Biomass development

by Ardiansyah -

Submission date: 09-Nov-2019 07:57AM (UTC+0700)
Submission ID: 1210119210
File name: eld_under_Unmaintained_Alternate_Wetting-Drying_Irrigation.docx (653.38K)
Word count: 2830
Character count: 15233

Biomass Development in SRI Field under Unmaintained Alternate Wetting-Drying Irrigation

Ardiansyah[1], Chusnul Arif[2], Krissandi Wijaya[1], Asna Mustofa[1]

[1]Department of Agricultural Engineering, Jendral Soedirman University, Purwokerto, Indonesia, email : ardi.plj@gmail.com, cc : ard@unsoed.ac.id

[2] Department of Civil and Environmental Engineering, Bogor Agricultural University, Bogor, Indonesia

Abstract. The aim of this research are to observe biomass development of SRI on farmers practice in three plots with different level. This research observe the farmer practice of SRI and Non SRI during the uncertainity of irrigation water supply and it effects on paddy biomass development during growth stages and final stage of crop. A farmer group that already understand the principle of SRI, applied this method into several plots of their rented paddy field. Researcher intervention were eliminated from their action, so it is purely on farmers decision on managing their SRI plots. Three plots from both SRI and Non-SRI were choosen based on the position of the plot related their access to water. First plots had direct access to water from tertiary irrigation channel (on farm). Second plots were received water from previous upper plots and drainage water into another plots. Third plots were in the bottom position, where they received water from upper plot, and drainage water into farm drainage channel. Result shows there are similar pattern of root, straw, and leaves of biomass during crop growth. On the other hand, during generative phase, grain develoment shows different pattern and resulting different biomass in harvest time. Second plot, (of SRI) that has water from first plot has the average of biomass grain per plant of 54.4, higher than first plot and third plot, which are 33.8 g and 38.4. Average biomass in second plot is 74.6 g, higher than fisrs and third plot, which are 49.9 g and 52.3 g.

Keywords: Biomass, Alternate Wetting and Drying Irrigation, System of Rice Intensification, Farmer Practice

1. Introduction

SRI cultivation method emphasize on increasing rice productivity by improving surrounding environment, be it above or below the ground [1]. Over 50 countries reported the effectiveness of SRI method to increase yield [2] as well as decrease water consumption in paddy field [3,4] The high yield observed as influenced by the activity of microbe in aerobic condition [5–7]Alternate wetting and drying irrigation is the key factor to provide aerobic condition.

Eventhough SRI practice said to be excellent in water-saving, still water availability during vegetative stage is important to maintain alternate wetting-drying irrigation pattern. The irrigation pattern should be managed well during the early stage of crop season. The actual problem farmer face in the field, that is during early stage of crop, when alternate wetting-drying irrigation applied, irrigation schedule is not well maintain due to water availability. Often, water is not available when irrigation scheduled, and conversely water is plenty during drying time.

Training on correct SRI methods has been one of interest for government instructor (Penyuluh Pertanian Lapang) and university's teacher (under university community service program). The training usually conducted to make farmers aware to practice SRI well according to it's principles. However, after the training, farmers adopt the technology according to their flavour to match their schedule, time, or local practice. Water availability during vegetative stage is important to maintain good plant structure growth and preparing for generative stage [8]. According to common practice by the farmer, continuous flooding is good practice [9,10] . However, when the water management shifting from continuous flooding to alternate wetting and drying, farmers need adjustment in their practice.

The aim of this research are :

1. Observe biomass development on SRI rice field under farmer's alternate wetting and drying irrigation practice
2. Comparing SRI to Non-SRI fields, under farmers management
3. Creating baseline for growth model callibration from water management pont of view

2. Material and Methods

This research observe the farmer practice of SRI during the uncertainity of irrigation water supply and it effects on paddy biomass development during growth stages and final stage of crop. A farmer group that already understand the principle of SRI, applied this method into several plots of their rented paddy field, while at the same time, they're also applied Non-SRI (conventional practice of continuous flooding) into several plots of theirs. Researcher intervention were eliminated from their action, so it is purely on farmers decision on managing their SRI and Non-SRI plots. Three plots were choosen from both SRI and Non-SRI practice to make total six plot. The selection is based on the position of the plot related their access to water. First plots of both SRI and Non-SRI had direct access to water from tertiary irrigation channel (on farm). Second plots of both were recived water from previous upper plots and drainage water into another plots. Third plots were in the bottom position, where they received water from upper plot, and drainage water into farm drainage channel.

Biomass of leaves during growth stages were estimated by using image processing technique [11,12]. Biomass of root were approximated using exponential growth equation model [13]. Initial value were measured from young crop seedling, while final value measured from after harvested crop samples. Model parameters were obtained by fitting parameters procedure.

2.1. Biomass Model for Plant Growth and Development

Growth pattern for all plots were evaluated by fitting growth pattern data into biomass growth model. The biomass growth model used in this research is Shierary Rice Model [14]. This model convert radiation intercept by plant into biomass production through coefficient called radiation efficiency to biomass production (ϵ). Crop growth and development occur by the concept of Thermal Unit (TU) [15–17]. The phase of development need certain amount of TU. If the amount of TU is not fulfilled, there will be no biomass improvement in the phase.

Potential biomass production (dW) modelled by equation (1) :

$$dW = \epsilon \, . \, Q_{intercept} \quad (1)$$

Where ϵ = 1.65 $g\,MJ^{-1}$ is effiency of radiation convertion into biomass. Intercepted radiation ($Q_{intercept}$, $MJ\,.\,m^{-2}$) is calculated using equation (2) :

$$Q_{interception} = (1 - \tau)\,.\,Q_s \quad (2)$$

Where τ ($\tau = e^{-k\,.\,LAI}$ or $\tau = \frac{Q_{trans}}{Q_s}$) is ration between transmitted radiation by crop canopy to daily incoming radiation, and Q_s is daily incoming radiation ($MJ\,.\,m^{-2}$).

Biomass growth in Equation (1) the allocated into organs namely root, straw, leaves and grains. Proportion of allocated biomass into organs were different following growth phase. Equation (3) describe the allocation mechanism :

$$dW_x = \eta_x dW - R_g - R_m \quad (3)$$

dW_x = amount of biomass gain for certain organ (x) ($g\,m^{-2}$), and η_x = biomass proportion allocated for certain organ (root, straw, leaves, or grains). Growth respiration (R_g, $g\,m^{-2}$) and maintenance respiration (R_m, $g\,m^{-2}$) [18] is taken as biomass subtracter, that calculated using Equation (4) and Equation (5) :

$$R_g = k_g\,.\,\eta_x\,.\,dW\,. \quad (4)$$

$$R_m = k_m\,.\,W_x\,.\,Q_{10} \quad (5)$$

dimana k_g = growth respiration coeficcient = 0.0108 (Sulistiono, 2005), dan k_m = maintenance respiration ceoficcient = 0.13 (Sulistiono, 2005). W_x = organ biomass at computing time(g), Q_{10} [19] were formulated as $Q_{10} = (\frac{K_2}{K_1})^{\frac{10}{(T_2 - T_1)}}$ which accordingly can be stated as :

$$Q_{10} = 2^{\frac{10}{(T - 20)}} \quad (6)$$

3. Result and Discussion

3.1. Irrigation Pattern

As previously observed in the field, irrigation for SRI plots were highly depend on water availability in paddy field channel. Figure 1 shows Non-SRI plots applying continuous irrigation and drainage as water always exsist in the field, while SRI plots applying intermittent irrigation and drainage. Water availability were scarce in the 50th days after transplanting. It create drying condition for both SRI and Non-SRI plots. However, in the days after transplanting below 60, water scarcity were no longer problem. Irrigation were returned to normal according to farmers practice.

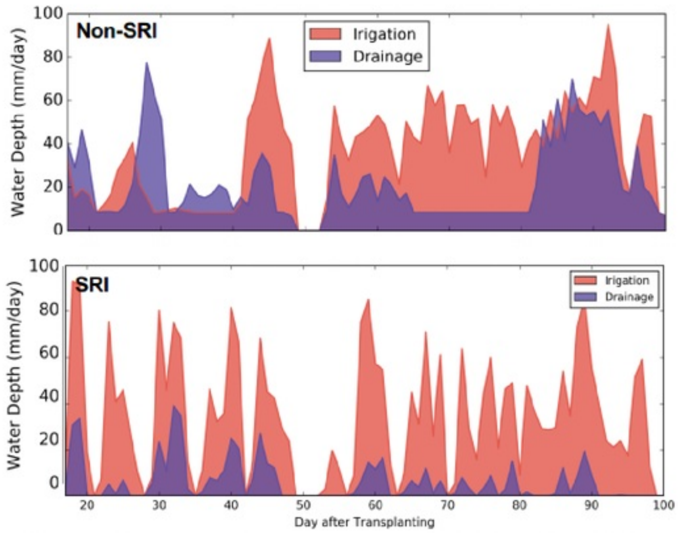


Figure 1. Irrigation and drainage pattern for SRI and Non-SRI plots

3.2. Biomass and Growth

Statistical analysis between Non-SRI and SRI shows there is not significant biomass difference between SRI plots and Non-SRI plots. Totally, biomass developed in Non-SRI plots and SRI plots are similar. However, looking deeper into plants organs, there is significant biomass difference between Non-SRI and SRI in Root and Straw, while leaves and Grains are statistically equal (Table 1). During vegetative phase of plant development, root and straw biomass in Non-SRI plot were develop higher than in SRI plots, while leaves were develop equally for both groups. Entering generative phase, where grains biomass developing, there were no difference between Non-SRI and SRI groups.

Table 1. Level of significance difference between Non-SRI and SRI

	Root	Straw	Leaves	Grains	Total Biomass
Non-SRI to SRI Significance Level	+	+	-	-	-

+ : significant

- : not significant

Table 2 shows significance among 6 plots. Straw shows significant biomass difference for all plots, while leaves, grains, and total biomass shows no biomass difference. Average biomass for each plants organ for 6 plots were shown in Figure 2, which visually confirms the results of Table 1 and Table 2.

Plot 2 in SRI shows highest grain biomass of all 6 plots, however, the other SRI plots (Plot 1 and Plot 3) considered similar with other Non-SRI plots.

Table 2. Level of significance difference between Non-SRI plots and SRI plots

Cropping Practice	Plot No.	Root	Straw	Leaves	Grains	Total Biomass
Non-SRI	Plot 1	-	+	-	-	-
	Plot 2	+	+	-	-	-
	Plot 3	+	+	-	-	-
SRI	Plot 1	-	+	-	-	-
	Plot 2	-	+	-	-	-
	Plot 3	+	+	-	-	-

+ : significant

- : not significant

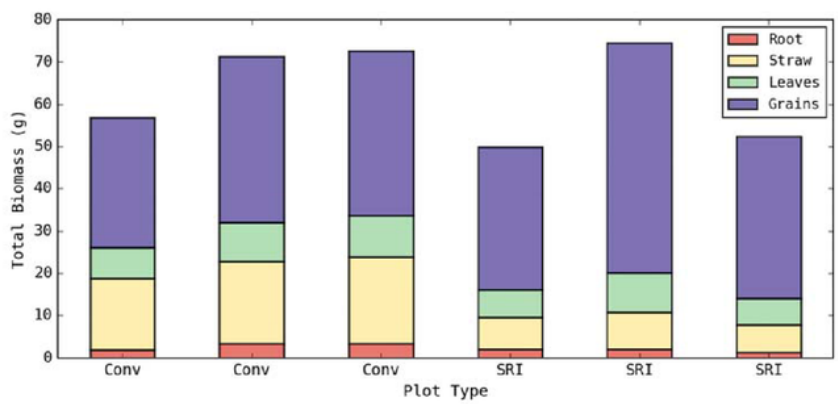


Figure 2. Total biomass of both SRI and Non-SRI plots

Result shows in Figure 3 confirms the similar pattern in the growth of root, straw, and leaves of biomass during crop growth and development. On the other hand, during generative phase, grain development shows different pattern and resulting different biomass in harvest time. For example, second plot in SRI, which has water from first plot has the average of biomass grain per plant of 54.4, higher than first plot and third plot, which are 33.8 g and 38.4. Average biomass in second plot is 74.6 g, higher than fisrs and third plot, which are 49.9 g and 52.3 g. SRI group develop less straw than all Non-SRI group (Figure 2 and Figure 3), however the yield (grain) consistent on the statement that "higher yields (higher grain biomass) are in line with the higher leaves biomass". From Figure 2, we can see second plot in SRI group, that has higher grain biomass, develop comparatively smaller straw biomass. In spite of that, leaves biomass are similar to third plot in Non-SRI group, which make grain biomass for both quite similar.

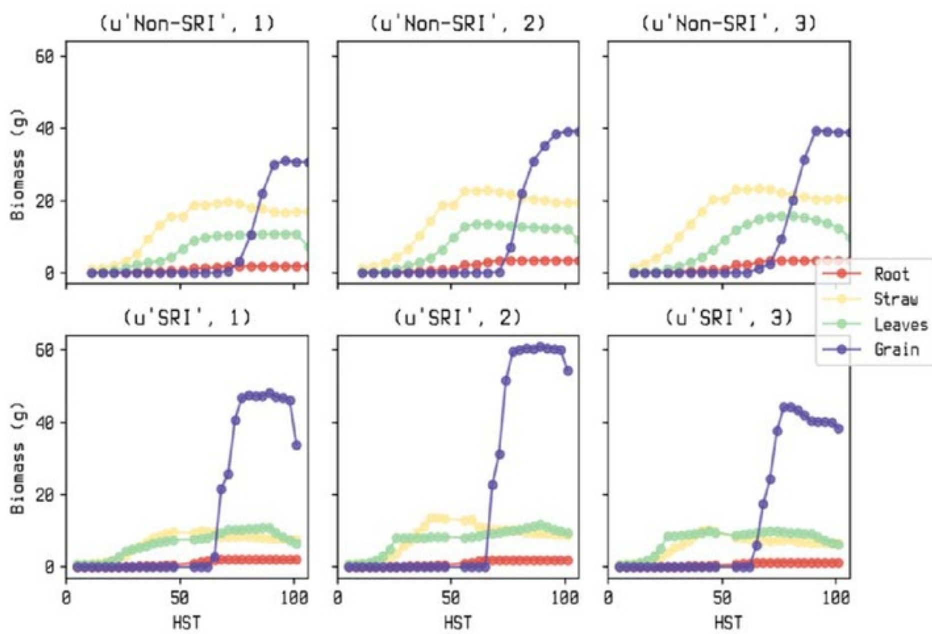
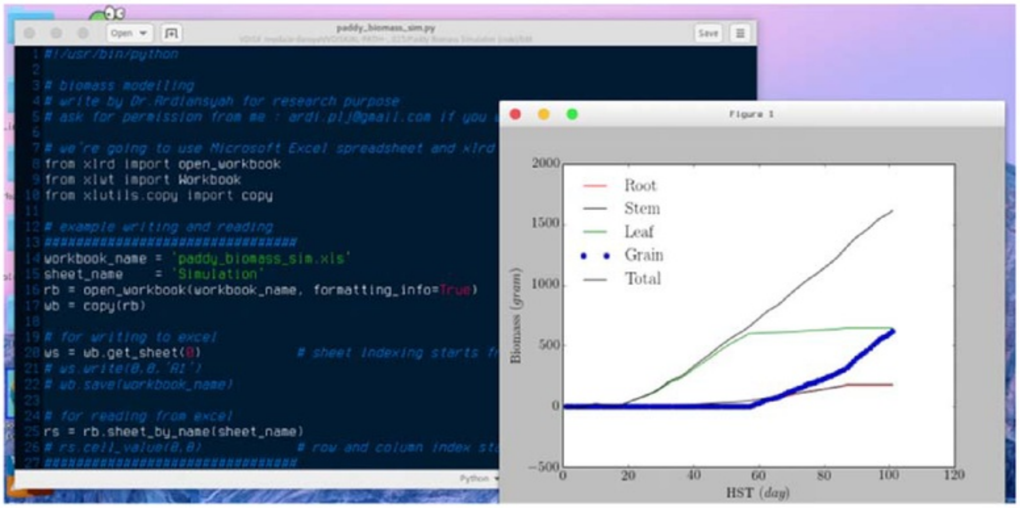
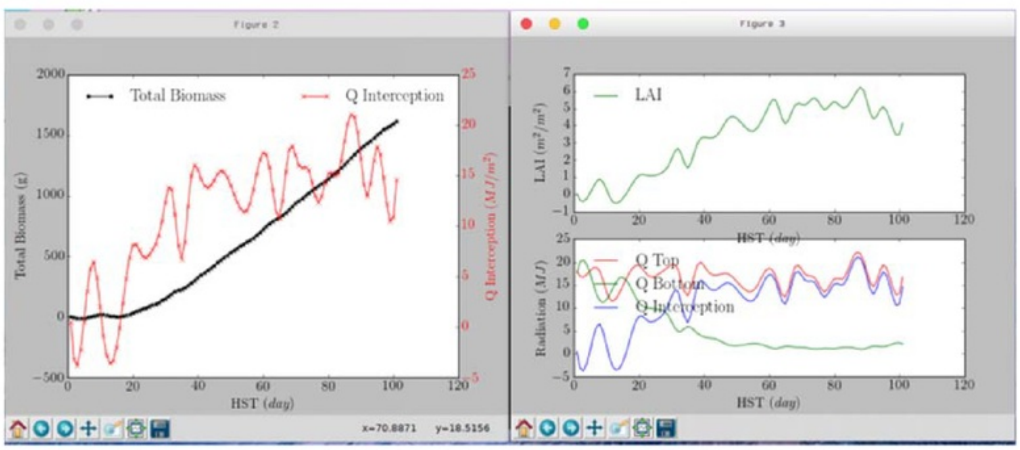


Figure 3. Biomass development of plant organs during crop growth

3.3. Growth Model and Simulation

Realizing that biomass depend on the availability of water, there is a need to include "water management factor" the existing growth model. Shierary Rice Model [14] separated growth phase by distinguish its biomass allocation to plant organ. Each phase marked by different portion of biomass allocation to root, straw, leaves and grains. Figure 4 and Figure 5 shows the result of model without callibration for water management. During vegetative stage, when farmers applying water management on rice plant, whether continuous flooding or alternate wetting and drying,





According to plant growth model, each phase (s) of crop growth has different allocation value for plant organ development. Equations needed to describe the nature of this allocation. The portion of allocation (η) can be 0 (no biomass allocation) or 1 (all biomass allocation goes to the organ) or the value in between. For example, the model that result shows in Figure 4 and Figure 5, the allocation formulation is as follows :

1. In plant emergence phase (beginning of the crop, s<0.25), biomass allocation to plant organs is following the equation of :

   $\eta_{root} = 0.01\, e^{(1.53.\, s)}$, for root

$$\eta_{straw} = 0.01\, e^{(6.42.\, s)}$$, for straw

$$\eta_{leaes} = 1 - \eta_{root} - \eta_{straw}$$, for leaves

$$\eta_{grain} = 0$$, for grain

2. During vegetative stage (s between 0.25-0.5) biomass allocation to plant organs is following :

$$\eta_{root} = 0.01\, e^{(1.24.\, s)}$$, for root

$$\eta_{straw} = 0.02\, e^{(3.55.\, s)}$$, for straw

$$\eta_{leaes} = 1 - \eta_{root} - \eta_{straw}$$, for leaves

$$\eta_{grain} = 0$$, for grain

3. In generative stage (s between 0.5-0.75) biomass allocation to plant organs is following :

$$\eta_{straw} = 0.08 \log(s) + 0.24$$, for straw

$$\eta_{straw} = 0.11 \log(s) + 0.12$$, for leaves

$$\eta_{straw} = 0.25 \log(s) + 0.60$$, for grain

$$\eta_{root} = 1 - \eta_{straw} - \eta_{leaes} - \eta_{grain}$$

4. Finnaly, in plant maturity stage (s>0.75), biomass allocation equations are :

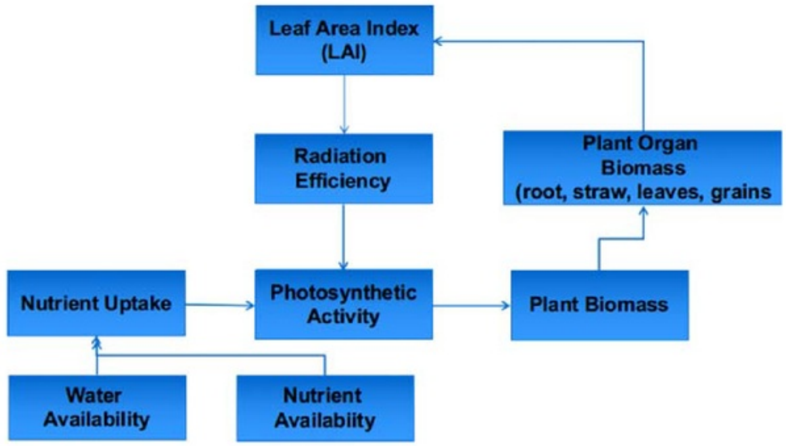
$$\eta_{straw} = 0$$, for straw

$$\eta_{root} = 0$$, for root

$$\eta_{leaes} = 0$$, for leaves

$$\eta_{grain} = 1$$, for grain, where all the biomass growth allocated to grain

From the model point of view, total biomass or allocated biomass to plant organs is the circular effect of photosynthetic activity and radiation efficiency (ϵ) that influenced by leaf area index (Figure 6). Therefore, high biomass can be resulting from good growth vegetative stage, which depend on nutrient uptake by plant root. As generally known well, soil nutrient is available (can be uptaked) by the root in the forms of ion [20–22]. Soil solution is important in nutrient uptake process, thus water availability is also important. Alternate wetting and drying irrigation is the way to shifting from water filled porosity in soil to partially air filled porosity that can influence active decomposition bacteria. The callibration for “water management” should be influence allocation equations in vegetative stage (s between 0.5-0.75).



4. Conclusion

From the result, it can be conclude that unmaintained alternate wetting-drying in SRI make insignificant biomass increase in SRI. It probably causes by the soil water soil water were not fully alternating from wet to dry. It sometimes create extremely dried soil water in upper root zone layer that is intolerable for early stage of growth. Aeration is important in drying paddy field in vegetative stage, so that it can create different environment for soil bacteria responsible for providing nutrition. The biomass itself, is result of complex and interdependency among soil water availability, nutrien availabiity, and radiation efficiency. The latter is very much depend on leaf area (further Leaf Area Index), that higher leaf area will lead to higher grain biomass. Callibration for water management should be further concern in estimating biomass using growth model.

References

[1] Hidayati N, Triadiati, Anas I. Photosynthesis and Transpiration Rates of Rice Cultivated Under the System of Rice Intensification and the Effects on Growth and Yield. HAYATI J Biosci 2016. doi:10.1016/j.hjb.2016.06.002.

[2] Katambara Z, Kahimba FC, Mahoo HF, Mbungu WB, Mhenga F, Reuben P, et al. Adopting the System of Rice Intensification (SRI) in Tanzania: A Review. Agric Sci 2013;4:369.

[3] Mati B, Nyamai M. System of Rice Intensification (SRI): Growing More Rice While Saving on Water. KenyaSRIManual Httpsri Ciifad Cornell Educountrieskenyaindex Html 2012.

[4] Ndiiri JA, Mati BM, Home PG, Odongo B, Uphoff N. Comparison of Water Savings of Paddy Rice Under System of Rice Intensification (SRI) Growing Rice in Mwea, Kenya. Int J Curr Res Rev 2012;4:63–73.

[5] Ardiansyah, Setiawan BI, Arif C, Saptomo SK, Mizoguchi M. Soil Macro Nutrient (N, P, K) during Growth Stages under Conventional and SRI (System of Rice Intensification) Practices in Tropical Soil. PAWEES 2012 Chall. Water Environ. Manag. Monsoon Asia, Thailand: 2012.

[6] Ardiansyah A, Arif C, Wijaya K. Nitrogen Uptake of Sri Paddy Field Compared to Conventional Field. J Teknol 2016;78. doi:10.11113/jt.v78.7259.

[7] Case SDC, McNamara NP, Reay DS, Whitaker J. The Effect of Biochar Addition on N2O and CO2 Emissions from a Sandy Loam Soil – the Role of Soil Aeration. Soil Biol Biochem 2012;51:125–34. doi:10.1016/j.soilbio.2012.03.017.

[8] Virk P, Virman SS, Lopena V, Cabangon R. Enhancing Water Productivity in Irrigated Rice. Proceeding 4th Int. Crop Sci. Congr., The Regional Institute Ltd; 2004.
[9] Datta SKD. Principles and Practices of Rice Production. Int. Rice Res. Inst.; 1981.
[10] Mambani, Datta, Redulla. Soil Physical Behaviour and Crop Responses to Tillage in Lowland Rice Soils of Varying Clay Content. Plant Soil 1990;126:227–35. doi:10.1007/BF00012826.
[11] Lati RN, Filin S, Eizenberg H. Robust Methods for Measurement of Leaf-Cover Area and Biomass from Image Data. Weed Sci 2011;59:276–84. doi:10.1614/WS-D-10-00054.1.
[12] Tackenberg O. A New Method for Non-destructive Measurement of Biomass, Growth Rates, Vertical Biomass Distribution and Dry Matter Content Based on Digital Image Analysis. Ann Bot 2007;99:777–83. doi:10.1093/aob/mcm009.
[13] Goudriaan J, Monteith JL. A Mathematical Function for Crop Growth Based on Light Interception and Leaf Area Expansion. Ann Bot 1990;66:695.
[14] Yuliawan T, Handoko I. The Effect of Temperature Rise to Rice Crop Yield in Indonesia uses Shierary Rice Model with Geographical Information System (GIS) Feature. Procedia Environ Sci 2016;33:214–220.
[15] Marques BS, Silva APP, Lima RSO, Machado ECR, Gonçalves MF, Carvalho SJP. Growth and Development of Sourgrass Based on Days or Thermal Units. Planta Daninha 2014;32:483–90. doi:10.1590/S0100-83582014000300003.
[16] Murakami T. Paddy Rice Ripening and Temperature. Jpn Agric Res Q 1973;7:1.
[17] Parthasarathi T, Velu G, Jeyakumar P. Impact of Crop Heat Units on Growth and Developmental Physiology of Future Crop Production: A Review. ResearchGate 2013;2:2319–3395.
[18] Lötscher M, Klumpp K, Schnyder H. Growth and Maintenance Respiration for Individual Plants in Hierarchically Structured Canopies of Medicago Sativa and Helianthus Annuus: The Contribution of Current and Old Assimilates. New Phytol 2004;164:305–16. doi:10.1111/j.1469-8137.2004.01170.x.
[19] Adu-Bredu S, Yokota T, Hagihara A. Temperature Effect on Maintenance and Growth Respiration Coefficients of Young, Field-Grown Hinoki Cypress (chamaecyparis Obtusa). Ecol Res 1997;12:357–62. doi:10.1007/BF02529465.
[20] Roose T, Fowler AC, Darrah PR. A Mathematical Model of Plant Nutrient Uptake. J Math Biol 2001;42:347–360.
[21] Barison J. Nutrient-Use Efficiency and Nutrient Uptake in Conventional and Intensive (SRI) Rice Cultivation Systems in Madagascar. 2002.
[22] LU YX, LI CJ, ZHANG FS. Transpiration, Potassium Uptake and Flow in Tobacco as Affected by Nitrogen Forms and Nutrient Levels. Ann Bot 2005;95:991–8. doi:10.1093/aob/mci104.

Biomass development

ORIGINALITY REPORT

3%	1%	3%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

MATCH ALL SOURCES (ONLY SELECTED SOURCE PRINTED)

1%

★ Victoriano Joseph Pascual, Yu-Min Wang. "Utilizing rainfall and alternate wetting and drying irrigation for high water productivity in irrigated lowland paddy rice in southern Taiwan", Plant Production Science, 2016

Publication

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		