International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

https://ijpsat.org/
Vol. 51 No. 2 July 2025, pp. 96-106

Growth And Yield Response Of Potato Plants (Solanum Tuberosum L.) To Application Of Various Doses Of Solid Decanter And Urea

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Potato (*Solanum tuberosum* L.), a horticultural crop, is widely consumed by Indonesians as a supplementary carbohydrate source and as a vegetable due to the high nutritional value of its tuber. Healthy vegetative growth of potato plants tends to result in more tubers and greater tuber weight. This research was conducted to determine the best interaction between solid decanter and Urea on potato plant growth, identify the optimal solid decanter dosage for growth and yield, and verify the best urea dosage for growth and yield. The study was carried out at the Experimental Farm of the Agricultural Instrument Standards Application Center (BPSIP) in West Sumatra from January to April 2024. The experiment was designed using a Randomized Complete Block Design with two factors and three levels of treatment. The first factor was Solid decanter with doses of 4, 8, and 12 tons/ha, while the second factor was Urea with doses of 150, 300 and 450 kg/ha. The data were analyzed using ANOVA, followed by Duncan's New Multiple Range Test (DNMRT) at a 5% significance level. The results revealed that interaction between Solid decanter at 8 tons/ha and Urea at 150 kg/ha produced the largest leaf area. The application of Solid decanter did not significantly affect the growth and yield of potato plants. However, applying Urea at 150 kg/ha resulted in the tallest plants, the highest number of tubers per plant, and the heaviest tubers per plant.

Keywords- interaction, potato, solid decanter, urea, yield

I. INTRODUCTION

Potato plant (Solanum tuberosum L.) is a plant that produces tubers, which are used as an additional source of carbohydrates for most Indonesians. The demand for vegetables including potatoes in Indonesia continues to increase every year along with the increasing population and income levels [1]. Total potato consumption in Indonesia in 2022 reached 3.16 kg/capita/year. Potato production in Indonesia in 2022 according to the Indonesian Central Statistics Agency (BPS) reached 1.5 million tons. The imports of potato that reached 716 thousand tons at the beginning of 2023 illustrates that the needs of potatoes for both consumption and industrial products are still not met [2]. Potato demand tends to increase along with population growth and public awareness of the importance of nutrition for health. To anticipate the demand for potato products in accordance with market preferences, intensive guidance efforts need to be made so that all production centers in the center area can be increased in production and quality [3].

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The vegetative growth of potato plants is closely related to tuber production. When vegetative growth increases, the number and weight of tubers will also increase. Potato plants with good vegetative growth tend to produce more tubers with greater weight [4]. The use of nitrogen fertilizer is expected to increase vegetative growth of potato plants. Nitrogen promotes cell elongation and vegetative growth in plants, which in turn increases the number and weight of tubers. Nitrogen has an important role in photosynthesis, helping potato plants increase vegetative growth. The use of nitrogen can increase the number of leaves and plant height, which in turn can increase tuber production. Research shows that applying a certain dose of nitrogen can increase the number and weight of tubers per plant and reduce the percentage of rotten tubers. In addition, the nitrogen content in potato tubers also affects their quality. Appropriate nitrogen application can increase the protein content in tubers, which is important for maintaining the quality of these tubers [5].

Conventional farming systems use inorganic fertilizers for potato crops, with inorganic fertilizer doses of 100-150 kg N/ha (equivalent to 217-326 kg Urea/ha), 100-150 kg P_2O_5/ha, and 100-150 kg K_2O/ha. Nitrogen nutrient levels that are too low will produce tubers with small sizes, while if nitrogen nutrients are too high it can reduce the yield and quality of tubers [6]. Urea, as a nitrogen source, contributes to leaf and stem growth. Nitrogen is required for the synthesis of chlorophyll, which is essential for photosynthesis. However, excess nitrogen can accelerate leaf and stem growth, diverting energy from tuber formation. As a result, although vegetative growth increases, tuber yield may decrease [7]. The use of Urea can increase the vegetative growth of potato plants. Urea promotes leaf and stem growth, which in turn increases the number and weight of tubers. Urea application affects the quality of potato tubers. Appropriate nitrogen fertilizer can increase tuber size and weight, and reduce reducing sugar levels in tubers, which is important for yield quality [8].

Organic matter acts as a contributor of nutrients and increases the efficiency of fertilization and nutrient uptake by plants so that the plants growing on it can develop properly. Intensive use of chemical fertilizers without return causes a decrease in organic matter in the soil. Improvements need to be made to increase organic matter in the soil, such as using chemical fertilizers combined with organic fertilizers [9]. Like chemical fertilizers, the types of organic fertilizers are very diverse, determined by the origin of the material formed. One type of organic material that can be utilized is palm oil waste. Oil palm waste is the remaining products of oil palm plants that are not included in the main product. Waste from palm oil processing can be divided into liquid waste and solid waste in the form of coir, shells, empty baskets and solid (solid mud).

Solid decanter is one of the waste in the form of solids from the processing of Fresh Fruit Bunches (FFB) at PKS (Palm Oil Mill) using a decanter system. Solid decanter contains high nutrients and organic substances. The high content of protein, fat, and cellulose are triggers for microorganisms to grow well in Solid decanter. Solid decanter can be used as fertilizer as a soil improver. Giving Solid decanter as a base material for organic fertilizer at various doses can increase growth increments in oil palm seedlings [10]. The nutrients contained in Solid decanter based on the results of sample analysis research at the Laboratory of the Oil Palm Research Center in North Sumatra are Nitrogen content of 3.52%, Potassium 0.33%, and Magnesium 0.49% [11]. The results of research by [11], stated that the provision of Solid decanter 1.5 kg/m² in green eggplant plants (*Solanum melongena* L.) produced the highest production per plant, which was 1748.77 g and the highest production per plot was 21.89 kg. [10] stated that the application of Solid decanter in oil palm plants can increase the physical, chemical, and biological content of the soil. This research conducted to see the response of growth and yield of potato plant to several doses of Solid decanter and Urea.

II. MATERIALS AND METHODS

The materials used were Granola variety potato seeds, Solid decanter fertilizer, plastic mulch, glass plastic, plastic bags, plastic folders, rope, sacks, Urea, KCl, and TSP fertilizers. Insecticides made from Emamectin benzoate and Triazofo, and fungicide made from Mancozeb. The tools used in this research are books, stationery, hoes, bamboo, mulch tongs, wood, tacks, camera, meters, scissor, knife, ruler, belgi drills, scale, digital scale, analytical scale, oven, ImageJ® app, and STAR app.

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The experiment was designed using a Randomized Complete Block Design with two factors and three levels of treatment. The first factor was Solid decanter with doses of 4, 8, and 12 tons/ha, while the second factor was Urea with doses of 150, 300 and 450 kg/ha. The whole experiment consisted of 27 experimental units. Each experimental unit consists of 33 plants per plot, with 3 selective samples and 4 destructive samples in each experimental unit, so that the total number of selective sample plants is 81 plants, the number of destructive sample plants is 108 plants, and the total number of plants is 891 plants. Data obtained from the research will be analyzed using the F test. If the F count of the treatment is greater than the F table at the 5% level, it is continued with the Duncan's New Multiple Range Test (DNMRT) method at the 5% level.

III. RESULT AND DISCUSSIONS

A. Plant Height

Based on analysis of variance of potato plant height, it was found that the provision of Solid decanter gave no significant effect on potato plant height, while Urea gave a significant effect on potato plant height. Plant height data can be seen in the table below

TABLE 1. PLANT HEIGHT ON THE VARIOUS DOSES OF SOLID DECANTER AND UREA

Solid decanter	Urea			Average
	150 kgs/ha	300 kgs/ha	450 kgs/ha	
	--- cm ---			
4 tons/ha	34,63	31,34	36,47	34,15
8 tons/ha	36,86	34,52	30,20	33,86
12 tons/ha	38,07	30,46	30,69	33,07
Average	36,52 **a**	32,11 **b**	32,45 **b**	
CV = 10,37%				

Note: Numbers in the same row followed by the same lowercase letter are significantly not different according to the DNMRT test at the 5% level.

Based on Table 1, Solid decanter gives the same effect on potato plant height and Urea gives different plant height results for each treatment. The single factor Urea dose of 150 kg/ha gave the highest plant height results, which was 36.52 cm. Doses of 300 kg/ha and 450 kg/ha Urea did not show any difference in potato plant height, with the 300 kg/ha Urea treatment giving the lowest potato plant height of 32.11 cm. The single factor Solid decanter showed no difference in this experiment.

One of the main causes of low potato plant height is nutrient deficiency, especially potassium and nitrogen. Potassium plays an important role in tuber formation and vegetative growth. Potassium deficiency can result in stunted plant growth and small tuber size [12]. Nitrogen nutrients are very important for plant growth and development. Nitrogen fertilization increases nitrogen uptake by plants, which leads to increased growth and biomass production [13]. Organic fertilizers can improve soil structure and affect the activity of macroflora and microfauna organisms. Organic fertilizers provide macro nutrients (N, P, K, Ca, Mg, and S) and micro nutrients (Zn, Cu, Mo, Co, B, Mn, and Fe) needed by plants. In addition, organic matter can increase the cation exchange capacity of soil, which affects the availability of nutrients such as phosphorus [14]. The application of a combination of organic and inorganic fertilizers can increase the availability of P and

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ISSN: 2509-0119.

https://ijpsat.org/
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potassium (K) nutrients in the soil. Mineralization of applied organic matter can release complete plant nutrients, including N, P, K, Ca, Mg, S, and other micronutrients, although in relatively small amounts [15].

(a) 4 ton/ha Solid decanter and 150 kg/ha Urea
(b) 4 ton/ha Solid decanter and 300 kg/ha Urea
(c) 4 ton/ha Solid decanter and 450 kg/ha Urea
(d) 8 ton/ha Solid decanter and 150 kg/ha Urea
(e) 8 ton/ha Solid decanter and 300 kg/ha Urea
(f) 8 ton/ha Solid decanter and 450 kg/ha Urea
(g) 12 ton/ha Solid decanter and 150 kg/ha Urea
(h) 12 ton/ha Solid decanter and 300 kg/ha Urea
(i) 12 ton/ha Solid decanter and 450 kg/ha Urea

Fig 1. Picture of potato plants on various doses of Solid decanter and Urea in the 8th weeks after plant.

Nitrogen in Urea fertilizer is easily absorbed by plants and plays a role in the formation of chlorophyll needed for photosynthesis [16], [7]. However, excessive nitrogen use can reduce the availability of other nutrients such as potassium and phosphorus, which are also important for plant growth. This imbalance can inhibit plant height growth. Excessive use of Urea fertilizer causes plants to experience stress, so plants grow slower and do not reach optimal height. This stress can interfere with important physiological processes such as photosynthesis and water absorption [17].

B. Total Leaf Area

Based on the analysis of variance of the total leaf area variable, there is an interaction in the dose treatment of Solid decanter and Urea. Data on the average leaf area is in the following table.

International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

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TABLE 2. POTATO PLANT'S TOTAL LEAF AREA ON VARIOUS DOSES OF SOLID DECANTER AND UREA

Solid decanter	Urea		
	150 kgs/ha	300 kgs/ha	450 kgs/ha
	--- cm^2 ---		
4 tons/ha	610,74 **ab**	417,95 **b**	710,16 a
	AB	**B**	**A**
8 tons/ha	756,11 **a**	708,22 **a**	666,02 **a**
	A	A	**A**
12 tons/ha	422,38 **b**	637,89 **a**	504,64 **a**
	B	**A**	**AB**
CV = 20,26%			

Note: Numbers in the same column followed by same uppercase latters and numbers in the same row followed by lowercase letters are significantly not different according to DNMRT test at the 5% level.

Based on the data in Table 2 above, it can be seen that the treatment of Solid decanter and Urea doses interacted with the leaf area of potato plants. Giving a dose of Solid decanter 4 tons/ha gives the largest leaf area at a dose of Urea 450 kg/ha. Giving a dose of Solid decanter 8 tons/ha gives the same effect on all doses of Urea. This means that the application of Solid decanter 8 tons/ha and 150 kg/ha Urea is enough to increase the leaf area of potato plants. The application of 150 kg/ha of Urea gave the largest results at the dose of Solid decanter 8 tons/ha. However, the application of Solid decanter 4 tons/ha was sufficient to increase the total leaf area of potato plants.

Solid decanter fertilizer contains 2.32% nitrogen and Urea fertilizer is a single fertilizer containing nitrogen elements, where nitrogen is very important for plant growth. The use of nitrogen fertilizer can help increase the leaf area of potato plants. The right dose of nitrogen fertilizer is needed to stimulate lateral meristems, which in turn can increase plant height, leaf number, and leaf area [18]. In this study, the application of 8 tons/ha Solid decanter and 150 kg/ha Urea met the nitrogen needs of potato plants, including increasing leaf area, so an increase in the dose of both factors was not required. Research by [19] stated that the application of nitrogen fertilizer to purple eggplant plants (Solanum melongena L. var. F1 Antaboga Hybrid) was positively correlated with an increase in eggplant leaf area, where the application of 300 kg/ha of nitrogen fertilizer gave higher results than the application of 150 kg/ha nitrogen fertilizer. In wheat as well, high leaf area index values lead to higher yields. Nitrogen fertilization can affect leaf area index and yield by promoting vegetative growth and increasing biomass production [20].

Leaf area plays a very important role in the photosynthesis process because this process occurs in the leaves. The larger the leaf surface area, the more chloroplasts the plant has, which can increase the production of photosynthetic products. Larger leaf area correlates with increased photosynthesis and is often used as an indicator in plant growth analysis. In addition, the quality of light received by the leaves also affects photosynthetic efficiency. More intense light that is green, yellow, orange and red in color can increase photosynthesis. Larger leaves can absorb more light, which in turn increases the photosynthesis process [21], [22]. Leaf size affects how much photosynthesis can be done by the plant. Larger leaves can capture more light and produce more assimilate. Increasing the leaf area of plants can produce more assimilates. These

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ISSN: 2509-0119.

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assimilates are important as a food source for plants, supporting plant growth and development. Plants with larger leaves tend to have higher assimilate production [23], [24].

C. Number of Tuber per Plant

The variable number of tubers per plant did not show any interaction between the dose of Solid decanter and the dose of Urea based on the results of the analysis of variance. However, the treatment of various doses of Urea fertilizer gave a significantly different effect. Data on the average number of tubers per plant can be seen in the following table.

TABEL 3. NUMBER OF TUBERS PER POTATO PLANT ON VARIOUS DOSES OF SOLID DECANTER AND UREA

Solid decanter	Urea			Average
	150 kg/ha	300 kg/ha	450 kg/ha	
4 ton/ha	7,77	5,67	6,11	6,52
8 ton/ha	7,89	7,00	2,77	5,89
12 ton/ha	7,55	7,00	5,45	6,67
Average	7,74 **a**	6,56 **a**	4,78 **b**	
CV = 15,17%				

Note: Numbers in the same row followed by the same lowercase letter are significantly not different according to the DNMRT test at the 5% level.

Table 3 shows that there is no interaction between the various doses of Solid decanter and Urea on the number of tubers per potato plants. The treatment of various doses of Urea gave a different effect between the treatments of 150 and 300 kg/ha with 450 kg/ha, where the 450 kg/ha Urea treatment gave the least number of tubers from other Urea treatments. Urea 150 kg/ha has been able to increase the number of tubers per potato plant in this study.

Nitrogen fertilizer has a considerable influence on the number of tubers in a potato crop. In general, increased nitrogen levels lead to an increase in the total number of tubers, overall tuber yield, and average tuber size. More specifically, higher nitrogen applications can increase the number of tubers produced [25]. The optimal nitrogen rate to achieve the highest tuber yield may vary. Other factors include climate; for example, areas with high rainfall or cooler temperatures may require adjustments in nitrogen dosage. In addition, different potato varieties have different nitrogen requirements, so it is important to adjust the nitrogen dosage according to the variety planted to achieve the best yield [26], [27].

The low number of tubers harvested may be due to the spread of diseases that attacked potato plants during the study period. The high rainfall favored the development of diseases in the cultivation environment. High rainfall can make the soil wetter, which can accelerate the spread of diseases caused by both fungi and bacteria [28]. Diseases that attack potato plants during high rainfall can cause potato plants to be damaged and die, so that farmers do not get optimal yields. Sufficiently high rainfall can also disrupt the flowering, pollination, and tuber formation processes in potato plants. The number of tubers will reach maturity when moisture and nutrients are appropriate or available. Increased tuber formation and filling will result in a greater number of tubers with larger sizes and greater total tuber production weight per plant [29].

Solid decanter contains potassium nutrients that function in the tuber formation process. Potassium plays an important role in photosynthesis, carbohydrate synthesis, and the transfer of assimilates from leaves to tubers, which can increase the size and number of tubers produced. Potassium helps regulate osmotic potential, ion balance, and activates enzyme processes essential for tuber growth and formation. Optimal potassium dosage can increase tuber yield and quality. The use

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ISSN: 2509-0119.

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of effective potassium doses can increase the number, size, and quality of tubers and reduce physical damage and reduce tuber quality [30], [31]. Tuber formation is also influenced by the size of the seedlings used. The number of tubers formed can be an interpretation of the size of the seed tubers used. Small seed tubers weighing around 30 grams will produce large tubers, but in smaller quantities [32].

D. Tuber weight per plant

Based on the analysis of variance of the variable weight of tubers per plant, there is no interaction between the treatment doses of Solid decanter and Urea on the variable weight of tubers per plant. The average weight of tubers per plant can be seen in the following table.

TABLE 4. TUBER WEIGHT PER PLANT ON VARIOUS DOSES OF SOLID DECANTER AND UREA

Solid decanter	Urea		
	150 kg/ha	300 kg/ha	450 kg/ha
	--- gram ---		
4 ton/ha	226,07	253,75	196,42
8 ton/ha	329,58	272,88	108,11
12 ton/ha	289,33	217,92	173,68
Average	281,66 **a**	248,18 **a**	159,40 **b**
CV = 17,94%			

Note: Numbers in the same row followed by the same lowercase letter are significantly not different according to the DNMRT test at the 5% level.

Table 5 shows that the Solid decanter treatment gives no different effect on the variable weight of tubers per plant. The single Urea treatment gives an effect on the yield of tuber weight per potato plant, with the Urea dose treatment of 150 kg/ha giving the highest tuber weight per plant, which is 329.58 grams per plant. Based on the results of tuber weight per plant, the higher the dose of Urea, the weight of tubers per plant decreases, so that Urea fertilization at a dose of 150 kg/ha is sufficient to increase the weight of tubers per potato plant.

In contrast to the average number of tubers per plant, the treatment of various doses of Solid decanter and Urea had no interaction on the variable of tuber weight per plant. The yield of tuber weight per potato plant is thought to be related to the level of Phytophtora late blight attack, where the higher the late blight attack, the lower the yield obtained. Giving Solid decanter will increase plant growth and production so that storage tissue cells will form more and larger. The application of Solid decanter and Urea fertilizer showed the same effect on plant production. This is due to the nutrient content in Solid decanter that has not fully synergized with other nutrients needed by plants. As a result, the application of Solid decanter has not had the same impact on the amount of production per plant in terms of tuber weight. In addition, it is likely that other factors such as environmental conditions, absorption of nutrients by plants, and interactions between various nutrient components also influence the measured production results [33].

In addition to environmental influences, treatments provide interactions between observational variables with one another. [34] stated that the formation of more tillers accompanied by the emergence of more and larger leaves allows plants to capture sunlight optimally, which in turn can increase photosynthetic yields. With the increase in the number of

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ISSN: 2509-0119.

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leaves per plant, the leaf area will also increase. Based on research by [35], leaves is the main organ in photosynthesis; so the wider the leaves, the higher the capture of sunlight and CO_2 fixation, so that increased photosynthesis will produce more assimilate. This process contributes directly to plant tuber formation.

E. Tubers weight per hectare

The variable of tuber weight per hectare based on the analysis of variance did not show any interaction between the various doses of Solid decanter and the dose of Urea. Data on the average weight of potato tubers per hectare can be seen in the table below.

TABLE 5. TUBERS WEIGHT PER HECTARE ON VARIOUS DOSES OF SOLID DECANTER AND UREA

Solid decanter	Urea			Average
	150 kg/ha	300 kg/ha	450 kg/ha	
	--- ton/ha ---			
4 ton/ha	14,31	13,19	13,39	13,63
8 ton/ha	15,32	13,20	13,34	13,95
12 ton/ha	16,96	10,22	12,29	13,16
Average	15,53	12,20	13,01	
CV = 28,29%				

Note: Numbers in the row and column are significantly not different according to the DNMRT test at the 5% level.

The tuber weight per hectare in this experiment did not reach the level of the description of the Granola potato variety, which is about 26.5 tons/ha. Some potato tubers were visibly damaged after harvesting. These damaged tubers were most likely caused by the extreme weather and the spread of Phytophtora wilt disease on the plants during the study. Phytophtora infestans is the pathogen that causes late blight in potatoes, and is one of the most destructive diseases affecting potato production worldwide. Phytophthora infestans can infect potato tubers, causing rot and decay. This infection reduces not only the quality, but also the quantity of tubers that can be sold, ultimately resulting in large yield losses. The disease causes significant yield losses, with estimates reaching up to 10 billion USD annually, both in yield losses and management costs. If the disease progresses rapidly and attacks the crop at an early stage of its growth, which can drastically reduce yields [36].

High rainfall during the research also led to a decrease in potato crop production. Climate change can affect the spread of diseases in potatoes, including an increase in the severity of plant diseases. Climate change affects both pathogens and potato plants. Higher temperatures may be more detrimental to pathogens than plants, which could reduce disease severity. Changes in temperature and rainfall patterns can also affect disease development and yield losses. These changes may cause the disease to spread faster or slower, depending on the new environmental conditions [37]. In addition to rainfall, the application of nitrogen fertilizers, including urea, influences disease spread. High doses of urea can disrupt the balance between nitrogen and other nutrients, such as potassium and phosphorus. This imbalance can weaken the plant's defense system against disease. For example, potassium-deficient plants tend to be more susceptible to disease attacks, thus risking a decrease in the quality and quantity of the crop [38]. The balance between nitrogen and potassium is also very important for optimal tuber formation. An imbalance in the provision of these nutrients can inhibit tuber growth and reduce yields [39]. Over-application of urea can reduce tuber quality, including size and weight. The tubers formed may be smaller and

have lower nutrient content, due to the lack of food reserves available for tuber formation. In addition, inappropriate use of urea can lead to nitrate buildup in the soil, which negatively affects plant health and the environment [40].

IV. CONCLUSION

Based on the results of research on the growth response and yield of potato plants (*Solanum tuberosum* L.) on the provision of various doses of Solid decanter and Urea, it can be concluded that the interaction of Solid decanter 8 tons/ha and Urea 150 kg/ha gives the widest plant leaf area. Based on this research, Solid decanter does not affect the growth and yield of potato plants, also Urea 150 kg/ha gives the best results in plant height, number of tubers per plant, and tuber weight per plant.

ACKNOWLEDGEMENT

We would like to express our deepest gratitude to God Almighty for His blessings throughout this research journey. We also would like to thank all the lecturers at the Faculty of Agriculture, Andalas University for the insights and guidance during the research. Also, we thank our colleagues for the helps and supports.

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