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Research Article
The Use of Paclobutrazol and Shading Net on Growth and Yield of Potato 'Medians' Tuber of G_2 in Medium Land of Indonesia

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Abstract

Background and Objective: One problem in introducing potato cultivation in medium land of Indonesia is high temperature which causes low yield of the potato tuber. High temperature improves shoot growth but reduces the formation and development of tuber. To reduce high temperature and inhibit shoot growth, therefore new strategy must be conducted to resolve this problem such as by the application shading net and paclobutrazol during potato cultivation. The objective of this study was to evaluate the interaction effect between shading net and paclobutrazol on growth and yield of potato 'medians' tuber of G_2 in medium land of Indonesia. **Methodology:** Randomized block design was used in this study with two factors, consisted of three levels of shading net density (0, 30 and 40%) and 4 levels of paclobutrazol concentration (0, 50, 100 and 150 mg L^{-1}). All parameters were tested by two-ways of analysis of variance (ANOVA) using Fisher test followed by Duncan's multiple range test at the 5% significance level. **Results:** The result showed that no significant interaction between shading net density and paclobutrazol concentration at all observed parameters. Shading net 30% increased plant height, leaf area index, tuber number, tuber weight and percentage of tuber for seed size that was significantly higher than without and 45% shading net. Moreover, paclobutrazol suppressed plant height and leaf area but it increased chlorophyll content, tuber number and tuber weight/plant and percentage of tuber for seed size. **Conclusion:** Paclobutrazol suppressed plant height and leaf area, however it increased leaves chlorophyll content, tuber number and tuber weight/plant. The highest tuber number and percentage of class tuber for seed size were obtained from plant with 50 mg L^{-1} of paclobutrazol application.

Key words: G_2 seed, gibberellic acid, medium land, paclobutrazol, shading net

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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

Potato (*Solanum tuberosum* L.) is one of the important horticulture commodities in Indonesia. It has a high economic value and nutrition. In Indonesia, potato is used as an alternative food of carbohydrate source besides rice, wheat and maize. Therefore, potato was potential to be developed for food diversification program in Indonesia. Therefore, the study of potato emphasized in tuber initiation and development will be a great relevance with the program, particularly for area extensification toward medium land. There are some limitations in increasing of potato production in Indonesia, one of them is lack availability of high seed quality in genetic, physical and physiological features. Moreover, a limited high land area for potato seed production worsens this condition.

Propagation of potato is usually done by cloning method. The clonal seeds multiplication was started from plantlet at sterile bottle until produced extension seed or G_{2-4} generation. Meanwhile, the production of potato seed until ready for distribution (G_{2-4}) is generally located in high land[1]. Due to limitation of potato seed propagation in the high land, therefore, it was needed an alternative to produce the potato seed in a medium land with elevation about 300-700 m above sea level where it was available more in Indonesia[2]. However, there was a main problem on producing potato seed in a medium land, that temperature will become a limiting factor. Stark and Love[3] reported that potato plants are very sensitive to high temperature stress. The high temperature stress will affect in distribution process of assimilates from leaves to tuber. At the high temperatures, biosynthesis and activity of gibberellic acid on shoots will increase, except in mature leaves. Consequently, it will lead to inhibition of tuber formation[4] and tuber growth[5].

Microclimate manipulation by reducing temperature lower than ambient around the plant was one alternative technology for potato tuber multiplication in medium land. One of technologies of microclimate manipulations was shading treatment. On the daylight the shade can reduce temperature by reducing intensity of solar radiation, respectively, whereas in the evening the shade can preserve temperature level by maintaining radiation of heat from the earth into the atmosphere[6]. Shading net is one of the artificial shadings that mostly used in greenhouse in tropical. The using shading net 45% of density increased leaf area index (LAI) of potato, increased potato yield and increased tuber quality[7].

Another method to increase tuber quality can be reached by inhibiting gibberellin biosynthesis and paclobutrazol can be used to inhibit gibberellin that will inhibit cell elongation in apical meristem, reducing stem extension rate without affecting the growth and development of the leaves[8]. Application of paclobutrazol in potato increased net assimilation, yield/plant, tuber quality and weight of tuber but it reduced plants height and leaf area index[9,10]. There had an interaction effect between potato cultivar with retardant type on leaf area index and tuber weight per plant[11]. In this study reported the potential function of shading net and paclobutrazol in increasing growth and yield of potato 'medians' seed of G_2 planted in medium land.

MATERIALS AND METHODS

Preparation of plant materials and cultivation: The experiment was conducted in Experimental Field, Faculty of Agriculture, University of Padjadjaran, Sumedang, with elevation of ±685 m above sea level on inceptisol soil type from October, 2015 to January, 2016. The experimental design used was randomize block design with two factors and repeated four times. First factor was shading density (N) consisted of 3 levels: Without shading, 30 and 45% shading density, second factor was paclobutrazol concentration comprised of four levels, 0, 50, 100 and 150 mg L^{-1}.

First generation (G1) of potato tuber with a size of 10-20 g were planted 5-7 cm in depth. Shading net was installed before planting time with the shade percentage of 0, 30 and 45%. Shading net was constructed in tunnel form (semi-circle), with the height of the central part was 2 m and height of each side was 1.5 m. Paclobutrazol was sprayed to the potato shoot at 30 DAP with volume of 15 mL/plant for each concentration[10]. During the cultivation process, plant were fertilized by urea (46% N) 300 kg ha^{-1} at the planting time (0 DAP) and 30 DAP followed by SP-36 (36% P_2O_5) 150 kg ha^{-1} and KCl (60% K_2O) 100 kg ha^{-1} at the 0 DAP. Pest and disease were controlled by 2 g L^{-1} of mankozeb 80% and deltamethrin 2 cc L^{-1}, respectively. Harvesting time was conducted at 89 DAP when the stems and leaves were turned to yellow in the color and fall off also the tuber coat was not peeled off.

Plant growth and yield analysis: To elucidate the effect of shading net and paclobutrazol, several plant growth characters were evaluated. Plant height, leaf area, dry weight of plant and chlorophyll content were evaluated as plant growth characters. Whereas, the number of tubers per plant, tuber weight per plant, production per hectare and the percentage of tuber seed (20-60 g) were evaluated as yield characters.

Statistical analysis: All parameters were tested by two-way of analysis of variance (ANOVA) followed by Duncan's multiple range test at the 5% significance level to analyze the differences among the treatments.

RESULTS

Temperature, humidity, light intensity and rainfall data: Monthly average temperature and light intensity data were recorded from November, 2015 to February, 2016. The observation of the weather conditions during the experiments showed that shading net decreased in air temperature, soil temperature and intensity of light received by the plant. The average margin in several environmental parameters is: Air temperature was between ±1-2°C, the soil temperature was ±1.73-1.93°C and light intensity was ±587.5-1232.5 lux (Table 1).

The impact of this weather change type will probably lead to an increase in crop production but in fact the decrease of temperature followed by decrease of light intensity had negative effect on crop growth. Potato is a sun plant, in one side it requires full light but in other side it needs low temperature to form the tuber. This was a major problem for developing potato cultivation program in medium land.

Growth dynamics: The results of analysis of variance showed that there was no interaction effect between shading net and concentration of paclobutrazol on plant height, leaf area, plant dry weight and chlorophyll content. Independently, shading net 30% of density performed to be a significantly higher in plant height, leaf area index and dry weight than shading net 45% but there was no significant effect on shading net 30% compared to 0% of shading on potato during the rainy season (Table 2). Plant height and leaf area index of potato plants with application of paclobutrazol 50, 100 and 150 mg L^{-1} were lower than potato plant without paclobutrazol application.

The interaction between shading net density and paclobutrazol concentration was not significantly affected on tuber number per plant, tuber weight per plant, tuber yield per hectare and percentage of tuber seed. Individually, shading net density significantly affected on the number of tubers per plant, tuber weight per plant, tuber yield per hectare and percentage of tuber for seed size (Table 3). Cultivar medians plants grown in medium land with shading net 30% showed significantly higher result in tuber numbers and tuber weight per plant, as well as higher in the percentage of tuber for seed size than in 0 and 45% of shading net. The average of tuber numbers and weight were 9.5 knol and 396.71 g plant $^{-1}$, respectively and the yield reached of 15.75 t ha^{-1}. Applications of paclobutrazol 50, 100 and 150 mg L^{-1} significantly increased numbers of tuber and weight per plant, which was significantly different with without paclobutrazol application while the highest percentage of tuber for seed size was obtained from the plant treated by 50 mg L^{-1} of paclobutrazol.

DISCUSSION

Plant growth and development are affected by several factors such as by environmental condition. In this study

Table 1: Monthly average temperature, light intensity and rainfall (November, 2015-February, 2016)

No.	Shading density (%)	Air temperature (°C)	Maximum/minimum (°C)	Soil temperature (°C)	Relative humidity (%)	Light intensity (Lux)	Rainfall (mm)
1	0	23.6	28.57-14.30	26.8	88.50	3002.5	238
2	30	22.6	28.57-14.30	25.1	89.75	2415.0	238
3	45	21.6	28.57-14.30	24.9	90.75	1770.0	238
Optimum		18-24		14.9-17.7	80-90	3000-7000	200-300

Source: Climate station of experiment field faculty of agriculture UNPAD

Table 2: Effect of shading density and concentration of paclobutrazol on plant height, leaf area index (LAI), plant dry weight and chlorophyll content

Treatments	Plant height (cm)	LAI	Plant dry weight (g)	Chlorophyll content (CCI)
Shading density (%)				
0	38.48±8.81^{b}	2.67±0.27^{ab}	59.89±8.49^{a}	33.02±1.23^{a}
30	35.32±10.35^{b}	2.95±0.22^{b}	56.41±9.32^{a}	32.50±2.13^{a}
45	23.62±4.08^{a}	2.33±0.01^{a}	37.70±3.44^{b}	35.38±1.74^{a}
Paclobutrazol concentration (mg L^{-1})				
0	37.46±9.67^{b}	2.94±0.36^{b}	50.51±9.74^{a}	28.13.±1.19^{b}
50	29.73±5.32^{a}	2.48±0.27^{a}	50.34±5.41^{a}	35.66±1.61^{a}
100	29.22±6.70^{a}	2.46±0.11^{a}	50.83±6.73^{a}	37.44±4.12^{a}
150	33.47±9.57^{a}	2.70±0.08^{a}	52.66±6.54^{a}	33.31±1.46^{a}

The numbers followed by the same letter at the same treatment were not significantly different according to the Duncan's test at 5% significance level, Mean±SD

Table 3: Effect of shading density and paclobutrazol concentration on the number of potato/plant, tuber weight/plant, tuber yield/ha and percentage class tuber for seed size

Treatments	Tuber number/plant (knol)	Tuber weight/plant (g)	Tuber yield ha^{-1} (t)	Percentage class tuber for seed size (%)
Shading density (%)				
0	9.38±0.45^{ab}	376.84±9.17^{ab}	15.07±3.12^{ab}	80.76±1.55^{a}
30	9.50±0.74^{b}	396.71±5.77^{b}	15.86±2.11^{b}	84.89±2.13^{a}
45	5.60±1.19^{a}	270.21±6.34^{a}	10.80±2.24^{a}	85.47±1.99^{a}
Paclobutrazol concentration (mg L^{-1})				
0	6.56±1.38^{a}	242.27±5.53^{a}	9.69±1.12^{a}	84.81±0.87^{b}
50	9.23±1.29^{b}	369.49±8.92^{b}	14.77±0.89^{b}	94.56±2.80^{c}
100	8.15±0.55^{ab}	393.38±5.26^{b}	15.73±0.77^{b}	72.36±3.58^{a}
150	8.69±0.07^{ab}	326.54±15.51^{ab}	13.06±2.54^{ab}	83.89±1.66^{b}

The numbers followed by the same letter at the same treatment were not significantly different at the Duncan's test significance level of 5%, Mean±SD

investigated the effect of shading net density and the application paclobutrazol on the plant growth and yield of potato 'median' tuber of G_2 in medium land of Indonesia. Declining in plant height and leaf area index in the plant with 45% of shading net was suspected due to the decreasing of assimilation rate, as an effect of low in light intensity. Less of photosynthate content in plant might be affected by disruption of photosynthate distribution in plant. Contrasting result was reported by Albayrak and Camas[12], they stated that high temperature and low sunlight irradiation intensity increased net assimilation rate in radish. In plant, auxin works synergistically with gibberellin in stem elongation. This study showed that the application of shading net reduced light intensity, air and soil temperature but increased air moisture, those results agreed with previous studies[7,13]. It well known that optimal light intensity affects on stomatal activity in absorbing CO_2 for carbohydrates synthesis. Reduction of radiation percentage received by a plant affected in increasing of leaf area[14]. It was suspected that shade intensity can affect on leaf expansion of higher plant due to an accumulation of photosynthate in leaves which is reflected by the size of leaf area[15]. However, the shading net 45% affected in decreasing growth of potato, it might be due to less of photosynthesis efficiency as well as in shading net 0 and 45%.

Decreased plant height and leaf area index of potato plants with application of paclobutrazol 50, 100 and 150 mg L^{-1} agreed with previous studies, who stated that paclobutrazol inhibits the growth of plant height, as a result of the shortening of stem internode[10,16-19]. In addition, paclobutrazol increased the chlorophyll content of leaves. Plants sprayed with paclobutrazol were higher in chlorophyll content than without application of paclobutrazol but there was no significant effect among 50, 100 and 150 mg L^{-1}. Paclobutrazol is one of gibberellin synthesis inhibitors[20]. It inhibits plant growth resulted dwarf plant and increases chlorophyll content of leaves[21]. Increasing of chlorophyll content has a positive impact on distribution of photosynthate from leaves to tuber. Increasing in chlorophyll content was closely related to the inhibition of leaf chlorophyll degradation[21]. In this experiment, paclobutrazol application was able to increase potatoes tuber weight per plant (Table 3).

High temperatures leads to increase gibberellin biosynthesis in potato but it will not stimulate elongation of stem nonetheless inhibits tuber formation. The application of paclobutrazol inhibits the synthesis of gibberellins, it could be seen by in increasing of stolon percentage or tubers formation. The number of tubers per plant increased with the average value of 9.2 knol/plant. Plants grown in unsuitable environmental conditions due to high temperatures such as in the medium land showed increasing in the number of tubers/plant when it was treated by retardants such as paclobutrazol compounds as anti-gibberellin[10,21].

Application of paclobutrazol increased chlorophyll content of leaves and inhibited the formation of new shoots, so that photosynthate can be accumulated in the tuber. Consequently, the weight of tuber per plant can be increased. Proper exogenous application of growth regulators will change the ratio of the endogenous hormone. The changed of this ration will further affect on the rate of plant growth and development. The high result of yield on plant as an effect of paclobutrazol was identified to be associated with a higher percentage of stolon tubers forming. So that, it affected in increasing tuber number/plant[22]. The implications of the increasing of tuber number/plant increased tuber weight/plant variable then increased plant productivity per hectare[23]. This proves that the inhibition of gibberellins synthesis will accelerate tuber initiation and formation[16].

CONCLUSION

It can be concluded that there was no interaction effect on combination of shading net and paclobutrazol at all observed parameters. Plant height, leaf area index, number of tuber, tuber weight and percentage of class tuber for seed size

from plants grown under shading net with 30% of density were higher than without shading net having 45% of density. Paclobutrazol suppressed plant height and leaf area, however, it increased leaves chlorophyll content, tuber number and tuber weight per plant. The highest tuber number and percentage of class tuber for seed size were obtained from plant with 50 mg L^{-1} of paclobutrazol application.

SIGNIFICANCE STATEMENT

The study for the first time introduces potato production in medium land with high temperature. Shading net 30% and paclobutrazol 50 mg L^{-1} for potato in high temperature of medium land increased production of seed potato tuber (G_2). In Indonesia, potato tuber propagation of G_2 can be expanded to medium land.

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