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Improving the quality and quantity of hemp fiber (*Boehmeria nivea*) by giving indole acetic acid and gibberellic acid

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Abstract. *Rahman SF, Mudyantini W, Anggarwulan E. 2019. Improving the quality and quantity of hemp fiber (*Boehmeria nivea*) by giving indole acetic acid and gibberellic acid. Cell Biol Dev 3: 19-29.* Hemp plant (*Boehmeria nivea* (L.) Gaudich.) is an annual plant that is easy to grow and reproduce in a tropical region. Hemp fiber has a higher strength than cotton fiber, so it is not easily broken off. It provides less reduction than other fibers, the humidity of hemp fiber can achieve 12%, and hemp fiber has a smooth characteristic, long-lasting, and its glint is similar to silk. This research used complete random design (CRD) using two factors that were GA_3 with 3 concentration variations (G), such as 0 ppm, 175 ppm, 200 ppm, and 3 water availability variations (A), such as 50%, 75%, and 100%. The treatments were given to the rhizome before it was planted, and the water availability was given when the shoot started to form. The measured parameters were parameters of growth and fiber quality. This research concludes that GA_3 treatment influences the increase of shoot stem height, dry weight, fresh weight, and fiber pulling test (fiber's strength), but it does not influence the change of shoot number, leaf number, and elasticity of the fiber. The water availability treatment does not influence the entire parameter. The interaction between GA_3 and water availability influences hemp (*B. nivea*) fiber elasticity. The giving of GA_3 in the concentration of 200 ppm shows the best influence on the entire parameter of growth and fiber quality observed except in fresh and dry weight. Water availability treatment in SQ 100% strongly influences fresh and dry weight; in SQ 75%, it influences the fiber's elasticity.

Keywords: *Boehmeria nivea*, giberelat acid (GA_3), growth, pulling and elasticity test, water availability

INTRODUCTION

Indonesia is known for its fiber industry, consisting of natural, artificial, and filament yarn industries, as well as the spinning and dyeing industries. Indonesia is currently the world's seventh largest producer of artificial fiber, supplying 10% of the world's rayon fiber needs. Approximately half of the spinning industry's output is consumed domestically, with the remainder exported abroad (Miranti 2007). In the textile and textile product (IT-PT) industry, hemp fiber is currently limited to a mixture of cotton fibers. Because the need for hemp fiber as a supplement is not so great, which is around 11 tons per year and almost entirely met by imports from China, the length of hemp fiber is adjusted to the length of cotton fiber by cutting it first (Agriculture Department 2007).

Hemp (*Boehmeria nivea* (L.) Gaudich.) is an easy-to-grow annual that thrives in the tropics. Hemp fiber is a material that can be used to make high-quality fashion fabrics and cellulose (α-cellulose) manufacturing materials (Tarmansyah 2007). Because hemp fiber is stronger than cotton fiber, it is not easily broken. The disadvantages of hemp fiber include its lower elasticity and flexibility compared to cotton (*Gossypium* sp.). Clothing made from hemp fiber fabrics can absorb a lot of water and is easy to wash (Saroso and Sastrosupadi 2000; Brink and Escobin 2003). Hemp fiber, according to Hill (1972), is smooth, durable, and has a silky shine. Natural fibers derived from the hemp plant (*B. nivea*) have properties similar to cotton. They can be used as textile raw materials, one effort to reduce reliance on cotton (Buxton and Greenhalg 1989).

Plant growth and development are controlled by growth regulators, such as Gibberellic acid (GA_3) (Kastono 2005). According to Kusumo (1990), gibberellins aid cell division and RNA formation, allowing protein synthesis. Water is one of the most important aspects of plant cultivation because it serves as a solvent for plant nutrients in the soil and aids in the translocation f nutrients and photosynthates within the plant body (Gardner et al. 1991). The availability of sufficient water will aid plant growth; however, if there is too much or too little water, plant growth will be hampered, resulting in suboptimal yields (Levitt 1980).

The fiber's tensile strength indicates the amount of fiber strength that can be supported before breaking; the fiber's creep strength is defined as the length of the fiber that can creep before breaking (Lee 1999 in Indrawan 2007). Fiber quality can be improved using the right GA3 and enough water. Cellulose and lignin as cell wall constituents will increase as the number of phloem increases due to GA_3 administration. Cellulose influences fiber quality, whereas lignin increases fiber resistance.

With the GA_3 treatment and water availability in this study, it is expected that the tensile test, which is quite high, and elasticity, which is quite good, will be increased. The fiber produced from the first harvest of the hemp plant will have higher quality to increase the efficiency of the waiting time for harvest.

MATERIALS AND METHODS

Materials

The materials used in this study were rhizome hemp, planting media of a mixture of soil, sand, and manure, and GA_3: 175 ppm and 200 ppm. The material used in the tensile and elongation tests was hemp fiber that has been separated per strand.

Media preparation

The media was prepared by mixing soil, sand, and manure in a ratio of 1:1:1. The media mixture was weighed for each ½ kg polybag.

Preparation and planting of hemp rhizomes

Uniform rhizomes were chosen for this study and cut into 10 cm lengths, with each rhizome having one shoot. The rhizome pieces were then planted in the media in a polybag as deep as 5 cm, slightly tilted, and watered.

GA_3 administration treatment

GA_3 was administered once before planting. Each rhizome was sprayed with 5 mL of the hormone. After spraying, the plants were immediately stored in a dark and closed place before planting in polybags so that the hormones were not damaged by light and did not evaporate. Planting was done two days after treatment (Mudyantini 2008).

Determination of field capacity

The drained planting media mixture was weighed in a perforated polybag at the bottom and weighed 1/2 kg. The polybag was then watered until the water stopped dripping from the bottom hole, allowing the volume of water used for watering and its field capacity to be calculated. The following formula is used to calculate field capacity:

KL = (Weight of soil + polybag + water) – (Soil weight + polybag) (Patoni 2000).

Cultivation

Cultivation was carried out by watering once a day with various variations of water availability, including 50%, 75%, and 100% field capacity.

Growth observation

The number of shoots, shoot height, and leaves were calculated every 1 week, beginning on day 0 and continuing for 2 months. The fresh weight of the plants was determined by weighing all shoots that appeared on each rhizome at the end of the treatment. The dry weight of the plant was determined by drying all of the shoots that appeared on each rhizome and then weighing them.

Fiber tensile strength and creep test

Hemp fiber was separated into strands of ±10 cm in length. The media was made of cardboard (thick paper) and measured 10 cm by 2 cm. A rectangular hole with a length of 5 cm and a width of 1 cm was perforated in the center of the paper. The fibers separated by the strands are pasted in the center of the perforated paper media. The fiber ends were glued to the media with insulating tape and glue before being tested on the Tenso Lab tool, which will automatically display the tensile and elongation strength figures in statistical values (Textile Evaluation Laboratory 2008).

Data analysis

The obtained quantitative data were tested using analysis of variance (ANOVA) for the initial treatment/one treatment; GA_3 (ANCOVA) for continuous treatment; variation of water availability; and Univariate General Linear Model (GLM) for two treatments; and fiber quality analysis. The Duncans Multiple Range Test (DMRT) at the 5% test level was used to determine the true difference between treatments.

RESULTS AND DISCUSSION

Plant growth

Number of shoots

The results of the average number of shoots of *B. nivea* with GA_3 treatment are presented in Table 1. The analysis of variance (ANOVA) revealed that the GA_3 treatment did not affect the number of shoots that appeared. In Table 1, the highest number of *B. nivea* shoots were obtained in treatment G_0 (control), with an average of 4 pieces, while the lowest number of shoots were obtained in treatments G_{175} and G_{200}, with 2 and 1 fruit, respectively. This result is lower when compared to the control. This demonstrates that each plant requires the proper concentration for growth. Insufficient concentrations will inhibit rather than promote growth. According to Rahman et al. (2006), administration of GA_3 at a concentration of 250 ppm stimulated the growth of *Allium sativum* L. by 31.67%, but only 10.00% at a concentration of 500 ppm.

This minor effect was caused by the number of shoots that appeared, determined by the number of buds already present on the rhizome. The distance between the segments on the rhizome determines the number of buds in each piece of the rhizome, which is an internal factor of the hemp plant. As a result, even if the buds that have appeared have been cut before treatment, there can be a difference in the number of buds between pieces of rhizome that are the same length. Furthermore, according to Wahid (1990) in Hidayanto et al. (2003), the carbohydrate content of the cutting material, namely rhizomes, is a major factor in the development of shoot and root primordia.

Table 1. The average number of shoots of *B. nivea* with GA_3 treatment at 32 days after planting

GA_3 treatment	Number of shoots
G_0	4
G_{175}	2
G_{200}	1

Notes: G= Co. Theon of GA_3 (ppm), G_0= 0, G_{175}= 175, G_{200}= 200

Table 2. The average number of shoots of *B. nivea* with GA_3 treatment and variations in water availability 2 months after planting

GA_3 treatment	Water availability			Average
	A_1	A_2	A_3	
G_0	-	-	5.67	5.67
G_1	2.67	5.33	6.00	4.67
G_2	3.33	3.00	4.33	3.56
Average	3.00	4.17	5.33	

Notes: Concentration of GA_3 (ppm), G_0=0, G_1=175, G_2=200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

According to the results of the analysis of variance (ANCOVA) in Table 2, the GA_3 treatment, as well as the water availability treatment, did not have a significant effect on the number of shoots of *B. nivea.* Treatments G_1A_3 and G_0A_3 (control) had the highest average number of shoots (6 shoots), while treatments G_1A_1, G_2A_1, and G_2A_2 had the lowest average (3 shoots). Table 3 shows the average weekly increase in the number of shoots.

The number of shoots was counted every week. The table on the increase in the number of *B. nivea* shoots shows a weekly increase. Beginning in week 7, there was a decrease in G_1A_2, G_2A_1, and G_2A_3, followed by an increase in G_2A_2 in week 8. Figure 1 compares the increase in the number of shoots of *B. nivea* with GA_3 treatment and variations in water availability.

The concentration of GA_3 used in this study wwas0 ppm, 175 ppm, and 200 ppm. Of the three treatments, the highest number of *B. nivea* shoots were produced at a concentration of 0 ppm, while the lowest number of shoots were produced at 200 ppm. This demonstrates that each plant requires the proper concentration for growth. Insufficient concentrations will inhibit rather than promote growth.

According to Wareing and Phillips (1981), administration of IAA compounds at optimal concentrations causes meristematic cell division, increasing the number of shoots. Giving GA_3 to hemp rhizomes, on the other hand, did not affect the number of shoots produced because it did not increase the number of buds on the rhizomes. GA_3 is more effective at stimulating cell elongation, while IAA is more effective at stimulating cell enlargement (Davies 1995).

Variations in water availability in this study include 50%, 75%, and 100% KL. The highest number of shoots of *B. nivea* was produced at 100% KL treatment, while the lowest number of *B. nivea* shoots was produced at 50% KL treatment (Table 2).

The increasing availability of water causes the number of plant shoots to increase; if water availability decreases, the number of shoots will decrease. Fitter and Hay (1998) stated that water affects cell growth. The lower the availability of water, the lower the turgor pressure. This causes a decrease in the growth rate.

Water stress causes changes in the type and amount of carbohydrate compounds in plants. Plants that experience water stress experience a decrease in flour and an increase in sugar content. Research by Kramer (1977) in Islami and Wani (1995) shows that an increase does not always follow a decrease in flour content in sugar content. Even in bean (*Phaseolus* sp.) and tomato (*Lycopersicon* sp.) plants, continuous water stress reduced to flour, sugar, and total carbohydrate levels in chickpeas (*Phaseolus* sp.) and tomatoes (*Lycopersicon* sp.). The effect of water stress on carbohydrate and nitrogen metabolism can inhibit the formation of auxin in plants suffering from water stress. This activity was followed by a decrease in auxin transport to the cambium resulting in modification of the cambium activity. Water stress also causes a decrease in cytokinin activity and the supply of gibberellins to stems (Islami and Wani 1995). According to Mullet and Whitsitt (1996), the main effect of lack of water is a lower stem growth rate due to the accumulation of abscisic acid (ABA).

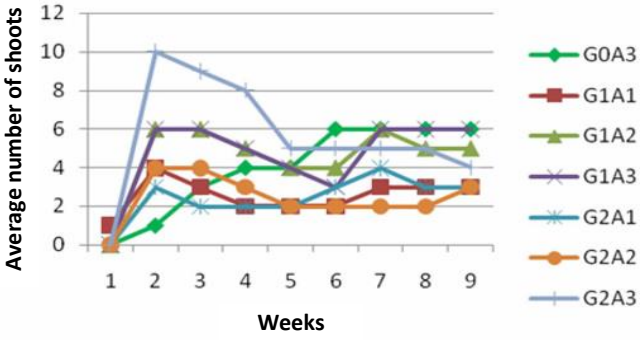

Figure 1. The average increase in the number of *B. nivea* shoots with GA_3 treatment and variations in water availability every 1 week. Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availabiity (%), A_1= 50, A_2= 75, A_3= 100

Table 3. The average number of shoots of *B. nivea* with GA_3 treatment and variations in water availability once a week (cm)

GA_3 and water treatment	The average number of shoots in the following week								
	1	2	3	4	5	6	7	8	9
G_0A_3	0	1	3	4	4	6	6	6	6
G_1A_1	1	4	3	2	2	2	3	3	3
G_1A_2	0	6	6	5	4	4	6	5	5
G_1A_3	0	6	6	5	4	3	6	6	6
G_2A_1	0	3	2	2	2	3	4	3	3
G_2A_2	0	4	4	3	2	2	2	2	3
G_2A_3	0	10	9	8	5	5	5	5	4

Notes: Concentration of GA_3 (ppm), G_0=0, G_1=175, G_2=200; Water availability (%), A_1=50, A_2=75, A_3=100

Shoot length

The results of the average shoot length of hemp plants with GA_3 treatment are presented in Table 4.

The analysis of variance (ANOVA) showed that GA_3 treatment significantly affected the shoot length of *B. nivea* plants. The average shoot length always increased with increasing GA_3 concentration. The growth of shoot length is accelerated by, among other things, the appropriate use of the GA_3 hormone. This result was per Sumiasri and Priadi's (2003) statement that the growth of sungkai branch cuttings (*Peronema canescens* Jack) at an optimum concentration of GA_3 5 mg/l increased the shoot height of the sungkai.

Based on the results of this study, the highest average shoot length was obtained in the G_{200} treatment, which was 22.92 cm, and the lowest average shoot length was in G_0 (control), which was 6.12 cm. This shows that every plant requires the appropriate concentration of GA_3 for growth. Inappropriate GA_3 concentrations will not stimulate growth but can inhibit growth. Salisbury and Ross (1995) state that active growth substances at low concentrations stimulate growth to a certain extent. According to Gul et al. (2006), administration of the hormone GA_3 300 ppm in *Araucaria heterophylla* (Salisb.) Franco affects weight. Aisyah (2004) also stated that applying GA3 to *Allium cepa* L. by immersion increases plant height and GA_3 concentrations up to 10 ppm. However, at concentrations below and above, it was even lower.

A common response in plants treated with GA_3 is stem elongation due to cambium activity in the internodes, causing the plant to grow taller than normal. Stem elongation is influenced not only by cambium activity but also by increased mitosis in the stem's subapical meristem area, which increases the number of cells in each internode. A higher cell count causes faster stem growth, resulting in a longer stem. This response in the trunk usually only results in increased length and does not result in an increase in increase formed (Wareing dan Phillips 1981).

According to the results of the analysis of variance (ANCOVA) in Table 5, the GA_3 treatment, as well as the water availability treatment, did not have a significant effect on the shoot length of *B. nivea*. The G_1A_1 treatment had the longest shoot length, with an average of 16.35 cm, while the G_1A_3 treatment had the shortest, with a shoot length of 4.89 cm. With an average shoot length of 7.48 cm, this result is lower than G_0A_3. This is related to the reduced cell elongation process caused by water stress.

Water availability variations in this study include 50 percent, 75 percent, and 100 percent KL. The *B. nivea* produced the longest shoot length at 50% KL treatment, while *B. nivea* produced the shortest shoot length at 100% KL treatment. Cell growth is a plant function that is affected by water scarcity. During the day, the meristem tissue water potential value frequently causes a decrease in turgor pressure below that required for cell development. This reduces protein synthesis, cell wall formation, and cell development, resulting in slower growth (Gardner et al. 1991). According to Dewi's (1993) research on two soybean cultivars (*Glycine max* (L.) Merry Willis and Lompo Batang), after 47 days of age under the most severe water stress, plant height decreased by nearly 50%, and stem diameter decreased by 47.7% for Willis and 42.14 percent for Lompo Batang. Anggarwulan et al. (2008) found that the 60% water availability treatment resulted in the best growth of kimpul (*Xanthosoma sagittifolium* (L.) Schott) at all shade levels. Table 6 shows the average increase in shoot length every week.

Table 4. The average shoot length of *B. nivea* with GA_3 treatment is 32 days after planting (cm)

GA_3 treatment	Shoot length (cm)
G_0	6.12^{a}
G_{175}	18.13^{ab}
G_{200}	22.92^{b}

Notes: G= Concentration of GA_3 (ppm), G_0= 0, G_{175}= 175, G_{200}= 200; Numbers followed by the same letter in the same column indicate no significant difference in the DMRT test at the 5% level

Table 5. The average shoot length of *B. nivea* with GA_3 treatment and variations in water availability 2 months after planting (cm)

GA_3 treatment	Water availability			Average
	A_1	A_2	A_3	
G_0	-	-	7.48	7.48
G_1	16.35	9.87	4.89	10.37
G_2	8.04	10.99	10.97	10.00
Average	12.20	10.43	7.78	

Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

Table 6. The average increase in shoot length of *B. nivea* with GA_3 treatment and variations in water availability once a week (cm)

GA_3 and water treatment	The average number of shoots in the following week								
	1	2	3	4	5	6	7	8	9
G_0A_3	0	0.56	2.06	4.58	5.23	3.95	5.00	5.79	7.48
G_1A_1	0.6	2.24	6.04	11.44	15.87	15.22	15.32	15.91	16.35
G_1A_2	0	1.18	15.22	8.32	10.6	11.35	8.65	9.51	9.87
G_1A_3	0	1.22	2.82	4.39	5.97	7.92	4.11	4.44	4.89
G_2A_1	0	3.11	10.88	14.89	16.23	12.34	9.87	8.23	8.04
G_2A_2	0	1.79	6.96	7.58	16.32	17.82	15.47	13.27	10.99
G_2A_3	0	1.04	4.67	6.02	11.74	14.05	13.58	7.42	10.97

Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

The length of the shoot is calculated once a week. The table of *B. nivea* shoot length increases shows that growth increases every week. There was a decrease beginning in the sixth week, except for which continued to increase until the ninth week. Figure 2 compares the increase in shoot height of *B. nivea* with GA_3 treatment and variations in water availability.

The concentration of GA_3 used in this study was 0 ppm, 175 ppm, and 200 ppm. *B. nivea* produced the longest shoot length at concentrations of 175 and 200 ppm, while the shortest shoot length was produced at a concentration of 0 ppm (Table 5).

Exogenous gibberellins that can be transported to the crown apex stimulate crown apical division. Gibberellins can stimulate cell division by increasing the hydrolysis of starch, fructan, and sucrose into glucose and fructose molecules. Gibberellins have a stronger influence on cell division by increasing cell wall plasticity, which leads to stem elongation, stem development, and young leaf development (Salisbury and Ross 1995). Taiz and Zeiger (1998) support this by stating that GA_3 plays a role in cell division, cell expansion, cambium activity, RNA formation, and protein synthesis, all of which cause an increase in stem height.

The increase in growth rate and plant height caused by GA_3 is explained by the physiological role of this growth substance, which supports cell wall development and stimulates cell elongation due to starch hydrolysis. It supports the formation of amylase enzymes, which can accelerate cell development (Wattimena 1998). Wuryaningsih and Sutater (1993) found that applying GA_3 25 ppm resulted in a significant difference in stem height and faster flowering. This is consistent with Sanjaya's (1991) study, which found that applying GA_3 at the optimum concentration of 25 ppm twice, at the ages of 6 and 8 weeks after planting, can increase plant height and significantly affect the length of the chrysanthemum flower stalk.

According to Weaver et al. (1982), the use of GA_3 promotes the formation of proteolytic enzymes that release tryptophan, an auxin precursor. This means that the presence of gibberellins increases the amount of auxin. Another mechanism proposes that gibberellins stimulate cell elongation by promoting the formation of -amylase through the hydrolysis of starch produced by gibberellins. As a result of this process, the sugar concentration rises, causing the osmotic pressure inside the cell to rise, causing the cell to grow (Weaver et al. 1972 in Abidin 1990).

Excessive water availability in the soil causes anoxia / reduced oxygen in the area around the roots, which can interfere with plant root absorption of nutrients from the soil (Pezeshki 1994). According to Suyana and Widijanto (2002), too much water in the soil can cause nutrient leaching, decreasing soil fertility. Water leaches nutrients from the surface of the adsorption complex and soil solution, depleting the soil.

Number of leaves

The results of the average number of leaves of hemp plants with GA_3 treatment are presented in Table 7.

The analysis of variance (ANOVA) results revealed that the GA_3 treatment did not affect leaves. Treatment G_0 (control) had the highest mean number of leaves (7 pieces), while treatments G_{175} and G_{200} had the lowest average number of leaves (5 and 3 pieces, respectively). When compared to the control, these results are lower. This demonstrates that each plant requires the proper concentration for growth. ConcentrationInsufficient concentrations rather than promote growth. The number of leaves is also affected by the occurrence of leaf shedding. Older leaves no longer active in photosynthesis will wither and fall, reducing the total number of leaves. According to Aisyah's (2004) study, soaking the tubers of *A. cepa* seeds with GA_3 does not increase the number of leaves and even tends to inhibit because all yields are under control. This is due to nutrient competition, gibberellins' interaction with other reproductive organs, and genetic or other unsuitable environmental factors. Gardner et al. (1991) stated that genetic and environmental factors influence the number and size of leaves. Genetic factors control the position of the leaves on the plant, and this leaf position influences the rate of leaf growth.

GA_3 is known to stimulate plant growth, including the growth of leaves and roots. If GA_3 is administered to transport it to the crown's tip, cell division and growth will increase, resulting in stem elongation and (in some species) the development of young leaves (Salisbury and Ross 1995). According to Anwarudin et al. (1996), GA_3 does not affect mangosteen growth.

Table 7. The average number of *B. nivea* leaves with GA_3 treatment 32 days after planting

GA_3 treatment	Number of leaves
G_0	7
G_{175}	5
G_{200}	3

Notes: G= concentration of GA_3 (ppm), G_0= 0, G_{175}= 175, G_{200}= 200

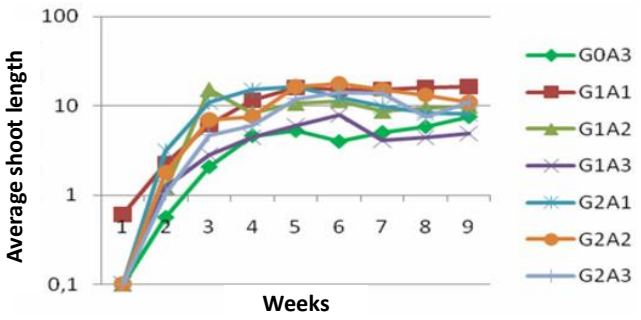

Figure 2. The average increase in shoot length of *B. nivea* with GA_3 treatment and variations in water availability once a week (cm). Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

According to the analysis of variance (ANCOVA) in Table 8, the GA_3 treatment and variations in water availability had no significant effect on the number of *B. nivea* leaves. The most leaves were found in treatment G_0A_3 (control), which had 29 leaves, while the fewest were found in treatment G_1A_1, which had 5 leaves. Table 9 shows the average increase in the number of leaves per week.

The number of leaves was counted once a week. The table on the increase in the number of *B. nivea* leaves shows a weekly increase. There was a decrease beginning in the seventh week, except for continued to increase until the ninth week. Figure 3 compares the increase in the number of *B. nivea* leaves with GA_3 treatment and variations in water availability.

Leaves will be able to play an optimal role in photosynthesis if they have access to water, light, and sufficient nutrients. The roots will absorb water and nutrients. Auxin promotes cell division, which leads to cell enlargement and the formation of leaf primordia (Loveless 1991; Salisbury and Ross 1995). One of GA_3's properties is that it promotes the formation of proteolytic enzymes that release tryptophan as an auxin precursor, increasing. The concentrations of GA_3 used in this study were 0 ppm, 175 ppm, and 200 ppm. The highest number of *B. nivea* leaves were produced at a concentration of 0 ppm, while the lowest number of *B. nivea* leaves were produced at 200 ppm (Table 8).

The highest number of *B. nivea* leaves produced at 100% KL treatment were 29 strands. This is because, in these conditions, the plants have sufficient water availability besides increasing the number of branches will also increase the number of leaves. The availability of sufficient water will support the increase in leaf area so that it is related to the level of plant production (Sulistyaningsih et al. 1994).

The lowest number of leaves in the 50% KL treatment was 5. In this condition, there is a loss of water (transpiration) that is not matched by a sufficient water supply, inhibiting plant growth. Water stress will result from insufficient absorption rates to compensate for water loss due to transpiration (Islami and Wani 1995). According to Fitter and Hay (1998), water influences cell growth; the lower the availability of water, the lower the turgor pressure. This results in a decrease in growth rate, as the number of leaves produced is low.

Fresh weight

The results of the average fresh weight of hemp plants from this study are presented in Table 10.

According to the analysis of variance (ANCOVA) results in Table 10, the GA_3 treatment significantly affected the fresh weight of *B. nivea*, with a significance value of 0.00. The availability of water did not affect the fresh weight and did not affect the treatment. Table 10 shows that the control treatment (G_0A_3) has the highest results (24.54 g), while the other treatments have lower results when compared to the control. The G_2A_1 treatment produced the lowest yield of 5.40 g. This demonstrates that each plant requires the proper concentration for growth. Inadequate concentration will not stimulate or even inhibit growth. Figure 4 compares the fresh weight of *B. nivea* with GA_3 treatment and variations in water availability.

Table 8. The average number of *B. nivea* leaves with GA_3 treatment and variations in water availability 2 months after planting

GA_3 treatment	Water availability			Average
	A_1	A_2	A_3	
G_0	-	-	29.33	29.33
G_1	5.00	19.33	17.33	13.89
G_2	10.33	12.33	17.00	13.22
Average	7.67	15.83	21.22	

Notes: Concentration if GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

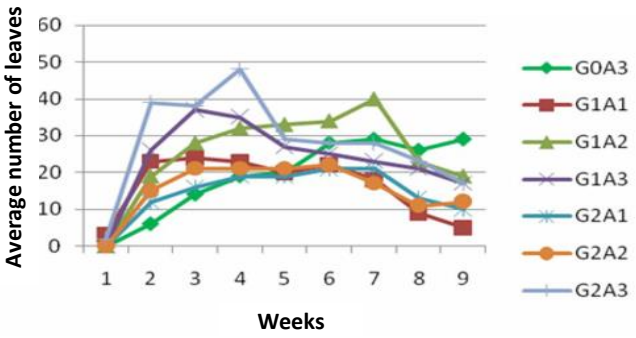

Figure 3. The average increase in the number of *B. nivea* leaves with GA_3 treatment and variations in water availability weekly. Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

Table 9. The average increase in the number of *B. nivea* leaves with GA_3 treatment and variations in water availability every 1 week

GA_3 and water treatment	The average number of leaves in the following week								
	1	2	3	4	5	6	7	8	9
G_0A_3	0	6	14	19	20	28	29	26	29
G_1A_1	3	23	24	23	20	22	18	9	5
G_1A_2	0	19	28	32	33	34	40	23	19
G_1A_3	0	26	37	35	27	25	23	21	17
G_2A_1	0	12	16	19	19	21	21	13	10
G_2A_2	0	15	21	21	21	22	17	11	12
G_2A_3	2	39	38	48	29	28	28	23	17

Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

Table 10 (Figure 4) depicts that the highest fresh weight of *B. nivea* was produced at a GA_3 concentration of 0 ppm, while the lowest fresh weight of *B. nivea* was produced at a GA_3 concentration of 200 ppm. For the water availability in this study, *B. nivea* produced the highest fresh weight at 100% KL treatment and the lowest fresh weight at 50% KL treatment. The water content in the tissue influences the plant's fresh weight. Because of the presence of cell enlargement, the new cell is larger than the parent cell. Increased cell size leads to increased tissue and organ size, ultimately increasing plant body and weight. A greater number of cells result from increased cell division. The increased cell count, including in leaf tissue, allows for more carbohydrate-producing photosynthesis, which can affect plant weight (Wareing and Phillip 1981; Salisbury Ross 1995).

Water is an essential component of plant growth. Growth is a process that uses appropriate substrate inputs to produce growth products. Organic matter and other elements absorbed by plants from the environment, such as carbon dioxide, nutrients, water, and sunlight, are processed into organic materials that can be measured by adding the plant's overall weight (Sitompul and Guritno 1995).

Water stress will result in inhibition of cell multiplication and enlargement. This is related to the effect of cell turgor pressure. Furthermore, a lack of water will disrupt cell metabolism, including the process of photosynthesis. Photosynthesis will be hampered if the main ingredient, water, is only available in limited quantities, resulting in lower photosynthesis results. Photosynthate production will also be hampered in its circulation to all parts of the plant, potentially reducing plant weight (Harjadi and Yahya 1988). The number of leaves will increase as the number of branches increases. The fresh weight of the plant increases as the number of leaves increases. According to Kusumo (1990), species with rapid and abundant leaf development will increase the photosynthesis rate overnight.

The results of the average dry weight of hemp plants from this study are presented in Table 11.

The analysis of variance (ANCOVA) results in Table 11 show that the GA_3 treatment significantly affected the fresh weight of *B. nivea*, with a significance value of 0.00. In the treatment, the availability of water did not have a significant effect on the fresh weight of *B. nivea*.

The dry weight reflects the accumulation of organic compounds synthesized by plants from inorganic compounds, particularly water and CO_2. Plants can effectively use the intensity of sunlight to increase the formation of carbohydrates used for growth. The absorption of nutrients and the availability of abundant water will contribute to an increase in plant dry weight. The highest results are shown in Table 11 for the control treatment (G_0A_3) of 5.46 g, while the other treatments are lower when compared to the control. The G_1A_3 treatment produced the lowest yield of 1.86 gr. This demonstrates that each plant requires the proper concentration for growth. Inadequate concentration will not stimulate or even inhibit growth.

The increase in dry weight is caused by an increase in protoplasm, which occurs as cell size and number increase. Changes in water, carbon dioxide, and inorganic salts into living materials result in protoplasm addition. This process includes photosynthesis, absorption, and metabolism, which produces carbohydrates and increases the plant's dry weight (Harjadi 1993; Lakitan 1996). Figure 5 compares *B. nivea* dry weight with GA_3 treatment and variations in water availability.

Table 10. The average fresh weight of *B. nivea* with GA_3 treatment and variation of water availability 2 months after planting (g)

GA_3 treatment	Water availability			Average
	A_1	A_2	A_3	
G_0	-	-	24.54	24.54[b]
G_1	5.84	9.56	5.48	6.96[a]
G_2	5.40	6.40	6.80	6.19[a]
Average	5.61	7.98	12.27	

Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100. *Numbers followed by the same letter in the same row and column indicate no significant difference in the DMRT test at the 5% level

Table 11. The average dry weight of *B. nivea* with GA_3 treatment and variations in water availability 2 months after planting (g)

GA_3 Treatment	Water availability			Average
	A_1	A_2	A_3	
G_0	-	-	5.46	5.46[b]
G_1	2.22	2.50	1.86	2.19[a]
G_2	1.88	2.19	2.20	2.09[a]
Average	2.05	2.34	3.18	

Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100. *Numbers followed by the same letter in the same row and column indicate no significant difference in the DMRT test at the 5% level

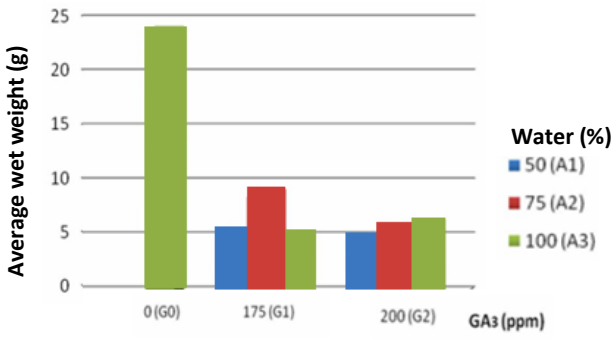

Figure 4. Fresh weight of *B. nivea* with GA_3 treatment and variations in water availability 2 months after planting. Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

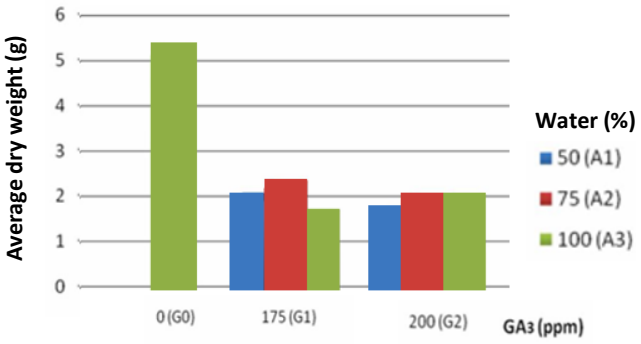

Figure 5. The dry weight of *B. nivea* with GA_3 treatment and variation of water availability 2 months after planting. Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

Table 11 (Figure 5) shows that the highest dry weight of *B. nivea* was produced at a GA_3 concentration of 0 ppm, while the lowest dry weight of *B. nivea* was produced at a GA_3 concentration of 200 ppm. The highest dry weight of *B. nivea* was produced at 100 percent KL treatment, and the lowest dry weight was produced at 50 percent KL treatment for the water availability given in this study.

According to Delvin and Withan (1983) in Rahardjo et al. (1999) dry weight of plants can indicate how much plants respond to water stress because water is the main limiting factor for plant growth. Gardner et al. (1991) stated that severe water scarcity could cause stomatal closure, reducing carbon dioxide uptake and stunted growth and dry weight production.

According to Fitter and Hay (1998), water affects dry weight because of metabolism, specifically photosynthesis. The total dry weight of crop yields is the sum of net CO_2 assimilation yields accumulated over the growing season. Among others, utilizing the results of photosynthesis by plants is for forming body structures and food reserves. Photosynthesis fixes CO_2 for hexose production and respiration. Water stress can reduce the rate of photosynthesis, reducing the synthesis/formation of body structure and food reserves and, as a result, dry weight. Although water is a raw material in the photosynthesis process, reducing water in the leaves indirectly affects the rate of photosynthesis. The effect of soil water content will cause a reduction in photosynthesis rate because of: reduced diffusion capacity of the stomata due to stomatal closure, decreased hydration of chloroplasts and other parts of the protoplasm, thereby reducing the effectiveness of the photosynthesis mechanism, accumulation of sugars and thus inhibiting further photosynthesis (Haddy 1987). According to Fitter and Hay (1998), the closure of the stomata prevents CO_2 diffusion from the atmosphere to the leaves. As a result, photosynthesis cannot occur, and in the long run, it interferes with other physiological processes, inhibiting plant growth.

Fiber quality

Fiber tensile strength

The results of the average tensile strength of hemp fiber with GA_3 treatment and water availability are presented in Table 12.

Analysis of variance of the General Linear Model (GLM) showed that the GA_3 treatment had a significant effect on the tensile strength of the fiber, with a significance value of 0.008. The treatment of water availability, as well as the interaction between GA_3 and the provision of water availability, did not affect the fiber's tensile strength. A comparison of the tensile strength of *B. nivea* fiber with GA_3 treatment and variations in water availability are shown in Figure 6.

Figure 6 shows that the highest tensile strength of the fiber is 326 in the GA_3 treatment of 200 ppm and 50% water availability (G_2A_1), while the lowest tensile strength is 58 in the GA_3 treatment of 0 ppm and 100% water availability (G_0A_3/control). Figure 6 shows that the greater the concentration of GA_3 application, the greater the tensile strength of the fiber.

Cellulose and lignin contribute to fiber strength. The higher the cellulose and lignin content, the stronger the resulting fiber. However, cellulose, the main constituent of cell walls, contributes to the fiber's strength. One of the most important properties of cellulose is its flexibility, which allows it to withstand strain. The lignin increases the wall's resistance to stress and prevents cellulose microfibrils from folding. The orientation of the different microfibrils is an important factor in determining the wall's strength (Mudyantini et al. 2006).

According to Salisbury and Ross (1995), an increase in endogenous GA_3 can also cause an increase in the hydrolysis of starch, fructan, and sucrose into glucose and fructose molecules. Incorporating glucose units into macromolecular compounds insoluble in all commonly used solvents is known as cellulose (Fengel and Gerd 1995). Abidin (1990) claims that GA_3 can produce starch hydrolysis, which aids in the formation of α-amylase. The glucose concentration will rise as a result of this process.

A lack of water will cause disruptions in cell metabolism, including photosynthesis. Photosynthesis will be hampered if the main ingredient, water, is only available in limited quantities, resulting in lower photosynthesis results (Harjadi and Yahya 1988). According to Islami and Wani (1995), water stress causes changes in the type and amount of carbohydrate compounds in plants. Plants exposed to water stress produced less flour and more sugar.

According to Hamid (2001) and Sjostrom (1995), cellulose biosynthesis begins with glucose. Therefore, by providing GA_3 and varying water availability, the glucose content in plants increases, which can then be used for cellulose photosynthesis, increasing cellulose content in plants.

Active glucosyl (UDP-glucose) is a precursor in cellulose synthesis. In the cytoplasm, UDP-glucose is produced from two sources: sucrose by sucrose synthase (i) (reversible reaction) and glucose by sequential reactions catalyzed by hexokinase (ii), phosphoglucomutase (iii), and UDP-glucopyrophosphosylase (iv). After passing through

the plasma membrane, UDP-glucose transfers the remaining glucosyl to the glucan growth chain (cellulose), releasing UDP. This incorporation is catalyzed by active sites on cellulose synthase complex subunits stored in the plasma membrane. The glucan chains that originate from one complex are thought to be linked by hydrogen bonds to form microfibrils, whose size varies between cell types. The orientation of the microfibrils can be determined as the synthesis progresses by complex motion in the fluid lipid bilayer. Microtubules on the inner surface of the plasma membrane can direct such movements (Sjostrom 1995).

Incrustation refers to the entry of additional materials into the cellulose framework of the cell wall. In higher plants, lignification is the most important incrustation process. Still, other materials such as suberin, tannins, cutin, quinine wax, and other organic and mineral materials can also coat the cell wall (Fahn 1991).

According to Neish (1968), Sarkanen (1971), Griseboch (1977), Gross (1977), and (1978) in Fengel and Gerd (1995), lignin biosynthesis starts from glucose. As a result of the addition of GA_3 and changes in water availability, the glucose content of plants increases, which can then be used for lignin photosynthesis, increasing the lignin content of plants.

Plants produce lignin macromolecules through complex biological, biochemical, and chemical systems. Many studies with radioactive carbon confirmed that p-hydroxy cinnamyl alcohol, p-coumaryl alcohol, p-coniferyl alcohol, and sinapyl alcohol are primary parent compounds (precursors) that serve as the building blocks for all lignin compounds (Fengel and Gerd 1995).

Lignin biosynthesis begins with glucose produced by photosynthesis. It is converted to shikimic acid, a byproduct of the shikimic pathway. As the pathway's final compounds, two aromatic amino acids, L-phenylalanine and L-tyrosine, are formed via reductive animation via prephenic acid. These are the starting materials (amino acid groups) for the enzymatic metabolism of phenyl propanoid (cinnamic acid pathway), which results in the formation of three cinnamyl alcohols via activated cinnamic acid derivatives. Amino acids are deaminated to cinnamic acid by deaminase (phenylalanine ammonia-lyase and tyrosine aminolyase). P-coumaric acid, caffeic acid, ferulic acid, 5-hydroxy-ferulic acid, and synaptic acid are produced from hydroxylation (by phenolase/hydroxylase). Cinnamyl alcohol (p-coumaryl alcohol, p-coniferyl alcohol, and sinapyl alcohol) is finally formed via the coenzyme-A trioster by enzymatic activation (CoA ligase) and reduction (NADP reductase, NADP hydrogenase) (p-coumaryl-alcohol). Aldehydes (p-coumaraldehyde, coniferal dehides, and synapyldehydes) (Fengel and Gerd 1995). The primary precursor compounds and building blocks of all lignin are p-coumaryl alcohol, coniferyl alcohol, and sinapyl alcohol (Fengel and Gerd 1995; Robinson 1995).

According to Biemelt et al. (2004), the administration of GA_3 increased lignin biosynthesis and stimulated xylem formation in transgenic tobacco. Li et al. (2003) stated that the administration of GA_3 during flowering and tiller induction increased the lignin content of *Myrica rubra* A.Chev. According to Mudyantini (2008), the administration of GA_3 increased the lignin content of *B. nivea*.

Fiber elasticity strength

The results of the average elasticity strength of hemp fiber with GA_3 treatment and water availability are presented in Table 13.

Table 12. Average *B. nivea* fiber tensile strength with GA_3 treatment and water availability 2 months after planting (gr)

GA_3 treatment	Water availability			Average
	A_1	A_2	A_3	
G_0	-	-	58	58[a]
G_1	102	148	82	110[a]
G_2	326	178	180	228[b]
Average	214	163	106	

Notes: Concentration of GA_3 (ppm), G_0=0, G_1=175, G_2=200 Water availability (%), A_1=50, A_2=75, A_3=100. *Numbers followed by the same letter in the same row and column indicate no significant difference in the DMRT test at the 5% level

Table 13. The average tensile strength of *B. nivea* fibers with GA_3 treatment and water availability 2 months after planting (%)

GA_3 treatment	Water availability			Average
	A_1	A_2	A_3	
G_0	-	-	1.88	1.88
G_1	0.94	2.09	1.26	1.43
G_2	1.74	1.66	2.23	1.88
Average	1.34[a]	1.87[b]	1.79[ab]	

Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100. *Numbers followed by the same letter in the same row and column indicate no significant difference in the DMRT test at the 5% level

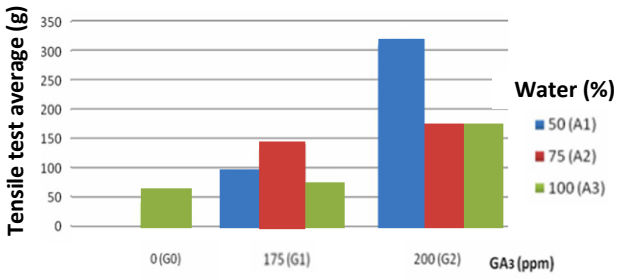

Figure 6. The *B. nivea* fiber tensile strength with GA_3 treatment and water availability treatment 2 months after planting. Notes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

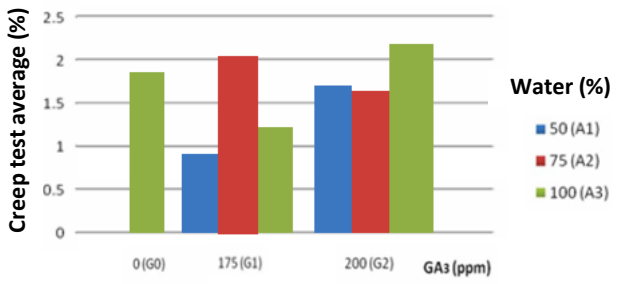

Figure 7. The elasticity strength of *B. nivea* fiber with GA_3 treatment and water availability treatment 2 months after planting. otes: Concentration of GA_3 (ppm), G_0= 0, G_1= 175, G_2= 200; Water availability (%), A_1= 50, A_2= 75, A_3= 100

According to the analysis of variance of the General Linear Model (GLM), the GA_3 treatment and water availability did not significantly affect the fiber elasticity strength. Still, the interaction between GA_3 and water availability did, with a significance value of 0.017. Figure 7 compares the elongation strength of *B. nivea* fibers with GA_3 treatment and variations in water availability.

Figure 7 shows that the highest fiber elasticity strength is 2.23 percent in the GA_3 treatment of 200 ppm and 100 percent water availability (G_2A_3). In comparison, the lowest elasticity strength is 0.94 percent in the GA_3 treatment of 175 ppm and 50 percent water availability (G_1A_1). This demonstrates that each plant requires the proper concentration for growth.

One of the most important properties of cellulose is its flexibility, which allows it to withstand strain. The lignin increases the wall's resistance to stress and prevents cellulose microfibrils from folding. The orientation of microfibrils is an important factor in determining wall strength. The tensile strength of cellulose is its most notable mechanical property, whereas the cellulose fibrils bend under compressive stress. Cell walls' physical properties include strain, strength, resistance to pressure, swelling, and permeability, which are determined by differences in the composition and structure of the lamellae, which continue to increase during the wall formation process. Structure differences can result from differences in the direction and density of cellulose microfibrils, differences in lignin content, and other factors (Fahn 1991).

Giving GA_3 and varying water availability can increase the glucose content in plants, which increases the cellulose content. According to Abidin (1990), GA_3 can produce starch hydrolysis, aiding in the formation of α-amylase. The glucose concentration will rise as a result of this process. According to Mudyantini (2008), GA_3 treatment can increase the cellulose content of plants by increasing the glucose content. The best GA_3 treatment for increasing cellulose in *B. nivea* was at a concentration of 200 ppm and cellulose content of 26.33% b/b.

Lack of water can slow photosynthesis because the turgidity of stomata guard cells decreases (Haryati 2003). According to Harjadi and Yahya (1988), photosynthesis will be hampered if water, the main ingredient, is only available in small quantities, resulting in lower photosynthesis results. According to Islami and Wani (1995), water stress causes changes in the type and amount of carbohydrate compounds in plants. Plants exposed to water stress produced less flour and more sugar. According to Lee (1999) in Indrawan (2007), Moisture affects the fiber's tensile strength. The higher the humidity, the higher the tensile strength of the fiber, while the lower the humidity, the lower the tensile strength.

Based on the research findings, it is clear that: (i) GA_3 treatment increased *B. nivea* growth at shoot length with a concentration of 200 ppm but decreased fresh and dry weight. The presence of GA_3 did not affect the number of shoots and leaves. At the same time, water availability treatment and the interaction between GA_3 and water availability did not affect all growth parameters of *B. nivea*. (ii) At a concentration of 200 ppm, GA_3 treatment increased the tensile strength of the fiber but did not affect the fiber's elasticity. The treatment of water availability did not affect all fiber parameters, but the interaction between GA_3 and water availability had a 75% effect on the elasticity strength of *B. nivea* fiber.

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