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Research Article
Effect of Shading Net and Interval of Watering Increase Plant Growth and Yield of Potatoes 'Atlantic'

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Abstract

Background and Objective: In cultivation of crops at medium plains which have a high temperature, the use of shade not only decreases the light intensity but also decreases the temperature and maintains the soil moisture in order to create suitable conditions for the growth of potatoes. Accordingly, the use of both shade and suitable interval of watering on potatoes cultivated at medium plains is expected to increase the yield. The objective of this study was to determine the effect of shade and water interval on plant growth. **Materials and Methods:** Experimental design used in this research was split- plot design with including some factors, namely, main-plot factor consisted of 2 levels of shading net (without and with), sub-plot factor consisted of 4 levels of watering interval (1, 2, 3 and 4 days). All parameters were tested by two ways of analysis of variance (ANOVA) by Fisher test followed by Duncan's Multiple Range Test at the 5% significance level. **Results:** The results showed that there was efficiency on potato yield cultivated in medium plains by watering with the application shade. In shade treated plants the highest yield is obtained at interval watering every 2 day. In treatment with shade, the highest yield was obtained at watering every 3 days, whereas in without shade plants, the highest yield was obtained at watering every 2 days. **Conclusion:** It would be concluded that the use of shade on Atlantic cultivars potatoes can increase the efficiency of water use so that watering can be done once every 3 days.

Key words: Medium land, potato, shading net, watering, yield, Atlantic cultivars

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

INTRODUCTION

Potatoes is adapting to low temperature. Moreover, the cultivation of potatoes has been done in high plains since it was introduced to Indonesia and it continuously affects environmental damages. Therefore, it requires new development to lower plains that are abundant in Indonesia[1]. The main problem in developing the cultivation from high plain to medium plains is the in adaptability of cultivars to the environment stress that affecting the plant productivity, especially due to high temperature and water deficiency in medium plain. Potato is one of the horticultural crops sensitive to high temperature stress and water-deficit stress[2,3].

In cultivation of crops at medium plain, the use of shade not only decreases the light intensity but also decreases the high temperature and maintains the soil moisture[1,4]. In order to create suitable conditions for the growth of potatoes. Accordingly, the use of both shade and suitable interval of watering on potatoes cultivated at medium plains is expected to increase the yield and the efficiency of the water use.

The sunlight intensity under a shade is 70.02 W m^{-2} (shade decreases 32% of light intensity compared without shade)[1]. The use of shade decreased the average of air temperature and soil temperature decrease up to 2.06°C. However, the use of shading net increases the air humidity up to 4.23% compared with without shade. Moreover, the use of shading net increases plant height, leaf surface area index and tuber weight per plant[1,5]. In addition, the use shade increased the yield of broccoli[6].

Potato plants are sensitive to groundwater condition. Potato plant with 85% water supply capacity of the field capacity shows the same height plant as those with 100% but on other parameters, water deficit inhibits the growth and yield[7]. Accordingly, if the ability of roots to absorb water is improved and the transpiration as well as evapotranspiration are reduced, the water can be used more efficiently and plants will be able to survive in a dry period. This is important because in certain areas, rain may fall late when the plants requires enough water. Therefore, the use of shading net as one of innovations in cultivation technique should be tried on potato plants cultivation in medium altitude with different shading net condition and different watering interval. The watering affects the moisture in the root zone but it can not maintain adequate moisture content for a long period. Therefore, it needs an irrigation. Shading net is expected to reduce the light intensity and also temperature as well as maintaining soil moisture and inhibit evapotranspiration, so with the shading net that can improve water efficiency and also provide suitable water for plant growth and the formation potato tuber. The aimed to observe the effect of shading net and intervals of water on growth and yield of plant.

MATERIALS AND METHODS

This experiment was conducted in Jatinangor, Indonesia from December, 2017-May, 2018. Experimental design used in this research was split-plot design consisted of main-plot factor as 2 levels of shade (with and without shade), sub-plot factor consisting of 4 levels of watering interval (1, 2, 3 and 4 days) and repeated fourth times.

Each treatment used 10 polybag with one plant each therefore there have 320 pots consisting of 96 pots for growth measurement analysis, 32 pots for chlorophyll content, leaf water potential and proline content measurement and 96 pots for yield observation and yield component.

As much as 20 kg of growing media that have been prepared in polybags is added by fertilizer i.e., 300 kg ha^{-1} of fertilizer N twice namely at the time of planting and at the age of 30 days after planting. Meanwhile 100 kg ha^{-1} of fertilizer K and 150 kg ha^{-1} of P fertilizer are given at the same time of planting. About 20 t ha^{-1} of manure is mixed in growing media and then, growing media are perforated with a diameter of 10 cm to plant potato seed. Potato tuber with the size of 30-45 g per grain is planted with a depth of 7.5 cm, 3 g of Furadan was spread around the seeds with a dose of 37.5 kg ha^{-1} in order to avoid insects and other soil pests. Before the planting, shading net is applied with 45% shading.

The maintenance includes watering done by until it meets the field capacity. The interval of the watering adjusted to the treatment by the volume of watering. The interval is maintained based on the need for water volume at field capacity condition.

The follow-up fertilization for N fertilizer is done simultaneously with weed and bamboo control. Pest and disease control is done by spraying fungicide dithane M-45 and insecticide Decis 2,5 EC. Harvesting is done after the top of the potato plant i.e., stems and leaves turn yellow and fall and the skin stops peeling.

Observation variable of growth and yield consists of: Daily air temperature in the morning, noon and afternoon and daily average humidity under with and without the shading net, soil temperature in the morning, noon and afternoon under with and without the shading net, sun radiation intensity under with and without the shading net. The observation variable of growth and yield consists of leaf Relative Water Content (RWC) can be calculated as below:

$$RWC = \frac{FW - DWO}{TW - DWO} \times 100\ (\%)$$

Where:

FW = Fresh weight of sample leaf

TW = Turgor weight obtained by soaking sample leaf for 2 h

DWO = Dry weight of sample leaf that has been completely opened

The total chlorophyll content is counted at the last vegetative phase i.e., at the age 56 after planting date by using Chlorophyll meter. Proline content was counted by Ninhydrin method. The average leaf area is measured busing Gravimetric method at each clump of 3 sample plant clumps. Dry weight of plant was obtained by drying whole plant until its constant at each clump. The observation of plant height is done by measuring the plant from the tip of leaf to the surface of soil at each clump. The observations of yield in the form of the weight of the tuber each plant. All parameters were tested by two ways of analysis of variance (ANOVA) followed by Duncan's Multiple Range Test at the 5% significance level.

RESULTS AND DISCUSSION

Condition of the environment under the shading: Sun radiation received by the canopy of potato plant without shade is 3072.5 lux and 1665.4 under shading net. Average air temperature under shading net is 21.37 and 23.32°C without shade. Air humidity under shading is 92.37 and 79.95% without shade (Table 1).

Leaf relative water content: Data in Table 2 showed that leaf relative water content at the treatment under shading net is higher than that no using shade. The reduction of the amount of watering resulted in a decreasing in leaf relative water content.

Data in Table 3 showed that the reduction of the amount of watering results in different proline content. The less the watering resulted in, the higher of proline content. Watering with interval every 4 days showed the highest proline content of all. The high accumulation of proline was occurred because proline is a compound that works in osmotic pressure and will be accumulated in plants during water deficit. Proline is synthesized in plants with low water supply as the consequence of osmotic cell, by increasing the levels of the solute in the cell so that the intra cell osmotic potential becomes lower or at least proportional to the osmotic potential of the surrounding medium. This is in line with research on spinach and tomato and potato[8,9].

Plant growth

Plant height, leaf area, plant dry weight and chlorophyll content: The interaction between the shade and watering interval has no impact on the parameter of the plant growth but in particular, the application of shade and watering interval have an impact on plant height, leaf area, plant dry weight and chlorophyll content (Table 4). The plant height and leaf area of potato plant growing under shading net shows a higher value than those growing without shade but the chlorophyll content is lower. Plant height, leaf area, plant dry weight and chlorophyll content at the watering interval every 2 days are better than those at other intervals (Table 5)

After comparing treatments under shading net with treatment without shade, the result showed that optimal light intensity will affect the activity of stomata to absorb CO_2 which is the raw material of carbohydrate synthesis, so that it is influential to increase the leaf area of potato plant[1,10]. Gardner *et al.*[11] stated that the less the light (%) received by plants, the broader the leaf area. Until certain intensity of shade, the plant is able to expand the leaves because the accumulation of photosynthate increases, making the cell production increase as well, that can be seen from the increasing size of the leaf area[6].

A heavier shade will lead to a decrease in growth due to the low efficiency of photosynthesis caused by the loss of some CO_2 hampering by the decreasing light intensity.

At watering intervals every 3 and 4 days, the growth of potato plant decreases. It can be seen by plant height, plant dry weight, leaf area and chlorophyll content that become all low. This situation indicated that during water deficit, the plant growth will be inhibited so as to decrease the yield[12-15]. It is because the cells become smaller and the leaves cannot grow optimally, resulting in reduced leaf area for photosynthesis.

Table 1: Influence of shade on light intensity, air temperature, soil temperature and air humidity

Treatments	Light intensity (lux)	Daily air temperature (°C)	Soil temperature (°C)	Air humidity (%)
Without shading net	3072.5	23.32	26.55	79.95
With shading net 45%	1665.4	21.37	24.67	92.37

Tuber weight: The result of variance analysis showed that there is an interaction between shade and watering interval to the tuber weight per plant. The use of shade with watering intervals every 3 days results in higher tuber weights than with watering intervals every 1, 2 and 4 days, Whereas for treatment without shade, the watering interval every 2 days results in a higher and different tuber weight from the intervals every 1, 3 and 4 days. It indicated that shaded potatoes are more efficient in water use. Watering interval was affected the availability of ground water that will affect the growth and yield of potato crops. This situation is related to the function of shade that can reduce sunlight intensity and lower the temperature, thus causing a decrease in evapotranspiration on shaded plants[1,4,6]. Potato crop is very sensitive to lack of water because it has a rather shallow root system and many physiological responses to water shortages[3,16].

Watering affects the moisture in the root area but it cannot keep enough groundwater content for a long time. Therefore, it requires watering at certain time. The growth of potato requires enough water until it dies since critical period of potatoes is the beginning of stolon formation and the beginning of tuber growth that requires relatively large amounts of water. Moreover, the variation of groundwater content has an effect on total yields of potato[17]. In addition, potato crops are very sensitive to water supply and poor aeration[2]. To achieve high potato yields, groundwater content at a depth of 15 cm should not be less than 50 (%) of the field capacity even up to 85 (%) of the field capacity[7]. Accordingly, watering is required if the water content is close to 50 percent. If the watering is delayed, potato yields will decrease due to the decrease in leaf area and photosynthesis per unit of leaf area[18,19]. It showed the importance of regulating water for potato crops. Watering interval that is good for potato crops is watering interval every 4 days[20]. According to Chaney[21], the ability of plant in adapting to drought stress is related to increase Abscisic Acid (ABA) synthesis. The effect of path redirection as in phytol formation and Inhibition in the ABA degradation

Table 2: Influence of shading net and the amount of watering on leaf's RWC

Treatments	Leaf's RWC
Shade	
Without shading net	0.76[a]
With shading net	0.81[b]
Watering interval (days)	
1	0.84
2	0.77
3	0.67
4	0.62

Table 3: Influence of shading net and the amount of watering on proline content (mol g^{-1} FW)

Treatments	Proline content (mol g^{-1} FW)
Shade	
Without shading net	0.25
With shading net	0.18
Watering interval (days)	
1	0.10
2	0.25
3	0.65
4	1.39

Table 4: Influence of shade, watering interval on plant height, leaf area, dry weight and chlorophyll content of potatoes at 56 days after planting

	Observation			
Treatments	Plant height (cm)	Dry weight of plant (g)	Leaf area (cm)	Chlorophyll content index (CCI)
Shade				
Without shade	38.57[a]	51.10[a]	712.39[a]	40.2[b]
With shade 45 (%)	52.64[b]	52.25[a]	1224.50[b]	34.6[a]
Watering interval (days)				
1	42.55[ab]	53.34[ab]	817.71[ab]	40.2[a]
2	48.80[b]	68.95[b]	1218.36[b]	40.4[b]
3	47.25[a]	50.29[ab]	716.83[a]	35.0[a]
4	33.70[a]	44.70[a]	616.02[a]	33.7[a]

Average numbers followed by the same letter are not different according to Duncan's multiple range test at level 5%

Table 5: Influence of shade and watering interval on tuber weight (g)

	Watering interval (days)			
Treatments	1	2	3	4
Shade				
Without shade	300.57[a]	464.695[b]	441.36[a]	294.68[a]
	A	B	B	A
Paranet shade	361.21[a]	307.055[b]	569.85[b]	351.61[a]
	A	A	B	A

Value followed by lowercase vertically and by uppercase horizontally are not significantly different according to Duncan's multiple range test at level 5%

process by inhibiting the enzyme acting on the pathway by paclobutrazol so that the concentration of ABA increases. The presence of ABA is important in the regulation of stomatal closure which prevents the amount of water lost into the air through transpiration.

CONCLUSION

- There is efficiency on potato yield growing in medium plains by watering with the application of shading net. In treatment with shade, the highest yield is obtained at watering every 3 days whereas in treatment without shade, the highest yield is obtained at watering every 2 days
- The use of shade can increase the leaf area but decreases the chlorophyll content
- Watering Interval every 4 days can decrease the leaf area, dry weight of plant and chlorophyll content

SIGNIFICANCE STATEMENT

This study discovered the how many days of appropriate interval of watering shaded and unshaded potatoes grown in medium altitude that can be beneficial for develop a potato cultivation in medium altitude that has high temperature and needs a shading net. This study will help the researcher to uncover the critical areas of potato cultivation in the high temperature area that many researchers were not able to explore. Thus a new theory on potato cultivation in high temperature may be arrived at.

Plant growth and yield of potato in medium land of Indonesia are reduced because of high of temperature. To increase the potato yield, therefore, some environmental modification are needed to reduce the high of temperature. The modification using shading net and interval of watering significantly increase the growth and yield of potato 'Atlantic' in medium, land of Indonesia that has high temperature.

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