

Nitrogen content, nitrate reductase activity, and biomass of kimpul (*Xanthosoma sagittifolium*) on shade and nitrogen fertilizer variation

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Abstract. Latifa IC, Anggarwulan E. 2009. Nitrogen content, nitrate reductase activity, and biomass of kimpul (*Xanthosoma sagittifolium*) on shade and nitrogen fertilizer variation. *Nusantara Bioscience 1*: 65-71. The aims of this research were to study the effect of shade and nitrogen fertilizer variation and also their interaction to nitrogen content, nitrate reductase activity, and biomass of kimpul (*Xanthosoma sagittifolium* (L.) Schott.). This research was arranged in randomized complete block design (RCBD) with two factor, they were shade variation which contained 3 levels (0%, 50%, and 75% of shade) and nitrogen fertilizer dosage variation which contained 4 levels (0; 0.0625; 0.125; dan 0.25 g ZA/kg of soil of the dosage of ZA fertilizer). The variables of the research were nitrogen content, nitrate reductase activity, fresh weight, dry weight, and shoot/root ratio. The collected data were analyzed with General Linear Model Univariate, and continued with Duncan's Multiple Range Test (DMRT) on 5% significantly levels. The result showed that the shade treatment affected nitrogen content, fresh weight, and shoot/root ratio. The fertilizer application and the interaction between shade and fertilizer application were affected to all variables. The treatment of 75% shade and 0.25 g ZA/kg of soil of ZA fertilizer dosage increased nitrogen content (5.32%) and fresh weight (420.88 g). The treatment without shade and 0.25 g ZA/kg of soil, dosage of ZA fertilizer increased nitrate reductase activity (260.58 μ mol $\text{NO}_2^-/\text{g}/\text{hour}$) and dry weight (53.92 g). The treatment of 50% shade and 0 g ZA/kg of soil of ZA fertilizer dosage increased shoot/root ratio (0.98).

Keywords: shade, nitrogen, nitrate reductase activity, *Xanthosoma sagittifolium*.

Abstrak. Latifa IC, Anggarwulan E. 2009. Kandungan nitrogen jaringan, aktivitas nitrat reduktase, dan biomassa tanaman kimpul (*Xanthosoma sagittifolium*) pada variasi naungan dan pupuk nitrogen. *Nusantara Bioscience 1*: 65-71. Penelitian ini bertujuan untuk mengkaji pengaruh variasi naungan dan pupuk nitrogen serta interaksinya terhadap kandungan nitrogen jaringan, aktivitas nitrat reduktase, dan biomassa tanaman kimpul. Penelitian dilakukan dengan rancangan acak kelompok lengkap (RAKL) pola faktorial dengan 2 faktor, yaitu variasi naungan yang terdiri dari 3 taraf (naungan 0%, 50%, dan 75%) dan variasi pupuk nitrogen yang terdiri dari 4 taraf (dosis pupuk ZA 0; 0,0625; 0,125; dan 0,25 g ZA/kg tanah). Variabel yang diukur adalah kandungan nitrogen jaringan, aktivitas nitrat reduktase, berat basah tanaman, berat kering tanaman dan rasio pucuk/akar. Data yang diperoleh dianalisis dengan menggunakan analisis sidik ragam (General Linear Model Univariate) kemudian jika ada beda nyata dilanjutkan uji jarak berganda Duncan (Duncan's Multiple Range Test) pada taraf 5%. Hasil penelitian menunjukkan bahwa perlakuan naungan berpengaruh terhadap kandungan nitrogen jaringan, berat basah tanaman, dan rasio pucuk/akar. Perlakuan pemupukan berpengaruh terhadap semua variabel yang diamati. Variasi naungan dan pupuk nitrogen berpengaruh terhadap semua variabel perlakuan. Perlakuan naungan 75% dan dosis pupuk 0,25 g ZA/kg tanah meningkatkan kandungan nitrogen jaringan (5,32%) dan berat basah tanaman (420,88 g). Perlakuan tanpa naungan dan dosis pupuk 0,25 g ZA/kg tanah meningkatkan aktivitas nitrat reduktase (260,58 μ mol $\text{NO}_2^-/\text{g}/\text{jam}$) dan berat kering tanaman (53,92 g). Perlakuan naungan 50% dan dosis pupuk 0 g ZA/kg tanah meningkatkan rasio pucuk/akar (0,98).

Kata kunci: naungan, nitrogen, aktivitas nitrat reduktase, *Xanthosoma sagittifolium*.

INTRODUCTION

Along with population growth, problems in food production limitations rises (the staple food in Indonesia is rice). It is not impossible in the future there will be imbalance of faster population growth, where population requires a large consumption of staple foods, and food production that is limited. Therefore, it is needed diversification of food consumption in addition to staple foods with other food products from agricultural commodities other than rice (Soetriono et al. 2006).

In some areas of Indonesia, tubers are alternative food sources, especially during a famine. One of the

carbohydrate-producing plants are wallet (*Xanthosoma sagittifolium* (L.) Schott.) (Chairul and Chairul 2006). Purse is a source of important world food. Tuber purse contains 15-39% carbohydrate, 2-3% protein, and 70-77% water, nutritional value is comparable with potatoes and perhaps more digestible (FAO 2008). The leaves of wallet contain 170-240 g protein/kg dry weight (DW), 218-398 g fiber/kg DW, as well as an important source of calcium (> 69 g/kg DW), sodium, iron, and manganese. Essential protein contains is amino acids with lysine ranging from 43-57 kg/g protein (Lylian et al. 2005). Leaves wallet is potential for livestock feed, although it has lower digestibility than the power taro leaves (Rodríguez et al. 2009).

Tuber purse in some regions of the world is used as a staple food, usually eaten in the form of simple foods that are processed without the difficult technology, for example, processed as boiled or steamed purse, wallet getuk, chips, meatball and so forth (Ling 1992). Tuber purse can also be used to manufacture chips (thin slices of dried tuber) and flour, even the oxalate content in the tuber purse can be reduced by dry salting and wet and dry way of husk ash (Harijono et al. 1994).

As with other crops, industrialization and diversification of this tuber for business purpose in Indonesia are very small. Farmers in Indonesia are used to planting a purse in the field or yard. Constraints cultivation in the garden uses canopy so that the intensity of light received is low. Solar radiation is an important element for plants is light intensity, light quality, and duration of irradiation. When the intensity of light received is lower than the amount of light should be received by each area of leaf surface at a certain time low (Gardner et al. 1991). Lack of light conditions results in disruption of metabolism that causes a decreased rate of photosynthesis and carbohydrate synthesis (Djukri and Purwoko 2003).

Optimal light intensity will increase plant growth purse. According to Salisbury and Ross (1995), high light intensity will increase levels of carotenoids, nitrogen content, and influence the anatomical structure of leaves. High light intensity will cause the leaf surface becomes more opened, but a very high light intensity will decrease leaf chlorophyll content. Shade lowered below the surface of the leaf stomatal density, and plant dry weight purse (Johnston and Onwueme 2005).

To increase crop productivity purse needs addition of nitrogen (N) fertilizer. According to Rubatzky and Yamaguchi (1998) high levels of nitrogen can stimulate vegetative growth, but the excess can delay plant maturity. Nitrogen is an essential element constituent of plant compounds that determine the quality of plant organic material. Nitrogen compounds present in various plant proteins, nucleic acids, hormones, chlorophyll and a number of primary and secondary metabolites. Nitrogen is also essential for cell division, cell enlargement, and for growth (Gardner et al. 1991; Anggarwulan and Solichatun 2001). Nitrogen deficiency symptoms appear gradually and are shown in the presence of chlorosis on mature leaves. The condition of nitrogen deficiency also resulted in accumulation of anthocyanin pigments, decreased protein content, the acceleration of flowering period, and inhibition of growth (Salisbury and Ross 1995).

N assimilation into organic molecules depends on the reduction of NO_3^- by nitrate reductase enzyme in plant tissue. Nitrate reduction that must occur before the production of amino acids, require electron. This is the primary electron donor nicotinamide adenine dinucleotide (NADH), which is the result of photosynthesis. Blazing light and a high rate of photosynthesis is a conducive condition for nitrate reductase enzyme activity. NR biosynthesis depends on the availability of nutrient nitrogen in the media, and its activity is induced by an ad in the leaf nitrate (Gardner et al. 1991).

Measurement of total plant biomass is a parameter that is best used as an indicator of plant growth for biomass production resulting in weight gain followed by a similar growth in other sizes at the same time. Total plant biomass is considered as the embodiment of all processes and events that occur in plant growth. This study aimed to examine the effect of shading and different doses of nitrogen fertilizer on tissue nitrogen content, nitrate reductase activity and biomass of wallet.

This study aims to assess: (i) tissue nitrogen content, nitrate reductase activity, and biomass crops in different shade levels. (ii) tissue nitrogen content, nitrate reductase activity, and biomass crops at different doses of nitrogen fertilizer. (iii) the interaction between shade and nitrogen fertilizer on the tissue nitrogen content, nitrate reductase activity, and biomass crops purse.

MATERIALS AND METHODS

Time and place

The study was conducted in June-October 2008 in the greenhouse Faculty of Agriculture, Sebelas Maret University Surakarta, and Sub-Lab Biology, Central Laboratory of Mathematics and Natural Sciences, Sebelas Maret University, Surakarta.

Experimental design

This research used randomized complete block design (RCBD) pattern with 2 factors. First factor: shading, in 3 levels, respectively as follows: N0 = no shade (0% shade), N1 = 50% shade, N2 = 75% shade. Second factor: levels of nitrogen fertilizer (ZA), in 4 level, namely: P1 = without fertilizer (dose 0 g/m²), P2 = ZA with a dose of 0.3125 g/m² (equivalent to 0.0625 g ZA/kg soil), P3 ZA = 0.625 g/m² dose (equivalent to 0.125 g ZA/kg soil), P4 = ZA with doses of 1.25 g/m² (equivalent to 0.25 g ZA/kg soil). So there were by 12 combinations of treatments as in Table 1. Each treatment with 3 replications.

Table 1. The combination of shade and fertilizer treatments ZA

Shade	ZA fertilizers			
	P1	P2	P3	P4
N0	N0 P1	N0 P2	N0 P3	N0 P4
N1	N1 P1	N1 P2	N1 P3	N1 P4
N2	N2 P1	N2 P2	N2 P3	N2 P4

Procedures

Field experiments. *Preparation of planting media.* Soil media sifted to be used with a sieve of 2 mm x 2 mm, then put in polybags. *Preparation of seedlings.* Stem tuber purse cut into several parts of each piece should have buds and skin. Stem tuber pieces planted on media sufficient with water sources and protected with a depth of 1 cm. Stem tuber pieces of land left in the seedbed and watered regularly every day until the growing shoots. *Planting.* Seedlings measured approximately 25 cm planted on the soil medium in polybags. The length of seed planted beneath the ground surface is 15 cm. Shade treatment and

the addition of ZA given after 2 weeks-old seedlings. **Fertilization.** Fertilization is done with appropriate dose of nitrogen fertilizer on the experimental design. Fertilizing is done 1 time on the 15th days after planting, by sprinkling fertilizer around the plant as far as 5 cm and 3 cm deep, then backfilled with soil. **Watering.** Watering is done by running water in accordance with field capacity every two days. Observation and research parameters. **Observations** were made at the end of the 8th week after treatment include growth, nitrate reductase activity and nitrogen content of tissues (Ling 1992).

Measurement of tissue nitrogen content. Destruction. A total of 0.1 g of dry material is weighed and put in a Kjeldahl tube. A total of 1 g of salt mixture and 3 mL of concentrated H₂SO₄ was added to the tube on top. Solution was heated to greenish. Solution was cooled and added to it as much as 30 mL of distilled water. Created a blank solution. **Distillation.** Solution of the above was put into the tube distillation. Added 10 mL of NaOH 45% and 2 grain Zn. The solution is heated by the reservoir H₃BO₃ 4% and 2 drops of mixed indicator to the volume of 40 mL. **Titration.** Performed titration with 0.1 N HCl until its color changed from blue to green to yellow.

$$\% N = \frac{(a-b) \times 0.1 \times 14}{\text{Sample weight (mg)}} \times 100\%$$

% N: nitrogen content

a: volume of sample solution

b: volume of blank solution (Sudarmadji et al. 1981).

Measurement of nitrate reductase activity. The third leaves from the shoots of plants were sliced into small pieces, and inserted into the tube, dark film filled 5 mL pH 7.5 phosphate buffer solution. After 24 hours of immersion replaced new 5 mL buffer solution and added 0.1 mL KNO₃ as a substrate, then incubated for 2 hours. Dye reagent consisted of 0.2 mL of 1% sulphanilamide in 3 N HCl and 0.2 mL 0.02% N-Naphtylethylene diamine was prepared in a test tube. After incubation for 2 hours, 0.1 mL of filtrate was taken from a dark movie tube and inserted into the test tube containing the dye reagent, and then wait until it was a pink as a sign to reducing nitrate to nitrite by nitrate reductase enzyme. One test tube is not given the filtrate and used as a blank. After the change of color added 2.5 mL of distilled water, and moved in cuvettes spectrophotometer, and the observed absorbance at a wavelength of 540 nm. How to calculate reductase activity is as follows:

$$\frac{\text{Sample absorbance} \times 1000}{\text{Standard absorbance}} \times \frac{1}{\text{WW}} \times \frac{50}{\text{IT}} \times \frac{50}{1000}$$

Standard absorbance = 0.0142

WW = weight of wet sample (g)

WI = incubation time (hours)

Units: $\mu\text{mol NO}_2^-/\text{g}/\text{hour}$ (Hartiko 1991; Listyawati 1994).

Measurement of biomass. Fresh plants weight were weighed after the plants were 8 weeks after treatment with destructive methods. Plants that have been harvested and

measured dry weight were put in paper bags and then roasted at a temperature of 60°C until dry, then weighed using analytical scales. Plant roots and shoots separated, then shoot and root dry weight ratio was calculated. Measurements were taken at the end of the study.

Data analysis

Data were analyzed using Analysis of Variance (General Linear Model Univariate) to know the difference of the treatment of tissue nitrogen content, nitrate reductase activity, and biomass plants. There are real differences followed by Duncan's Multiple Range Test (DMRT) at 5% significance test level.

RESULTS AND DISCUSSION

Tissue nitrogen content

Growth is due to the interaction between the various internal factors (genetic) and elements of climate, soil, and biological environment. A limitation of the growth factor results in a reduction in growth and development. Continuing growth of one of them is determined by the nitrogen element (Gardner et al. 1991). The average nitrogen content of tissue and treatment interaction graph and shade variations ZA dose is presented in Table 2, which indicated that the treatment shade gave a significant influence on plant leaf N content *X. sagittifolium*. Average N content increased with increasing shade. N is the smallest value at 0% shade. This is consistent with the results of research by Sirait (2006) that an increase in nitrogen content in canopy grass *Panicum maximum cv riversdale* is in line with increasing shading level.

Reduction reaction of nitrogen until the preparation of amino acids into proteins is influenced by light. Reduction of nitrogen with close relationship between photosynthesis results. Starting from NH₃ and results between photosynthesis forms amino acids and other organic nitrogen compounds. Through photophosphorylation, light-producing ATP for the process of dismantling the accumulated nitrogen into organic nitrogen can be utilized. Light is also working to activate enzyme nitrate reductase (Bonner and Vanner 1976; Pradnyawan 2004). According to Sutedjo and Kartasapoetra (1990), the availability of soil N is more to produce more protein, the higher the nitrogen giving the sooner the synthesis of carbohydrates are converted into proteins and protoplasm increased protein in the body of the plant will increase the levels of N in plant tissue.

N0P3 and N1P1 treatment did not differ from one another. N1P4 and N2P1 treatment were not significantly different from each other. So also in treatment N2P3 and N2P4, was not significantly different from each other. This happens because when light and nitrogen availability reaches its maximum, the more optimal nitrogen absorption happens. High light intensity resulted in the process of transpiration in plants increases, so the flow of water carrying nitrates from the soil to the leaves increases. At the time of the light and the availability of nitrogen was not optimal, the plants will lower light compensation point and

the use of organic N is available to accelerate the rate of photosynthesis. This resulted in the synthesis of carbohydrates which later transformed into proteins and protoplasm increases. Increased levels of proteins in plants will increase the levels of N in plant tissue.

Table 2. Average train tissue nitrogen content, nitrate reductase activity, fresh weight, dry weight, and root-shoot ratio of plants *X. sagittifolium* on dosage variations of shade and ZA.

Shade	ZA fertilizer dosage				Average
	P1	P2	P3	P4	
Tissue nitrogen content					
N0	3.04a	3.35b	3.52bcd	3.64cd	3.38l
N1	3.55bcd	3.45bc	4.61f	3.73de	3.83m
N2	3.73de	3.97e	5.09g	5.32g	4.52n
Average	3.44h	3.59i	4.40k	4.23j	
Nitrate reductase activity					
N0	218.62cd	120.23ab	108.19a	260.58d	176.90
N1	170.97abc	169.78abc	139.69abc	135.45abc	153.97
N2	136.01abc	215.75abc	150.83cd	198.21bcd	175.2
Average	175.2ef	168.58ef	132.90e	198.08f	
Fresh weight					
N0	255.86g	244.54g	395.32j	290.02gh	296.43m
N1	371.09ij	407.64j	328.4hi	360.99ij	367.03n
N2	288.76gh	249.63g	255.21g	420.88j	303.62m
Average	305.24k	300.60k	326.3kl	357.30l	
Dry weight					
N0	33.92abc	26.12a	34.52abc	53.92d	37.12
N1	28.58ab	42.2c	29.16ab	36.64 abc	34.14
N2	32.45abc	25.43a	38.16bc	31.58abc	31.90
Average	31.65e	31.25e	33.95e	40.71f	
Root shoot ratio					
N0	0.26k	0.37k	0.47kl	0.31k	0.35p
N1	0.98m	0.54kl	0.75lm	0.34k	0.65q
N2	0.46kl	0.22k	0.42kl	0.45kl	0.39p
Average	0.57o	0.37n	0.55no	0.37n	

Note: Numbers followed by the same letter on the same row and column showed no significant difference in DMRT test at 5% level. N: Shade; N0: 0%, N1: 50%, N2: 75% P: Dose ZA (g/m²); P1: 0 g/m²; P2: 0.3125 g/m²; P3: 0.625 g/m²; P4: 1.25 g/m². The treatment of different doses of ZA fertilizer effects on plant leaf tissue nitrogen content of *X. sagittifolium*. The content of fertilizer N increased from 0 to 0.625 g/m² g/m² and then down at dosages of 1.25 g/m². The results of research by Sitompul and Purnomo (2004) showed that maize leaf N concentration increased with increasing fertilizer N.

Treatment without shade and without fertilizer (N0P1) had the lowest nitrogen content. This is probably caused by high light intensity and low nitrogen availability resulting in roots that formed a little so that the absorption of nitrogen is not optimal. 75% shade treatment and dosage of 1.25 g/m² fertilizer had the highest N content. Levels of nitrogen in the soil will lead to greater root growth so that nitrogen absorption became more optimum.

Nitrate reductase activity

Activity of some enzymes from different plant metabolic pathways regulated by light. Nitrate reductase is

an enzyme regulator of nitrogen assimilation in plants, which is regulated by changes in light/dark. Although the response of nitrate reductase activity of the light/dark can vary in each species, in general activity was higher in light than dark conditions. Light increases the activity of nitrate reductase by accelerating decision-nitrate (Puranik and Srivastava 1985). The average nitrate reductase activity and interaction graphs shade treatment and dose variation ZA presented Table 2. From the table, it is known that shade treatment did not have a significant influence on the activity of nitrate reductase plant *X. sagittifolium*. The highest activity of nitrate reductase is in the treatment without shade (shade 0%). This is probably caused by nitrate reductase activity that is affected by light in a way to increase the rate of photosynthesis that would produce carbohydrates and NADH required for reduction of nitrate, which is produced from carbohydrates such when respiration. The results of Choo et al. (1998) showed that the nitrate reductase activity *CAREX spp.* is low at low light intensity and increased at high light intensity.

At 75% shade treatment of nitrate reductase activity was also high. This is probably caused by the plant efficient light capture by increasing the surface area of leaves. Increasing the rate of photosynthesis is followed by an increase in respiration, which will produce energy to reduce NO₃- to NO₂-. According to Noggle and Fritz (1983), photosynthesis is closely related to the formation of nitrate assimilation nitrate ion (NO₃-) to nitrite (NO₂-) and ammonia ion (NH₃⁺) into amino acids. Nitrate reductase activity affects the synthesis of amino acids.

In Table 2, it is known that nitrate reductase activity declines with the addition of nitrogen fertilizer dose and then increased at a dose of 1.25 g/m² of nitrogen fertilizer. The results of Shah (2008) on the plant *Nigella sativa* which was given additional nitrogen fertilizer (urea) showed an increase in nitrate reductase activity along with higher doses of nitrogen fertilizer. The highest activity of nitrate reductase present in the treatment dosage 352 mg/pot, then decreased at a dose of 442 mg/pot.

According to Sutedjo and Kartasapoetra (1990), ZA fertilizer in the soil will be hydrolyzed into ammonium (NH₄⁺) and sulfate (SO₄²⁻). Engelstaad (1997) argued that if the NH₄⁺ added to the soil, at first reacted with a complex exchange of cations to be adsorbed on the surface of particles of clay, then the mobility is reduced and the uptake by plants is limited to the absorption of NH₄⁺ solution which is in equilibrium with NH₄⁺ in exchange complex. Environmental conditions that support aerobic biological activity of most of the NH₄⁺ available land will be converted into a form that more easily move the NO₃⁻. According to Salisbury and Ross (1995) on moist, soil with neutral pH, NH₄⁺ will be oxidized to nitrite (NO₂⁻) and nitrate (NO₃⁻).

The highest activity of nitrate reductase found in treatments without shade and fertilizer 1.25 g/m² (N0P4). The intensity of full sunlight and high doses of fertilizer will increase the rate of plant photosynthesis. Nitrate reductase activity depends on the supply of photosynthesis in the form of carbohydrates, and will be used in the process of respiration. Reduction of NAD⁺ to NADH

occurs in respiration and NADP + to NADPH occurs in the process of photosynthesis. NADH or NADPH is an effort to reduce nitrate (NO_3^-) to nitrite (NO_2^-). NADH and NADPH serve as electron donor to be transferred to the coenzyme FAD as prosthetic groups or electron carriers (Hess 1975). Whereas the lowest activity of nitrate reductase present in the treatment without shade and fertilizer dose of 0.625 g/m^2 (N0P3), although the high light intensity and dose of fertilizer were sufficient, it did not appear to increase the activity of nitrate reductase of plants. According to Engelstaad (1997) when fertilizer N added to soil, N harvest can participate in the plant, grouped into the organic soil, denitrified, volatilized or lost along the water drainage.

Biomass

Wet weight

Biomass plants are accumulation of products of photosynthesis and absorption of nutrients in the form of organic compounds making up the entire network on vegetative and generative organs of plants (Bidwell 1979; Turmudhi 2002). Plant fresh weight measurements performed directly after the crop is harvested so as not to lose water. Plant fresh weight is the weight of plants at the time was still alive. In addition to organic matter, water content in plant tissues will affect the plant fresh weight (Sitompul and Guritno 1995). The average weight of wet treatment and dose variation of shade ZA presented in Table 2.

The average wet weight in the treatment without shade (0%) and 75% shade significantly different with 50% shade treatment. The highest fresh weight present in 50% shade treatment. The results Rosman et al. (2004) showed that giving 50% shade in *Pogostemon cablin* (*patchouli*) can increase the weight of wet leaves and stems of plants at the age of 16 weeks after planting. According to Sirait (2006), shade resulted in a reduction in the intensity of light reaching the plant. Shade provided physically not only reduce the intensity of solar radiation, but also affect the elements of other micro-climate. Shade will also affect the processes that occur in plants such as photosynthesis, respiration, transpiration, protein synthesis, translocation, and aging. Irradiation level during growth can affect the distribution of dry matter to the morphology of leaf, stem and root and leaf composition in higher plants. As a differentiator with the plants that grow on high irradiance, plants that grow on low-level irradiance, often allocate dry matter to leaves and has a specific leaf area (SLA, area per unit leaf dry weight) and total chlorophyll per unit dry weight of a larger, but the ratio of chlorophyll a: b and protein content are usually lower (Maule 1995; Katajima and Hogan 2003).

Increased provision of fertilizer will increase plant fresh weight. This was allegedly due to an increased dose of fertilizer will increase the nitrogen content in the soil so that the absorption of nutrient nitrogen increases as well. Uptake of nitrogen increases will result in leaf nitrogen content increasing as well. Nitrogen content in leaf tissue will stimulate increased rate of plant metabolism. Value

wet weight is influenced by tissue water content, nutrient, and metabolism (Salisbury and Ross 1995).

Engelstaad (1997) suggested that the increased yield can be affected by the addition of fertilizer N in stages. N sufficient nutrients are available resulting in the optimum vegetative growth resulting in increased wet weight. According to Lakitan (1996) granting the right of nitrogen will increase plant growth, increase plant metabolism, so that the formation of proteins, carbohydrates and starch are not inhibited. The result is in the form of an increase in growth and crop production.

Dry weight

Total dry weight is due to the efficiency of absorption and utilization of available solar radiation, during the growing season by a crop canopy (Gardner et al. 1991). According to Lakitan (1996), it reflects the accumulation of plant dry weight of organic compounds synthesized from inorganic compounds of plants, particularly water and carbon dioxide. Dry weight obtained by drying at 80°C for 2 days. Drying aims to eliminate all moisture content and stop the activity of plant metabolism (Sitompul and Guritno 1995). Table average dry weight of the treatment plant and ZA shade variations can be seen in Table 2. From this, it can be seen that the variation of shade treatment did not have a significant influence on plant dry weight of *X. sagittifolium*. Although such an increase resulted in a decrease shade of plant dry weight of *X. sagittifolium*. This is consistent with the results of research by Purwoko Djukri (2003), stating taro tuber dry weight shade-tolerant decreased in the presence of shade. Increased shade resulted in a decrease of light intensity received by the plants. According to Harjadi (1991), the amount of light that was caught in the process of photosynthesis shows the biomass, while the amount of biomass in plant tissue reflects the dry weight. According to Djukri and Purwoko (2003) shade resulting in increased leaf area as efforts of plant in the efficient capture of light energy for photosynthesis normally in conditions of low light intensity. Shade can reduce the primary radiation which is active in photosynthesis that results in decreased net assimilation, so photosynthate stored in the organ recipient will decline, resulting in decreased plant dry weight.

According to Gardner et al. (1991), total dry weight of crop yields is the result of accumulation of net assimilation of carbon dioxide (CO_2) during the growing season. Because the assimilation of CO_2 is the result of absorption of solar energy and solar radiation due to the major factors that affect the total dry weight yield is absorbed solar radiation and the energy utilization efficiency for CO_2 fixation. Leaves that are not in shaded conditions will be able to absorb the sunlight so that it can lead to increase net assimilation rate. This is supported by roots that serve as an absorber of nutrients as an ingredient in the process of photosynthesis in leaves that is converted into CO_2 and carbohydrates (Kastono 2005).

In Table 2 it can be seen that the treatment dose variation of ZA has an influence on plant dry weight of *X. sagittifolium*. The higher dose of fertilizer provided the

higher the plant dry weight. Dry weight of plants reflects the accumulation of organic compounds synthesized from inorganic compounds of plants, particularly water and carbon dioxide. Nutrients have been absorbed by the roots contribute to plant dry weight. Plant dry weight is the efficiency of absorption and utilization of solar radiation which is available throughout the crop by crop canopy (Kastono 2005).

Treatment interaction shade variation and dose ZA affect plant dry weight. Plant dry matter production is the resultant of three processes namely assimilation accumulation through photosynthesis, respiration and decreased accumulation assimilates due to the sink (receiver). There are two things that can increase the plant dry weight increase LAI (Leaf Area Index) until the optimum and increase the rate of photosynthesis per unit leaf area (Jumin 2002).

Light determines the process of photosynthesis through photosynthesis organizing organelle. Chlorophyll and ribulose biphosphate carboxylase enzyme oxygenase (Rubisco) are molecules that are most responsible for the process of photosynthesis. The nitrogen element is one of the elements that play a role in the synthesis of both the molecule. Therefore, N fertilization was always associated with an increased rate of photosynthesis (Dwyer et al. 1995; Sitompul and Purnomo 2004).

Increase in dry weight occurs because the rate of photosynthesis is the end result of metabolism processes. The final product of the process of photosynthesis is sugar. Sugar is the basic constituent of organic matter in the plant cells, such as compounds of structural, metabolic, and food reserves that are important. The parts of plant cells such as cytoplasm, nucleus and cell walls are composed of organic material. This process resulted in the accumulation of dry matter of plants (Salisbury and Ross 1995).

The ratio of shoot/root

Plant growth can be defined as the process of increasing the size and number of plant cells that is followed by the growth of plant dry weight, whereas plant growth can be interpreted as a process toward the achievement of adult. Plant growth and development are divided into two phases which are vegetative growth and generative growth phase. At the vegetative growth phase, the ratio of shoots and roots will determine subsequent developments, especially in terms of crop production itself (Tjionger's 2009).

Allometry of shoot and root growth is usually expressed as the ratio of the root tip, which can describe one type of tolerance to drought. Although the root-shoot ratio is genetically controlled, the ratio is also strongly influenced by environmental factors (Gardner et al. 1991). Homeostasis crowns and roots of plant organs is an effort to maintain physiological equilibrium, so that each organ can perform its function normally (Hidayat 2004). The average ratio of shoots and roots of plants *X. sagittifolium* treatment interaction graphs and ZA shade variations are presented in Table 2.

Shade treatments had a significant influence on plant root-shoot ratio of *X. sagittifolium*. Effect of shade 0% and 75% different from the shade of 50%. The highest root-

shoot ratio found in 50% shade treatment with the value 0.65. 50% shade resulted in increased plant auxin work so that higher shoot growth than root growth. The results of Sirait (2006) showed that the ratio of shoot/root of Bengal grass (*Panicum maximum cv riversdale*) increases with increasing shading level. The ratio of shoot/root of the highest in the shade 56% (1.25).

In the 0% shade treatment or full sunlight intensity, the work of auxin root growth will be inhibited higher than bud. Because of low auxin content would increase root growth. At 75% shade treatment appears that the division of photosynthate tends to the roots. This is likely due to the shade of 75% that resulted in microclimatic conditions that support the translocation of photosynthesis which tend to the roots.

According to Sirait (2006) in shaded conditions, one form of adaptation is to extend the leaves of plants to maximize the amount of light can be absorbed. Thus the raw materials produced in photosynthesis is used more to shoot than root growth. Chronology of transportation is the result of photosynthesis from leaves to the other parts that need such as trunks and roots through the phloem vessels. With this mechanism, on the condition of the roots will get photosynthate shade fewer than the shoots.

Table 2 shows that the treatment dose variation ZA significantly effects on the ratio of shoot/root crop *X. sagittifolium*. The treatment dose ZA 0.3125 and 1.25g/m² were not significantly different from each other, higher root growth than shoot growth. This is probably due to nitrogen fertilization encourage more roots, probably due to an increase in leaf area and more the result of assimilation for root growth.

The treatments without fertilizer have a higher ratio of shoots with roots than the 0.57 value. Soil nitrogen content is lower than other fertilizer treatment affect shoot growth. The treatment dose of 0.625 g/m² ZA shoots has a higher ratio than the root with a value of 0.55. This is thought to be caused by an increase in nitrogen content that tended to increase shoot growth. High nitrogen content allows the growth of shoots takes available carbohydrates. The results of Sirait (2006) showed that the ratio of shoot/root of Bengal grass (*Panicum maximum cv. riversdale*) increases with increasing the level of nitrogen fertilization. The ratio of shoot/root fertilization reaches its highest at 200 kg N/ha (1.14).

Root-shoot ratio of the highest value is in treatment N1P1 (0.98), and the lowest is N2P2 (0.22). According to Hidayat (2004) to maintain a physiological balance between shoots and roots, CO₂ that is bound by the leaf and water and nutrients that are absorbed by the roots must be balanced. Root elongation rate is influenced by internal factors, like supply of leaves photosynthate and environmental factors such as temperature and soil water content (Lakitan 1996).

The concentration of nitrogen in the soil is too high, then most will be absorbed by the roots to be transported to the leaves along with carbohydrates. In leaves, washed from the roots of carbohydrates coupled with existing carbs on the leaves will form a protein for the formation of shoots. Since vegetative growth is so rapid, the

carbohydrates that are transported to the roots become less. This causes the root got lack of carbohydrates so that the roots run much slower growth than shoot growth (Tjonger's 2009).

CONCLUSION

There are differences in tissue nitrogen content, wet weight, and ratio of shoot/root of *Xanthosoma sagittifolium* (L.) Schott in the treatment of shade variations. There are differences in tissue nitrogen content, nitrate reductase activity, fresh weight, dry weight, and ratio of shoot/root of *X. sagittifolium* in the treatment of various nitrogen fertilizers. There is interaction between treatment and nitrogen fertilizer shade variation: (i) 75% shade treatment and fertilizer 1.25 g/m² (N2P4) produces tissue nitrogen content (5.32%) and wet weight (420.87 g) the highest. (ii) treatment without shade and fertilizer dose of 1.25 g/m² (N0P4) resulted in nitrate reductase activity (μ mol NO₂-/g/hours 260.58), and dry weight (53.92 g) the highest. (iii) 50% shade treatment and fertilizer 0 g/m² yield ratio shoot/root (0.97) the highest.

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