soil and to the sides.

Components of yield and yield: For components of yield, the ditch distance affected the number of productive tillers and the weight of seeds per clump, while the number of seeds per panicle and the weight of 1000 seeds were not affected. When the total number of tillers (Table 1) was compared to the number of productive tillers (Table 2), there was the same tendency; for example, at a ditch distance of 2 m, the numbers were better than for the other treatments This indicated that the number of productive tillers was proportional, i.e., a high number of total tillers was also followed by a high number of productive tillers and vice versa. According to Yoshida[11], tillers growing at an early phase would develop to produce panicles, while those developing later may or may not produces panicles.

None of the treatments of ditch distance affected the number of seeds per panicle or the weight of 1000 seeds. This meant that the characteristics of these two parameters were not affected by different environments but were controlled by genetic factors. This was in accordance with the description of the Batang Piaman rice variety which showed the weight of 1000 seeds as more or less 27 g . The weight of 1000 seeds was affected by the size of the husk which was controlled genetically[11]. Fan *et al.*[12] reported that the weight of 1000 seeds was controlled by main quantitative locus. Further, Dou *et al.*[13] stated that the weight of 1000 seeds was not affected by soil environment and different water content, but it was affected by each cultivar. Sriwijaya and Bimanyu[14] also emphasized that the plant genetic effect was attached to variety.

The weight of seeds between ditch distances of 1 and 2 m was not significantly different, but these were different from those at 3, 4 and 5 m. In general, this indicated that the higher the water content, the heavier the weight of seeds per clump. The rice field with a ditch distance of 1 m had soil water content of 35.87%, at 2 m it was 35.52%, at 3 m it was 33.41%, at 4 m it was 31.42% and at 5 m it was 28.14%. Thus, it could be concluded that a ditch distance of 2 m was the best which was supported by the total number of tillers and the number of productive tillers. The higher the productive tillers the heavier the weight of seeds per clump.

Net Assimilation Rate (NAR), plant growth rate, total number of tillers, number of productive tillers and weight of seeds per clump were affected by the treatment of ditch distances. Characteristics that were not affected were number of seeds per panicle and weight 1000 filled out seeds. Generally, the best treatment was a ditch distance of 1 or 2 m. This was a result of higher soil humidity and an increase of micro-organism activity which sped up the C-organic decomposition process to form assimilates. Water in ditches moved horizontally through trough soil pores and the flow made areas passed more humid. According to Hidayat[10], water in rice fields penetrated below the soil and to the sides. Soil humidity is very much related to water content and soil aeration.

The close distance of ditches, such as the 1 and 2 m treatments, provided maximum water penetration horizontally around the ditches so that the soil had higher humidity with water content more or less 35.52-35.87% and could maintain this soil humidity for plant growth media. According to Uphoff *et al.*[15], SRI could increase soil quality and productivity for a long time through a combination practice of plant, water and nutrient management which contributed to the size, dynamic and diversity of the soil micro-organism community.

The highest weight of seeds per clump, which was 51.80 g clump^{-1}, was found at a ditch distance of 2 m. When converted into a width unit with a planting range of 25×25 cm or with a total population of 160,000 clumps per hectare, the productivity per hectare was 8.288 t of dried seeds (GKP).

The higher productivity at a 2 m ditch distance was supported by other parameters such as net assimilation rate, plant growth rate, total number of tillers and number of productive tillers. All the parameters determined the weight of seeds per clump. The result of this study was in accordance with that of Kariali and Mohapatra[16] who reported that seed weight was very dependent on effective tillers. Seed weight was a function of the interaction among several important yield components such as number of filled out seeds per panicle, productive tillers and weight of 1000 gabah[17]. Further, Aghamolki *et al.*[18] reported that the linear relationship between yield and yield components showed that an increase of effective tillers, number of seeds and weight of 1000 seeds were in accordance with an increase in yield.

According to Yang *et al.*[19], seed yield depended on the size and efficiency of the assimilation surface area after flowering, dried materials produced and stored in vegetative organs and the duration of the process. Assimilates available in the stem and other parts after flowering were finally combined and translocated into seeds. By implementing a system of rice intensification, rice plants had more tillers per clump, more seeds per panicle and the roots grew larger[20].

According to Gardner *et al.*[7] water functions as a solvent for organic and inorganic materials, as a basic material in photosynthesis, to control plant body temperature, to maintain turgor in cell development and to influence stomata opening. Lakitan[21] stated that water functions as a solvent for the transport of nutrients from the soil into plant tissue, for the photosynthetic transpiration from source to sink and for maintaining the turgidity in cell development and stomata opening and that water is an important element of the protoplasm, an energy form from sun light to biochemical energy and it can control plant temperature.

CONCLUSION

The best ditch distance for growth and production of rice is 2 m. Using a planting range of 25×25 cm, there were 160,000 rice clumps that produced 8.288 t of dried seeds per hectare. This value was higher than the yield of rice from the same variety (Batang Piaman) based on its description of 6 t ha^{-1}. Thus, the treatment could increase rice yield by 38.13%.

SIGNIFICANCE STATEMENTS

This study discovers a new cultural technique for rice cultivation by implementing a height of water in a ditch 10 cm under the soil surface, which is a modification of System of Rice Intensification (SRI), this could increase the productivity of the Batang Piaman rice variety by 38.13%. It could certainly increase the income of rice farmers. This result could contribute to an increase in rice productivity in Indonesia, which is still low at 5.341 t ha^{-1}.

REFERENCES

1. Kementerian Pertanian-RI Direktorat Jendral Pangan Tanaman Pangan, 2014. Laporan Tahunan Ditjen Tanaman Pangan Tahun 2013. http://sakip.pertanian.go.id/admin/tahunan/LAPORAN%20TAHUNAN%20DITJEN%20TP%20TAHUN%202013.pdf

2. Venkateswarlu, B. and R.M. Visperas, 1987. Source-sink relationships in crop plants. International Rice Research Institute, Manila, Philippines, pp: 1-19.
3. Prasetyo, B.H., J.S. Adiningsih, K. Subagyono and R.D.M. Simanungkalit, 2004. Mineralogi, Kimia, Fisika dan Biologi Tanah Sawah. In: Tanah Sawah dan Teknologi Pengelolaannya, Agus, F., A. Adimihardja, S. Hardjowigeno, A.M. Fagi and W. Hartatik (Eds.). Pusat Penelitian dan Pengembangan Tanah dan Agroklimat, Bogor, pp: 29-82.
4. Visser, E.J.W., L.A.C.J. Voesenek, B.B. Vartapetian and M.B. Jackson, 2003. Flooding and plant growth. Ann. Bot., 91: 107-109.
5. Kasli and A.R.A. Effendi, 2012. Effect of various high puddles on the growth of aerenchyma and the growth of rice plants (*Oryza sativa* L.) in pot. Pak. J. Nutr., 11: 461-466.
6. Mutakin, J., 2008. Budidaya dan keunggulan padi organik metode SRI (System of Rice Intensification). http://pustakapertanianub.staff.ub.ac.id/files/2012/12/ARTIKEL-SRI.pdf
7. Gardner, F.P., R.B. Pearce and R.L. Mitchell, 1991. Physiology of Crop Plants. The Iowa State University Press, Iowa, USA.
8. Halder, K.P. and S.W. Burrage, 2004. Effect of drought stress on photosynthesis and leaf gas exchange of rice grown in Nutrient Film Technique (NFT). Pak. J. Biol. Sci., 7: 563-565.
9. Pascual, V.J. and Y.M. Wang, 2017. Impact of water management on rice varieties, yield and water productivity under the system of rice intensification in Southern Taiwan. Water, Vol. 9. 10.3390/w9010003.
10. Hidayat, A., 2001. Modul program keahlian budidaya tanaman. Mengatur pemberian air. Direktorat Pendidikan Menengah Kejuruan. Jakarta. https://www.scribd.com/document/58274169/Mengatur-Pemberian-Air
11. Yoshida, S., 1981. Fundamentals of Rice Crop Science. 1st Edn., International Rice Research Institute, Phillipines, ISBN: 971-104-052-2, Pages: 267.
12. Fan, C.C., Y.Z. Xing, H.L. Mao, T.T. Lu and B. Han *et al*., 2006. GS3, a major QTL for grain length and weight and minor QTL for grain width and thickness in rice, encodes a putative transmembrane protein. Theor. Applied Genet., 112: 1164-1171.
13. Dou, F., J. Soriano, R.E. Tabien and K. Chen, 2016. Soil texture and cultivar effects on rice (*Oryza sativa*, L.) grain yield, yield components and water productivity in three water regimes. PLoS ONE, Vol. 11. 10.1371/journal.pone.0150549
14. Sriwijaya, B. and A. Bimanyu, 2012. Respon macam pupuk dan varietas terhadap pertumbuhan dan hasil padi dalam SRI (System of Rice Intensification). J. AgriSains, 4: 35-50.
15. Uphoff, N., S. Rafaralaby and J. Rabenandrasana, 2002. What is system of rice intesification. Cornell International Institute for Food, Agriculture and Development, New York.
16. Kariali, E. and P.B. Mohapatra, 2007. Hormonal regulation of tiller dynamics in differentially-tillering rice cultivars. Plant Growth Regul., 53: 215-223.
17. Bashir, M.U., N. Akbar, A. Iqbal and H. Zaman, 2010. Effect of different sowing dates on yield and yield components of direct seeded coarse rice (*Oryza sativa* L.). Pak. J. Agric. Sci., 47: 361-365.
18. Aghamolki, M.T.K., M.K. Yusop, H.Z. Jaafar, S. Kharidah, M.H. Musa and P. Zandi, 2015. Preliminary analysis of growth and yield parameters in rice cultivars when exposed to different transplanting dates. Electron. J. Biol., 11: 147-153.
19. Yang, J., J. Zhang, L. Liu, Z. Wang and Q. Zhu, 2002. Carbon remobilization and grain filling in japonica/indica hybrid rice subjected to postanthesis water deficits. Agron. J., 94: 102-109.
20. Berkelaar, D., 2001. SRI, the system of rice intensification: Less can be more. ECHO Development Notes, January 2001, ECHO Inc., USA., pp: 1-6.
21. Lakitan, B., 2000. Dasar-Dasar Fisiologi Tumbuhan. Raja Grafindo Persada Jakarta.