The effect of different levels of nitrogen fertilizer on the growth and yield of coffee trees (*Coffea arabica* L.)

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Abstract

A study was carried out at the experimental farm of the Agriculture Faculty, Ibb University, Yemen, during (2011-2013). This study aims at investigating the effect of different doses of nitrogen fertilizer on the growth and yield of coffee trees. The treatments were applied using humus 2kg/tree as control (T1), nitrogen fertilizer as urea with different doses 6g/tree (T2), 13g/tree (T3), and 19.6 g/tree (T4). Tri-superphosphate (5g), potassium sulfate (5g) and humus (2kg) /tree were added to all treatments except of the control. A randomized complete block design was used. The study period was two years, the morphological characters and coffee productivity were studied. As shown in the results in the 1st year, the height's gain of trees were increased in T4 and T2. Concerning the gain of branches number, they were increased in all treatments, with no significant differences among treatments. In the 2nd year, the gain of height was highly increased in T4 (72.38) followed by T3 and T2 (65.45 and 61.55 cm, respectively) compared with T1 (54.95). A high significant difference ($p \leq 0.05$) on the gain of height between T4 and T1 was observed. The gain of branches number was significantly ($p \leq 0.05$) increased in T4 (25.8) as compared to T1, T3 and T2 (20.9, 19.9 and 19.6). The coffee yield was the highest in T3 (703.3 g/tree) followed by T4 (676.4 g/tree).

Key words: Yemen, *Coffea arabica* L., Nitrogen Fertilizers, Growth, Yield.

Introduction

Coffee belongs to the genus Coffea, in the Rubiaceae family. Of all the species, only two (*Coffea Arabica L.*) and (Coffea canephora Pierre ex. Frohen) have a commercial value in the world coffee industry. *Coffea arabica* is the most popular and widely cultivated coffee species in the world, dominating 70 % of the total coffee production and over 90 % of the market.(25). *Coffea arabica L.* has two distinct botanical variety *C. arabica* (usually called Typica) and *C. arabica* var. bourbon (usually called Bourbon)(23). Coffee was first cultivated by Arabs during the 14th century and introduced into the new world and much of the rest of the tropics during the 17th century(24).

Yemen is well known in coffee culturing since ancient time. Bay Bab Almendeb played a significant role in the world trade of coffee production. Mucha coffee was attributed to Mucha port name, the essential and first port for coffee exportation in Yemen. Historians have different ponts of view about the origin of coffee, and no one provided evidence that coffee was traded from other countries except of Yemen (11). On the other hand, the origin of the word "coffee" is Arabic as, transferred to Turkish as Cahveh, and then borrowed by the English language as to "coffee" the foreigners (11). A study by Alkhawi (1) assumed that the origin of coffee is the region (cafa) in Ethiopia. *Coffea arabica* is the first quality worldwide. It is considered one of the important cash crops in Yemen. Coffee trees are cultivated in mountainous amphitheaters in Yemen at 600-2500 m above sea level. The areas of coffee culturing in Yemen are divided, according to the height above sea level, to three zones, the altitude zone (2000-2500 m), the low zone (800-1000 m), and the amphitheaters (900-2200 m) (9).

In 2012, the area of coffee cultivation was 34987 hectares with a total production of 19828 tons (0.568 ton/ha). Coffee is cultivated in 15 governorates of the Republic of Yemen including Ibb governorate with production of 691 tons (0.63 T/ha) in 1097 ha. (5). There are many varieties of coffee in Yemen and are known according to the name of the cultivation region, such as

Hammady, Harazy, Yafay, Matary, Odainy etc…(10). There are some types of varieties called based on morphological characteristic of their trees and fruits such as Doairy, Tofahy, which are common in Yemen. All varieties belong to *Coffea arabica L.*

Al-Dhubaibi et al, (8) reported that coffee productivity decreased by 0.6 t/ha during 2005-2009. Almabrazy (9) mentioned that the high yield of one tree was 900-1200g which is equal 2281-2850kg/ha during 2002-2003, the middle yield was 600-900g (1223-1536kg/ha), while the low yield was 290-600g (711-1323kg/ha); the studded trees were at the age from 3 to 31 years, neither normal shadow nor mineral fertilizers were used, except of some humus. The productivity of coffee in Yemen ranged from 0.41 to 0.63 t /ha in 2012 (5). In the period from 2009 to 2012, coffee productivity in Yemen was 0.55 ton/acre that is equal (1.36 t/ ha) (6). Another study have reported that the productivity of coffee at the age of 3-10 years is 0.2 kg/tree (2).

Nitrogen has frequently been found to be the mineral element having the greatest effect on crop growth and productivity (22).

Yemeni farmers avoid using fertilizers due to their expensive prices, difficulties of its transportation and storage, and their little knowledge about minerals fertilizer, in addition to the inadequate technical information about the types of mineral fertilizer, rates, seasons, and their methods of use (3). Because of the economic importance of coffee, which comes in the second rank in world trade after oil, the lake of coffee production in Yemen, which didn't exceed 0.15% of the world production (4), in addition to the rejection of using mineral fertilizers by Yemeni farmers, the importance of this study is valuable. The aims of this study to investigate the effect of different levels of nitrogen fertilizer on the vegetative growth and yield of coffee.

Materials and Methods

The source of seedling and culturing conditions

The study was carried out at the experiential farm of the Agriculture Faculty, Ibb University, Yemen, during (2011-2013)**.** Coffee seedling; Altofahy cv. was obtained from the nursery of agriculture and irrigation office- Ibb. The seedling age was one year, and then they were put in the sunshade for adaptation for two weeks at normal conditions of the Plant Production Department - Faculty of Agriculture and Veterinary Medicine - Ibb University, Yemen. They were treated in the farm after 9 months of planting. The farm altitude is 1913 m above sea level, and its latitude Coordinate is 13º57'29" N and 44º10'29" E (18). The average air maximum temperature range was 24 ºC to 26 ºC, while the minimum temperature is between 6 to 13 ºC. The relative humidity was 70%. Average annual rainfall was 750–1200 mm (4, 13). The Soil was loam-silty. The average air maximum, minimum ,and mean temperature range In 2011and 2012 were 31.2 , 0.0, 15.6 , 32.0 , 3.5, 17.8 ºC, while the relative humidity mean(%) 53 and 50 , rainfall total (mm) 1177.0 and 784.6 respectively (7) .

The spacing was 2 m between seedlings and rows. The farm was irrigated with drip irrigation system with about 45 times, the period of irrigation was 4 -10 days; the discharge of drips was 4L/h with the total irrigation quantity of (497.5 m^3/ha) and rainfall of (79.939 mm) (7) equal (799.39m^3/ha). The field was irrigated with well water, during dry season (Oct. – Apr.). During rainfall season (May – Sep.) it depended on rainfall. The infection by *Stephanoders hompe F.* was aggressive, using Royal Super Acid (15 ml/20L water) twice per year specially in the second year, when the first production was started. The weeds were removed six times manually/year (twice in autumn and winter, and four times in summer). The soil was grubbed twice per year in winter and summer. The trees were clipped in March, 2013.

Experimental design

A random Complete Block Design (RCBD) was used in this experiment with four treatments. Each treatment contained four replicates and each replicate contained four trees at the same age.

Treatments

For the period of 2 years, the treatment contained different doses of urea as follows: T1: 2kg /tree humus (control); T2, 6g urea +5g tri-superphosphate +5g potassium sulfate + 2 kg humus /tree; T3, 13 g urea+ 5g tri-superphosphate +5g potassium sulfate + 2 kg humus /tree; T4, 19.6 g urea+ 5gr tri-superphosphate +5g potassium sulfate + 2 kg humus /tree. All fertilizers were applied in the first month of each experimental year. The quantities of fertilizers were the same in the two years. At the end of the experiment, coffee berries were harvested as the first production. The berries were dried for 15 days by sunlight using wood table to avoid humidity; the berries were covered at night using tent cloth blue.

Measurements

Morphological characters

Tree height (cm) of four trees for each replicate was measured monthly from the surface of land to the highest peak of the tree, and the number of branches were accounted monthly on day 4 of each month from April 2011 till March 2013.

The changes in tree height and the number of branches were calculated for every month by taking the differences of the tree height and branches number between every two months.

Productivity

After harvesting, the berries of each tree was weighed as fresh weight and dry weight, then the yield was calculated for each replicate per tree and hectare.

Statistical Analysis

Statistical analysis was carried out using Renew SAS Software V. 9.2 (21). The mean and standard error were determined. ANOVA was obtained by Linear General Models (LGM), and the multiple LSD test was determined at level $p \leq 0.05$. The results were calculated for the four replicates.

Results and Discussion

Morphological characters

As presented in (Table 1), the results showed that the height of coffee tree was insignificantly increased in all the treatments except of T3 in the first year (April 2011- March 2012. This may be due to that all trees were fertilized with the same fertilizer and same quantities (5g tri-superphosphate, 5g potassium sulfate and 2kg humus) except with nitrogen fertilizer which was used in small quantities; this caused no significant difference. Several factors in *Coffea arabica* growing zones worldwide indicated as causes of the tree growth periodicity, including, drought temperature, photoperiod, soil N availability, and reproductive growth (17).

In addition, other factors, such as nutrient leaching and water stress, are also invoked to account for the growth oscillations (15). Other studies have investigated that coffee trees grow better in response to urea than to nitrate fertilizers (12,19). In addition, Figure 1 showed the monthly rise in height (cm) among the treatments of coffee trees during the first year (April, 2011to February, 2012), T3 and T4 were increased as compared with T1, but not significantly $P \geq 0.05$.

Table (2) revealed the number of coffee branches for all experimental groups during the first 12 months of the experiments, the gain of branches number was elevated with no significant difference at the end of the first year. In addition, Figure2 showed the rate of monthly rise in branches number among treatments of coffee trees during the first year (April, 2011 to February, 2012), branches number in T4 was highly increased as compared with T1, T2 and T3, with no significant difference $P \geq 0.05$.

The results of plant height for the second year (April 2012- March 2013) are illustrated in (Table 3). The increasing of trees' height dispirited from month to other, the gain of height for T4 (72.38 cm) was significantly elevated ($P \leq 0.05$) as compared with T1 (54.95 cm). No significant difference ($P \geq 0.05$) was found among T2, T3 and T4 (61.55, 65.45 and 72.38 cm, respectively).

Figure 3 shows the rate of monthly rise height among treatments of coffee trees during the second year (April, 2012 to February, 2013). The increasing of trees' height dispirited from month to other in all treatment groups.

Table (4) shows the branches number of coffee trees for all experimental groups during the second year of the experiments, the gain of branches number was significantly ($P \leq 0.05$) increased at the end of the second year. The gain of branches number for T4 (29.70) was significantly elevated ($P \leq 0.05$) as compared with T1, T3 and T2 (21.90, 22.90 and 21.6, respectively). This may be due to the high dose of urea (19,6 g/tree) that affected coffee growth. No significant difference ($P \geq 0.05$) was found among T1, T3 and T2. Figure 4 represents the rate of monthly raise in branches number among the treatments of coffee trees during the second year (April, 2012 to February, 2013). The increasing of branches number dispirited from month to other in all treatment groups.
The results revealed the effect of nitrogen fertilizer on the branches number of coffee trees during 2012/2013. It showed positive effects of using urea in the vegetative growth through the elevation of branches quantity, at the end of the experiment.

The final gains both of height and branches numbers of coffee trees, are illustrated in Figures 5,6. It is appeared that there are clear differences in each of the studied characteristics.

The first productivity of coffee trees of this study is shown in Figure (7). The results are expressed as (g/tree). It is observed that the highest yield was in T3 (703.7), followed by T4, T1 and T2 (676.4, 650.7 and 641.3 g/tree, respectively) with no significant difference ($P \geq 0.05$) among all the treatments. Even at low levels, fertilization often enhances yields dramatically, although excessive fertilizer application can negatively affect crop nutrient efficiency and produce diminishing financial returns (15). In addition to diverting large amounts of carbohydrates, coffee fruits, particularly during their rapid expansion phase, may draw over 95% of the total uptake of N (14). An experiment was carried out on coffee plantations at Makerere University Agricultural Research Institute (MUARIK) to identify the most limiting nutrient(s) in order to manage fertilizer regime. Inorganic fertilizers were applied as N at a rate of 150 kg $ha^{-1}yr^{-1}$, N was the most limiting nutrient having resulted in the highest yield increase of 324 kg ha^{-1} (20). In this study, although nitrogen doses were less than that study, the productivity was better than yield obtained by Naakubuza et al (20). The use of different nitrogen levels after pruning in a coffee field grown on soils with high organic matter content and traditionally fertilized with 350 kg of N per hectare per year, did not improve yield, with or without pruning (16). In contrast with the present study, the yield of coffee tree improved in parallel with the increase of nitrogen concentration. The results of this study indicated that the yield of coffee trees gave high quantities of coffee beans production as compared with the data of all previous studies about coffee productivity in Yemen, and this may be attributed to the use of fertilizers use.

Conclusions and Recommendations

The results of the present study concluded that the use of mineral fertilizers in particular urea improved the growth of Yemeni coffee (*Coffea arabica L.*) cv. (*Tofahy*). The productivity of this coffee trees was the highest by using nitrogen fertilizer. Supplement with urea by 13 g/tree provided the highest quantity of coffee beans. Growth improvement of coffee trees synchronized with yield enhancement. Using of urea by 19.6 g/tree increased the height and branches number of coffee trees.

Based on the experimental data, it is recommended for the management of soil fertility in the coffee plantations in Yemen, especially in Ibb city, using urea fertilizer, and should give it the other nutrients. Further studies should be carried out to use a high dose of urea fertilizer on this species of coffee trees. Intensive course programs should be carried out for the Yemeni farmers to guide them about the importance of coffee fertilizing and the methods of using fertilizers.

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Table 1. Effect of nitrogen fertilizer on height (cm) of coffee trees 2011/2012

Treatment	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	**GH
T 1	52.15[a]	56.63[a]	59.4[a]	62.33[a]	63.33[a]	68.75[a]	72.03[a]	73.87	78.23[a]	85.2[a]	86.33[a]	92.8[a]	40.65[a]
T2	49.56[a]	55.38[a]	58.63[a]	61.94[a]	64.56[a]	68.31[a]	71.88[a]	74.07[a]	78.06[a]	82.06[a]	85.13[a]	90.44[a]	40.88[a]
T3	47.58[a]	49.78[a]	51.73[a]	55.73[a]	58.85[a]	63.23[a]	67.83[a]	70.15[a]	72.9a	77.08[a]	79.65[a]	86.53[a]	38.95[a]
T4	41.95	45.65[a]	51.35[a]	54.4[a]	57.48[a]	58.4[a]	65.65[a]	68.8[a]	73.78[a]	76.2[a]	77[a]	83.45[a]	41.5[a]
MSE	4.14	4.14	4.88	5.15	5.56	5.16	5.57	5.64	5.92	5.85	5.85	6.30	3.63
P	0.39	0.26	0.52	0.55	0.80	0.47	0.84	0.86	0.61	0.67	0.67	0.74	0.96

[a- c] Means values within a columns with different superscripts are significantly different ($P < 0.05$), **Gain of height= the difference between the last month, March 2012 and the first Month, April 2011

Table 2. Effect of nitrogen fertilizer on number of branches t of coffee trees 2011/2012**.**

Treatment	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	#GBN
T 1	13.6[a]	16.85[a]	18.03[a]	19.9[a]	20.73a	23.90[a]	25.65[a]	26.2[a]	27.6[a]	29.33	31.15[a]	33.83[a]	20.2[a]
T2	12.23[ab]	15.73[ab]	17.13[ab]	17.9[ab]	18.70[ab]	21.73[ab]	23.53[ab]	24.98[ab]	26.65[a]	29.15	30.35[a]	32.23[ab]	20.0[a]
T3	9.98[ab]	11.28[bc]	13.23[ab]	14.73[ab]	15.78[ab]	17.33[b]	19.28[b]	20.28[b]	23.03[a]	24.1	25.77[a]	27.50[b]	17.5[a]
T4	7.98[b]	10.03[c]	11.83[b]	11.83[b]	13.48[b]	14.83[b]	17.2[b]	19.98[ab]	20.9[a]	23.48	23.7[a]	27.68[b]	19.7[a]
MSE	1.51	1.65	1.72	1.87	1.81	1.79	1.73	1.84	2.06	1.87	2.00	1.93	1.41
P	0.09	0.03	0.07	0.11	0.14	0.51	0.07	0.10	0.24	0.09	0.23	0.09	0.53

[a- c] Means values within a columns with different superscripts are significantly different ($P < 0.05$), # gain of branch number = the difference between the last month, March 2012 and the first Month, April 2011.

Table 3. The effect of nitrogen fertilizer on height of coffee trees 2012/2013.

Treatment	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	**GH
T 1	103.1[a]	107.5[a]	116.1[a]	123.3[a]	126.4[a]	131.2[a]	134.7	138.3[a]	143.3[a]	147.3[a]	152[a]	158[a]	54.95[b]
T2	95.48[a]	104.2[a]	112.3[a]	124.6[a]	126.9[a]	130.9[a]	134.3[a]	137.8[a]	141.5[a]	147[a]	152.3[a]	157[a]	61.55[ab]
T3	95.83[a]	98.43[a]	105.1[a]	113.9[a]	114.8[a]	122[a]	127.2[a]	134.2[a]	140.3[a]	147.9[a]	154.7[a]	161.3[a]	65.45[ab]
T4	90.1[a]	94.53[a]	102.6[a]	111.4[a]	111.5[a]	120.1[a]	126.8[a]	134.3[a]	141.2[a]	148.5[a]	155.3[a]	162.5[a]	72.38[a]
MSE	7.49	7.25	7.49	7.63	7.68	8.30	7.95	7.28	18.26	6.12	5.36	4.84	3.80
P	0.69	0.60	0.57	0.54	0.47	0.70	0.83	0.96	0.63	1.00	0.96	0.83	0.044

[a- c] Means values within a columns with different superscripts are significantly different ($P < 0.05$), **gain of height= the difference between the last month, March 2013 and the first Month, April 2012

Table 4. Effect of nitrogen fertilizer on the branches number of coffee trees during

2012/2013.

Treatment	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	#GBN
T 1	35.45[a]	37.89 [a]	41.13 [a]	44.35 [a]	45.78 [a]	46.85 [a]	47.35a	49.65[ab]	48.1[a]	53.2[ab]	53.33[ab]	57.33[ab]	21.9[b]
T2	34.75[ab]	37.13[ab]	38.81[ab]	42.06[ab]	43.88[ab]	45.69 [ab]	46.98a	52.9a	50.65[a]	52.65[ab]	54.6[ab]	56.33[b]	21.6[b]
T3	29.5 b	31.65[b]	34.28 [b]	36.2 [b]	38.33 [b]	40.93 [b]	42.23a	41.53[b]	45.7[a]	48.2[b]	49.63[b]	52.4[b]	22.9[b]
T4	32.51[ab]	35.2[ab]	38.34[ab]	41.65[ab]	44.25[ab]	46.28[ab]	47.98a	47.85[ab]	52.4[a]	55.4[a]	58.75[a]	62.2[a]	29.8[a]
MSE	1.90	1.95	2.06	2.03	2.05	1.89	1.97	3.30	2.18	1.21	2.02	1.82	1.35
P	0.17	0.16	0.18	0.08	0.11	0.16	0.20	0.15	0.20	0.07	0.05	0.02	0.035

[a-c] **Means values within a columns with different superscripts are significantly different ($P < 0.05$) # gain of branch number = the difference between the last month, March 2013 and the first Month, April 2012**

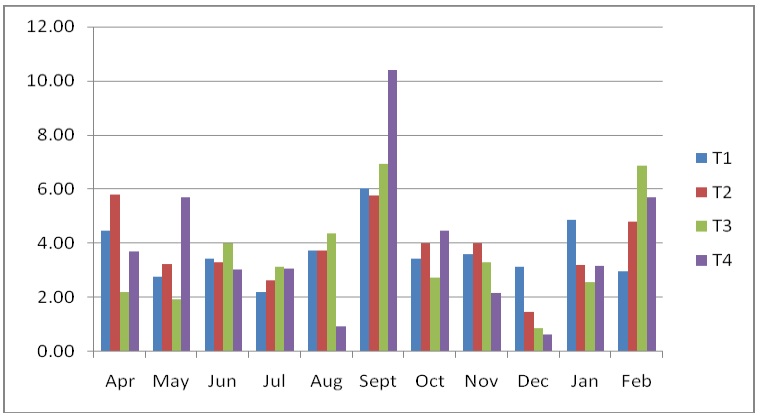

Figure 1 The monthly raise in height(cm) of coffee trees during 2011/2012.

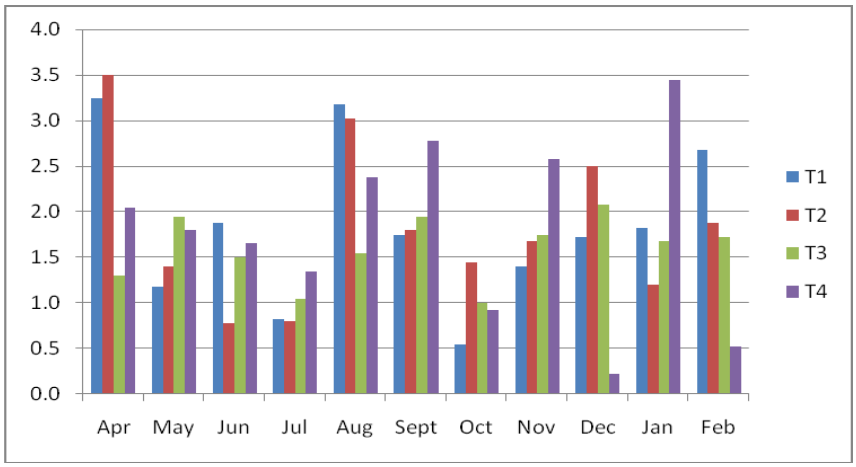

Figure 2 The rate of monthly raise in branches number of coffee trees during 2011/2012

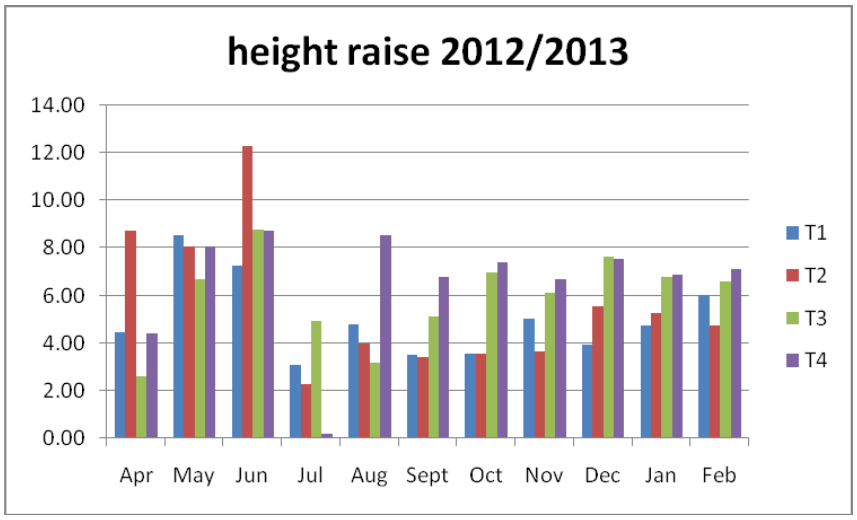

Figure 3 The rate of monthly raise in height(cm) of coffee trees during 2012/2013

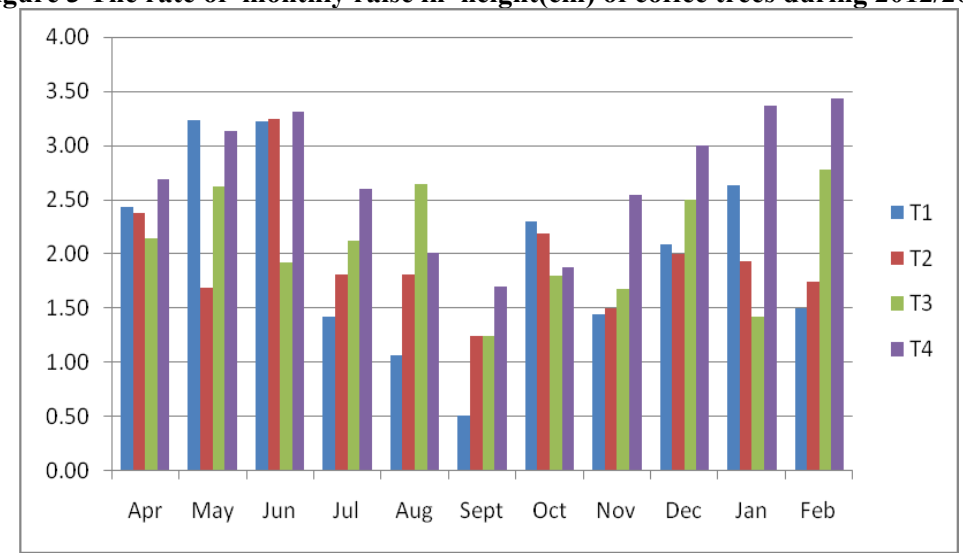

Figure 4 The rate of monthly raise in branches number of coffee trees during 2012/2013

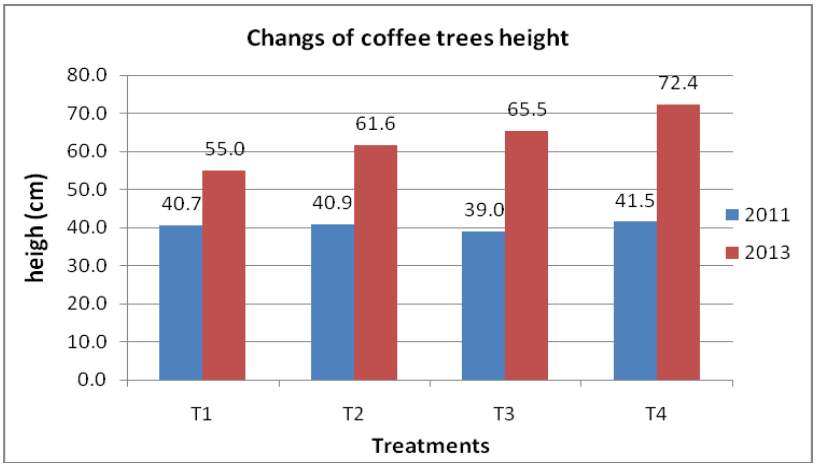

Figure 5. Changes in height of coffee trees

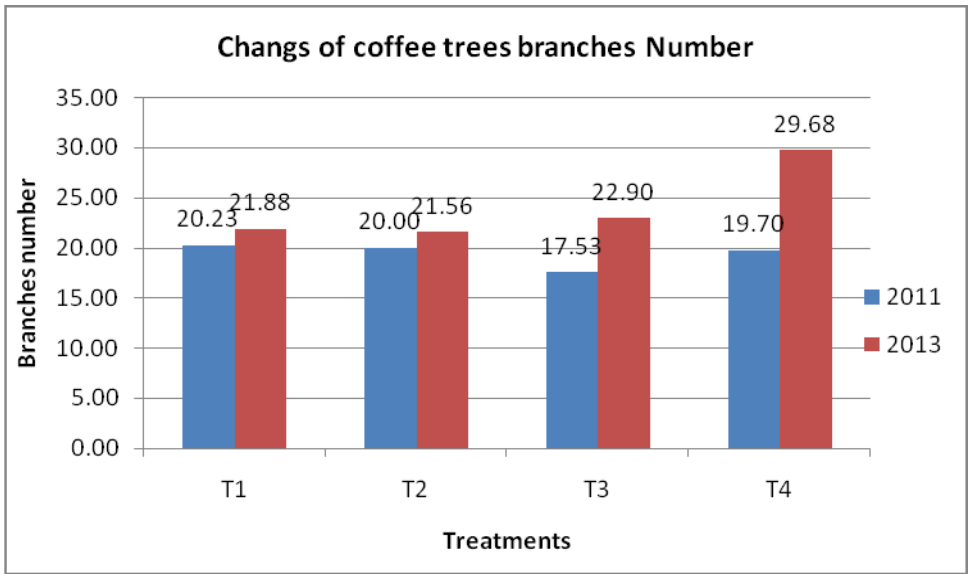

Figure 6. Changes in branches number of coffee trees

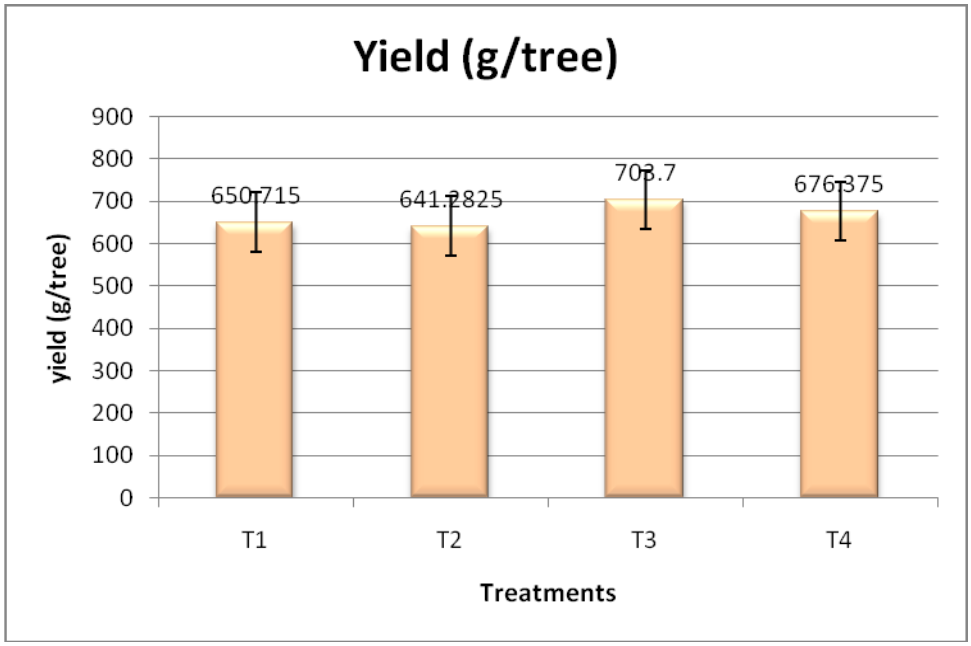

Figure 7 The yield of coffee trees 2013

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تأثير مستويات مختلفة من السماد النيتروجيني على نمو وإنتاجية أشجار البن (*Coffea arabica L.*)

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الملخص

أجريت هذه الدراسة في مزرعة التجارب في كلية الزراعة، جامعة إب. اليمن خلال الأعوام (2011-2013). هذه الدراسة تهدف إلى دراسة تأثير مستويات مختلفة من السماد النيتروجيني (يوريا) على نمو وإنتاجية أشجار البن (*Coffea arabica*)، أجريت المعاملات باستخدام 2كجم سماد عضوي كشاهد (T1) المعاملة الثانية 6 جرام \شجرة (T2)،المعاملة الثالثة 13جرام \شجرة (T3) والمعاملة الرابعة19.6 جرام \شجرة (T4) مع إضافة 5جرام\شجرة لجميع المعاملات من السماد الفوسفاتي (سوبر فوسفات ثلاثي) والبوتاسي(كبريتات البوتاسيوم) و2 كجم\ شجرة سماد عضوي متحلل ما عدا الشاهد الذي أضيف له فقط 2كجم\شجرة سماد عضوي، تم استخدام تصميم القطاعات العشوائي الكامل. وكانت مدة الدراسة سنتين، درست فيها الصفات المورفولوجية والإنتاجية لأشجار البن. و أظهرت النتائج في السنة ألأولى الزيادة في ارتفاع الأشجار كانت في T4 و T2. وبالنسبة للزيادة في عدد الفروع، كان هناك ارتفاع في كل المعاملات، ولكن لا توجد فروق معنوية بين المعاملات. وفي السنة الثانية، الزيادة في الارتفاع ارتفع بشكل زائد في T4 (72.38) تلتها كلا منT3 و T2 بزيادة 65.45 و 61.55 سم على التوالي، بالمقارنة مع .T1 54.95 سم. ظهرت فروق معنوية في الارتفاع عند ($p\leq 0.05$) بين T4 و T1. الزيادة في عدد الفروع كانت مرتفعة معنويا لدى T4 (25.8) بالمقارنة مع T1 و T3 و T2 (20.9 و19.9 و 19.6 على التوالي). إنتاجية البن كانت الأعلى لدى المعاملة T3 (703.3) يليها T4 (676.4).

الكلمات المفتاحية: اليمن ، *Coffea arabica* L، الأسمدة النيتروجينية, النمو، الحاصل.