The Pharma Innovation Journal 2023; SP-12(7): 2045-2048

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(7): 2045-2048

www.thepharmajournal.com
Received: 07-04-2023
Accepted: 18-05-2023

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Development of volumetric equation for medicinally important timber yielding tree species *Gmelina arborea* Roxb.

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Abstract
The present trial was carried out in the Navsari Agricultural University, Navsari, Gujarat during 2022-23 to develop volumetric equation of *Gmelina arborea*. For the trial, two hundred twenty-five number of sample trees were selected randomly which were categorised into diameter class wise to develop the volumetric equation with the measured tree parameters. The biometrical parameters of *G. arborea* such as DBH, mid diameter, height, form quotient and stem volume varied in the range of 8.40- 39.24 cm, 7.63-18.48 cm, 6.70-14.43 m, 0.47- 0.91and 0.036-0.835 m^3 respectively in the diameter class of 5-10 cm to 35-40 cm. Among all the linear regression equations developed, equation $V = 0.00004D^2H + 0.043$ having maximum R^2 value of 0.881 was found best. Further, for quick estimation of volume standing *G. arborea* trees, this equation can be useful for farmers, foresters and wood merchants.

Keywords: Diameter, *Gmelina arborea*, stem volume, tree parameters, tree height, volumetric equation

Introduction

Gmelina arborea, commonly known as Gmelina or Gamhar, is an indigenous fast growing and economically important tree species found in various parts of India. *G. arborea* is native to Southeast Asia and is widely distributed in countries like India, Bangladesh, Nepal, Myanmar and Sri Lanka. In India this species found in different regions including the central Himalayan region, Gangetic plains and other parts of North and South India (Chaturvedi *et al.*, 2012; Luna, 2005) [7, 11].

It is moderate to large deciduous tree with a straight trunk and wide spreading leaves (Kumar *et al*., 2003) [10]. It has numerous branches forming a large shady crown, attains a height of 12-30 m or more and 60-100 cm in diameter (Luna, 2005) [11]. *G. arborea* is well suited to a range of climatic conditions and can tolerate diverse soil types. It grows on various soils such as acidic, laterites and calcareous loams, doing poorly on thin or poor soils with hardpan, dry sands, or heavily leached acidic soils, well drained basic alluviums, but it prefers well drained soils with a pH range of 6-7.5 (Chaturvedi *et al.*, 2012; Kumar *et al*., 2003) [7, 10]. It thrives in tropical and subtropical climate up to 1200 m elevation and with an optimal average annual rainfall of 900-2500 mm. *G. arborea* has also shown resilience to drought conditions, making it suitable for areas with water scarcity (Sharma *et al.*, 2016; Luna, 2005) [6, 18, 11].

G. arborea has gained significant attention and popularity due to its multiple uses and economic value. It has a wide range of applications in various industries, including timber, furniture, agroforestry, medicinal products and paper production. It is used in the construction of furniture, doors, window frames, musical instruments, and decorative veneers (Srivastava and Chaturvedi, 2014; Luna, 2005) [23, 11]. In addition, *G. arborea* has been utilized in traditional medicine systems for its various medicinal properties and biological activities including antidiuretic, anti-diarrhoeal, anti-pyretic, anti-analgesic, anti-oxidant, anti-diabetic, anti-helminthic, anti-bacterial, anti-fungal, cardio protective, insecticidal, anti-ulcer, gastro-protective, anti-cancer, anti-hyperlipidaemic and immunomodulatory activity. It has been reported for its applications in treatment of bone fracture, hypertension and regeneration of B-cells. The main chemical constituents of *G. arborea* include Lignans, iridoid glycoside, flavonoids, flavones, flavone glycoside and sterols (Arora and Tamrakar, 2017) [3]. Different parts of the tree, including the leaves, barks and roots, are used to treat ailments such as fever, inflammation, wounds and digestive disorders (Chaturvedi *et al.*, 2012) [7].

Efficient management and utilization of *G. arborea* requires accurate estimation of its volume and biomass. The forest estate lacks baseline data on estimate of growing stock of forest resources. For timber productions, an estimate of growing stock is often expressed in form of timber volume, which can be estimated from easily measurable tree dimensions (Akindele and Le May, 2006) [1]. Volumetric equations play a crucial role in estimating the volume of standing trees and timber, which are essential for forest inventory, growth modelling and sustainable management practices. For volume estimation of standing trees, mathematical models developed through multiple regression analyses are found most convenient as felling of trees is avoided (Pandey *et al.*, 1998) [14]. Volumetric equations establish relationships between easily measurable variables, such as diameter at breast height (DBH) and height, with the volume of the tree. They provide a standardized approach for estimating the volume of individual trees and stands, aiding in decision making processes related to harvesting, transportation and utilization of timber resources. Regression models have been most widely used for estimating tree volume. A good model should provide information that is sufficiently precise and comprehensive to execute the intended purpose in a simple manner, be easily understood and also helpful for drawing inferences and regression models have served these purposes (Giri *et al*., 2019) [9].

Indian researchers and foresters have recognized the significance of developing specific volumetric equations for different tree species by conducting studies focused on these species. Therefore, with these views or ideas, the present study was carried out in local level basis having the objective to develop the volumetric equation for *Gmelina arborea.*

Materials and Methods

The present study was carried out in Navsari Agricultural University campus, Navsari, Gujarat, India during 2022-23, India. In order to develop volumetric equation, 225 trees located in the conventional block plantation, boundary plantation and scattered conditions were selected. Further, G. *arborea* trees belonged to different diameter classes D1: 5-10 cm, D1: 10-15 cm, D3: 15-20 cm, D4: 20-25 cm, D5: 25-30 cm, D6: 30-35 cm and D7: 35-40 cm was considered and various biometric parameters such as DBH (cm), Mid-diameter (cm) and tree height (m) were recorded. Further, using these data, Form Quotient and Volume (m^3) of standing trees were estimated (Behera *et al.*, 2022) [5]. After compiling all the database and arrangement, data were subjected to statistical analysis and volumetric equation was developed using regression equation following standard method.

Results and Discussion

In the present study, trees of *G. arborea* with DBH ranged from 5 to 40 cm were used for estimation of volume. Total 7 diameter classes *viz.* D1: 5-10 cm, D2: 10-15 cm, D3: 15-20 cm, D4: 20-25 cm, D5: 25-30 cm, D6: 30-35 cm, D7: 35-40 cm and D7: 40-45 cm was made. The biometrical parameters of *G. arborea* such as DBH, mid diameter, height, form quotient and stem volume varied in the range of 8.40-39.24 cm, 7.63-18.48 cm, 6.70-14.43 m, 0.47-0.91and 0.036-0.835 m^3 respectively in the diameter class of 5-10 cm to 35-40 cm (Table 1). Linear regression equations were developed by considering stem volume (V) as dependent variable and other parameters such as D (Diameter at Breast Height), H (Height), D^2, H^2, D^2H and DH^2 as independent variables (Table 2). The various linear equations developed such as- V=0.0269x - 0.2766 (V & D relationship, R^2=0.722); V=0.0545x - 0.3469 (V & H relationship, R^2= 0.533); V= 0.0006x + 0.0037 (V & D^2 relationship, R^2=0.743); V=0.0023x - 0.036 (V & H^2 relationship, R^2=0.560); V=4E-5x + 0.043 (V & D^2H relationship, R^2=0.882) and V=8E-05x + 0.016 (V & DH^2 relationship, R^2= 0.857). The R^2value varied in the range of 0.560 to 0.882 for all the relations. Considering the maximum R^2 value of volume and D^2H index relationship (R^2=0.882), the linear regression equation, V= 4E-05x+0.043 (R^2 = 0.882), can be simplified as- V= $0.00004D^2H + 0.043$ where, D (DBH in cm) and H (Height in m) was found best. Moreover, this equation can be adopted for volume estimation of G. *arborea* trees (Figure 1).

The development of good regression equations depends upon the correct selection of sample trees, their correct proportion in different diameter class along with accurate measurement of biometrical parameters and less variation among values within a group of diameter class (Behera *et al.*, 2019) [4]. Various authors developed site specific volumetric equation for *G. arborea* by using diameter, height as variable such as Oyebade *et al*. (2020) [13]; Paul *et al*. (2019) [15]; Das *et al*. (2017) [8]; Bharali *et al.* (2016) [6]; Prasad and Das (2016) [16]; Singh *et al*. (2014) [21]; Singh *et al.* (2013) [20]; Tewari and Singh (2005) [25]; Singh (1995) [19]. Moreover, Saha *et al.* (2019) [17] developed volumetric models in *G. arborea*, $V_1 = 0.12500- 2.40265D + 21.43248D^2$ was found to be the best using single independent variable (D), while $V_2 = 0.03177 + 1.032D^2H$ was the best model using D and H as independent variables; whereas volumetric equations *i.e.* total volume over bark, V=0.24950005+ 0.000018027(DBH^2ht) and V= 0.000537511($DBH^{0.943497899}ht^{1.229083295}$) were developed by Mattia and Dugba (2015) [12] in *G. arborea*, Similarly, Akinnifesi and Akinsanmi (1995) [2] developed equation, V = $0.0206 + 0.00004D^2H$ having higher R^2 value of 0.975 in *G. arborea*. Authors also developed volumetric equation in other tree species such as in *Eucalyptus tereticornis* having equation V=0.0003+0.7842 D^2H; R^2= 0.96) by Kumar *et al.* (2003) [10]; similarly, Tewari and Singh (2018) [24] in *Tectona grandis* developed equation $V_{ob}=0.000055*D^{2.775723}$ (R^2 =0.906). Moreover, Behera *et al.* (2019) [4] developed volumetric equation *i.e.* V = $0.00004D^2H + 0.014$ (R^2 =0.908) for *Tectona grandis* and moreover, developed volumetric equation, $V=0.0621+0.000037D^2H-0.0003D^2+0.0009DH-0.0104H$ (R^2 = 0.951) in *Eucalyptus* spp. by Behera *et al*. (2022) [5] in South Gujarat condition.

Table 1: Biometric parameters of standing trees of across *Gmelina arborea* different diameter classes

Diameter class (cm)	DBH (cm)	Mid diameter (cm)	Height (m)	FQ	Stem Volume (m^3)
5-10	8.40 ± 1.07	7.63 ± 1.19	6.70 ± 1.20	0.91 ± 0.03	0.036 ± 0.013
10-15	13.32 ± 1.26	10.24 ± 1.42	9.80 ± 1.71	0.77 ± 0.09	0.107 ± 0.034
15-20	17.49 ± 1.37	12.33 ± 2.25	11.30 ± 2.34	0.71 ± 0.12	0.193 ± 0.063
20-25	22.57 ± 1.25	13.97 ± 2.66	11.99 ± 2.37	0.62 ± 0.11	0.299 ± 0.092
25-30	27.26 ± 1.49	15.81 ± 3.19	12.65 ± 2.56	0.58 ± 0.11	0.433 ± 0.146
30-35	31.81 ± 1.32	17.62 ± 3.37	14.88 ± 1.90	0.56 ± 0.11	0.663 ± 0.179
35-40	39.24 ± 0.81	18.48 ± 3.61	14.43 ± 1.31	0.47 ± 0.08	0.835 ± 0.247

Table 2: Various volumetric equations developed in *G. arborea*

Regression equation developed between variable(s)	Regression equation and R^2 value
Vol-DBH	Y=0.0269x-0.276, R^2 = 0.722
Vol-H	Y=0.0545x-0.346, R^2 = 0.533
Vol-DBH^2	Y=0.0006x+0.003, R^2 = 0.743
Vol-H^2	Y=0.0023x-0.036, R^2 = 0.560
Vol-D^2H	Y=4E-05x+0.043, R^2 = 0.882
Vol-DH^2	Y=8E-05x+0.016, R^2 = 0.857

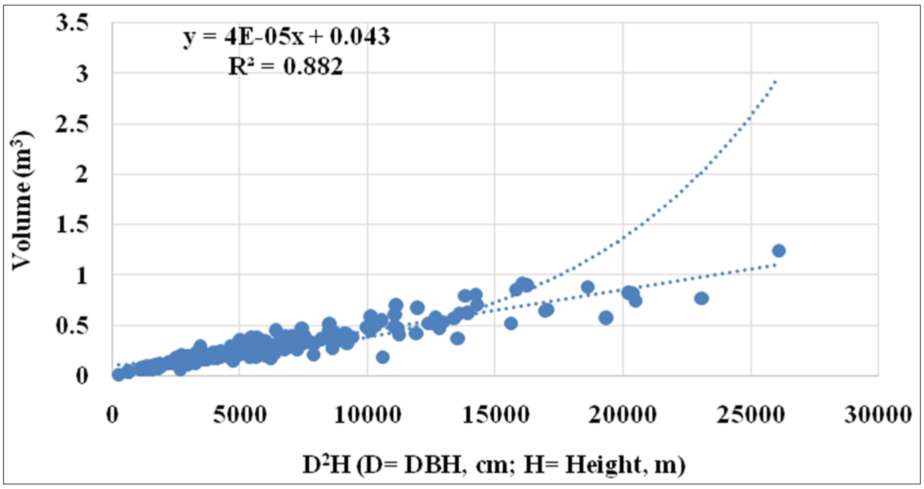

Fig 1: Regression equation developed using D^2H values for assessment of volume of standing *Gmelina arborea* trees

Conclusion

The volume of standing *G. arborea* trees can be estimated by adopting volumetric equation, V= $0.00004D^2H + 0.043$ having DBH of 5 to 40 cm.

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