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THE EFFECT OF NITROGEN DOSAGE ON N EFFICIENCY AND PROTEIN CONTENT IN POTATOES

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ABSTRACT
The availability of nutrients in the soil, especially nitrogen (N), significantly affects the production and quality of potato tubers. Case N is a very dynamic nutrient. Uncontrolled application of N fertilizer causes low farm efficiency and even results in environmental pollution. This study aims to analyze N fertilizer use's efficiency and analyze the optimum dose that can increase the protein content of potato tubers. Field trials were carried out on farmers' land in the village of Sumberejo, Batu, East Java, Indonesia, at an altitude of 710 above sea level. The study used a randomized block design with four N dosage treatments, namely: 40, 80, 120, 160 N kg ha^{-1}. The treatment was repeated six times, with each replication consisting of 5 plant samples. N fertilizer source comes from ZA, which is applied two times, at the time of planting and on the 35th day after planting. The results showed that N fertilizer's application at various doses had a significant effect on N nutrient efficiency and protein content in potato tubers. Giving a dose of N of 120 kg ha^{-1} showed the highest yields on dry canopy weight, N in the canopy, chlorophyll, and tuber protein at harvest. The minimal nitrogen use efficiency (NUE) was achieved at a dose of 151.84 N kg ha^{-1}. The optimum dose of tuber mineral content was achieved at 138.56 N kg ha^{-1}, namely 5.40%.

KEY WORDS
Nitrogen, potato, protein, efficiency, optimal dosage.

Potatoes (*Solanum tuberosum L.*) are among the main foodstuffs in demand in the world after wheat, rice, and corn (Reyniers et al., 2020; Saidi & Hajibarat, 2020). Potato also is one of the most important food crops worldwide but its cultivation is affected by numerous challenges including pests, diseases and high fertiliser requirements which have associated environmental problems (Aloo et al., 2019). Potatoes are consumed as a fresh or processed product that has the potential for food diversification. As a plant that is consumed by its tubers, potato is quite prominent in its nutritional content. The protein and carbohydrates ratio in potato tubers is higher than in plants derived from other cereals and tubers. The amino acids in potato tubers have a balanced composition, which is good for health (Wichrowska & Szczepanek, 2020a). Leucine, phenylalanine, lysine, valine, arginine, tryptophan, threonine, histidine, and arginine are amino acids found in potatoes. Potatoes contain low fat and cholesterol, but carbohydrates, protein, vitamin C, iron, calcium, and vitamin B6 are relatively high (Bogucka & Jankowski, 2020; Kurnianingsih et al., 2020).

The availability of nutrients in the soil will determine the yield and quality of tubers. N is a very dynamic nutrient (Koch et al., 2020). Uncontrolled N's application will increase farming costs. If plants cannot absorb its presence, it will cause environmental pollution. Moreno et al., 2003; Lerna et al., 2011). Currently, potato fields receive a very high N intake. In contrast, potatoes have a shallow root system, which creates a high risk of N loss due to leaching (Neumann et al., 2012). Efforts to maintain high yields and minimize loss of nutrient N are challenges in potato cultivation.

In potato cultivation production, a relatively high amount of fertilizer is required. Apart from potassium, nitrogen is an essential element and an essential structural component of various proteins. At the same time, starch is an essential component of potato tubers, which account for 17% - 21% of the tuber's fresh weight. The amount of fertilizer needed is also influenced by soil type, variety, crop rotation, and water supply (Wichrowska & Szczepanek, 2020). Excessive nitrogen fertilizers cause the accumulation of dry matter on parts of plants other than tubers, increase leaf growth, delay tuber differentiation, the bulking period is delayed, so that tuber yields and tuber dry matter are reduced (Abbasi et al., 2005, Yagi et al., 2020, Fontes et al., 2010). Low N application can reduce tuber yield and tuber size due to reduced leaf area, shorter tuber initiation period, and increased tuber moisture content resulting in low starch content.

Effective nutrient management is very important for potato farming. Each variety grown in an area requires a specific number of nutrients. An adequate amount of N will increase the number of roots and shoots, and tuber size. Loss of N can occur through washing, evaporation, denitrification, utilization by weeds, erosion by water flow, and sedimentation (Shadrack et al., 2016). Determination of nitrogen rates related to nitrogen use efficiency is essential to maximize farm profits by reducing waste of resources or production costs and ultimately reducing environmental pollution (Powel et al., 2010). Nitrogen use efficiency is a yield-determining parameter that can be calculated using either the amount of nitrogen extracted or nitrogen used for tuber formation. Besides, food consumption fulfillment will be better if the materials consumed also contain some minerals needed by the body as additional nutritional intake.

Research on nitrogen dosage on N efficiency in various plants has been carried out in several countries, including (Aloo et al., 2019; Gholipouri & Kandi, 2012; Karimov, 2013; Saidi & Hajibarat, 2020). In the potato crop has been done by (Assunção et al., 2020; Gholipouri & Kandi, 2012; Ierna et al., 2011). In this study, two objectives were set: to analyze the efficiency of N fertilizer use and to analyze the optimum N dose, which could increase the protein content of potato tubers. The research was conducted on farmers' land in the village of Sumberejo - Batu, East Java, at an altitude of 710 above sea level. The study used a randomized block design (RBD) with four N dosage treatments, namely: 40, 80, 120, 160 N kg ha-1. The treatment was repeated six times, with each replication consisting of 5 plant samples. The source of N fertilizer comes from ZA, which is applied two times, at the same time as planting time and on the 35th day after planting. The research results are expected to obtain information on N fertilizers' efficient use and find the optimum dosage that can give the highest potato production as indicated by the Nitrogen Use Efficiency (NUE). Besides that, the optimum dose of potato tuber protein content was also obtained. The results are expected to become a policy reference to increase potato production in East Java, Indonesia.

MATERIALS AND METHODS OF RESEARCH

The research was carried out experimentally on farmers' land in the village of Sumberejo - Batu with an altitude of 690 m above sea level, an average temperature of 21^{o} C, 89% humidity, and clay textured soil. Genotypes of potato grown At 4. Soil and plant analysis was carried out at the Chemistry Laboratory of the Muhammadyah University of Malang and the Laboratory of Soil and Plants of the Karangploso Agricultural Research and Development Agency.

The tools used: sprayer, analytical scale, measuring cup, meter, oven, calipers, spectrophotometer, glass beaker, dropper pipette, filter paper, burette, measuring flask, glass funnel, chlorofilmeter SPAD Minolta 502, volumetric pipette, and tools for analysis of the protein content of potato tubers. The materials used were: chicken manure, rice straw for mulch, furadan, broccoli waste, paclobutrazol, ZA fertilizer, SP-36, KCl, and chemicals soil analysis, potato tuber starch content analysis.

The study used a simple randomized block design (Rancangan Acak Lengkap/RAK), which consisted of four doses of nitrogen fertilizer, namely: D1 = 40, 80, 120, and 160 N kg ha-1. Each treatment was repeated six times, and each treatment in the replication contained five plant samples. The potato seeds planted came from G1, which already had ± 2 cm shoots and 20-30 g / tuber weight. Organic chicken manure is spread evenly on the mounds at a dose of 15 t ha-1, while broccoli waste is given by chopping ± 2 - 3 cm at a dose of 5 t ha-1. Chicken manure is given ten days before planting, while broccoli waste is given one week before planting. The spacing used is 30 x 60 cm. Inorganic fertilizers are given two times, namely as basic fertilizer (1/2 dose of N (Za), SP-36 100 kg ha-1 and K2O 75 kg ha-1) and as additional fertilizers are given when the plants are 35 days after planting (1/2 dose of N (Za), SP-36 50 kg ha-1 and K2O 75 kg ha-1). Plants are maintained intensively and watered by frying. Rice straw was used as mulch, which was given by spreading it on an experimental plot with a thickness of 5 cm and given at seven days after planting. Paclobutrazol is given when the plants are 28 days after planting with a concentration of 0.2 g l-1. The spray volume is 15 ml per plant. Spraying is carried out on all leaves evenly. The variables observed in this experiment included: leaf number, total chlorophyll, crown dry weight, shoot N, tuber N, dry tuber weight, nitrogen uptake efficiency, and tuber protein.

Data analysis used the F test following the design used. If there is a real effect, then proceed with the BNJ test at the 5% level. Regression analysis was used to determine the optimal fertilizer dosage using Minitab 16. The variables analyzed in this research were leaf number, total chlorophyll, dry crown weight, shoot N, tuber N, dry tuber weight, nitrogen uptake efficiency, and tuber protein.

RESULTS AND DISCUSSION

The results of observing the number of leaves at the age of 61 days after planting showed that the administration of various doses of N had a significant effect ($p \geq 0.05$) (Table 1). The number of leaves tended to increase with the increasing dose of N applied. However, the application of 80, 120, and 160 N kg ha^{-1} resulted in the number of leaves that were not significantly different, with results of 274.92, 298.92, and 305.08 strands.

The results of chlorophyll observations on the leaves of potato plants aged 35 days after planting showed that the administration of various doses of N had a significant effect ($p \geq 0.05$) (Table 1). Leaf chlorophyll increased with increasing N dose. It can be seen that at a dose of 120 N kg ha^{-1}, it produced 51,740 chlorophyll, which was not significantly different from the N dose of 160 N kg ha-1, which was 50,832.

Table 1 – Number of leaves and chlorophyll

N	Number of Leaves	Chlorophyll
40 kg N ha-1	228.50 a	46.263 a
80 kg N ha-1	274.92 ab	48.993 b
120 kg N ha-1	298.92 b	51.740 c
160 kg N ha-1	305.08 b	50.832 bc
BNJ 5%	67.06	2.086

Note: Numbers accompanied by different letters in the same column shows a significant difference in the BNJ test %.

The results showed that the administration of various N doses significantly affected dry shoot weight and dry tuber weight produced at harvest (Figure 1). Treatment N 160 N kg ha-1 showed the highest crown dry weight per plant compared to other treatments, with a yield of 21,865%. Treatment N 40 N kg ha^{-1} showed the lowest canopy dry weight per plant, namely 8.885%. The tubers' dry weight showed the lowest yield at a dose of N 40 N kg ha^{-1}, amounting to 14,352% and significantly different from other N dose treatment.

The results showed that the administration of various N doses had a significant effect on the N content in the shoots and N in the tubers (Figure 2). Increasing the N dose applied to the N dose of 120 N kg ha^{-1} would increase the canopy's N content. However, if the N dose were increased to 160 N kg ha^{-1}, it would not increase the canopy's N level. The N content in the highest canopy was obtained at 5.607%. It was not significantly different if the N dose was added with the result of 5.624%. The results of NUE observations show that the lower the dose of N applied, the NUE value will increase. Applications of N 120 and 160 N kg ha^{-1} showed the lowest values, namely 0.930 and 0.590%, respectively.

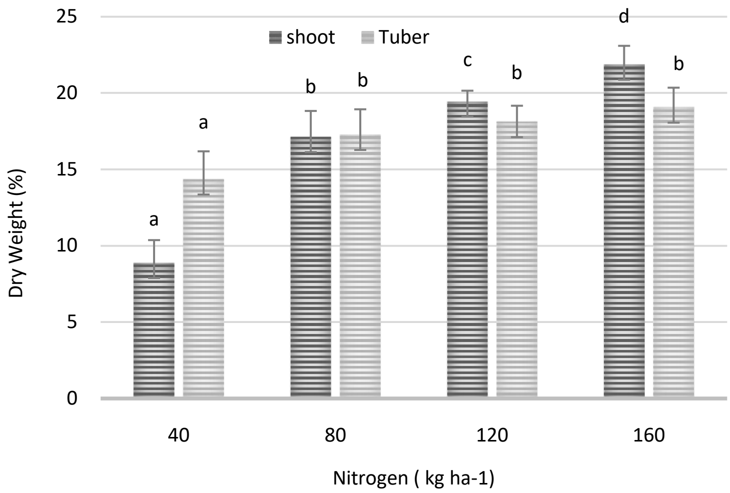


Figure 1 – Canopy and tuber dry weight at various doses of N

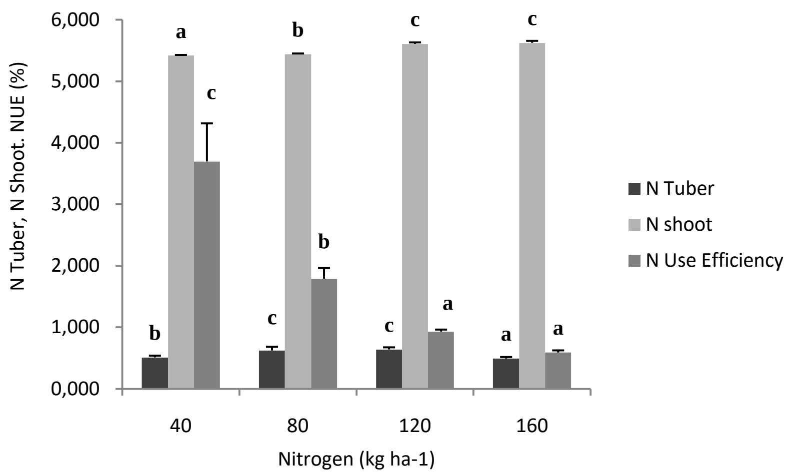
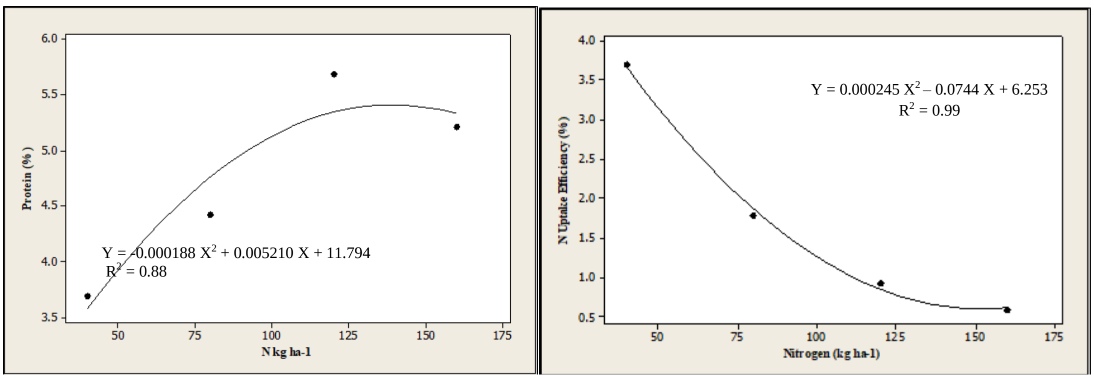


Figure 2 – Tuber N, N Shoot and NUE at Various N Doses



A B

Figure 3 – The relationship between N dose application and tuber protein content (A) and N and NUE dosage application (B)

Figure 3A shows the relationship between N dose application and tuber protein content at harvest. With the N dose application, which is greater up to 120 N kg ha^{-1}, the tuber protein content will increase. However, if the N fertilizer dose is added to 120 N kg ha^{-1}, it will not affect tuber protein. Through the equation Y = -0.000188 x2 + 0.005210 x + 1.794, the optimum dose is 138.564 N kg ha^{-1} which can produce a maximum protein content of 5.40%. Figure 3B shows the relationship between N dose application and NUE. The application of higher N doses up to 160 N kg ha^{-1} tended to reduce NUE. Through equation Y = 0.000245 x2 - 0.744 x + 6.253, the minimum NUE is achieved in applying 151.84 N kg ha^{-1}.

The application of larger N doses to the limit of N 120 N kg ha^{-1} will increase plant leaves and chlorophyll. This can be understood because nitrogen has a role in the formation of plant tissue. Nitrogen is an essential structural component to form chlorophyll and various proteins (Gholipouri & Kandi, 2012; Shunka et al., 2017). Low N supply not only reduces growth but affects tuber size due to reduced leaf number and area. A higher level of N has a positive effect on the growth variable. It increases the number and yield of tubers. This is associated with more leaves. Photosynthesis will be more active, and photosynthate can be transferred to the tubers (Kumar et al., 2007)(Assunção et al., 2020). Appropriate N application is needed to optimize potato yield and quality. According to Jatav et al. (2017), giving N has a significant effect on growth parameters. A similar result was obtained by Kolodziejczyk (2014). N application led to a significant increase in the productivity of potato plants compared to smaller doses.

The increase in the number of leaves increases the leaf area of the plant. It does not always end with an increase in the organ's dry weight, which is economically valuable. Leaves are not only a producer of photosynthate but also as users of photosynthate. Photosynthate will be allocated first to the crown and the next to the economically valuable plant. This can be seen in the observation of the dry weight of the tubers. The dry weight of the tubers increased when the fertilizer dose was increased to 80 N kg ha^{-1}. Furthermore, if it were increased to 160 N kg ha^{-1}, it would not increase the tubers' dry weight. This occurs because the higher N application results in the accumulation of dry matter in other parts of the plant, an increase in the number and area of leaves, inhibition of tuber differentiation, delayed bulb enlargement period, finally, the yield of tubers and tuber dry matter decreases (Yagi et al., 2020)(Abbasi et al., 2005; Fontes et al., 2010).

N is added through fertilizers to achieve maximum results. Efficiency can be improved by knowing the actual plant N nutrient requirements (Gholipouri & Kandi, 2012; Wichrowska & Szczepanek, 2020). Observation of crown N content showed that doses of 120 N kg ha^{-1}and 160 N kg ha^{-1} resulted in high crown N. Meanwhile, N tubers tend to decrease when the N dose is increased to 160 N kg ha^{-1}. Many factors and processes influence the relationship between N uptake and availability, including the initial amount of N before planting, immobilization, denitrification, washing, and evaporation. In agricultural production systems, nitrogen leaching can reach 50 - 75% (Asghari and Cavagnaro, 2011). This can affect human health as a result of water pollution (Umar and Iqbal, 2007). Besides, soil pH, texture, drought, and waterlogging conditions. In general, higher N applications will increase high dry matter and high N content. Also, it was found that increasing the dose of N would increase the protein content of tubers. The results obtained are in line with what Abu-Zinada (2009) did. In NUE observations, high results were obtained from N's application at a low dose (40 N kg ha^{-1}). These results are consistent with the findings of Kakuhenzire et al. (2005). The same thing was conveyed by Bertrand et al. (2011), which stated that it is important to measure NUE to determine excessive fertilizer application while still paying attention to the yields that have economic value so that they provide good benefits for farmers. The strategy that can be done to increase NUE's value is to choose the varieties to be planted (Hirel et al., 2007) because NUE has specific characteristics for varieties (genotypes).

CONCLUSION

This study describes the optimal dosage and fertilizer management to increase the protein content of potato tubers. The field research was conducted on a farmer's land in the village of Sumberejo, Batu, East Java, Indonesia. The study used a randomized block design (Rancangan Acak Kelompok/RAK) with four N dosage treatments, namely: 40, 80, 120, 160

N kg ha^{-1}. The treatment was repeated six times, with each replication consisting of 5 plant samples. The source of N fertilizer comes from ZA, which is applied twice. The results of the study have a significant effect on all observed variables. Application of N 160 N kg ha^{-1} will increase leaf chlorophyll, N crown, and tuber protein. The higher the N application, the lower the NUE (Nitrogen use efficiency) value. The minimum NUE was achieved at a dose of 151.84 N kg ha^{-1}. The optimum dose of tuber protein content was achieved at the provision of 138.56 N kg ha^{-1} of 5.40%.

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