Research Article

Growth Performance and Biomass Productivity of *Arundo donax* in Wetlands of Kashmir Valley, India

F.M. Sofi, G.M. Bhat, M.A. Islam*, P.A. Sofi, G.N. Bhat and J.A. Chopan

Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal-191201 (J&K), India

Abstract

Arundo donax is a well-known giant reed occurring naturally in the wetlands and is a major source of livelihood to the local people occupied in tobacco pipe making in rural Kashmir. This study investigated the growth performance and biomass productivity of *Arundo donax* in different wetlands *viz*., Shallabug, Manasbal, Dal and Nigeen located in central districts of Kashmir valley. Descriptive and analytical statistics were used to analyze the data. Results indicated that the growth and biomass parameters of the species differed significantly from place to place. The leaf initiation started in March and leaf fall began in November and completed in December in all the four sites. Among all the sites, most excellent growth performance and biomass productivity was shown by the culms at Shallabug, Ganderbal with the maximum average height (2.94 m/ clum), average diameter (1.98 cm/ culm), leaf area (91.45 cm^2), number of culms/ clump (5.41/ clump), number of culms/ m^2 (18.76/ m^2), above ground biomass (14515.00 kg/ ha), below ground biomass (24689.10 kg/ ha), yield (39204.30 kg/ ha), number of nodes (14.61/ clump), maximum internodes (15.36/ clump), number of leaves (29.65/ clump) and length of internodes (19.81cm/ clump). Hence, the quality plant materials of *Arundo donax* in Shallabugh, Ganderbal is of paramount characteristics for mass multiplication to meet the raw material needs of tobacco pipe cottage industries in the valley.

Keywords: *Arundo donax*, Growth, Biomass, Wetland, Tobacco pipe, Kashmir

***Correspondence**
Author: M.A. Islam
Email: ajaztata@gmail.com

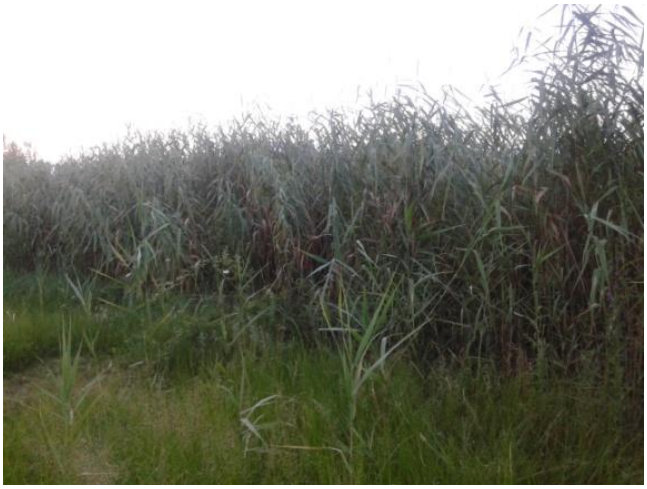
Introduction

Arundo donax locally known as "*Nartond*" is the famous giant reed once grown by farmers in their farms to meet local needs of hookah pipe is now restricted to wetlands in natural habitat only in the Kashmir valley. The giant reed is a tall perennial cane originating from the Indian subcontinent and belonging to the Kingdom Plantae, Class Angiosperms, Order Poales, Family Poaceae, Sub-family Arundinoideae and Tribe Arundineae. The reed is a widely distributed naturally growing perennial rhizomatous grass with a segmented tubular structure like bamboo [1], which has been considered as one of the promising non-wood plants for pulp and paper industry [2]. In the developed world, although wood is still by far the main raw material for pulp and paper manufacture, a market exists for high-value-added papers from these fibres. The high productivity makes the reed very attractive as an alternative source of fibres [3]. The reed is utilized for many purposes like as windbreak, ornamental, wind musical instruments, paper and pulp, garden stakes and building material [4]. The species was grown earlier by the farmers traditionally for different uses *viz*., garden stakes, fishing rods, wind musical instruments and tobacco pipes in Kashmir valley. But, today the plantation of the reed in farmlands is totally forbidden and all the extraction of the reed is fully procured from wetlands in the forests of the valley. The forests of Jammu and Kashmir are spreading over an area of 22539 sq. km [5]. The state has distinct agro-climatic zones comprising subtropical, intermediate temperate and cold arid zone. The valley of Kashmir falls under temperate zone and the forests consist mostly of evergreen conifers and broad leaved tree species occupying an area of 8128 sq. km, whereas Jammu and Ladakh has 12066 and 36 sq. km of forests, respectively [6]. As the demand of the culms is immense and pressure in the wetlands is huge, it is imperative to produce good quality culms of the species outside the forested areas. Considering these facts the present study was undertaken to evaluate best quality plant materials of the reed in different wetlands for further mass multiplication outside the forests to meet the local demands in the valley.

Material and Methods

The present study was conducted in four wetlands *viz*., Shallabug, Manasbal situated in Ganderbal district and Dal and Nigeen located in Srinagar district of Kashmir valley. The data with regard to growth performance and biomass productivity of *Arundo donax* recorded were leaf initiation, leaf fall, number of culms/ clump, number of culms/ m^2, height of the culm (m), diameter/ culm (cm), number of nodes, number of internodes, length of internodes/ culm, number of leaves, leaf area (cm^2), total biomass (kg) and yield/ ha (kg). The observations were recorded and monitored during one growing season (**Figures 1** and **2**) as follows:

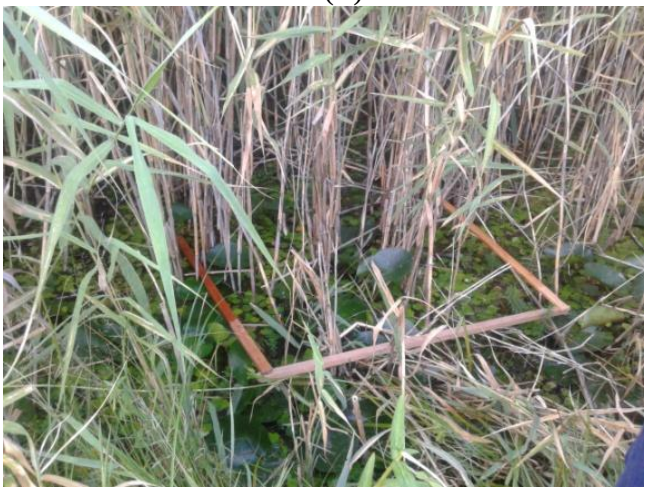
- Leaf initiation and Leaf fall: Leaf initiation was recorded visually by weekly visits to the wetlands from February till its completion while the leaf fall was recorded on the onset of Autumn season *i.e*. September onwards.
- No. of culms/ clump and No. of culms/ m^2: These parameters were recorded manually after completion of one growing season.
- Height of the culm (m): The height was measured using metric scale.
- Diameter/ culm (cm): The diameter was recorded using digital caliper.
- No. of nodes, No. of internodes, No. of leaves and Length of internodes/ culm: The data related to these parameters were recorded manually.
- Leaf area (cm^2): Leaf area was recorded with the help of leaf area meter.
- Total biomass and Yield/ ha (kg): Plots of one square meter were laid in a replicated manner in all the sites. The crop was harvested after completion of one growing season and sun dried. The average productivity obtained in one meter square was multiplied by ten thousand meter square to calculate the yield per hectare.



(A)

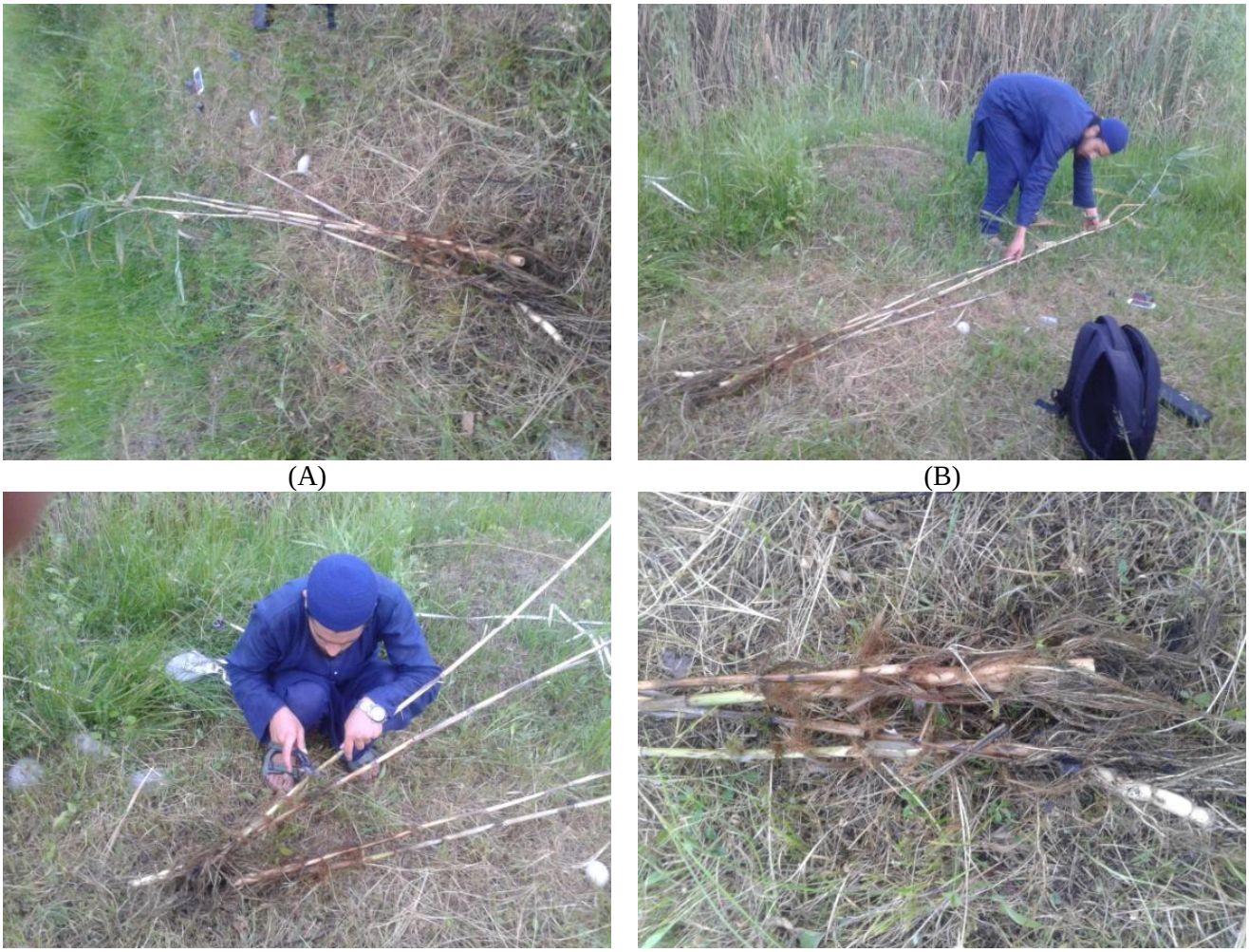
(B)

(C)



(D)

Figure 1(A) *Arundo donax in* wetland, (B) Height measurement, (C) Diameter measurement, (D) Lay out of quadret



(A) (B)

(C) (D)

Figure 2(A) Sample collection, (B) Data recording, (C) Dissection for biomass observations, (D) Below-ground part

Results and Discussion

Growth performance

The **Table 1** revealed that the leaf initiation started in the month of March and completed in the April at all the sites. The leaf initiation took place a bit earlier at Dal and Nigeen as compared to Shallabug and Manasbal. The colour of leaves changed from light green to green and then finally to golden yellow in autumn. The leaf fall took place when the colour changed from green to golden yellow and it started earlier in Dal and Nigeen in the month of November whereas the leaf fall took place later in Shallabug and Manasbal in December. The differential leaf appearance in different wetlands is due to the variation in the temperature because as we move from lower altitude to higher altitude there is drop in mean temperature which has a direct bearing on leaf initiation. *Arundo donax* is well suited to warm temperate to sub-tropical climates and the time of leaf initiation and leaf fall may varied from place to place depending upon the temperature [7]. Average maximum height (2.94 m/ culm) was recorded at Shallabug whereas minimum (2.10 m) was at Manasbal. Conversely, the maximum collar diameter (1.98 cm) was recorded at Shallabug and minimum (1.76 cm) was at Dal. The maximum leaf area (91.45 cm^2) was also recorded at Shallabug while minimum (85.16 cm^2) was at Manasbal. The paramount performance in terms of height, collar diameter and leaf area by the culms of Shallabug may be due to the reasons that the wetland has less interference of public and tourists while the other wetlands are famous tourist resorts of the valley having maximum human interference. *Arundo donax* is considered one of the tallest herbaceous grasses because it can reach more than 8 m under optimal growth conditions [8-10]. *Arundo donax* is the largest member of the genus and is among the largest of the grasses growing to a height of 8 m [11]. The average maximum number of nodes (14.61/ culm) was recorded at Shallabug while minimum (12.14/ culm) was at Manasbal. Average number of internodes/ culm (15.36), number of leaves/ culm (29.65) and intermodal length/ culm (19.81) followed the same trend. The maximum number of nodes, internodes and leaves

recorded higher at Shallabug was due to its maximum height and collar diameter. The number of leaves/ plant ranged between 29-24 in *Arundo donax* [12]. The *Arundo donax* is similar to bamboo and can grow up to 10 m in height, its biomass yield can reach up to 78 t/ ha annually, the culms' walls range from 2 to 7 mm in thickness and the internodes can reach 30 cm in length [13]. The study [14] reported that *Arundo donax* can grow up to 2-10 m in height with a clum wall thickness ranging between 2-7 mm and the internodes can reach 30 cm in length. In case of *Bambusa vulgaris* no. of nodes was recorded as 9.83 nodes/ culm [15].

Table 1 Growth performance of *Arundo donax* in different wetlands of Kashmir valley

Sites	Leaf initiation	Leaf fall	Height of culm (m)	Diameter/ culm (cm)	Leaf area (cm^2)	No. nodes	No. of inter-nodes	No. of Leaves	Length of inter-node/ culm (cm)
Shalabug	April	December	2.94	1.98	91.45	14.61	15.36	29.65	19.81
Manasbal	April	December	2.10	1. 83	85.16	12.14	13.54	24.34	14.32
Dal	March	November	2.53	1.76	87.81	13.94	14.38	25.21	14.63
Nigeen	March	November	2.55	1.94	88.06	14.34	15.27	28.15	19.20
C.D (P≤0.05)			0.16	0.02	2.17	0.15	0.41	0.72	0.17

Biomass productivity

The average number of culms/ clump was recorded maximum (5.41) in Shallabug and minimum (3.37) in Manasbal (**Table 2**). There was no significant difference between Site 3 (Dal) and Site 4 (Nigeen). The average number of culms/ m^2 was maximum (18.76) in Shallabug followed by Nigeen (16.63), Dal (15.17) and Manasbal (14.91 culms/m^2). Site 2 (Manasbal) and Site 3 (Dal) were at par with each other. The total average above ground biomass was maximum (14515.2 kg/ ha) in Shallabug while it was minimum (13214.6 kg/ ha) in Manasbal. As regards the average below ground biomass it was maximum (24689.1 kg/ ha) in Shallabug and minimum (19899.9 kg/ ha) in Manasbal. As far as the average yield is concerned, it was maximum (39204.3 kg/ ha) in Shallabug whereas it was minimum (33114.5 kg/ ha) in Manasbal. The highest above ground and below ground biomass recorded at Shallabug is obviously due to maximum height, collar diameter and number of culms/ clump recorded in the study site. The study [16] reported that in southern Germany, 16 shoots/ plant (43 plants/ m^2) were counted in third production year of *Arundo donax*. The original location of *Arundo donax* might influence growth parameters like number of shoots, height and dry matter yield [17]. Screening trials with 200 *Arundo donax* populations in Italy, France and Greece showed a reduction of shoots /m in populations grown in northern Italy and Greece with a mean of 7-8 shoots/ m^2, when compared with results obtained in southern parts in Italy, Greece and France (mean 10-15 shoots/ m^2).

Table 2 Biomass productivity of *Arundo donax* in different wetlands of Kashmir valley

Sites	No. of culms/ clump	No. of culms/m^2	Above ground biomass (kg/ha)	Below ground biomass (kg/ha)	Yield (kg/ha)
1. Shalabug	5.41	18.76	14515.2	24689.1	39204.3
2. Manasbal	3.37	14.91	13214.6	19899.9	33114.5
3. Dal	4.56	15.17	13789.5	20237.1	34026.6
4. Nigeen	4.23	16.63	14265.8	24500	38765.8
C.D (P≤0.05)	0.41	0.28	69.18	312.5	58.4

Conclusion

The *Arundo donax* is growing naturally in the wetlands of district Srinagar and Ganderbal in the Kashmir valley. In spite of huge demand of the culms the farmers are not cultivating the species on their farm lands as they extract it from wetlands in the forests. To alleviate the massive raw material pressure on wetlands for sustaining tobacco pipe cottage industries in the valley, the cultivation of *Arundo donax* outside the wetlands is imperative. The study led to conclude that the quality plant materials (QPM) of the species in Shallabug are of prime characteristics for propagation and mass multiplication as depicted by their paramount growth performance and biomass productivity. Hence, to meet the burgeoning raw material demands for tobacco pipe cottage industries, large scale plantations of the species needs to be done using the QPM collected from Shallbug in the valley.

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