COVER PAGE

I. Manuscript Title

II. SHALLOT GROWTH AND YIELD SUPPORTED BY IRRIGATION AND NITROGEN APPLICATION IN UTILIZING DRY LAND AREA IN MESUJI, LAMPUNG PROVINCE

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VI. The main findings and why they are important and useful.

Shallot cultivation has promising possibility in Lampung dry land area with adequate water availability and moderate amounts of N fertilizer. The Precipitation index and AquaCrop are good methods in evaluating area suitability for certain crops cultivation

VII. Why the readers of the journal would be interested in the work.

Readers could use similar methods in evaluating area suitability to certain crops from field work to climate evaluation and product simulation

VIII. Suggested Reviewers: *(2 reviewers from different country with authors, and Scopus H-index minimum 2)*

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SHALLOT GROWTH AND YIELD SUPPORTED BY IRRIGATION AND NITROGEN APPLICATION IN UTILIZING DRY LAND AREA IN MESUJI, LAMPUNG PROVINCE

ABSTRACT

Shallots (Allium ascolicum L.) are strategic horticultural commodities. Mesuji Regency, Lampung Province, Indonesia has potential dry land of 21,863.5 ha and uncultivated land of 10,325.6 ha which has been dominated by plantation and food crops. Horticulture crops often encounters obstacles such as low soil fertility and limited water. The purposes of this research were: analyzing shallots growth and yield on dry land with different nitrogen fertilization doses and different irrigation volumes and analyzing Mesuji suitability for developing shallot. The treatments were: N0 (without N), N80 (80 kg N/ha) and N160 (120 kg N/ha) and N240 (240 kg N/ha), and irrigation levels: W25 (25% of ET), W50 (50% of ET), W0.75 (75% of ET) and W100 (100% of ET); ET was evapotranspiration rate. Mesuji suitability for shallot growth was evaluated using Standardized Precipitation Index (SPI) compared to Brebes, Central Java as the main shallot producer in Indonesia and potential yield was simulated using AquaCrop model. The simulation gave good yield estimation if water and fertilizers requirement are fulfilled, which was at least 75% of the evapotranspiration and 160 kg/ha N. The SPI showed that Mesuji has similar drought wet events percentage compared to Brebes. Therefore, Mesuji is promising for shallot plantation.

Keywords: AquaCrop, standard precipitation index, yield simulation, water availability

INTRODUCTION

Shallots (Allium ascolicum L.) is Indonesia's strategic commodities in the horticultural sector (Buda, Agung and Ardhana, 2018; Suddin et al., 2021). In 2021, approximately 1.94 million metric tons of shallots were produced in Indonesia. The provinces that produced the most shallots including Central Java, East Java as well as West Nusa Tenggara (Statista Research Department, 2022). Demand for shallots in Indonesia increases in line with population growth trend. National economic census in 2019 predicted than in 2021, shallot consumption would reach 876.479 tonnes or in average 3.2 kg/capita/year (Bina Tani Sejahtera, 2020). The need for shallots also will continue to grow due to the growth of the processing industry with shallots as one of the ingredients. Shallots are mostly produced in Java (75%); Shallot production in Lampung Province in 2020 was 2,105 tons lower compared to production in 2019 which was 3,634 tons (BPS Lampung 2021).

Mesuji Regency in Lampung Province, Indonesia with an area of 2,184 Km2 (BPS, 2021a) has the potential dry land in the form of gardens/moorlands of 21,863.5 ha and uncultivated land of 10,325.6 ha. (BPS, 2021b). Dry land is land that is not irrigated most of the time of the year or throughout the year but is still an agroecosystem with great potential in agriculture, both for food crops, horticulture, annual crops, and livestock including shallot. In Lampung Province so far, the use of dry land has been dominated by plantation crops (palm and rubber) and food crops (cassava), while horticultural commodities are still very limited, since utilizing dry land for horticultural farming often encounters various obstacles such as low soil fertility and limited water. This will be increasingly difficult for horticultural crops to grow in dry land because of the prediction of rising air temperatures due to climate change (Hilman et al., 2019). Therefore, adaptive technology is needed in response to various limiting factors of dry land and climate change.

Low fertility of the soil must be overcome by applying fertilizers as additional nutrients to the soil. Sufficient and balanced macro nutrients NPK are highly needed for shallot to increase productivity and bulbs quality (Suddin, et al., 2021). There were numbers of research about fertilizers application in shallot cultivation. Two experiments in Indonesia dry land were conducted in Bangli, Bali (Buda, Agung, and Ardana, 2018) and in Enrekang, South Sulawesi (Suddin, et al., 2021). In Bali the results showed that increased rates of N fertilizers up to 200 kg N/ha significantly increased bulb diameter by 31.03%, bulb fresh weight 40.57% and dry weight 35.95% in true seed shallot variety and similar results for bulb-propagated variety except for bulb diameter. In Sulawesi NPK fertilizer with 16:16:16 composition at a dose 700-900 kg/ha gave high growth and yields (15.5 -16.3 t/ha).

Water resources management through irrigation technology in shallots cultivation in dry land is very important because water scarcity is the main limiting factor that often occurs and consequently slow the production process. In arid and semiarid regions, shallot production is entirely dependent on irrigation (Mohammadi et al., 2010). Research in India revealed that drip irrigation system performed better plant morphology, yield and quality bulb compared to surface irrigation (Bhasker et al., 2018). In Ethiopia, deficit irrigation plus plastic mulch resulted that water availability 100% ET_C gave maximum yield (Temesger, 2018). However, in water shortage area, farmers can adopt deficit irrigation level with 70% Etc under plastic mulch and get good yield.

Perez-Ortola and Knox (2015) confirmed that onion seasonal water requirements are highly variable depending on the local agro-climate and crops growth stage; shallot crop coefficients range from 0.4 to 0.7 (initial stage), 0.85 to 1.05 (middle development) and 0.6 to 0.75 (final stage). Research to investigate which stages crucial to shallot growth and yield had been done in Ethiopia and resulted that water deficit (50% and 75% Etc) at first and fourth stages gave non-significant yield from the optimum application, but the yield was significantly different if the water deficit applied on the second and the third stages (Bakele et al., 2007). El Balla at al. (2013) added that water stress at any stage of shallot reproductive growth especially on bolting followed by anthesis will significantly reduce seed yield. Apparently, all researchers agreed that full irrigation applications gave the best results or at least 80% of the ET (Kumar et al.,2007).

Lampung could be potential for shallot cultivation since shallot have adapted to grow in a wide range of soil and agr-climatic conditions. In Indonesia, Brebes (Central Java) is the largest shallot producer; it contributes 18.5 % of national production. However, even in the centre of area production the limiting factor is still water availability. Water is excessive in rain season but experienced water shortage during dry season (Rahayu, Mujiyo, and Arini, 2018). As dry land Mesuji region in Lampung Province is prospected to be transformed into productive shallot plantation, it is necessary to conduct research for analysing its suitability.

Therefore, the objectives of the research are:
1. Analysing growth response and yield of shallots on dry land with applying different nitrogen (N) fertilization doses and different sprinkle irrigation volumes.
2. Analysing the suitability of the local area for developing shallot cultivation

MATERIAL AND METHODS

Time and place of research:

N fertilizer and irrigation application for shallot growth and yield

The experiment was conducted at the experimental station owned by BPP Mesuji District Lampung from January to March 2022.

The tools used in this research for sprinkle irrigation include soil drill for soil sampling, water pump machine, solenoid valve, timer, digital scale, caliper, PVC pipe (¾ inch and ½ inch), 7 mm PE hose, head sprinkler spray hose, and tensiometers for soil moisture observation.

For shallot cultivation: shallot bulbs from Brebes, NPK chemical fertilizer, manure, and dolomite.

Area climate data source for this research obtained from Mesuji's AAWS (Automatic Agroclimate and Weather Station) BMKG (Indonesian Weather Bureau), and NASA power source data. Microclimate data of the field: air temperature and humidity were measured by automatic data logger.

Soil physic data obtained from direct soil sample and analyzed in Soil physics laboratory, POLINELA, Lampung.

The experimental design

The experiment design was a factorial experiment designed in split block with N fertilizer doses as the main plot and irrigation volume as a subplot. The main plot (Nitrogen) consisted of several treatment levels: N0 (without N), N80 (80 kg N/ha) and N160 (120 kg N/ha) and N240 (240 kg N/ha). The sub-plots consisted of irrigation levels: W25 (25% of ET), W50 (50% of ET), W75 (75% of ET) and W100 (100% of ET); ET was the evapotranspiration rate previously calculated from the climate data.

Figure 1. Experimental Design Layout

The source of nitrogen (N) fertilizer used in this experiment was urea fertilizer with a N content of 46%. Fertilizer applications were divided into 2 applications, the 1st application (50%) at the age of 10-15 DAP and the 2nd application (50%) at the age of 30-35 DAP.

The reference evapotranspiration (ETo) value was estimated using FAO's ETo Calculator program based on the Penman-Monteith model. Crop evapotranspiration was calculated from ET0 x Kc (crop coefficient). On this research the Shallot kc was determined following Sumarno (2017): initial Kc is 0,7; vegetative stage is 0,9; tuber formation 1,2 and maturing 1,2.

Analyzing area climate suitability for shallot cultivation

Comparison of Mesuji (Lampung) precipitation and Brebes (Central Java) was investigated using Standard Precipitation Index (SPI). The SPI was calculated using Rstudio program from total monthly precipitation (mm) data from the years 2000-2020. Source: https://rdrr.io/cran/spi/man/spi.html

Shallot yield simulation

To estimate whether Shallot production will be in good comparison with national product, a simulation was done with FAO AquaCrop model (https://www.fao.org/aquacrop). This model needs local data that was obtained from Mesuji's AAWS (Automatic Agro climate and Weather Station) and direct air temperature and humidity observation. Crop canopy coverage was captured using an application called Canopeo (https://canopeoapp.com); soil texture, field capacity and permanent wilting point obtained with taking soil sample and laboratory analyses.

RESULTS

Field experiment on shallot growth and yield was evaluated from plants height, leaves number, tubers fresh and dry weight, biomass fresh and dry weight, bulb diameter, and root length. The results were presented in Table 1 – 3.

Table 1. Average shallot plants height

Note: the same letter on the table means no difference at LSD 5%. CV is coefficient of variance

Table 2. Interaction of tubers fresh weight (gr/plant) and biomass fresh weight (gr/plant)

Table 3. Average shallot bulb diameter, root length, tubers dry weight and biomass dry weight

Note: the same letter on the table means no difference at LSD 5%. CV is coefficient of variance

The Standard Precipation Index comparing two places Mesuji and Brebes was presented in Fig.2 and number of events of wet and dry on those locations was presented in Table 4.

Climate, crop characteristics, and soil characteristics of shallot cultivation in Mesuji which were used for yield simulation using AquaCrop model were presented in Figs 3 – 5; while the yield simulation was presented in Fig. 6.

Figure 2. Standardized Precipitation indices of Mesuji (research area)and Brebes (central producers)

Table 4. Standardized Precipitation Index values (six months) from precipitation data 2000-2020

Figure 3. Mesuji main climate data (rainfall, air temperature, and evapotranspiration) as inputs to AquaCrop model

Figure 4. Planted shallot main crop characteristic

Figure 5. Field soil characteristics

Figure 6. AquaCrop simulation for shallot cultivation in Mesuji, Lampung

DISCUSSION

At shallot growth phase indicated by plant height and number of leaves; Tables 1 shown that water adequacy affected those variables. The results showed that at growth phase up to 40 DAP, shallots require sufficient water, at least available for 75% ETc. In addition to water availability, application of N fertilizers gave better plant height than without N application. Likewise on number of leaves variable at 20-40 DAP, the more N fertilizer available, the more leaves were produced. Interesting to observe that water should be available at early growth stage, because sufficient water is required to dissolve the applied N fertilizer so that it is available to plants especially for leaves formation. The field has somewhat low C/N ratio (11) which means that N was available but could lose easily since there was not much carbon to compose the soil materials. Generally, a C/N ratio value of 18 is required for adequate growth and treatment efficiency. This research resulted that N fertilizers 160 kg/Ha was adequate for good growth.

In Ethiopia, a country that produce shallot, low yield of onion is reported due to low soil fertility and inappropriate fertilizer rate. Application of 100 kg N/ha and P at at 70 kg/ha P_2O_5 is a promising combination for high quality onion seed yield (Limeneh, et al., 2020). Another research in the same country showed that bulb diameter and weight were in good performance which finally leaded to increased yield using 150 kg N/ha and spacing of 20 cm (Biru, 2015), and application of 150 kg N/ha increased marketable and total bulb yields by 26% over the control (Tesfa, Woldetsadik, and Bayu, 2014)

In the generative phase, an interaction occurred between water needs and N fertilizer application (Tables 2). Water availability 75%-100% and N fertilizers at 160 dan 240 kg N/ha produced the best fresh weight of shallot planting bulbs and biomass. It can be concluded that for the cultivation of shallots in the Mesuji area, water availability of at least 75% ETc and N fertilizer doses of 160 kg N / ha is enough to produce a high fresh weight of bulbs and onion biomass. This is also in line with the results seen in all Tables 1 to 3.

In Table 3, both irrigation and applying N fertilizer affect the diameter of the bulbs, on the contrary, the more sufficient the availability of water, the shorter the length of the onion roots will be. Water availability (75%-100%) and dissolved N (160 -240 kg N/ha) fertilizer will be more allocated for tuber enlargement and not for root elongation. Sufficient water availability made it unnecessary for the roots to extend to reach the water; further which, the increases diameter of the tubers directly increases the dry weight of fresh tubers. The absorbed element N led to an increase formation of dry matter in tubers through the formation and division of cells.

Deficit irrigation research on onion growth and yield gave results that onion would experience great yield loss when the critical water requirement was not met, and 80 % ETc application was a limit, less than that the yield losses were severe (Enchalew, et al., 2016). Similar results found from research in Kenya (80% ETc) (Rop, Kipkorr and Taragon, 2016) and in Western Ethiopia (75% ETc) (Tolosa, 2020). Water stress during growth establishment should be avoided while during establishment and ripening could be tolerated (Zheng et al., 2013). The field results on this research were in good agreement with that previous research that water should be available at least 75% of ETc and N fertilizer 160 kg/ha will give good shallot growth and yield.

Standard Precipitation Index

The Standard Precipitation Index is an indicator of drought based on the analysis of monthly total rainfall series. The SPI is a simple, powerful, and flexible index since it required only precipitation as the input parameter. A drought event occurs when the SPI shows negative value -1,0 or less and it ends when the SPI becomes positive (WMO, 2012). In this study 6 months SPI was used; 6 months SPI is for agricultural drought. Comparison of drought events between Mesuji and Brebes was presented in Table 4.

In both places the SPI indicated that more than 65% was in near normal conditions, however even in smaller percentage (total 16.9% for Brebes and 19.43% for Mesuji) both area had experienced dry conditions. From the field observation water availability is important in shallot cultivation; shallot grows well if the water available for at least 75% of the ETc rate. Therefore, this research continued with Aquacrop model using local climate data, planted shallot characteristics and field soil texture to simulate wheter planting shallot in Mesuji will give good yield compare to national production.

AquaCrop model simulation

AquaCrop was developed by the food an Agricultural Organization (FAO). It is a growth simulation model, a represetation of crop growth interact with weather, and soil nutrients. The AquaCrop model is capable of predicting crop productivity, water requirements, and water us efficiency under water limiting factor. However, this research foculs only on harvest with assumtion all the water requirement is fulfilled. The results were presented in Tables 3- 6 above.

Mesuji Climate during the field research was expressed with average RH 87.42%, total rainfall 799.43 mm, average T max 28.3 ^oC and T min 24.3 ^oC, average net radiation 17.08 MJ/m^2 and wind speed

1.62 m/s. With planting distance 20 x 15 cm, initial canopy cover was 0.83%. Soil texture was sandy loam with field capacity 45 % volume and permanent welting point was about 20.9 % volume. Shallot growth was considered sensitive to soil fertility and soil salinity. Shallot crop coefficient (Kc) during growth period was 1.2. The simulation gave production estimation 13.955 tons/ha for biomass and 7.164 tons/ha as dry yield. In 2022, approximately 1.94 million metrics tons of shallot were produced in Indonesia. The provinces that produced the most shallots were Central Java, east Java as well as West Nusa Tenggara (Statista Research Department, 2022). Shallot plantation area in Indonesia is approximately 159,195 ha; thus, the national shallot production was about 12,20 tons/ha. The AquaCrop simulation gave a good estimation if water and fertilizers requirement are fulfilled, which from the field observations was at least 75% from the evapotranspiration rate and 160 kg/ha N fertilizer.

CONCLUSION

Based on the field research, the climate data and the yield simulation, there is good potential to develop Mesuji area in Lampung into productive shallot plantation with the caution that irrigation facilities should be provided to maintain water requirement at least 76% of ETc, while moderate N fertilizer will be adequate for shallot growth and yield.

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FIGURES AND TABLES

N80	N0	N160	N240	N160	N80	N0	N240	N0	N240	N80	N160
W75	W75	W75	W75	W25	W25	W25	W25	W50	W50	W50	W50
W50	W50	W50	W50	W100	W100	W100	W100	W75	W75	W75	W75
W100	W100	W100	W100	W50	W50	W50	W50	W100	W100	W100	W100
W25	W25	W25	W25	W75	W75	W75	W75	W25	W25	W25	W25

Figure 1. Experimental Design Layout

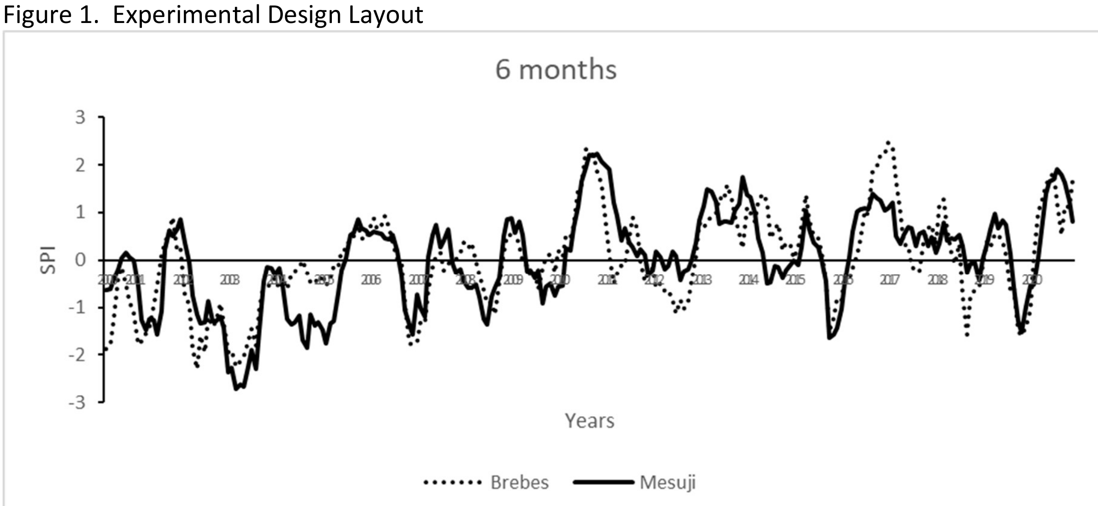

Figure 2. Standardized Precipitation indices of Mesuji (research area)and Brebes (central producers)

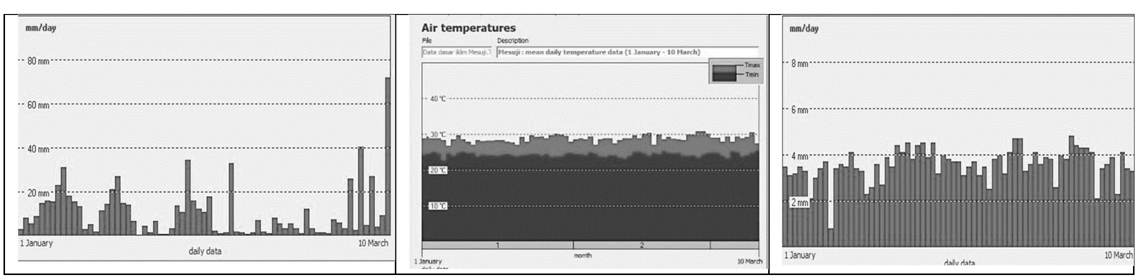

Figure 3. Mesuji main climate data (rainfall, air temperature, and evapotranspiration) as inputs to aquacrop model

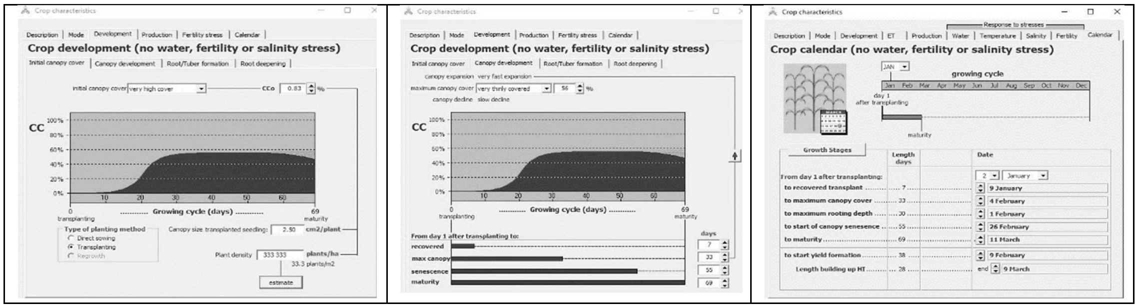

Figure 4. Planted shallot main crop characteristic

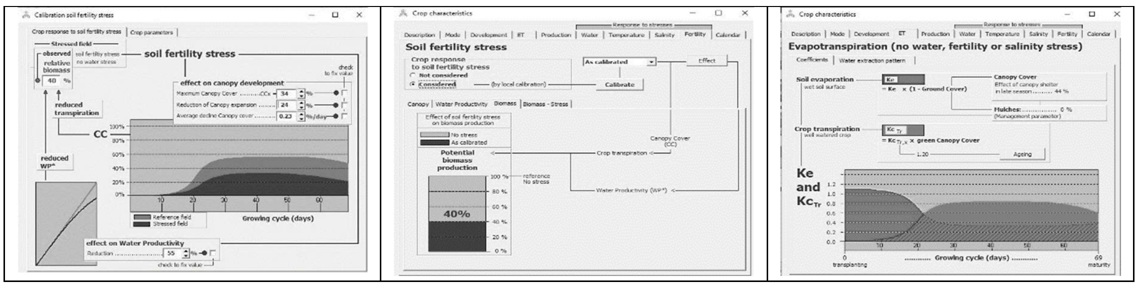

Figure 5. Field soil characteristics

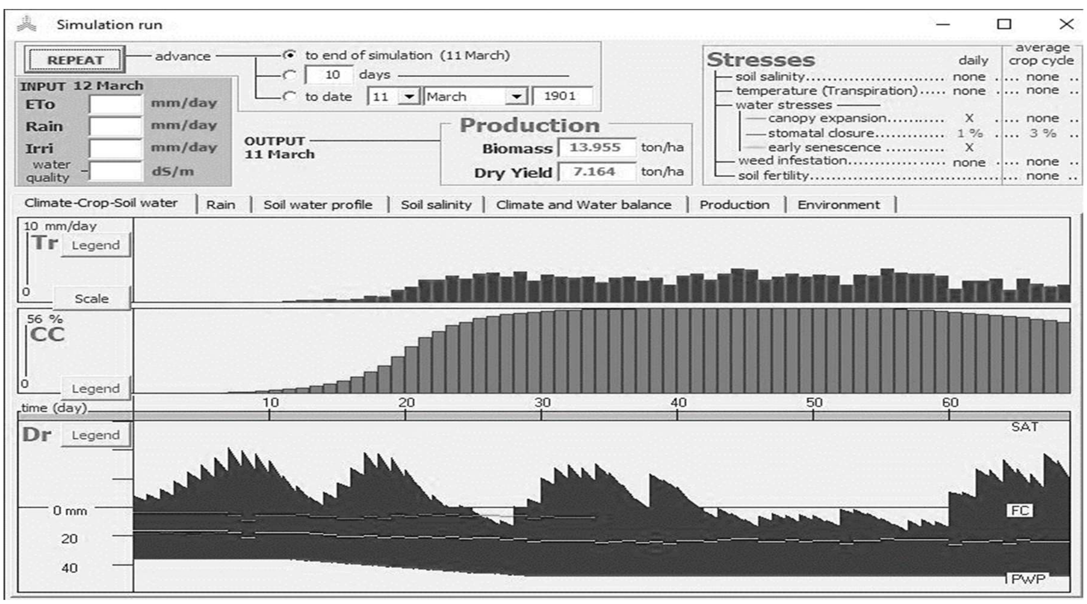

Figure 6. AquaCrop simulation for shallot cultivation in Mesuji, Lampung

Table 1. Average shallot plants height

Treatments	Plant height (cm)			Average leaves number (strands/plant)		
	20 DAP	30 DAP	40 DAP	20 DAP	30 DAP	40 DAP
Nitrogen Fertilizer						
N0	17.043b	20.747b	22.057b	11,586c	16.119c	20.133c
N80	19.133a	22.578a	23.574a	11,898c	18.104b	21.810c
N160	19.468a	22.618a	23.404a	12,892b	19.029b	23.717b
N240	20.001a	23.253a	23.721a	14,748a	21.653a	27.077a
LSD 5%	1,33	1,01	0,92	0,76	1,58	1,70
	CV = 7,02 %	CV = 4,5%	CV = 3,9%	CV =5,9%	CV =8,4%	CV = 7,3 %
Irrigation						
W25	16,582d	20b	20.451c	10,988d	16,232b	20,717b
W50	18,108c	21,097b	21.915b	12,146c	18,333ab	23,294ab
W75	19,547b	23,720a	24.848a	13,359b	19,407a	24,122a
W100	21,408a	24,378a	25.543a	14,631a	20,933a	24,604a
LSD 5%	0,70	1,13	1,41	0,97	3,12	2,63
	CV = 3,72%	CV = 5,06 %	CV = 6,1 %	CV = 7,6 %	CV 16,7%	CV = 11,3%

Table 2. Interaction of tubers fresh weight (gr/plant) and biomass fresh weight (gr/plant)

Treatments	Irrigation Tubers Fresh Weight (gr/plant)				Irrigation Biomass Fresh Weight (gr/plant)			
Nitrogen Fertilizer	W25	W50	W75	W100	W25	W50	W75	W100
N0	6.41^{Cc}	8.13^{Cb}	10.360^{Ca}	9.56^{Ca}	$6,356^{Cd}$	$8,31^{Cc}$	$10,83^{Db}$	$12,39^{Da}$
N80	7.75^{Bc}	9.10^{BCb}	12.063^{Ba}	12.40^{Ba}	$10,20^{Bb}$	$12,63^{Ba}$	$13,37^{Ca}$	$13,90^{Ca}$
N160	10.16^{Ac}	10.11^{ABc}	13.886^{Ab}	15.88^{Aa}	$12,30^{Ac}$	$12,28^{Bc}$	$14,95^{Bb}$	$19,73^{Aa}$
N240	10.69^{Ac}	11.04^{Ac}	12.650^{Bb}	14.97^{Aa}	$12,08^{Ac}$	$14,45^{Ab}$	$16,45^{Aa}$	$17,66^{Ba}$
	Interaction CV = 5,68% LSD = 1,06				Interaction CV = 5,84% LSD = 1,30			

Table 3. Average shallot bulb diameter, root length, tubers dry weight and biomass dry weight

Treatments	average shallot bulb diameter (cm)	average shallot root length 55 dap (cm)	average tubers dry weight (gr/tuber)	average biomass dry weight (gr/plant)
Nitrogen Fertilizer				
N0	11,760^{b}	23,708	0,280b	2,403b
N80	12,899^{ab}	21,767	0,292b	2,797b
N160	13,448^{a}	21,908	0,452a	3,914a
N240	13,682^{a}	24,958	0,512a	4,668a
LSD 5%	1,29	ns	0,06	0,24
	CV = 19,98 %		CV = 5,96 %	CV = 12,17 %
Irrigation				
W25	11,688^{b}	24,958^{a}	0,354b	3,143b
W50	11,902^{b}	25,808^{a}	0.339b	2,907b
W75	13,819^{a}	21,733^{b}	0.337b	3,464ab
W100	14,379^{a}	19,842^{b}	0,499a	4,115a
LSD 5%	0,71	2,72	0,06	0,19
	CV = 11,04 %	CV = 11,81 %	CV = 6,64 %	CV = 9,41 %

Table 4. Standardized Precipitation Index values (six months) from precipitation data 2000-2020

Characteristic	Brebes		Mesuji	
	No of events	Percentage	No of events	Percentage
Extremely Wet	7	2,83	5	2,02
Very Wet	12	4,86	9	3,64
Moderately Wet	17	6,88	24	9,72
Near Normal	171	69,23	161	65,18
Moderately Dry	17	6,88	32	12,96
Severely Dry	19	7,69	9	3,64
Extremely Dry	4	1,62	7	2,83