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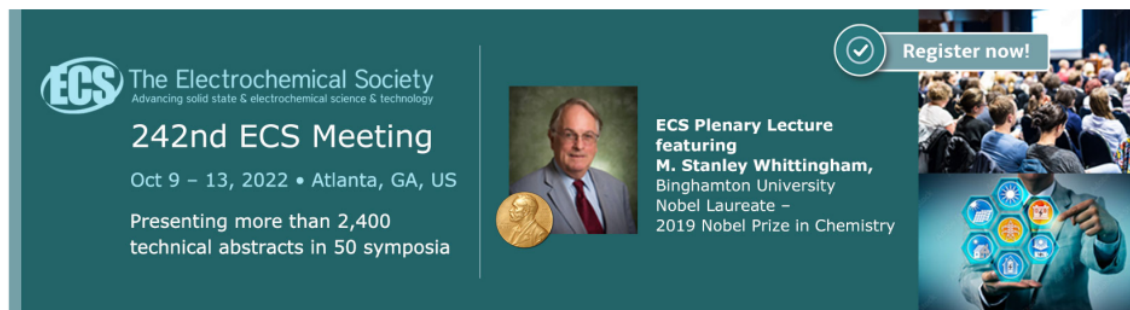
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Simulation and production of soybean plant growth (*Glycine max* (L) Merrill) using the DSSAT model with different scenarios of water supply and compost

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Simulation and production of soybean plant growth (*Glycine max* (L) Merrill) using the DSSAT model with different scenarios of water supply and compost

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Abstract. This study aims to study the response of soybean plants to various scenarios of water supply and compost using the DSSAT model. This research was conducted at the Laboratory of Agro-climatology and Statistics, Department of Agronomy, Faculty of Agriculture, Universitas Hasanuddin, Makassar. This research was conducted in February-March 2016. Simulation of the DSSAT model was determined from primary data in the form of plant management data, soil data, and other supporting data, and secondary data in the form of climate data. The results of the study, based on the paired t-test, the DSSAT model for simulating soybean plants can predict each treatment on the parameters of vegetative weight and number of pods. A t-test on leaf root weight showed that the DSSAT model could predict all treatments except in the treatment of watering every ten days and 3.0 tons/ha of compost. Based on the value of MSE, the DSSAT model for simulating soybean plants can predict the yield of each treatment for the parameters of the number of seeds. The average difference between simulation and observation on seed weight of 314.44 kg/ha and simulation results tend to predict below observation in the field.

1. Introduction

Planning and improving the function of crop production on land can be identified by using a simulation. Simulation is a process of imitation of something concrete along with its surroundings. The application of the simulation can be completed using a model found in a simulation program in the form of software. One of the software used to predict plant growth, and production is DSSAT. Decision Support System for Agrotechnology Transfer (DSSAT) is software developed by the International Benchmark Systems Network for Agrotechnology Transfer (IBSNAT). The use of DSSAT in various plant simulations can give reliable predictions. Based on the results of the research of [1] on rice plants, that tons/ha make the right and immediate decision in rice crop planning, a model that can predict crop yields is needed. The DSSAT plant model issued by IBSNAT is reliable enough to predict production; this is reflected in the relationship between simulation and observation resulting in an r^2 value of 87% for Ngawi and a standard error of estimate of 0.49. The use of DSSAT software for soybean plants is still lacking, especially in Indonesia.

Efforts to meet the soybean needs (*Glycine max* (L) Merrill), which is commonly known in the form of processed tempeh (fermented soybean cake) and tofu in Indonesia, is constrained by the low



domestic soybean production. One of the limiting factors in soybean production is the relatively low availability of water and nutrients during the growth period and change in rain patterns. This obstacle can be controlled by implementing arrangements for water management and proper composting. Water management is an obstacle with the availability of water, which is limited to certain months in a soybean planting area; therefore, it requires more efficient and appropriate water regulation; thus, soybean production can be maximized. According to Sasmita *et al.* [2] application of water supply at 0-75 days according to available soil water content gave the highest average number of pods per plant, pod weight per plant, number of seeds per plant, namely 134.34 pods / plants, 43.62 g / plant, and 273 seeds / plants, respectively. Lack of water causes a significant decrease in growth and yield even 25th. Whereas, the application of water supply in the interval of 0.5 L / day during 7-14 days after planting and 21-28 days after planting resulted in the highest growth rate of soybean plants with an average plant growth rate of 1.83 cm/day and 2.16 cm/day [3].

Soybean plants are not resistant to drought. Mapegau [4] suggested that water stress can affect soybean growth and production. Growth and yield of Willis soybean cultivar began to show a decrease in the water stress level of 60% of available soil water content, while Tidar cultivar experienced a decrease in growth and the results occurred at 40% of available soil water content. The lack of available water in the soil during the dry season can be overcome by adding organic material which acts as a mulch, and the organic matter content of K can keep the turgor when plant lack of water [5]. Apart from water, fertilizer is also a problem in soybean nutrition during the growth period. The continued use of inorganic fertilizers causes a decrease in soil fertility and damage to soil structure. The use of organic fertilizers such as compost is expected to be able to restore nutrient content and improve soil structure. According to Primantoro research [3], 7.5 tons/ha of compost fertilizer produced the highest soybean plants at 7 days after sowing (DAS) and 14 DAS with an average plant height of 16.57 cm and 27.53 cm, respectively.

One solution is needed to overcome the problems in soybean crop cultivation that combines climate, soil and plant components in the form of appropriate prediction models to determine the influence of climate, soil, and plants to be planted. In applying the model analysis software is needed that can analyze crop cultivation and issue output in the form of crop production. The DSSAT model was developed to integrate soil conditions, climate, plants, and agricultural land management systems to provide information about the growth and development of modeled plants [6]. The information is used to formulate decisions in managing agricultural land; therefore, optimal crop yield can be produced by maximizing soil conditions, climate, and plant characteristics. The data needed to run this model are data of climate, soil, and data on agricultural land management. Plants that can be modeled in this simulation model have different genotype data depending on the plant variety [7].

2. Research Methods

The research was conducted in the Laboratory of Agro-climatology and Biostatistics, Department of Agronomy, Faculty of Agriculture, Universitas Hasanuddin, Makassar from February-March 2016. An experiment was carried out in Appanang village, Liliriaja district, Soppeng Regency applying the same scenario simulated in the model with planting dates on October 24, 2015.

2.1. Daily climate data

Daily climate data includes solar radiation, minimum temperature, maximum temperature, duration of irradiation, wind speed, and rainfall obtained from the nearest station, the Malanroe Climatology Station during the planting period.

2.2. Plant management data

Plant management data includes data on plant varieties, planting time, spacing, population, water regulation, and compost.

2.3. Soil data

Land data includes information on land in the study area which are soil type, soil color, soil texture, organic matter, pH, cation exchange capacity (CEC), nitrogen, phosphorus, potassium, calcium, and aluminum content.

2.4. Other supporting data

Other supporting data, such as the geographic location of the research, land slope, and altitude.

DSSAT is software used in the simulation of plant growth and production. The simulation was created by using new then the experiment that will be developed by arranging all the inputs and outputs used. The DSSAT model will be determined from primary data and secondary data. Primary data includes plant management data, soil data, and other supporting data, while secondary data includes climate data from the nearest station.

Scenarios compiled for simulation by DSSAT are the frequency of water supply (W), and compost (K):

1. Control (W0) which consists of without water + without compost
2. Watering every 5 days (W1) with compost 1.5, 3, and 4.5 t / ha
3. Watering every 10 days (W2) with compost 1.5, 3, and 4.5 t / ha
4. Watering every 15 days (W3) with compost 1.5, 3, and 4.5 t / ha

From the above factors, 16 scenarios were used. For each treatment, normal watering was applied until 14 days after planting (DAP), and watering treatments were started subsequently. Scheme of watering in the experiment is shown in figure 1.

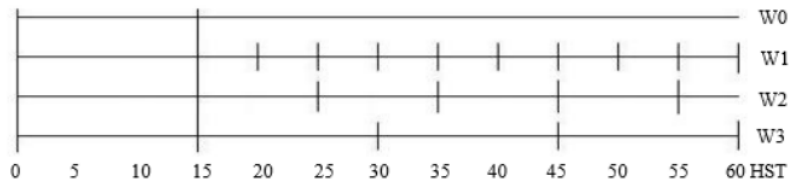


Figure 1. Schedule of water supply.

2.5. DSSAT Simulation and Field Observation

The DSSAT simulation was run the UHIN1501.SBX file which is an experiment file for soybean data in this study. Then, output in GBuild thus, the graph appeared between the simulation and observation in the field. Graphs were constructed based on observational parameters that show trends in data between DSSAT simulations and field observations. The graph used is a line graph that shows plant growth from the beginning of planting to harvest.

2.6. Model Verification

Verification was conducted by performing paired t-tests and calculation of RRMSE and MSE on each treatment between model predictions (simulation) and measurement results in the field (observation). Verification used observational data of the experiment that have been carried out in Appanang Sub-District, Liliraja Subdistrict, Soppeng Regency planting dates on October 24, 2015. Differences between models with observations are significant $P < 0.05$ and not significant when $P > 0.05$.

3. Results

3.1. Vegetative Weight

Figure 2 shows a graph of DSSAT predictions forming a parabolic curve that gives a picture of growth at 0 up to 20 DAP on vegetative weight parameter. At 20 to 50 DAP, a large increase in vegetative weight occurred. The largest vegetative weight peak was at 54 DAP following weight reduction at 54 days to 58 DAP, and then increased again at 58 to 60 DAP. During 65 to 80 DAP, a major reduction in vegetative weight occurred. The reduction in vegetative weight was the phase of plant aging.

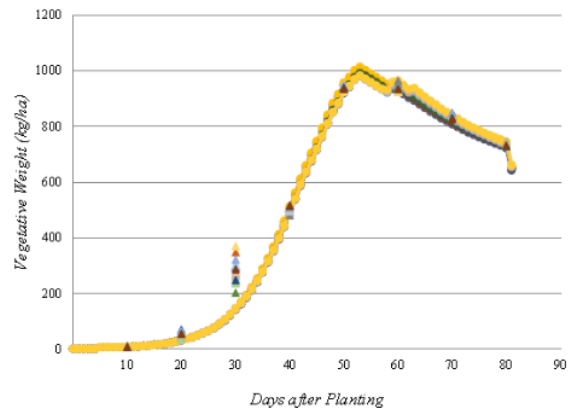


Figure 2. DSSAT Prediction and Field Observation for Vegetative Weight (Leaves + Stems). Symbols represent observed data and lines represents simulated data for all treatment combinations.

The effect of water supply and compost from the predictions of the DSSAT simulation and field observations showed different results on vegetative weight. DSSAT prediction did not show a difference from 0 to 50 DAP; therefore, a line coincides with all treatments. On the other hand, differences in each treatment occurred at 50 to 80 DAP. For field observations, the treatment was different in each treatment. The major difference occurs at 30 DAP.

3.2. Root Weight

Data on root weight in grams per plant converted in units of kg/ha in each treatment predicted by the DSSAT model is shown in figure 3. The figure shows a graph of DSSAT prediction forming a parabolic shaped curve that gives a picture of growth at 0 to 30 DAP. During the period, a minor root weight addition occurred. At 30 days to 50 DAP, there was a major increase in root weight. The highest peak of root weight was at 50 DAP following a large reduction in root weight from 50 to 80 DAP. The reduction in root weight was the phase of plant aging.

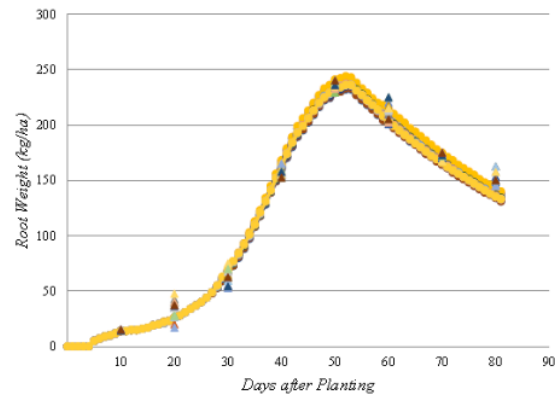


Figure 3. DSSAT Prediction and Field Observation for Root Weight. Symbols represent observed data and lines represents simulated data for all treatment combinations.

DSSAT prediction did not show a difference from 0 to 30 DAP; therefore, a line that coincides with all treatments is formed. At 30 to 80 DAP, differences occurred in each treatment. For field observations, the treatment was different from each treatment with a major difference occurred on the 20 DAP.

3.3. Pod Number

The number of pod data predicted by the DSSAT model and observed in the field trial for each treatment is shown in Figure 4. The figure shows a graph at DSSAT prediction, forming a growth curve at 0 to 40 DAP at the zero lines or no pods have been formed. From 40 to 67 DAP an increase of a large number of pods is shown following a decline at 67 to 73 DAP. The decreasing number of pods was due to the number of pods falling to the ground. At 73 to 80 DAP a stable amount occurred.

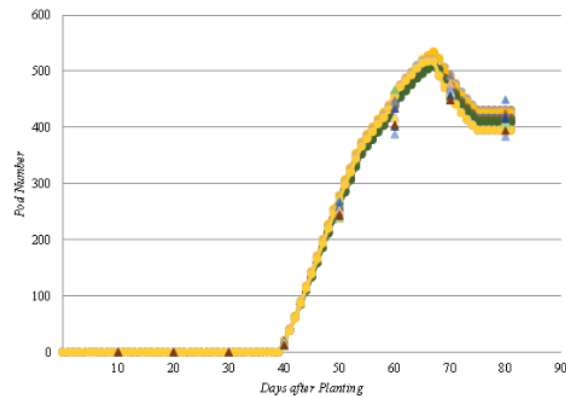


Figure 4. DSSAT Prediction and Field Observation for Number of Pods. Symbols represent observed data and lines represents simulated data for all treatment combinations.

DSSAT prediction did not show a difference from 0 to 40 DAP; therefore, the line coincides with all treatments. From 40 to 80 DAP, differences occurred for each treatment. For field observations, the treatment was different for each treatment with the largest difference occurred at 60 DAP.

3.4. Number of Grain

The number of grain data predicted by the DSSAT model with field observations is shown in figure 5 in a graphical form for each treatment. Figure 5 shows the differences between simulation and observations in the field. The highest results in the simulation were found in the treatment of no water supply + 1.5 tons/ha of compost (W0K1) with the number of grain of 948 while the highest results in the observed data were in the control treatment (W0K0) with 953 grain.

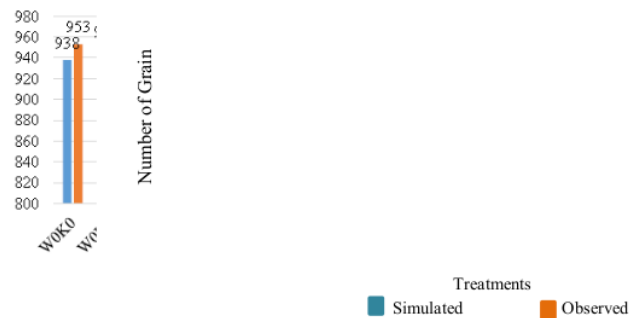


Figure 5. DSSAT prediction and field observation for number of grain

DSSAT prediction did not show a difference from 0 to 40 DAP so that a line coincides with all treatments. From 40 days to 80 days, a difference was shown for each treatment. For field observations, the treatment was different from each treatment. The biggest difference occurs at 80 days.

3.5. Grain Weight

Grain weight data predicted by the DSSAT model and observed data from the field are shown in figure 6. The graph shows the differences between simulations and observations in the field. The highest results in the simulation were found in the treatment of no water supply + 4.5 tons/ha of compost (W0K3) with the grain weight up to 1093 kg/ha while observed grain weight is shown by the control treatment (W0K0) with grain weight of 1508 kg/ha.

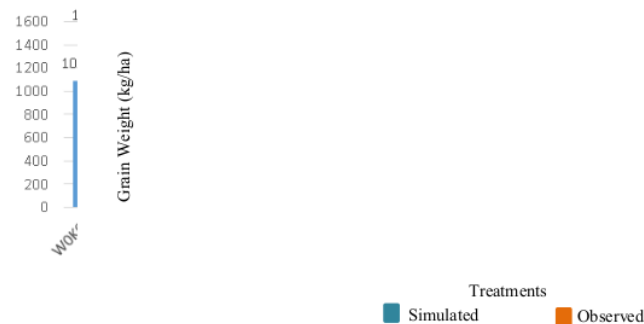


Figure 6. DSSAT prediction and field observation for grain weight.**3.6. Model Verification**

Calculation of RRMSE, p values of paired t-test and MSE of observed and predicted value are shown in table 1.

Table 1. P-value, RRMSE, and MSE of predicted and observed of growth and production parameter of Soybean on different water supply and compost application

Frequency of water supply and the dose of compost application	Vegetative Weight		Root Weight		Number of Pod per plant		Number of Grain	Grain weight
	RRMSE	P-value	RRMSE	p value	RRMSE	P-value		
Control	0.104	0.105 ns	0.089	0.214 ns	0.084	0.294 ns	0.025	7.72
No Water supply + 1.5 ton/ha	0.066	0.170 ns	0.056	0.195 ns	0.061	0.163 ns	0.122	2.98
No Water supply + 3 ton/ha	0.103	0.194 ns	0.073	0.412 ns	0.117	0.099 ns	0.366	4.54
No Water supply + 4.5 ton/ha	0.132	0.202 ns	0.071	0.371 ns	0.076	0.102 ns	0.255	3.72
Every 5 days + No Compost	0.093	0.074 ns	0.083	0.178 ns	0.045	0.249 ns	0.082	6.47
Every 5 days + 1.5 ton/ha	0.086	0.097 ns	0.076	0.051 ns	0.024	0.112 ns	0.002	6.7
Every 5 days + 3 ton/ha	0.107	0.076 ns	0.080	0.156 ns	0.043	0.256 ns	0.010	7.26
Every 5 days + 4.5 ton/ha	0.046	0.060 ns	0.105	0.057 ns	0.079	0.097 ns	0.0005	6.51
Every 10 days + No Compost	0.108	0.110 ns	0.085	0.132 ns	0.109	0.131 ns	0.171	4.55
Every 10 days + 1.5 ton/ha	0.091	0.160 ns	0.080	0.295 ns	0.088	0.152 ns	0	6.12
Every 10 days + 3 ton/ha	0.081	0.137 ns	0.069	0.047 ns	0.135	0.132 ns	0.128	4.32
Every 10 days + 4.5 ton/ha	0.149	0.172 ns	0.100	0.075 ns	0.063	0.105 ns	0.163	3.3
Every 15 days + No Compost	0.118	0.145 ns	0.080	0.212 ns	0.192	0.155 ns	0.273	6.42
Every 15 days + 1.5 ton/ha	0.067	0.163 ns	0.081	0.094 ns	0.157	0.16 ns	0.072	4.75
Every 15 days + 3 ton/ha	0.075	0.157 ns	0.096	0.132 ns	0.150	0.228 ns	0.002	4.73
Every 15 days + 4.5 ton/ha	0.098	0.194 ns	0.080	0.14 ns	0.138	0.127 ns	0.023	4.88

Output DSSAT v.46 (UHIN1501.SBX). ns=not significant; s=significant.

For the parameter of vegetative weight, the highest RRMSE value was shown in the treatment of giving water every 10 days + 4.5 tons/ha of compost (W2K3) with RRMSE value of 0.149 and the lowest RRMSE value in the treatment of water every 5 days + 4.5 tons / ha compost (W1K3) with RRMSE value of 0.046. For root weight parameters, the RRMSE value was highest in the treatment of giving water every 5 days + 4.5 tons/ha of compost (W1K3) with RRMSE value of 0.105 and the lowest RRMSE value in the treatment without water + 1.5 tons/ha of compost (W0K1) with RRMSE value of 0.056. Whereas for the parameters of the number of plant pods, the highest RRMSE value was in the treatment of giving water every 15 days + without compost (W3K0) with RRMSE value of 0.192 and the lowest RRMSE value in the treatment of water every 5 days + 1.5 tons / ha of compost (W1K1) with RRMSE value of 0.024.

The p-value of the paired t-test results for all treatments for vegetative weight parameters and the number of pods per plant showed no significant results ($P < 0.05$) between simulation and observations in the field except for root weight parameters. The value of p-value for root weight parameters showed significant difference ($P > 0.05$) between the simulation and observations in the field on the treatment of water supply every 10 days + 3.0 tons/ha of compost (W2K2).

Verification of crop production was done by comparing the yield of plants. The verification was carried out at the time of harvesting so that the difference between the simulations of the DSSAT model can be seen at 82 DAP with observations in the field at harvest time with the same age. The highest MSE value for parameter of number of grain was found in the treatment of no water supply + 3.0 tons / ha of compost (W0K2) with MSE value of 0.366% and the smallest MSE value in the treatment of giving water every 10 days + 1.5 tons / ha of compost (W2K1) with an MSE value of 0%. The MSE values shown in table 1 indicate that the model is valid in predicting the number of grain of soybean plants in various scenarios of water supply and compost application.

The highest MSE value was found in the treatment without water + no compost (W0K0) with the MSE value of 7.72% and the smallest MSE value in the treatment no water supply + 1.5 tons/ha of compost (W0K1) with MSE value of 2.98 %. Based on MSE values, the model prediction was valid (MSE value of $< 5\%$) for the scenario of no water supply with compost application of 1.5, 3.0, 4.5 tons/ha, respectively, treatment of water supply every 10 days without compost and with compost of 3.0, 4.5 tons / ha, and treatment of water supply every 15 days with compost application of 1.5, 3.0, and 4.5 tons / ha. Except for these treatments, the prediction of grain weight was invalid due to the MSE value of $> 5\%$.

4. Discussion

DSSAT simulation is built by entering data in the form of climate, genetics, and soil data, as well as information about land and treatment in the field. The plant simulation model is a representation of plant growth and development calculation processes that are influenced by interactions between the environment (climate), genotypes (varieties), and management of plants [9]. The influence of climate influences the data used in the form of station location and equipment conditions and accuracy in collecting data at the station. In the study, the distance between the experimental field and the station was 3.6 km. Data from the station can still be used to represent data on the experimental field. However, this data can be the cause of the accuracy of the DSSAT prediction model. According to Singh and Ritchie [10], one way to achieve a good level of accuracy is to use sufficient weather data and historical data at a specific location [11].

The DSSAT model provides a limited variety; thus, the use of the Argomulyo variety requires an input of plant genetic data. The accuracy of the DSSAT model also influences the genetic information entered. Information in the form of data that is not included in the description of varieties and genetic information on varieties but is needed in the input of genetic information in DSSAT cause the selection of default information or general genetic information on soybean plants is carried out. These conditions affect the accuracy of the model.

Another condition is information that must be the same as conditions in the field. The information includes planting spacing, planting time, population, irrigation, fertilization, pests and diseases, and harvest. This information can affect the accuracy of the model, especially on pest and disease information. Conditions in the field that indicate pest attacks but cannot be identified and cannot be retrieved data and data retrieval techniques that are not yet known from requests for data on pests and diseases from DSSAT software affect the accuracy of the model. The use of pest data can be ignored in building a DSSAT model. Pest attack factors were assumed to have no effect on plant growth in the field [12].

5. Conclusion

Based on the results of the study, it can be concluded as follows:

- Based on the paired t-test, the DSSAT model for simulating soybean plants can predict each treatment on the parameters of vegetative weight and number of pods.
- A t-test on leaf root weight showed that the DSSAT model could predict all treatments except in the treatment of watering every 10 days and 3.0 tons/ha of compost.
- Based on the value of MSE, the DSSAT model for simulating soybean plants can predict the yield of each treatment for the parameters of the number of seeds.
- The average difference between simulation and observation on seed weight of 314.44 kg/ha and simulation results tend to predict below observation in the field.

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