Study of Growth and Yield of Potato Plants (*Solanum tuberosum* L.) under Several Gibberellin Application during The Dry Season

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Abstract. Potatoes (Solanum tuberosum L.) are a vegetable crop that is the third most important carbohydrate food source in the world after rice and wheat. Potatoes growth and yield may be improved by applying plant growth regulators. This study purpose was to determine the outcome of several gibberellin plant growth regulator applications on the growth and yield of 'Granola' potato grown during the dry season. The study used a randomized completely block design with six factors, which were combinations of gibberellin (GA) doses and forms, namely: 1) liquid GA form with a dose of 0.1 ml.L^{-1}, 2) liquid GA form with a dose of 0.2 ml.L^{-1}, 3) liquid GA form with a dose of 0.4 ml.L^{-1}, 4) powdered GA form with a dose of 0.01 g.L^{-1}, 5) powdered GA form with a dose of 0.02 g.L^{-1}, 6) powdered GA form with a dose of 0.04 g.L^{-1}, and 7) Control (without GA application). All GA treatments, both liquid and powder, could increase tuber weight and yield per plot compared to the control plants. GA affects growth by increasing leaf area index, while plant height was not significantly affected. The treatment of 0.2 ml. L^{-1} liquid GA was the finest in producing the largest tuber size, tuber weight per plant, and tuber weight per plot. This treatment could increase the yield by 57.46% compared to 'Granola' that did not receive GA3 treatment. The results of this study can be used to improve potato tuber yield during the dry season.
Keywords : Potato Growth, Gibberellin Application, Tuber Yield, 'Granola' Potato, Dry Season Agriculture

1 Introduction

Potato (Solanum tuberosum) is a versatile and widely cultivated crop that holds significant importance as a staple food source and a valuable economic commodity worldwide [1], with 400 million tons yield every year [2]. Potato cultivation plays a crucial role in the socio-economic fabric of Indonesia. It provides a source of income and employment for numerous smallholder farmers, contributing to rural livelihoods and poverty alleviation. Potato cultivation in Indonesia faces several challenges that affect productivity and

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profitability [3]. One significant challenge is to enhance potato plant growth and productivity.

Gibberellins are essential plant hormones that control many characteristics of plant growth and development[4-5]. Gibberellic acid (GA3) is indeed a stirring plant growth hormone classified as a diterpenoid carboxylic acid within the gibberellin's family. The effects of exogenous GA3 on potato plants are significant for enhancing crop productivity and optimizing tuber formation and development [6] GA3 is commercially produced and can be found in various formulations, including liquid and solid forms. These different formulations have specific advantages and considerations [7].

GA3's limited stability in the presence of water is associated with liquid formulations, leading to a shorter shelf life. Specific solvents are employed to address the degradation of GA3, which, however, brings about flammability concerns, requiring meticulous packaging, transportation, and storage. Due to the drawbacks of liquid formulations, solid formulations emerge as a safer alternative. However, they also come with their own limitations, including the potential for dust generation during pouring, transferring, or measuring. Furthermore, there is a potential for the generation of residues in both plants and the container, along with the likelihood of clod formation. [8].

Fluid or dense formulations of GA3 could be administered using traditional ground or aerial methods of application. The concentration of gibberellin will differ based on the specific potato cultivars and the unique characteristics of the region, including the seasonal conditions during potato planting [7]. This current research aimed to assess the impact of different application methods and dosages of gibberellin plant growth regulator applications forms and dosages on the development and yield of 'Granola' potato grown during the dry season.

2 Methods

The study was held in the Indonesia Vegetable Research Institute (1250 asl). This research used a two-factors arranged in a randomized completely block design with six factors and five repetitions. The factors were combinations of gibberellin (GA) doses and forms, namely: 1) liquid GA form with a dose of 0.1 ml.L-1, 2) liquid GA form with a dose of 0.2 ml.L-1, 3) liquid GA form with a dose of 0.4 ml.L-1, 4) powdered GA form with a dose of 0.01 g.L-1, 5) powdered GA form with a dose of 0.02 g.L-1, 6) powdered GA form with a dose of 0.04 g.L-1, and 7) and control (without GA application. All treatment in this study used commercial GA3 (Progibb, Valent Bio Science, USA) and 'Granola' cultivar. The spacing plant was 80 x 30 cm with manure fertilizer of 40 ton. ha-1 and NPK 16:16:16 as much as 1000 kg. ha-1. Plant maintenance, such as pest and disease control, irrigation, and weeding, were carried out intensively by the recommendations of the Indonesia Vegetable Crops Research Institute. Gibberellin was applied at 14 weeks after planting (WAP), 30 WAP and 45 WAP by spraying all over the plant using a high-volume semi-automatic back sprayer (500 – 700 L. ha -1).

Measurements of plant height (cm) and leaf area index (LAI) were conducted at 3, 5, 7, and 9 weeks after planting (WAP), with a sample size of 20 seedlings per experimental unit. The yield components included tubers weight and number per plant, also tuber weight per plot was observed 100 days after planting (DAP). The data collected were analysed statistically using ANOVA completed in the SAS version 9.4 software, followed by the Duncan Multiple Range Test (DMRT), both at 95% confidence level.

3 Result and discussion

Visual observations showed that there were no signs of plant damage, yellowing (chlorosis), or any other abnormal symptoms on any part of the Granola potato variety treated with GA3 in all experimental conditions. Significantly pest and disease attacks on potato plants during their growth until harvest were almost non-existent, except for an early stage (around one month of age) when there was a 5% occurrence of bacterial wilt disease orignating from the seedlings. However, the spread of the disease was limited as the affected plants were promptly uprooted and destroyed. Overall, the growth of the potato plants, both those treated with GA3 and the control group, was satisfactory and healthy, despite unfavourable conditions such as high environmental temperatures and suboptimal soil moisture. Visually, it was observed that potato plants with GA3 application had greener leaves compared to the control group.

The plant height growth presented in Table 1 indicates that the application of GA3, both in liquid and powder form, up to the highest dosage with three applications (at 14, 30, and 45 days after planting/DAP), did not increase the height of potato plants at 3,5,7, and 9 weeks after planting (WAP) compared to the control plants that did not receive GA3 treatment. This indicates that gibberellin in the 'Granola potato variety does not affect plant height growth. These findings contrast from result of the others study [9], which demonstrated that gibberellins could enhance plant growth and height in potato plants. Furthermore, other research indicates that the use of diniconazole, a gibberellin synthesis inhibitor, suppresses the height of potato plants [1]. The dry season condition may influence result of this study. Drought poses a significant challenge to crop production in tropical countries as it results in reduced rainfall and negatively affects plant growth. Drought stress elevates leaf osmotic pressure, leading to a reduction in plants' transpiration, stomatal conductance, turgor pressure, and water potential [10]. Consequently, these effects may reduce the ability of gibberellin to promote cell elongation, resulting in no significant difference in plant height.

Table 1. Plant height of 'Granola' potato under different types and doses of GA3

GA3 Treatment	Plant height (cm) on …week after planting			
	3	5	7	9
Liquid GA3 0.1 ml. L^{-1}	12.23 a	34.37 a	52.13 a	55.39 a
Liquid GA3 0.2 ml. L^{-1}	12.03 a	30.37 a	47.17 a	53.89 a
Liquid GA3 0.4 ml. L^{-1}	14.70 a	34.40 a	47.50 a	56.39 a
Powder GA3 0,01 g. L^{-1}	13.03 a	30.93 a	51.37 a	56.50 a
Powder GA3 0,02 g. L^{-1}	12.97 a	28.90 a	51.27 a	55.53 a
Powder GA3 0,04 g. L^{-1}	12.43 a	32.70 a	52.13 a	56.39 a
Control (without GA3)	12.63 a	30.47 a	51.07 a	54.03 a
CV (%)	13.04	11.96	4.89	2.38
DMRT (5%)	ns	Ns	ns	ns

Note: The values with the same letter within the same column were not significantly different at a 5% significance level using DMRT.

Leaf area index values are shown in Table 2.The application of GA3 did not significantly different in terms of leaf area index (LAI) values for Granola cultivar in the fifth and ninth weeks after transplantation. In the third and seventh weeks, the use of low doses of GA3, either in liquid form (0.1 ml. L^{-1}) or powder form (0.01 g. L^{-1}), could not make a notable increase in LAI compared to the control. However, at higher doses of up to 0.4 ml. L^{-1} in liquid form or 0.04 g. L^{-1} in powder form, GA3 application was able to

increase LAI. One of the roles of GA3 in plant growth is to regulate physiological mechanisms that can stimulate leaf expansion through induction of transcription of genes involved in cell elongation and cell division [11]. The high dose of GA3 in this experiment was able to increase the leaf area index of potato plants. At low doses (0.1 ml. L^{-1} in liquid form or 0.01 g. L^{-1} in powder form), GA3 might not significantly impact LAI because the concentration of the growth regulator may be insufficient to trigger noticeable growth responses in the plants. At this lower level, GA3 may not effectively stimulate cell elongation and division, which are crucial processes for increasing leaf area.

Table 2. Leaf Area Index of 'Granola' potato under different types and doses of GA3.

GA3 Treatment	Leaf Area Index on …week after planting			
	3	5	7	9
Liquid GA3 0.1 ml. L^{-1}	0.134 bc	1.227 a	2.276 c	4.379 a
Liquid GA3 0.2 ml. L^{-1}	0.120 cd	1.570 a	3.833 a	4.614 a
Liquid GA3 0.4 ml. L^{-1}	0.169 ab	1.471 a	3.470 ab	4.305 a
Powder GA3 0,01 g. L^{-1}	0.167 ab	1.683 a	3.324 abc	4.257 a
Powder GA3 0,02 g. L^{-1}	0.172 a	1.326 a	2.610 bc	3.742 a
Powder GA3 0,04 g. L^{-1}	0.125 cd	1.208 a	3.531 ab	3.352 a
Control (without GA3)	0.099 cd	1.221 a	2.216 c	3.109 a
CV (%)	14.61	17.28	18.12	16.79
DMRT (5%)	s	ns	s	ns

Note: The values with the same letter within the same column were not significantly different at a 5% significance level using DMRT.

The use of liquid GA3 resulted in the highest LAI value during the seventh week of observation. Liquid GA3 formulations can be easily mixed with water, ensuring a uniform distribution of the growth regulator when applied to the plants. This homogenous distribution helps achieve a consistent response throughout the plant population. In contrast, powder formulations might be more challenging to mix evenly, potentially leading to uneven application and variable growth responses. As a result, the active compound of GA3 in the liquid formulation can reach the target sites more efficiently, leading to a more rapid and pronounced growth response, including an increase in the leaf area index.

Table 3. Yield Component of 'Granola' potato under different types and doses of GA3.

GA3 Treatment	Tuber weight (g. plant $^{-1}$)	Yield per plot (kg. 28.08 $^{-2}$)
Liquid GA3 0.1 ml. L^{-1}	0.362 ab	38.28 ab
Liquid GA3 0.2 ml. L^{-1}	0.537 a	45.30 a
Liquid GA3 0.4 ml. L^{-1}	0.511 a	41.44 ab
Powder GA3 0,01 g. L^{-1}	0.254 ab	39.99 ab
Powder GA3 0,02 g. L^{-1}	0.308 cd	33.58 bc
Powder GA3 0,04 g. L^{-1}	0.364 bcd	33.31 bc
Control (without GA3)	0.297 d	28.77 c
CV (%)	17.16	2.87
DMRT (5%)	s	s

Note: The values with the same letter within the same column were not significantly different at a 5% significance level using DMRT.

GA3 application both in liquid and powder form could increase tuber weight per plant and yield per plot compared control plant (Tabel 3). GA3, in liquid form, generally produces larger potato tuber weights per plant than powdered GA3. There were no

noteworthy variances in tuber weight per plant and yield per plot between the liquid GA3 applications of 0.2 and 0.4 ml. L^{-1}. However, the dosage of 0.2 ml. L^{-1} lead to the uppermost tuber weight per plant and yield per plot.

The application of liquid GA3 at all concentrations proved to be more effective in enhancing the production of large-sized potatoes (Grade A) than the control (Tabel 4). However, the implementation of powdered GA3 at 0.02 g. L^{-1} concentration also resulted in an increase in potato size in Grade A. Conversely, increasing the dosage of powdered GA3 to 0.04 g. L^{-1} lead to a reduction in the size of Grade A tubers related to the control, with no significant difference.

Table 4. Yield Component of 'Granola' potato under different types and doses of GA3.

GA3 Treatment	Grading size		
	Grade C	Grade B	Grade A
Liquid GA3 0.1 ml. L^{-1}	55.83 bc	102.50 cd	303.33 ab
Liquid GA3 0.2 ml. L^{-1}	26.50 d	197.00 a	325.00 ab
Liquid GA3 0.4 ml. L^{-1}	53.33 bc	119.17 bcd	338.33 a
Powder GA3 0,01 g. L^{-1}	44.17 a	127.50 bc	242.50 bcd
Powder GA3 0,02 g. L^{-1}	54.17 bc	93.33 cd	362.50 a
Powder GA3 0,04 g. L^{-1}	41.67 cd	118.33 bcd	204,17 d
Control (without GA3)	37.50 cd	64.17 d	215,00 cd
CV (%)	22.46	22.75	17.46
DMRT (5%)	s	s	s

Note: The values with the same letter within the same column were not significantly different at a 5% significance level using DMRT.

In this study, the exogenous application of GA3, both in liquid and powdered form, enhanced leaf area index, tuber size, and yield per plot of 'Granola' potato. Nonetheless, the most consistently effective treatment across all observed factors was the usage of liquid GA3 at a rate of 0.2 ml per liter. Liquid formulations of GA3 often incorporate certain additives and/or adjuvants to enhance product stability, provide protective effects, extend shelf life, or increase plant nutritional factors [12-13]. It may result in the liquid formulation with the ideal dosage could lead to enhanced effectiveness in stimulating the growth and yield of 'Granola' potato plants.

4 Conclusion

Exogenous application of GA3 in liquid and powdered form enhanced leaf area, tuber size, and yield per plot of 'Granola' potato plant in a dry session with the optimum dosage was 0.2 ml. L^{-1} and 0.02 g. L^{-1} respectively. An increase in yield with this treatment could increase the yield by 57.46% compared to plants that did not receive GA3 treatment in 'Granola'.

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