Effect of Nitrogen (N) Concentration on the Morphology of Teak (*Tectona grandis*) Seedlings

Puji Lestari, Handojo H. Nurjanto, and Listianti

Abstract Teak (*Tectona grandis*) is a timber tree species which is commonly grown by farmers due to its high quality and commercial value. One of nutrient that affects the physiological processes of teak plants is nitrogen (N). This study aims to determine the morphological symptoms of teak seedlings affected by several concentration levels of N and to determine the optimal concentration of N for the best teak seedling growth. This study was conducted using Completely Randomized Design (CRD), which consisted of five treatments, namely minus N nutrient solution (N0), half strength N nutrient solution (N1), full strength N nutrient solution (N2), 1.5 full strength N nutrient solution, 2 full strength N nutrient solution (N4), and aquadest as control (C). Each treatment was replicated 3 times. This research was conducted at the Laboratory of Intensive Silviculture Klebengan from June to November 2016. Parameter observed included height, diameter, nodal distance, and morphological symptoms of leaf. The results showed that variation of N concentration affected teak growth (height, diameter, and nodal distance). They also affected morphology and color of the leaves. Symptoms of N deficiency were the yellowing (chlorosis) and drying of the leaf tips and the presence of yellow spots in the leaf inter veins. N concentration of 995 ppm resulted the best growth, but it caused necrotic in the interveinal area. However this was suspected due to deficiency in Magnesium (Mg). Without N (N0 and Control) caused the lowest seedling growth. The greatest N concentration of 1335 ppm did not give the best growth for teak seedling.

Keywords Chlorosis · Leaf · Nitrogen · Teak · Seedling

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1 Introduction

Teak (*Tectona grandis*) is a timber tree species which is commonly grown by farmers [1]. It constitutes 35% of total community forest in Indonesia [2]. Various products are manufactured from teak wood, for instance construction and decoration material, and furniture. As much as 48% of small-scale furniture industries in Jepara Regency, a city in Central Java which has been widely known for its wooden furniture industries, use teak wood from community teak plantation for their raw material [3]. Nowadays, teak is not only planted in Java but also in Kalimantan. There are about 1000 ha teak plantation in East Kalimantan [4]. The high price of teak stimulates the farmers to plant this species although it needs long period before harvesting [3, 5]. The teak price in PERHUTANI, especially in KPH Cianjur, West Java ranges from IDR 1.9 to 6.3 million depends on the quality classes [6]. While in international market it reaches USD 1400–3000 per m^3 [7]. Farmers harvest and sell teak whenever they need fund for family espences such as wedding ceremony or school fees. In this system, the wood quality and price are disregarded. It is usually low quality and cheaper price.

Teak is considered as slow growing species. A conventional (un-improved) teak has mean annual increment of 2–5 m^3 per hectare [8], therefore, formerly, teak in PERHUTANI the conventional teak was harvested at 80 years old or more. At present, PERHUTANI uses vegetatively-propagated for teak. This, coupled with the proper preparation of hole and application of fertilizer, which is termed as JPP (Jati Plus PERHUTANI = Prospective Teak of PERHUTANI) package, can increase the mean annual increment of at least 13.8 m^3/ha/year [9]. A plantation trial of JPP conducted in Wonogiri Region, Central Java Province, has obtained growth increment of about 21.49 m^3 per ha per at year 10 years of age [7].

In spite of the fast growth achievement, there is still a wide variation of the improved teak grown in various locations. Several researches have been conducted to determine appropriate fertilizing treatment for teak addressing the type and dosage of fertilizer and the fertilization intensity in a particular location [10–13]. However none of the research determined nutrient concentration required for optimum physiological process and growth of the improved teak. This research was conducted to address that issue, particularly nitrogen concentration and to describe morphological symptoms resulted by deficiency and/or excessive application of nitrogen in a greenhouse. Focus was given to nitrogen because this nutrient is the most important macronutrient which plays many important roles in plant physiological processes. Nitrogen involves in chlorophyll formation [14], therefore deficiency of N is commonly shown by chlorotic leaves. Results of this experiment hopefully can be used as guidance for quick diagnosis of nitrogen status of the improved teak in the field.

2 Materials and Methods

2.1 Materials

Media for growing the teak seedlings was silica sand. The sand was sieved to pass 8–30 mesh sieves and was washed with tap water to remove big materials and debris prior to filling to a 19 cm diameter × 20 cm height plastic polybags. The base of plastic polybags was perforated to allow excess nutrient solution to drip out. The teak seedlings used in this experiment were propagated using shoot cutting. Six months old seedlings were cut to form stump of about 17 cm long before being planted to the sand media. Stock solution of major nutrient was prepared individually. Chemical compound and concentration of the stock solution were shown in Table 1. Micronutrient solution consisting of Fe EDTA 13.2%, Manganese sulphate 31.8%, Zink sulphate 22%, Copper sulphate 25%, Boric Acid 99.9% and Sodium molybdate 39% was made following [15]. All chemicals used in this experiment were laboratory grade.

2.2 Methods

This research was conducted in a greenhouse of Intensive Silviculture Laboratory, Faculty of Forestry, Universitas Gadjah Mada, Yogyakarta for 5 months from June to November 2016. After being transplanted to sand media, the stumps were watered with distilled water for 5 days to allow acclimatization (adaptation). After that, the seedlings were treated with nutrient solutions which were made by mixing a certain volume of stock solution, depending on the treatment (Table 2). The treatments were free-N nutrient solution (N0), half strength-N nutrient solution (N1), full strength-N nutrient solution (N2), 1.5 full strength-N nutrient solution, and 2 full strength-N nutrient solution (N4), and for control treatment (C) distilled water was applied instead of nutrient solution. As much as 500 mL nutrient solutions were applied to the media daily. Concentration of major nutrients in the nutrient solutions were shown in Table 3. The full strength-N nutrient solution refers to [15] which applied

Table 1 Chemical composition of major nutrient and the concentration of stock solution

Chemical compound	Concentration (M)
NaH_2PO_4	1
$Ca(NO_3)_2.4H_20$	1
KNO3	1
K_2SO_4	0.5
$MgSO_4$	0.5
$(NH_4)_2SO_4$	1
$CaSO_4.2H_2O$	0.01
KH_2PO_4	1
$Mg(NO_3)_2$	0.5
$NaNO_3$	1

Table 2 Volume of stock solution used for making nutrient solutions

Chemical compound	Treatments (mL L^{-1})					
	C	N0	N1	N2	N3	N4
NaH_2PO_4	–	0.75	0.6	1	1	0.5
$Ca(NO_3)_2.4H_20$	–	–	1	2	2	2
KNO3	–	–	0.5	1	1.6	2.4
K_2SO_4	–	5.4	4.2	4	3	0.8
$MgSO_4$	–	2.5	2.5	2.5	1	30.8
$(NH_4)_2SO_4$	–	–	1.5	1.5	2.3	3.2
$CaSO_4.2H_2O$	–	12.5	7	–	–	–
KH_2PO_4	–	0.25	0.5	–	–	0.6
$Mg(NO_3)_2$	–	–	–	–	0.3	1.9
$NaNO_3$	–	–	–	–	0.4	0.1
Micronutrient solution	–	1	1	1	1	1

Table 3 Nutrient concentration of each treatment

Treatments	Concentration of Nutrient (ppm)					
	Nitrogen	Phosphor	Potassium	Calcium	Magnesium	Sulfur
C	0	0	0	0	0	0
N0	0	251	1282	29	122	682
N1	330	269	1278	161	122	744
N2	660	258	1283	290	122	894
N3	995	258	1290	290	63	898
N4	1335	266	1278	290	128	901

on teak by [24]. The treatments were arranged in a completely randomized design with five treatments and three replications per treatment. All seedlings were grown in a shade area with light intensity reaching the plants as much as 60%. A month after treatment singling was done on seedlings which produced more than one sprouts, leaving only one sprout per seedling.

Effect of nitrogen concentration on seedlings growth were observed at 2 months after treatments by measuring seedling height, stem diameter and node length every 2 weeks. Seedlings height was measured from stem base (root neck) to the growth point. The stem diameter was measured at height of 1.5 cm from the stem base. Visible symptoms appeared on leaves were also observed.

3 Results and Discussion

3.1 Growth of Teak Seedling at Various Level of Nitrogen Concentration

The growth of plants can be measured through its height and diameter. Five months after establish and treat by some treatments, the result shows that 1.5 full strength N

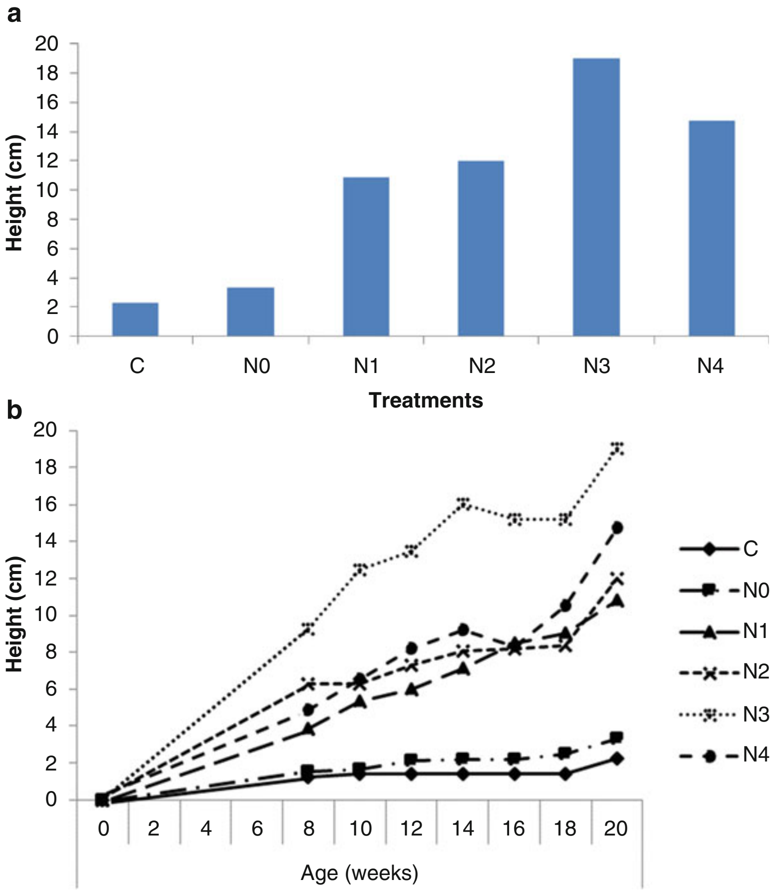

Fig. 1 (**a**) The height of teak seedling after 20 weeks, (**b**) The growth of height seedling for 20 weeks, observation started after 8 weeks

nutrient solution (N3), which concentration of N was 995 ppm lead to the highest seedling. While the control treatment, without addition any nutrient create the lowest seedling. The height of teak seedling in C, N0, N1, N2, N3, and N4 treatment were 2 cm, 3 cm, 11 cm, 12 cm, 19 cm, and 15 cm respectively (Fig.1a). Figure 1b show that the height growth of seedling which treated by 1.5 full strength N nutrient solution (N3) is faster than others treatment consistently. In nodal distance parameter also revealed the same trend. The of teak seedling in C, N0, N1, N2, N3, and N4 treatment were 0.3 cm, 0.4 cm, 1.1 cm, 1.4 cm, 1.5 cm, and 1.2 cm respectively (Fig. 2). Thus, concentration of N positively affected the height of teak seedling until certain level. In this study 995 ppm is the peak of concentration. The greatest concentration (1335 ppm) showed decreasing of height. Each plant has peculiar requirements for nutrient. The requirements of N for the growth of vanilla (*Vanilla*

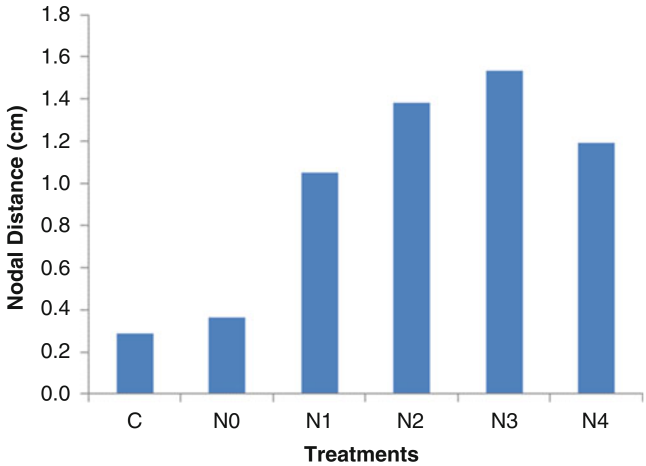

Fig. 2 The nodal distance of teak seedling after 20 weeks

planifolia) was ranged from 90.7 to 453.9 mg NO_3 l^{-1}. At the range of application, the higher nutrient applied, the better growth response were observed [16]. *Mono acer* seedlings treated with N fertilizer exhibited significantly greater plant height (about 40 cm) and root diameter (about 5 mm) than untreated (i.e., 0 g N) controls, and values for both parameters were highest in seedlings treated with 10 g N, followed by those for seedlings treated with 15 and 5 g N, respectively [14].

At the beginning of observation, the diameter growth of teak seedling which treated by 1.5 full strength N nutrient solution (N3) more rapidly than others, but after 18 weeks the growth was decrease. The diameter of seedling after 20 weeks were 4, 6, 8, 7, 8, and 8 for C, N0, N1, N2, N3, and N4 treatment respectively (Fig. 3a). Control (C) and N0 resulting the lower diameter than treatment that contain nitrogen. This result show that nitrogen affect the diameter growth of teak, but the deep information about the concentration still need more observation. Field research carried on 3 months teak seedling at typic tropudults soil showed that diameter of seedling which did not applied by urea significantly smaller than applied ones, but the dosage of urea did not affect the diameter significantly [9]. On the other hand [16] mentioned that vine stem diameter of vanilla (*Vanilla planifolia*) is more vulnerable to nitrogen compared to vine stem height.

The effect of nitrogen to the growth of teak seedling related to the function of nitrogen in physiological process of plant. Nitrogen had a role as a constituent of chlorophyll. *Mono acer* seedlings treated with N fertilizer exhibited significantly greater levels of chlorophylls a (about 1.6 FW) and b (about 0.9 FW) and carotene (about 0.5 FW) and values for all three parameters were greatest in seedlings treated with 10 g N [14]. Respiration of plant treated with high concentration of N is higher than the low one, resulting more energy for plant to grow [17]. mentioned that leaf meristems of *Festuca arundinacea* Schreb receiving high (336 kg per hectare) produce more monosaccharides than low nitrogen (22 kg per hectare) with the result

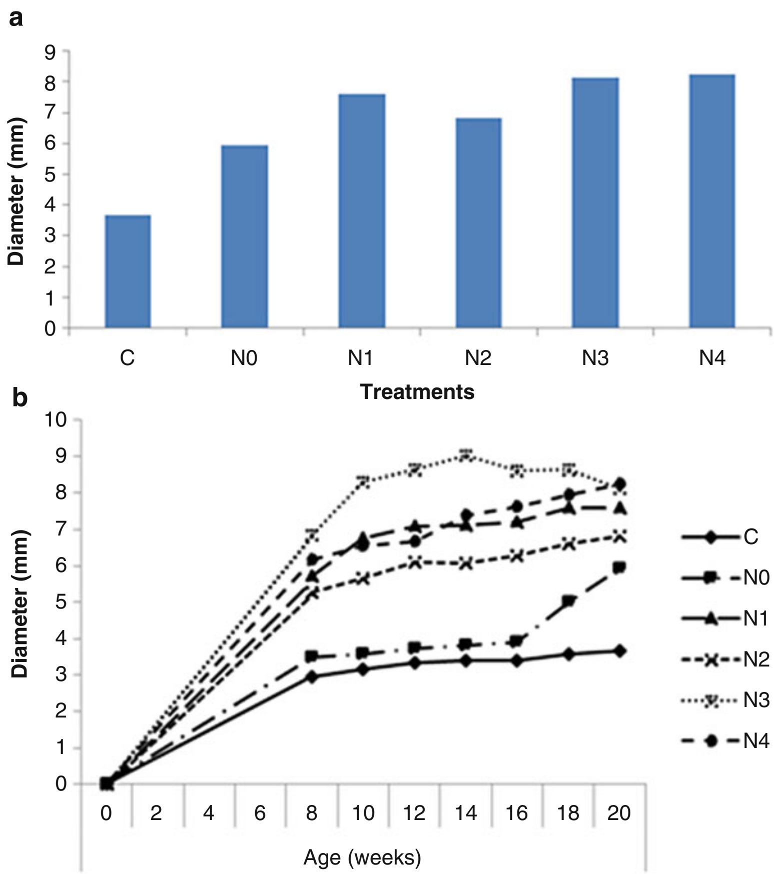

Fig. 3 (**a**) The diameter of teak seedling after 20 weeks, (**b**) The growth of diameter seedling for 20 weeks, observation started after 8 weeks

had dark respiration rates of 5.4 and 2.9 microliters O_2 consumed per milligram structural dry weight per hour, respectively. Consequentially, leaf elongation rate increase 140%.

Commonly, in Java Island teak plants in grumosol which contain adequate calcium and phospor [18]. N-total in grumosol soil from Gunung Kidul, Yogyakarta is about 0.09% [19] while in Sragen, Central Java range 0.05–0.3% depend on management system [20]. Teak seedlings planted in acidic lateritic red soil substrate, its growth traits were significantly affected by nitrogen. To effectively cultivate teak seedlings in acidic soil substrates, 1.68 g kg^{-1}quicklime (CaO) and 0.65 g kg^{-1} urea was suggested to be added to neutralize soil acidity, urea should not be added without quicklime [21].

3.2 Leaves Morphology of Teak Seedling at Various Level of Nitrogen Concentration

Leaves take essential role in plant metabolism. This organ has chlorophyll where photosynthetic process was held. Photosynthetic generate glucose as source of energy for its growing step, and oxygen which useful for it and other organism to respiration process. Moreover, leaves also contribute in transpiration process then support the process absorption water and nutrient from the ground.

Various level of nitrogen concentration resulting different leaves morphology of teak seedling. The best performance of young leaves observed in N3 treatment, which contain 955 ppm of nitrogen. It have bright green color and normal form. The leaves of seedling which watering by aquadest (C) showed the small size and green color, while leaves of seedling which treated by zero concentration of N (N0) revealed green color but its tip was curve. Abnormal form of young leaves at N0 might was caused by low level of calcium in this treatment (29 ppm) (Table 2). Calcium is required for membrane integrity and function, it most occurs in cell wall [22]. At *Swietenia macrophylla* deficiency symptom of calcium identified by deformation of younger leaves that had bent to their ventral surface [23]. Half strength N nutrient solution (N1) resulting the color of leaves were green purplish and interveinal were yellowish green. The edge of leaves were yellowing followed by necrotic symptom started from the tip were observed at N2 treatment. Whereas, N4 treatment showing the color of leaves were green but the edge, tip, and interveinal were yellowing.

Older leaves morphology showed that N2 treatment, which contain of 660 ppm of nitrogen led to the best appearance, its leaves color were dark green without any abnormal symptom. The leaves of seedling that untreated by nutrient (C) consistently showed the smallest size. Omission of nitrogen (N0) caused yellowing and drying of leaf tips and edge. While, half strength N nutrient solution (N1) resulted yellow spots in the inter veins and edge of leaves. The yellowing of older leaves as symptom of nitrogen deficiency, which is also observed in the studies by [24, 25]. Interveinal leaves of seedling which treated by 1.5 strength N nutrient solution (N3) were drying, but it probably due to deficiency of magnesium (63 ppm) (Table 2). The main function of magnesium is as co-ordinated metal in chlorophyll, generally symptom of plant which lack of magnesium is necrotic in the inter veins [22, 26]. Interveinal chlorosis still was found at leaves of seedling that treated by the greatest N concentration (N4).

4 Conclusions

Variation of N concentration affected teak growth (height, diameter, and nodal distance). They also affected morphology and color of the leaves. Symptoms of N deficiency were the yellowing and drying of leaf tips and the presence of yellow spots in the inter veins. N concentration of 995 ppm resulted the best growth, but it caused necrotic in the interveinal area, probably due to deficiency in Magnesium (Mg). Without N (N0 and Control) caused the lowest seedling growth. The greatest N concentration of 1335 ppm did not give the best growth for teak seedling.

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