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GROWTH ANALYSIS OF AGAR PLANTS AT DIFFERENT AGES AND CHARACTERISTICS OF PLANTATION GARDEN SOIL

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Abstract

The experiment was carried out from April to September 2018 in Sujanagar village in Barlekha upazila of Moulvibazar district to observe the growth and biomass of the agar plants ranging from 1 to 15 years of age and soils characteristics of the plantation areas. Fifteen agar gardens were selected, and data were collected from 20 sample plants from each garden on growth, biomass, and soil nutrients. The plant height from bottom to top ranged from 1.11 m to 10.21 m, while it was 0.57 m to 4.80 m for the bottom to collar region height. The measured plant circumference ranges from 2.64 to 56.97 cm at the base (20 cm above ground level) and 1.59 to 32.27 cm at the collar region. The trend was similar for plant diameter, which ranges from 0.90 to 14.23 cm at the base and 0.53 to 9.14 cm at the collar region. The diameter at breast height ranges from 1.42 cm in to 12.32 cm in a 15 years old plants. From a 3 years old plants 3 years old plants to 15 years old plants, the estimated biomass ranges from 16 to 44 kg plant^{-1}. The plant height, branches, circumference, and biomass were found to increase in early-aged plants but became slow after eight (08) years. The pH of the soil was acidic (pH value ranging from 4.1 to 4.8), with organic matter ranging from 1.0 to 3.0% and N (%) from 0.09 to 0.15%. Available phosphorus and sulfur were found to be below the critical levels, with phosphorus ranging from 2.0 to 10.0 ppm and available sulfur ranging from 3.0 to 9.0 ppm. In the plantations, the exchangeable potassium ranged between 0.10 and 0.25 meq/ 100g soil. The nutrient availability was found to be very low, which limits biomass production.

Keywords: *Aquilaria malaccensis*, Agar, Growth analysis, Plant age, Biomass.

Introduction

Agarwood (*Aquilaria malaccensis* Lam.), Family Thymelaeaceae, is one of the 13 accepted species names of Aquilaria reported as a fragrant resin producer (Lee and Mohammed 2016). *Aquilaria* and *Gyrinops* tree species produce the sticky wood known as agarwood, which is highly regarded as a premium raw material used in perfumes and traditional remedies. Agarwood is highly valued for its medicinal, incense, and perfumery properties. The agarwood plant is a sizable evergreen tree that grows to a height of 20 meters, girths out to 1.5 to 2.4 meters, and has a relatively straight and fluted bole. Alternate, white, 0.5−10 cm by 2−5 cm, oblong-elliptic, caudate-acuminate leaves. Flowers come in auxiliary and terminal umbellate sizes, are pedicellate, and are bisexual. Pedicels are thin and 0.5−0.8 cm long. Perianth is 1.3−1.5 cm long and persistent in fruit, ten stamens, ten anthers with sub-sessile disks, a sub-sessile ovary, and a big sub-sessile stigma is present. The fruit is 3-5 cm long, oval, and has an ovoid pericarp and seeds. Generally, it is propagated by seed .It naturally occurs in 12 countries in southeast Asia, including Bangladesh, Bhutan, Cambodia, India, Indonesia, Lao PRD, Malaysia, Myanmar, Philippines, Thailand, Vietnam, and Papua New Guinea (Zich and Compton, 2001; Tabin and Shrivastava 2014).

Agar trees thrive in high to medium-elevation, well-drained terrain with wet, shaded circumstances. They grow best in tropical sand hills and mountains in monsoon regions with 2,000 millimeters of yearly rainfall. It may also thrive in arid, sandy soil and can withstand both cold and heat. *A. malaccensis*, which grows to about 40 m, is evergreen tropical species (Talucder et al., 2016; Hye et al., 2021).

Identifying the small percentage of trees that have agar is difficult and harmful, which contributed significantly to the near-extinction of natural tree stands (Blanchette, 2006). Aquilaria trees are located in forested places, although many of those areas have been destroyed by extensive logging. Consequently, the naturally occurring old-growth Aquilaria trees, the current supply of agarwood, are disappearing (Hansen, 2000).

In Bangladesh, *Aquillaria malaccensis* are grown in massive amounts in Sylhet and Chittagong divisions. Agar has never been widely cultivated commercially. Agarwood plantations on a smaller scale and owned by individuals have also been mentioned in reports from Sylhet, Habiganj, and the Chittagong Hill Tracts.

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Agar's biochemistry is known to alter in response to a number of conditions. As a result, agar yield and quality are closely related to season (Price and Bielig, 1992; Chirapart and Ohno, 1993), environmental factors (Hurtado-Ponce, 1994), growth (Christiaen et al., 1987), reproductive cycle (Soriano et al., 1998), and the plant part of an agar tree. They also depend on the agar's unique characteristics. *Agarophytes* were discovered to display seasonal changes in biomass and agar output, though not necessarily in the same way. There is scanty information on agar growth and development and biomass estimation at different plants age and the soil characteristics of agar gardens. Hence, with the view of keeping this in mind, the experiment was conducted to observe the growth and development of the agar plant in various age groups and to observe the agar plant's biomass distribution throughout several age groups.

Materials and Methods

The study site was conducted at Sujanagar village of Barlekha upazila of Moulvibazar district and carried out from April to September 2018. To gather data on growth and biomass estimation, fifteen (15) existing agar garden sites with agar plants that range in age from one to fifteen (15) years) were chosen from the logs. Twenty plants from each garden were chosen for data collection, and each plant was treated as a replication.

Using a measuring tape, the heights of each plant under various ages were estimated from the ground to the up and from the ground to the point of the collar. The measurement was made in meters (m). Using a measuring tape, the diameter and circumference of each agar plant were measured at the base (20 cm above the ground), breast height (1.37 m above the ground), and middle, and collar regions. Although the plant was shorter than 1.37 meters (breast height) up until two years of age, the breast height was measured from the plant's ages of three (03) to fifteen (15) years. Each garden's total number of primary branches under each age category of plants was also counted.

The above-ground portion of the agar tree's biomass was estimated using a nondestructive method. Live tree biomass is typically broken down into main parts: root biomass, foliage biomass, branches/top biomass, and marketable biomass of stem (also known as biomass of bole, which includes both wood and bark). We concentrate on measuring the biomass of live trees above ground, including the stump, stem, branch, and summit. For calculating Agar tree biomass, the following models were used:

i. $TSV = (10-2.615591 + 1.847504) * \{\log(DBH) + 1.085772 \times \log(HT)\}$ (Bracket 1977)

ii. $BOLE = TSV * WD$ (Xiaoping and Hemstrom, 2009)

iii. $BRK = (3.20 + 9.10) * (DBH\_cm/100)^2 * TH\_m$ (Standish 1985)

iv. $BCH = (7.80 + 12.30) * (DBH\_cm/100)^2 * TH\_m$ (Standish 1985)

v. $TAB = BOLE + BRK + BCH$ (Xiaoping and Hemstrom, 2009)

Total stem volume from root to tip is known as TSV (feet^3). Wood density is termed as WD (kgft^{-3}). Bole biomass or BOLE (kg). Bark biomass is BRK (kg). Biomass of branch is termed as BCH in kilogram. Total above-ground biomass, excluding foliage, is termed TAB in kilograms. Breast height diameter is termed as DBH in inches. TH is the overall height from the bottom to the top in feet. DBH_cm is the diameter at breast height in centimeters. TH_m is the total height from the bottom to the top in meters. The base10 logarithmic function is called log.

After estimating each plant's biomass, the biomass was transformed by multiplying the number of agar plants on a per-ha basis. Samples of soil were taken from the plough depth layer (0-15 cm). To create a composite sample, the materials were carefully mixed after being collected using an auger from ten separate places throughout the whole experimental site. For physical and chemical analyses, the composite sample was air dried, ground, sieved through a 20-mesh sieve, and stored in a plastic bag. A glass electrode pH meter was used to measure the pH of the soil using a 1:2.5 soil water solution. Wet oxidation was used to determine the volumetric amount of organic carbon, and the OM content was computed by multiplying that amount by the 1.73 Van Bemmelen ratios. The Micro-Kjeldahl technique was used to determine the total nitrogen content of the soil. The Olsen method was used to extract the soil's available phosphorus by shaking 0.5 M $NaHCO_3$ solutions at a pH of 8.5. Potassium was calculated from the extricated Flame Photometer and calibrated with a standard Potassium curve. Exchangeable Potassium was extricated with 1 N NH_4OAc (pH 7.0). The amount of available sulfur was determined by using CaCl2 solution (0.15%) to extract the soil samples. A spectrophotometer was used to quantify the S concentration of the extract turbidimetrically.

Results and Discussion

Agar plant height

Plant height from ground to top was ranged from 1.11 m of 1 year old plants to 10.21 m of 15 years old plants. Increase of plant height per year ranged from 1.0 m in 13th year to 4.8 m in 15th year. However, the increase was not consistent every year. At collar region the heigh ranged from 0.57 m in 1st year to 4.8 m in 15 years. The increasing trend was also inconsistent in this regard. The number of branches per plant ranged from 4.95 to 22.55 which were also inconsistent for increasing per year (Table 1).

Plant heights of agar plants at different positions were increased with the age of the plantation. The plants showed the increment of height at a very fast rate up to 6 years for measurement regarding every position. But after the ages of 6 or 7 years the height of the plantation increases but at low pace. Although the agar plant was found to be increasing at its height every year, the percentage of the growth rate at each year based on previous year shows a declining trend (Figure 1). The growth rate of the Agarwood plant was reported as slow in Malayasia (Rini et. al., 2020). Hossen & Hossain (2016) reported a mean annual increment in height of 0.92 m/year at Barlekha of Bangladesh, and both studies corroborate the findings supported by the current study.

Table 1. Plant height and number of branches of agar plants at various ages of agar plant

Age of plant (years)	Plant height (m)						Primary branches/plant	
	Ground to top			Increase/ year	Ground to collar region	Increase/ year	No.	Increase/ year
1	1.11				0.57		4.95	
2	1.65			0.54	0.87	0.3	6.85	1.9
3	2.48			0.83	1.30	0.43	10.35	3.5
4	3.19			0.71	1.47	0.17	11.95	1.6
5	3.69			0.5	1.71	0.24	14.50	2.55
6	4.25			0.56	1.92	0.21	15.20	0.7
7	4.74			0.49	2.19	0.27	16.15	0.95
8	5.19			0.45	2.49	0.3	17.10	0.95
9	6.12			0.93	2.81	0.32	18.60	1.5
10	6.73			0.61	3.17	0.36	19.60	1
11	7.36			0.63	3.68	0.51	19.95	0.35
12	8.15			0.79	4.11	0.43	20.60	0.65
13	9.15			1	4.46	0.35	21.55	0.95
14	9.85			0.7	4.64	0.18	22.03	0.48
15	10.21	0.36	4.80	0.16	22.55	0.52		

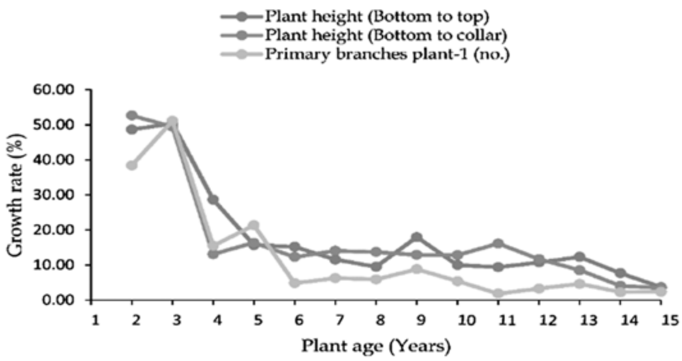

Figure 1: Percent growth rate of agar plant at different ages.

Plant circumference

The agar plant circumference was measured at the ground or base, height at the breast, mid and collar region. The plant circumference at base was ranged from 2.64 cm in first year to 56.97 cm in 15 years old plant and the increase per year was ranged from 1.64 cm in 1 year old pant to 5.30 cm in 15 years old plants and the increasing trend was inconsistence with increasing the age of the plants. The plant circumference at breast height ranged from 4.51 cm to 43.99 in 1st year to 15th year old plants. The circumference at mid and collar region ranged from 1.99 and 1.59 cm to 56.97 cm and 32.27 cm respectively. In these cases, the increasing trend was also inconsistent with increasing the plant's age (Table 2). The estimation of the percent increase of circumference at each year between circumferences at each point was highest at the early growth stages of the Plants. Still, the increasing rate decreases sharply up to 8 years. After that age, the circumference was increasing for each year interval but at a lower rate (Figure 2).

Table 2: Circumference of agar plant at various positions under various age groups.

Agar plants age	Circumference (cm) at							
	Base	Increase year^{-1}	Breast height	Increase year^{-1}	Mid region	Increase year^{-1}	Collar region	Increase year^{-1}
1	2.64	-	-	-	1.99	-	1.59	-
2	4.28	1.64	-	-	3.19	1.20	3.01	1.42
3	8.53	4.25	4.51	-	5.83	2.64	5.04	2.03
4	12.11	3.58	8.71	4.20	9.3	3.47	7.35	2.31
5	16.69	4.58	13.44	4.73	14.43	5.13	10.56	3.21
6	21.53	4.86	15.45	2.01	20.43	6.00	15.26	4.70
7	27.37	5.84	17.81	2.36	26.37	5.94	16.49	1.23
8	28.40	1.03	20.25	2.44	29.40	3.03	18.17	1.68
9	30.90	2.50	23.05	2.80	30.90	1.50	19.65	1.48
10	35.97	5.07	25.59	2.54	34.97	4.07	21.62	1.97
11	40.20	4.23	28.38	2.79	40.20	5.23	23.35	1.73
12	41.98	1.78	30.92	2.54	41.98	1.78	24.78	1.43
13	47.20	5.22	35.55	4.63	47.20	5.22	26.55	1.77
14	51.67	4.47	38.87	3.32	51.67	4.47	28.5	1.95
15	56.97	5.30	43.99	5.12	56.97	5.30	32.27	3.77

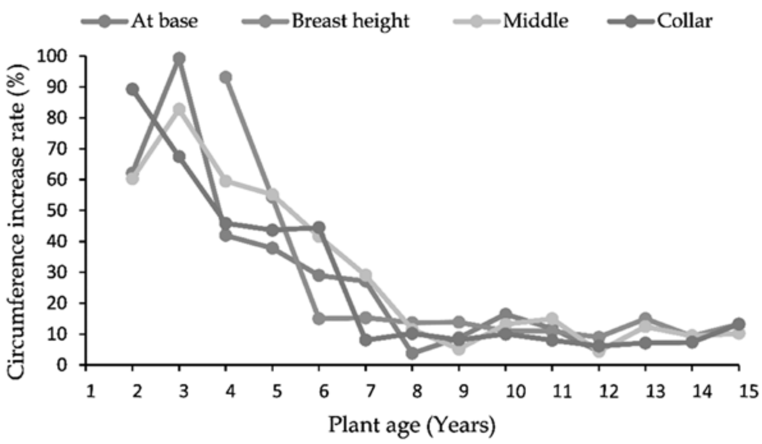

Figure 2. Circumference increase rate of agar plant at different heights at different age intervals

Plant diameter

Diameter at the base (from soil level to 20 cm height), breast height, middle and collar level were measured. Similarly, with increasing plants age, diameter of a plant at its base, breast height and collar region showed a growing tendency

(Table 3). The calculated percent of diameter increment for different years showed a higher increment rate of diameter at an early stage of the plantation, which diminished with the aging of the plantation (Figure 3).

Table 3. Diameter of agar plants at various positions under various age groups

Agar plants age (years)	Diameter (cm) at							
	Base (20 cm from bottom)	Increase Year^{-1}	Breast height	Increase Year^{-1}	Mid region	Increase Year^{-1}	Collar region	Increase Year^{-1}
1	0.90		-	-	0.68	-	0.53	-
2	1.34	0.44	-	-	1.03	0.35	0.86	0.33
3	2.21	0.87	1.42	-	1.45	0.42	1.43	0.57
4	3.27	1.06	2.61	1.19	2.4	0.95	2.61	1.18
5	5.02	1.75	4.41	1.8	3.27	0.87	3.19	0.58
6	6.98	1.96	5.24	0.83	4.49	1.22	3.73	0.54
7	8.38	1.4	5.78	0.54	5.57	1.08	4.51	0.78
8	8.94	0.56	6.61	0.83	6.56	0.99	5.18	0.67
9	9.47	0.53	6.96	0.35	6.86	0.3	6.06	0.88
10	10.32	0.85	7.66	0.7	7.51	0.65	6.82	0.76
11	11.27	0.95	8.70	1.04	8.26	0.75	7.12	0.3
12	11.74	0.47	9.17	0.47	8.79	0.53	7.51	0.39
13	12.77	1.03	10.32	1.15	9.65	0.86	8.01	0.5
14	13.94	1.17	11.19	0.87	10.42	0.77	8.43	0.42
15	14.23	0.29	12.32	1.13	11.41	0.99	9.14	0.71

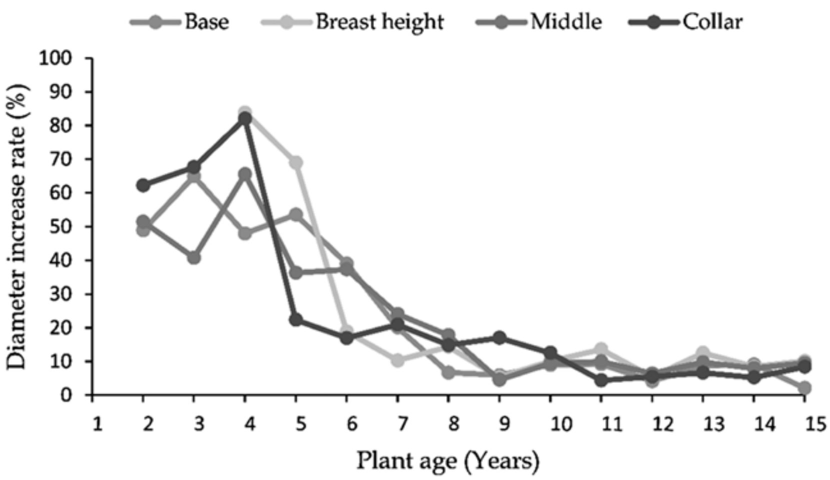

Figure 3. Diameter increment rate of agar plant at different heights at different age of plants

Plant biomass

Between the ages of three and fifteen years, the biomass of agar plants was estimated and presented in table 4. The estimated biomass of agar plants increased with increases of plants age which was faster at early stage that is up to six years of plants age but after that it showed a slower growth rate.

Table 4. Agar plants' biomass production assessment among age groups

Agar plants age	Plant biomass (kg $plant^{-1}$)	Increase/ year	Biomass of agar (t ha^{-1})	Increase/ year
03	15.8	-	39.5	-
04	20.8	5.0	52.1	12.6
05	24.8	4.0	61.9	9.8
06	28.2	3.4	70.5	8.6
07	30.5	2.3	76.2	5.7
08	32.3	1.8	80.8	4.6
09	34.2	1.9	85.5	4.7
10	36.2	2.0	90.5	5.0
11	37.7	1.5	94.2	3.7
12	39.0	1.3	97.6	3.4
13	40.7	1.7	101.8	4.2
14	42.6	1.9	106.4	5.6
15	44.2	1.6	110.6	4.2

The estimated result of the percent of biomass increment showed a similar trend of increment aligned with other growth data The increment rate of biomass production decreased with increasing of plant age sharply from early stage up to 6 years of plant age and after that the increment rate was at lower pace (Figure 4).

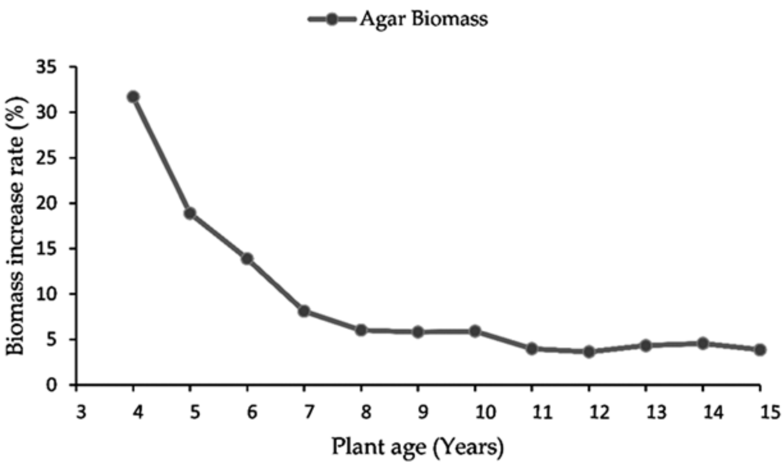

Figure 4. Biomass increment rate of agar plant at different age of plants

Soil nutrient status in agar plantation

Under the Barlekha upazila, the soil nutrient quality of various aged (1–15 years) agar plantations was examined and the data were presented in table 5 and figure 5-10. The data revealed that the soil characteristics varied in different soils of different aged agar garden of which pH ranged from 4.1 to 4.8 (Figure 5) Organic matter percentage ranged from 1.15 to 3.0 (Figure 6), total nitrogen percentage 0.09 to 0.15 (Figure 7), available phosphorus 2.0 to 10.0 ppm (Figure 8), potassium 0.10 to 0.25 meq/100 gm (Figure 9) and available sulfur 3.0-9.0 ppm (Figure 10).

Table 5. Soil chemical composition under various aged agar plantations in Barlekha Upazila

Agar garden's age	Soil pH	Organic Matter (%)	Total Nitrogen (%)	Available Phosphorus in ppm	Potassium in meq /100 g	Available Sulphur in ppm
01	4.70	2.95	0.140	7.0	0.230	8.0
02	4.50	2.36	0.120	6.0	0.200	4.0
03	4.20	2.04	0.110	5.0	0.210	5.0
04	4.60	3.00	0.150	8.0	0.180	7.0
05	4.10	1.15	0.090	2.0	0.100	4.0
06	4.30	1.44	0.100	3.0	0.110	3.0
07	4.80	2.80	0.150	10.0	0.250	6.0
08	4.30	2.61	0.140	8.0	0.220	4.0
09	4.50	2.42	0.130	7.0	0.190	8.0
10	4.40	2.15	0.120	6.0	0.160	7.0
11	4.20	2.27	0.120	7.0	0.170	9.0
12	4.50	2.01	0.110	5.0	0.150	8.0
13	4.60	2.58	0.130	7.0	0.160	5.0
14	4.30	2.71	0.140	9.0	0.120	8.0
15	4.40	2.87	0.140	8.0	0.160	9.0

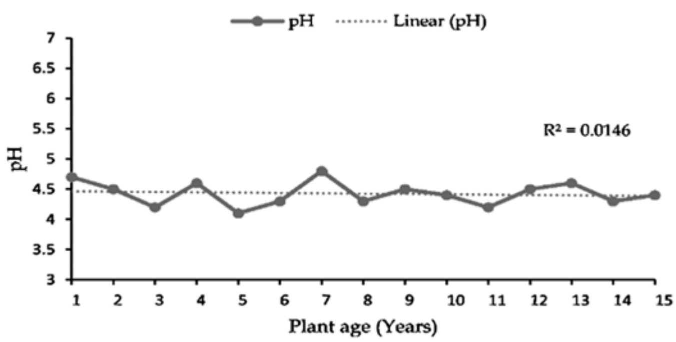

Figure 5. The trend of pH value in different aged agar plantations

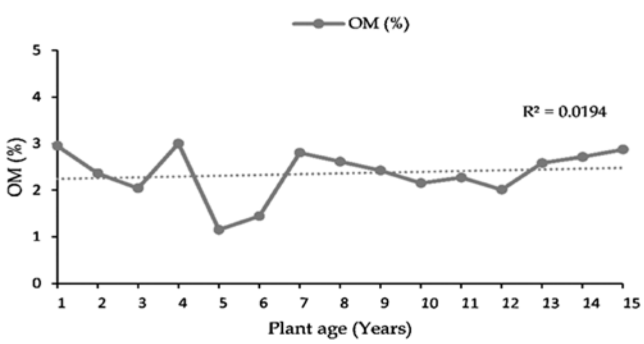

Figure 6. The trend of OM(%) in different aged agar plantations

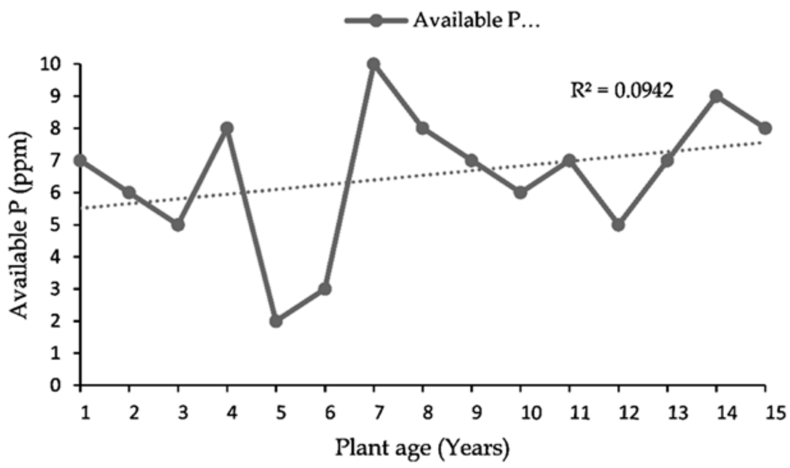

Figure 7. The trend of total P value in different aged agar plantation

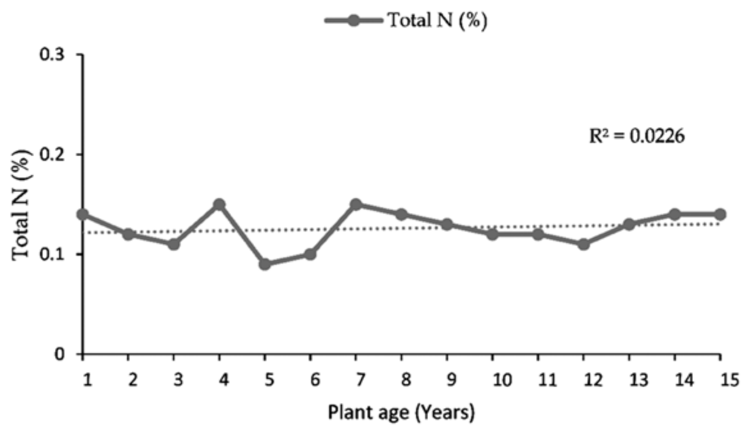

Figure 8. The trend of total N value in different aged agar plantation ranges

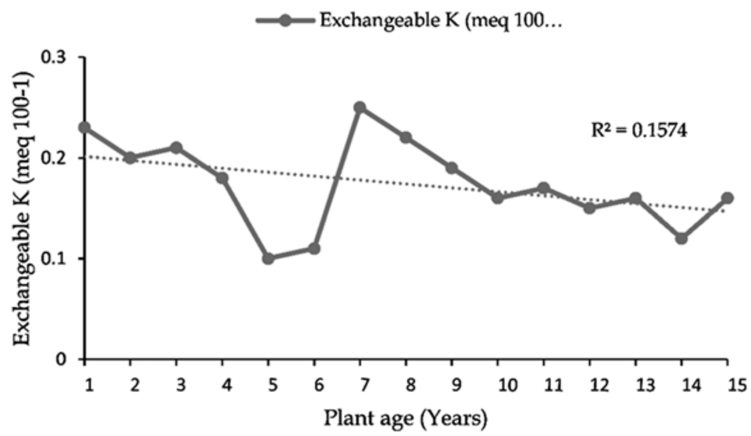

Figure 9. The trend of exchangeable K value in different aged agar plantations

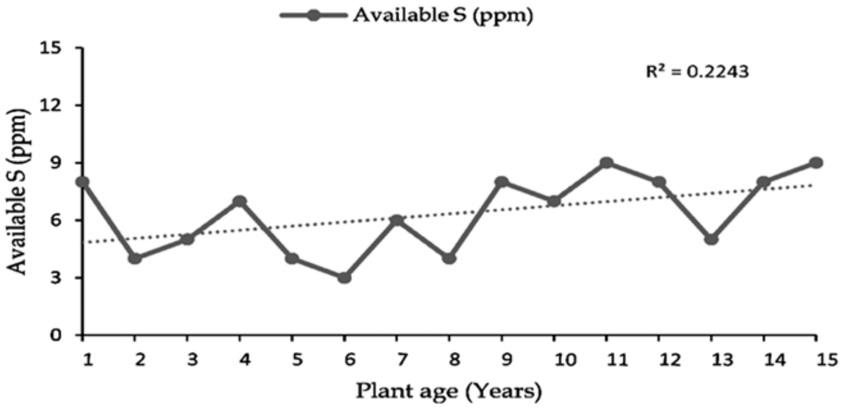

Figure 10. The trend of available S value in different aged agar plantations

Conclusion

The experiment's findings demonstrated that as a plantation gets older, it grows larger in terms of height, girth, and diameter, as well as the number of branches. The increment varies between 15 to 20 folds in general in 15 years compared to the first year of age. However, this growth is not linear i.e., the rate of increment was very high at the early age of plantation, which decreases with the aging till 7 to 8 years. Afterward the growth increases at a lower but constant rate. The biomass of the plants follows a similar trend i.e., the increment rate was higher at the initial stage but drops till 7 to 8 years and then increases at a lower but stable rate. Compared to a 3-year stand, the biomass of a 15-year stand increased by three times to 44.2 kg/plant and 110.6 t/ha.

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