



MORPHOLOGICAL CHARACTERISTICS AND CHEMICAL PROPERTIES OF *TYPHA LATIFOLIA* L. AND *TYPHA DOMINGENSIS* PERS. ON HADEJIA-NGURU WETLAND AND THEIR POTENTIALS IN PULP AND PAPER PRODUCTION

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ABSTRACT: One of the major problems hampering agricultural productivity on Hadejia-Nguru wetland and of regional concern is the invasion and colonization of the wetland by typha. Attempts at managing the wetland had focused solely on the removal of the plant without exploring its industrial potentials. Being a fibrous plant, this study assessed the Morphological characteristics and chemical properties of the plants for potential application in pulp and paper production. Two major species of typha on the wetland; *Typha latifolia* and *Typha domingensis* were harvested from the shore and the centre of the wetland at Rufan-Kwuanu axis of Hadejia-Nguru wetland in Yobe State. The plants were assessed for their height, diameter, leaf number and leaf length and width. The leaves were chopped, dried to less than 10% moisture content in the oven and milled to less than 1 mm for extractive, crude fibre, ash, silica, lignin and cellulose content determinations. The results revealed that *T. latifolia* on the shore of the wetland had better dimensional growth while *T. domingensis* grows better on deep part of the wetland. The ethanol-benzene extractive, ash and silica content is < 10 while the 1% sodium hydroxide extractive is < 20 which is an indication of low possibility of biochemical deterioration in storage and low liquor consumption during pulping. Also, the plant had low lignin (< 20%) and high α -cellulose contents (> 40%) which classified the plant as promising fibre materials requiring mild pulping condition.

Keywords: *Typha latifolia*, *Typha domingensis*, Extractive contents, cellulose content, Hadejia-Nguru-Wetland.

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1. INTRODUCTION

There has been persistence increase in paper and paper product consumption globally. At the non-wood

fibre symposium, Hurter and Riccio (1998), reported the world paper consumption between 1996 and 1997 to be 300 million tonnes which they further projected to increase to 400 million tonnes by the year 2010. In a more

extensive work, O'Brien (2006), projected the global demand for pulp and paper products to increase to over 490 million tonnes per year-by-year 2020. These will more than double the demand for cellulosic fibre for paper and paperboard production. The implication of this projection is that, the available wood supply in many countries, which the major raw material for paper production will not meet the growing demand. Therefore, the satisfaction of society's needs for fibre based products requires an expansion of the current raw material base, particularly to non-wood plants with similar pulp properties like wood. One of such plants with good fibre properties is typha.

Typha is a perennial herbaceous plant fibre source with potential to compliment timber in different sectors of wood industry (Bajwa *et al.*, 2015). It is found throughout the tropical and temperate regions of the world (Mark *et al.*, 2010) and grow to a height of up to 3-4 meter (Hears, 2006). The plant is capable of self-regeneration through its rhizomes and its persistent seed that can withstand dry spell. The rate of re-emergence according to Gomes *et al.* (2003) is very rapid after each removal. In view of this, lots of efforts are being directed toward its removal without success.

Typha, though regarded as natural plant-fibre with potential industrial benefits in many parts of the world (Jahan *et al.*, 2007; Sana *et al.*, 2014; Bajwa *et al.*, 2015; Rezig *et al.*, 2016), in Nigeria, it is regarded as invasive plant hindering agricultural development along Hadejia-Nguru wetland where they are found in abundance (Sabo *et al.*, 2010). Despite the World Bank intervention on the management of typha through TRIMING project, little effort has been made on exploring the potential of the plant for developmental project.

As a natural plant fibre, there is need for research focus on utilizing the plant for the manufacture of fibre based products. As a first step, analysis of chemical composition of the plant is necessary to ascertain its potential for pulp and paper products. This is because chemical composition of a plant material is fundamental to fibre quality. At present, analysis of the chemical composition of have not been intrinsically linked with pulp yield and by extension, paper properties. Since plant properties vary based on location and genetic make-up, this study centres on the investigation of chemical analysis of the two commonly found typha plants in both the shore and centres of Hadejia-Nguru wetland. The main objective of the study therefore is to carry out biometrical assessment of typha stem morphology and chemical composition with the aim of exploring its potential for pulp and paper production.

1. MATERIALS AND METHODS

The stems of *T. latifolia* and *T. domingensis* used for this study were harvested in Rufan-Kwuanu located on Latitude 10° 22'N and Longitude 12° 46'E of Hadejia-Nguru wetland, in Nguru local Government Area of Yobe State, Nigeria (Fig.1). The stems were harvested and classified based on the point in which they were harvested on the wetland. The two points are the shore (the bank of the wetland) and the centre which is about 15 km from the shore (Fig.2). To aid in species classification, harvesting of both *T. latifolia* and *T. domingensis* were carried out in July when the full flowering had already taken place and identification possible with the aid of a Botanist. Each species from each harvesting point were baled separately and transported fresh to the laboratory for analysis.

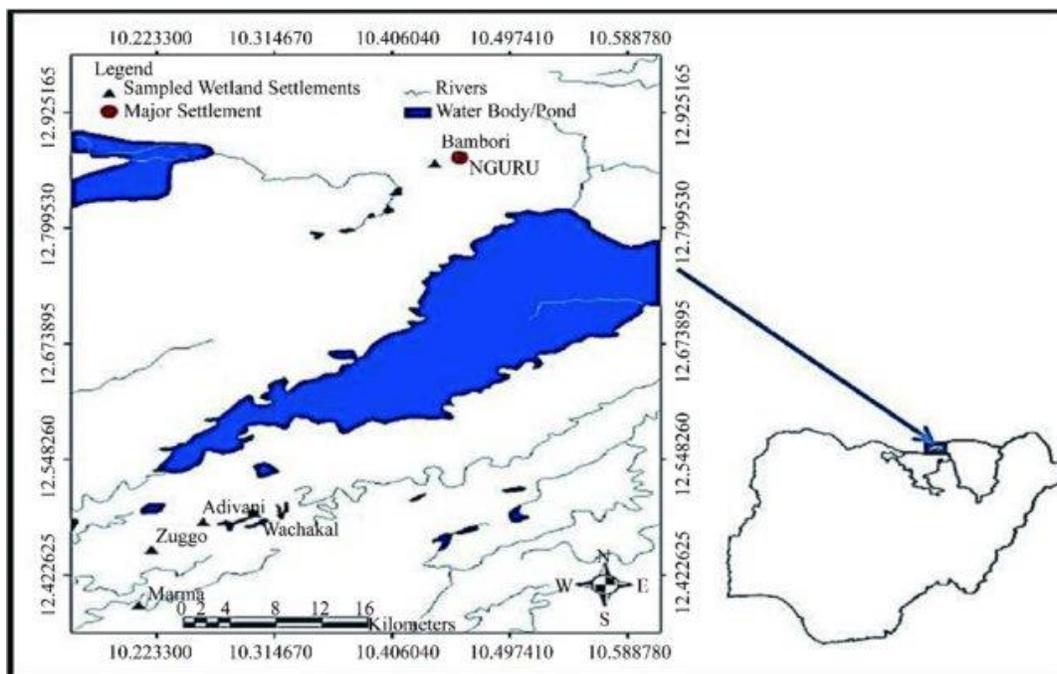


Figure 1: Map of Hadejia-Nguru Wetland



Figure 2: Typha harvesting points; A is the shore and B is the centre of the wetland

2.1 Assessment of *T. latifolia* and *T. domingensis* Morphology

Stem morphology of the typha plants were assessed for quantitative characteristics. The quantitative characters measured include the stem height, stem diameter, leaf

length, number of leaves per stem and, leaf width at the base, middle and top of the leaf length. Twenty stems were randomly selected from each species and harvesting point on the wetland. the diagrammatic representation of typha plant showing the measurement points is presented in Figure 4 using a modified Kim *et al.* (2003) method.

2.2 Extractive contents determination

For extractive content determination, ten stems from each species and harvesting location were randomly selected, cut into short length of about 5 cm, dried separately at first for 2 hours at 105 °C and then 17 hours at 60 °C to constant moisture content. The oven dried samples were milled to less than 1 mm diameter. The ethanol-benzene extractive content was determined by extracting 5g of the milled samples with ethanol-benzene for 8 hours in the ratio of 1:2 followed by extraction with 95% ethanol in soxhlet apparatus using ASTM International D1107-56 (1972). For 1% sodium hydroxide solubility test, 2 g of air-dried moisture-free milled sample was extracted with 1% NaOH in boiling water bath for 1 hour followed by thorough washing with hot distilled water and 10% acetic acid using ASTM International D1109-56 (1972). The hot water extraction was carried out by extracting 2 g moisture free sample in Erlenmeyer flask attached to reflux condenser in boiling water bath for 3 hours following ASTM International D1110-56 (1977). The cold water followed the same procedure with hot water extraction. But, in this case, extraction was done in cold water at room temperature for 48 hours.

2.3 Chemical contents determination

The crude fibre content was determined based on acid-alkaline extraction method described in Association of Analytical Chemist (AOAC, 1990) with Fibretec system which consist of hot (1020 hot extractor) and cold (1021 cold extractor) extraction units. Ash content was estimated in accordance with ASTM Designation D1102-50T (1950). The silica content was determined from the ash using TAPPI designation T244 0m-93 method. The lignin content (acid-insoluble) was determined by digesting the extractive free samples obtained previously with 72% cold sulphuric acid based on ASTM D1106-96. The holocellulose, content of the extractive free samples was determined by extraction, using 50ml of 95% ethanol and hot ethanol-monoethanolamine solution based on ASTM D1104-50 as adopted by Sotannde and Oluwadare, (2014). Holocellulose obtained was later treated with sodium hydroxide (NaOH) and glacial acetic acid to obtain its alpha-cellulose content based on ASTM D1103-60.

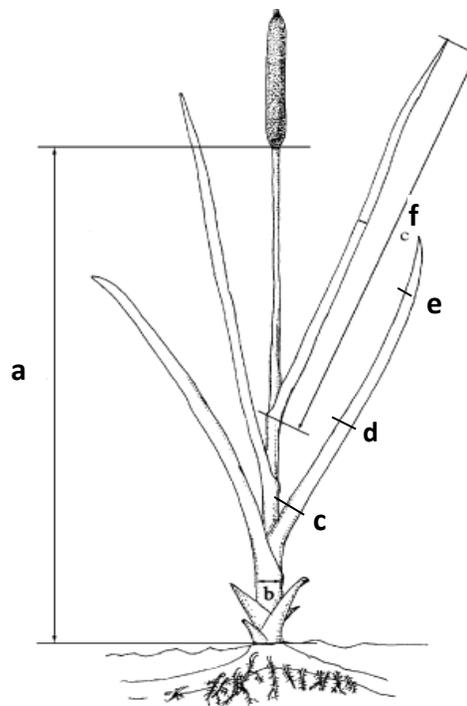


Figure 3: Diagrammatic representation of a mature Typha plant (Source: Kim *et al.*, 2003). a: stem height (m); b: Stem diameter at the base (cm); c: leaf width at the base (cm); d: leaf width at the middle (cm); e: leaf width at the top (cm); f: leaf length (m)

3. RESULTS AND DISCUSSION

3.1 Morphological biometry of typha plants

The mean and standard deviation of the quantitative morphological characters of the typha species were presented in Table 1. The variation of the characters with respect to the harvesting points on the wetland were illustrated in Figure 4. The two species differs in their vegetative morphological characters. *T. domingensis* was averagely 0.52 m taller than *T. latifolia*. Likewise, it has averagely higher leaf number which are narrower but longer than that of *T. latifolia*. The leaf surface area (related to leaf length and width), varies according to water depth (Grace and Wetzel, 1982; Kim *et al.*, 2003). *T. latifolia* harvested at the shore of the wetland had higher dimensional growth as evident in their higher height and diameter growth, longer and wider leaves and higher leaf number. In contrast, *T. domingensis* harvested toward the centre of the wetland had higher dimensional growth than those harvested at the shore of the wetland.

The significant species differences and variations in the portion of the wetland had significant effect of the dimensional characteristics of the plant. The higher morphological growth of *T. latifolia* on the shore of the lake confirmed the assertion made by Grace and Harrison (1986) which described *T. latifolia* as an upslope of *T. augustifolia*. In a more recent work on the shoot growth of typha plant on Kokemaenjoki river delta, Aulio (2014), reported that the strongest stands of *T. latifolia* are found growing in area bordering the river channel and the open spaces and, are more productive in shallow water with mean depth of 19 cm. *T. domingensis* on the other hand thrive better on water with average depth of

42.17 cm. Kim *et al.* (2003) and Grace (1989), posited that the greater tolerance of *T. domingensis* to deep water was a reflection of the fact that it grew well at all depth while *T. latifolia* eventually died out from depths greater than 95 cm. Meanwhile, from pulp and paper production perspective, the average size of typha plant like many other nonwood is small which implied that large volume will be required to achieve full digester capacity. This has been one of the impediments to the utilization of non-wood plant fibre in major large mills (Pahkala, 2001). However, considering that typha plants regenerate at a fast rate though seed and rhizomes, its availability on sustained basis can be assured.

Table 1: Stem morphological characteristics of *T. latifolia* and *T. domingensis*

Parameters	<i>T. latifolia</i>	<i>T. domingensis</i>	Mean difference	Significance (<i>P</i> -value)
Average stem height(m)	2.25±43.97 ^x	2.77±22.55	0.52	0.005*
Stem diameter at the base(cm)	3.63±5.36	3.50±11.17	0.13	0.124 ^{ns}
Average Leaf number	5.79±0.41	5.54±0.51	0.25	0.060 ^{ns}
Leaf Length(m)	2.16±6.20	2.51±3.00	0.35	0.015*
Leaf width @ Base(mm)	2.79±5.69	2.33±4.34	0.46	0.008*
Leaf width @ Middle(mm)	1.96±1.75	1.48±1.49	0.48	0.005*
Leaf width @ the Top(mm)	1.45±2.44	0.91±1.62	0.54	0.002*

^x Mean±Standard. Each value is an average of 20 replicates and *P*-value > 0.05 is not significant

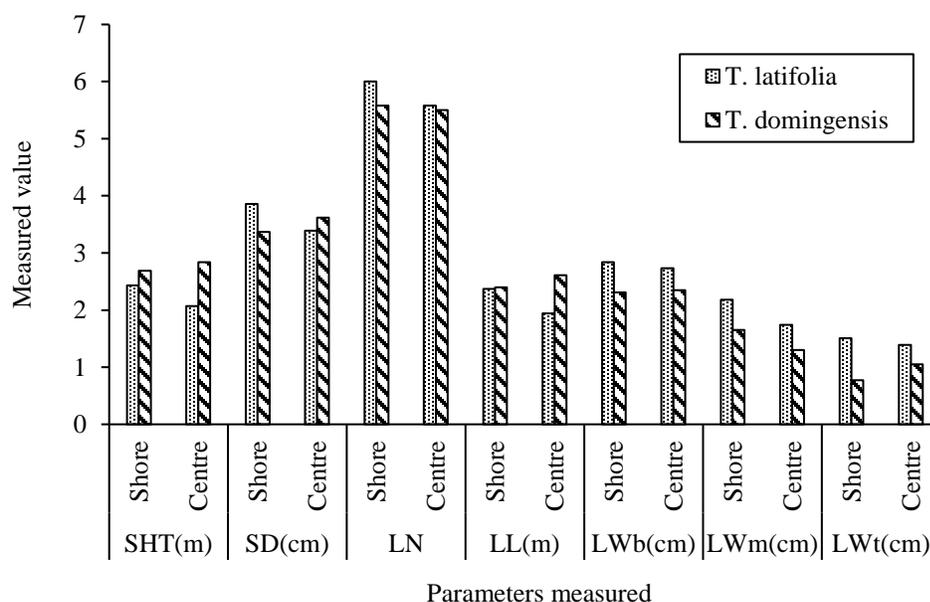


Figure 4: Influence of harvesting point on the wetland on the morphological characteristics of typha plants. SHT: stem height; SD: stem diameter; LN: leaf number; LL: leaf length; LWb, m and t: leaf width at the base, middle and top of the leaf height.

3.2 Extractive properties

The presence of extractives in lignocellulosic materials present special relevance due to their high impact in

paper pulp manufacturing (Marques *et al.*, 2010). They pose many problems in pulp and paper processes and decrease the quality of the final product. For example, a higher extractive content may lead to a lower pulp yield

from the kraft and soda processes (Jahan *et al.*, 2008; Jahan *et al.*, 2010). The results illustrated in Figure 5 revealed that typha plants harvested deep into the wetland were higher in extractive contents compared to those harvested at the shore. However, with exception of 1% sodium hydroxide solubility, the differences in extractive contents of the two typha species were not significant in both samples harvested deep into the wetland and the shore (Table 2). The mean ethanol benzene and 1 % sodium hydroxide extracts of *T. latifolia* were 3.53% and 27.86% while for *T. domingensis*, the amount of extracts were 4.13% and 32.43%, respectively (Table 2). The implication of this is that the presence of low-molecular-weight carbohydrates, salts and resinous materials in typha is not expected to create much pitch problems thereby expected to enhance a more homogeneity in paper sheet (Agnihotri *et al.*, 2010). Nevertheless, the ethanol benzene extractive contents obtained in this study is a bit higher than 1.4 and 1.3% recorded for typha in northern and eastern regions of Bangladesh (Jahan *et al.*, 2007) but has values similar to 3.52% in rice straw (Tutus *et al.*, 2010), 4.0% in reed (Kirci *et al.*, 1998), 3.88% in kenaf and 4.28% in hemp (Dutt *et al.*, 2009) and fall within the range of 1 – 8% extractive contents in most softwoods (As *et al.*, 2002). The 1% soda extractives recorded for typha in this study is lower compared with 39.1 and 38.2% recorded for typha harvested in northern and eastern regions of Bangladesh (Jahan *et al.*, 2007) but compared well with a range of 24.9 – 32.8% for *T. domingensis* harvested in Sudan (Khider *et al.*, 2012), 25.3% obtained in reed (Kirci *et al.*, 1998), 28.30% in

hemp and 28.50% in kenaf stalk (Dutt *et al.*, 2009). On the average, the moderately low alkali soluble extracts of typha plants obtained in this study is more favourable for good pulping since it has been shown to be negatively correlated with pulp yield (Singh *et al.*, 2011). This is more advantageous since extra cost on biotechnical and enzymatic pre-treatment commonly used for non-woody plants to prevent bio-deterioration will be low, thereby reducing cost of pulping as much as possible.

Water soluble extractive estimates a part of extraneous components, such as inorganic compounds, tannins, gums, sugars and colouring matter present in the lignocellulosic materials and hot water estimates, in addition, starches. Though, not significant in both harvesting locations, the mean values of hot and cold-water soluble extracts in *T. latifolia* are lower than that of *T. domingensis* by 1.7 and 0.84%, respectively (Table 2). In comparison, the mean hot and cold water soluble extract recorded for *T. latifolia* are 13.99 and 13.0%, respectively while that of *T. domingensis* are 15.69 and 13.84% in same order (Table 2). The value recorded here were lower compared to 24.7 and 18.7% respectively recorded for *T. domingensis* whole plant harvested in Sudan (Khider *et al.*, 2012) but similar when compared to 12.7 and 11.9% hot water-soluble extract obtained from typha plant in northern and eastern region of Bangladesh (Jahan *et al.*, 2007). The variations in extractive content of typha species could be attributed to the ecological differences, age, genetic variation, water depth and growth conditions of the plant.

Table 2: The average extractive contents of the plants

Parameters	<i>T. latifolia</i>	<i>T. domingensis</i>	Mean difference	Significance (<i>P</i> -value)
Ethanol Benzene	3.53±2.42 ^x	4.13±3.12	0.60	0.885 ^{ns}
1% NaOH	27.86±3.99	32.44±2.49	4.58	< 0.001*
Hot water Solubility	13.99±3.15	15.69±2.16	1.70	0.071 ^{ns}
Cold water Solubility	13.00±4.32	13.84±1.82	0.84	0.153 ^{ns}

^x Mean±Standard. Each value is an average of 3 replicates and *P*-value > 0.05 is not significant

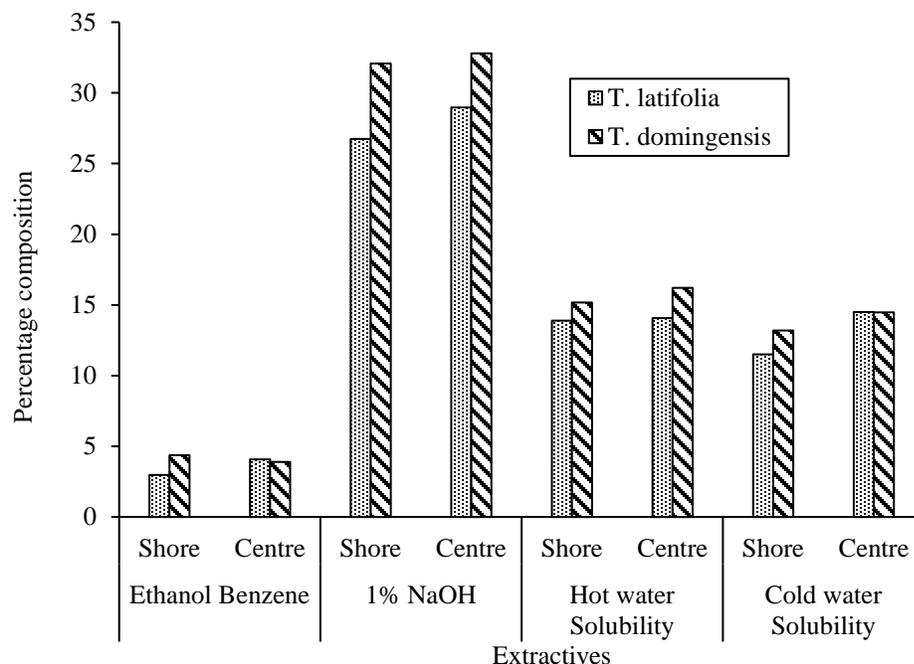


Figure 5: Influence of harvesting point on the wetland on the extractive contents of typha plants

3.3 Chemical properties

The comparative analysis presented in Table 3 revealed little differences in chemical composition of typha plants. *T. latifolia* is richer in crude fibre, holocellulose and alpha-cellulose contents by 0.59, 1.82, and 0.73%, respectively. In contrast, ash, silica and lignin content is higher in *T. domingensis* compared to *T. latifolia* by 2.22, 1.13 and 0.95%, respectively. Despite the differences obtained, the chemical compositions in *T. latifolia* did not differ significantly from that of *T. domingensis* except in terms of lignin and holocellulose contents which shows significant variation among species and location on the wetland (Table 3, Fig. 6).

Crude fibre content of a plant gives an idea of the total amount of cellulose content in a lignocellulosic material. For fibre production, high crude fibre content in a raw material is always desirable. The non-significant crude fibre content between the two species is advantageous for pulping purpose due to the opportunity of being combined in the same charge during pulping process. High crude fibre accumulation in *T. latifolia* stem harvested on the shore (64.33 %) as against 60.84% for those harvested deep into the centre of the wetland (Figure 6) implied that the point of harvest had significant effect on the growth of the plants which by extension influenced the crude fibre content. The results obtained in this study showed that *T. latifolia* and *T.*

domingensis could be classified as fibrous plant based on their high crude fibre content (62.59 and 62.0%, respectively).

In terms of ash content, *T. domingensis* had significant higher ash accumulation than *T. latifolia* with a mean difference of 2.22% (Table 3). As illustrated in Figure 6, *T. latifolia* and *T. domingensis* harvested on the shore of the wetland had ash content of 1.5 and 0.73%, respectively more than those harvested deep into the wetland. Unlike ash content, *T. latifolia* and *T. domingensis* harvested deep into the wetland had higher silica content (0.57 and 0.72%, respectively) compared to those harvested on shore. Also, silica content was observed to be higher in *T. domingensis* than in *T. latifolia*, irrespective of the point of harvest (Fig. 6). Among the possible explanations for high silica content in plant harvested deep into the wetland could be due to deposition of silicon as silica crystals in the epidermis of the plant (Ilvessalo-Pfaffli, 1995) which is not exposed to leaching (Pahkala, 2001). High ash and silica contents are not desirable as they complicate chemical recovery of the cooking liquor (Rodriguez *et al.*, 2008).

As with ash and silica, lignin deposition is higher in *T. domingensis* than in *T. latifolia* irrespective of the harvesting point (Fig. 6). The concept of lignin in pulp and paper production process has been extensively discussed. It is an undesirable polymer and one of the

main reasons for pulping is to remove it from wood and other lignocellulosic materials. The 13.65 and 14.57% obtained in *T. latifolia* and *T. domingensis*, respectively in this study is a bit lower than 16.8% and 16.2% obtained in typha plant grown in the northern and eastern region of Bangladesh (Jahan *et al.*, 2007) and, 21.5 and 17.5% in the bark and whole plant of *T. domingensis* respectively harvested in Sudan (Khider *et al.*, 2012). The difference in lignin accumulation in typha plant from different eco-region could be attributed to the age as well as the genetic makeup of the plant from each eco-region. Nevertheless, the less than 20% lignin content in typha from Hadejia-Nguru wetland is satisfactory, which is an indication that low amount of energy and pulping liquor will be required to achieve satisfactory pulping of the plant.

The fibre contents in typha plants is high which is important in determining the response of the fibres to processing conditions and the development of physical properties in final products. The crude fibre accounted for 62.59%, holocellulose (69.75%) and α -cellulose (46.11%) in the leaf of *T. latifolia*. In *T. domingensis*, crude fibre accounted for 62.00%, 67.93% holocellulose and 45.38% α -cellulose (Table 3). In terms of the harvesting point, *T. latifolia* harvested on the shore of the wetland are always in cellulose content compared to those harvested deep into the wetland. conversely, the

cellulose content in *T. domingensis* harvested deep into the wetland are higher than those harvested on the shore (Fig. 6). This could be due to variation in the tolerance of each species to the increase in depth of water. The values recorded for *Typha* species in this study is similar to those in the northern and eastern region of Bangladesh (Jahan *et al.*, 2007) and Sudan (Khider *et al.*, 2012). It also compared well with those of notable nonwoods like kenaf and hemp stalk (Dutt *et al.*, 2009), kenaf bast (Udohitinah and Oluwadare, 2011), sugarcane bagasse (Agnihotri *et al.*, 2010), soft and hardwoods (Eroglu, 1998). In rating candidate plant for papermaking, Nieschlag *et al.* (1960) cited in Veveřis *et al.* (2004), rated plant materials with α -cellulose content of 34% and above as promising for pulp and paper manufacture. In chemical pulping, pulp yield had been found to be positively correlated with holocellulose and alpha-cellulose content of the raw material (Shakhes *et al.*, 2011). The high holocellulose content of typha plants obtained in this study confirmed the 71.0% holocellulose content obtained in typha plants harvested from in the northern and eastern region of Bangladesh reported by Jahan *et al.* (2007). Holocellulose defined the total content of carbohydrate materials and as a whole adds to the overall strength of a paper (Singh *et al.*, 2011). High holocellulose content, therefore, is considered desirable for pulp and paper production.

Table 3: Percentage chemical composition of *T. latifolia* and *T. domingensis*

Parameters	<i>T. latifolia</i>	<i>T. domingensis</i>	Mean difference	Significance (<i>P</i> -value)
Crude Fibre content	62.59±4.09 ^x	62.00±2.55	0.59	0.207 ^{ns}
Ash content	8.85±2.36	11.07±1.93	2.22	< 0.001*
Silica content	3.20±1.65	4.33±1.49	1.13	0.024 ^{ns}
Lignin Content	13.62±3.59	14.57±3.48	0.95	0.054 ^{ns}
Holocellulose content	69.75±6.02	67.93±5.18	1.82	0.013*
α -cellulose content	46.11±7.13	45.38±4.03	0.73	0.087 ^{ns}

^x Mean±Standard. Each value is an average of 3 replicates and *P*-value > 0.05 is not significant

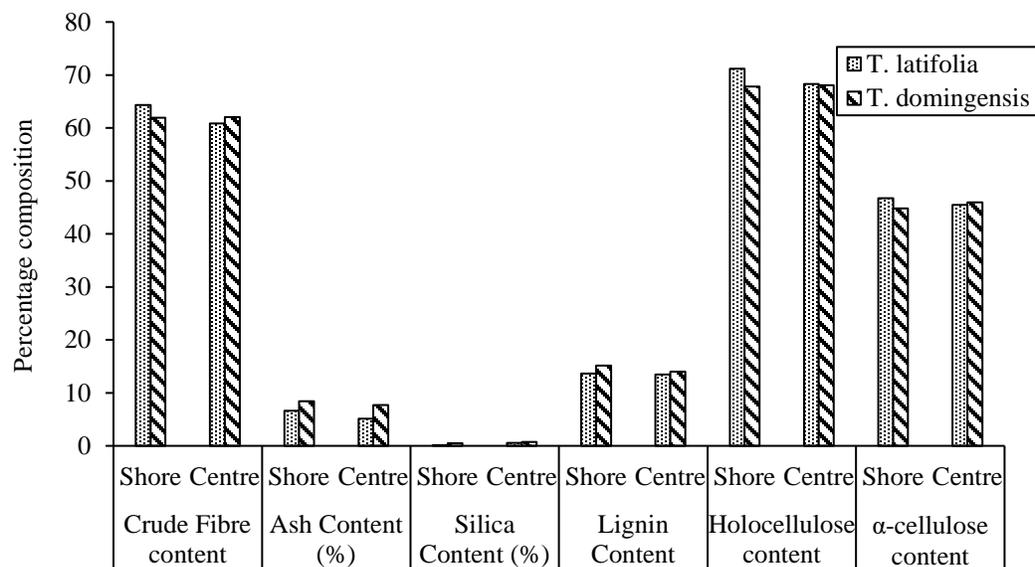


Figure 6: Influence of harvesting point on the wetland on the chemical composition of typha plants

4 CONCLUSION

Based on the finding from this study, the following conclusions are made:

1. In terms of physical description, *T. domingensis* was averagely taller than *T. latifolia*. It has comparatively higher leaf number which are narrower but longer than that of *T. latifolia*.
2. *T. latifolia* grows better on the shore of the wetland while *T. Domingensis* performed better at the centre of the wetland.
3. The extractive contents in both species are low and compared well with what obtains in notable non-woods like kenaf, reed and jute.
4. The lignin content in typha is less than 20%, which implied that mild pulping condition will be required to pulp to acceptable yield and quality.
5. The crude fibre and holocellulose content is greater than 60%. while, alpha-cellulose is greater than 34. these implied that the two typha species can be classified as fibrous plants with great potentials for pulp and papermaking.

References

- Abdul Khalil, H.P.S., Alwani, M.S. and Mohd Omar, A.K. (2006): Chemical composition, anatomy, lignin distribution and cell wall structure of Malaysian plant waste fibres. *Bioresour. Technol.*, 1: 220-232.
- Agnihotri, S., Dutt, D., and Tyagi, C.H. (2010): Complete characterization of Bagass of Early species of

- Saccharum officinerum*-Co 89003 for pulp and paper making, *BioResources*, 5(2):1197-1214.
- As, N., Koc, H., Dogu, D., Atik, C., Aksu, B. and Erdinler, S. (2002): The Chemical, Mechanical, Physical and Anatomical Properties of Economically Important Wood in Turkey, *IU Istanbul, J. For.* pp. 70-88.
- Association of Official Analytical Chemist, A.O.A.C. (1990): Crude fibre. AOAC method 7.061. In: Pahkala, K., Non-wood plants as raw material for pulp and paper, *Agricultural and Food Science in Finland*. Vol. 10(2001): Supplement 1. 101p.
- ASTM D 1110-56 (1956): Test for water solubility of wood. American Society for Testing and Materials ASTM International, West Conshohochen, Philadelphia, PA www.astm.org/standard/D1110.htm
- ASTM D1103-60 (1974): Method of Test for Alpha-cellulose in wood, (withdrawn 1985) American Society for Testing and Materials ASTM International, West Conshohochen, Philadelphia, PA.
- ASTM D1104-50 (1978): Method of Test for Holocellulose in wood. American Society for Testing and Materials ASTM International, West Conshohochen, Philadelphia, PA www.astm.org/standard/D1104.htm.
- Aulio, K. (2014): Shoot growth in *Typha angustifolia* L. and *Typha latifolia* L. in the Kokemäenjoki River delta, western Finland. *International Letters of Natural Sciences*, Vol. 28: 34-46.
- Bajwa, D.S., Sitz, E.D., Bajwa, S.G. and Barnick, A.R. (2015): Evaluation of cattail (*Typha* spp.) for manufacturing composite panels. *Industrial Crops and Products* 75 (2015) 195–199.

- Deniz, I., Kirci, H. and Ates, S. (2004): Optimization of Wheat Straw Triticum drum Kraft Pulping, *Ind. Crops Prod.* 19: 237-243.
- Dutt, D., Upadhyay, J.S., Singh, B. and Tyagi, C.H. (2009): Studies on *Hibiscus cannabinus* and *Hibiscus sabdariffa* as an alternative pulp blend for softwood: An optimization of kraft delignification process. *Industrial Crops and Products* Vol. 29 (1): 16-26.
- Eroglu, H. (1998): Fiberboard industry, Karadeniz Technical University. Publication No: 304, Trabzon, p. 30.
- Gomes, H., Alves, E., Dau, M.A. (2003): Dealing with Flooding and Ponding Regime in Jigawa State.
- Grace, J.B. and Harrison, J.S. (1986): The biology of Canadian weeds. 73. *Typha latifolia* L., *Typha angustifolia* L. and *Typha xglauca* Godr. *J. Plant Sci.* 66: (1): 361- 379.
- Grace JB (1989). Effect of water depth on *Typha latifolia* and *Typha domingensis*. *Amer. J. Bot.* 76(5): 762 – 768.
- Hears, M., (2006): Constructed wetlands under different geographic conditions. Evaluation of suitability and criteria for the choice of plants productive species. Master thesis, Faculty of Life Sciences, Hamburg University of Applied Sciences. Germany, pp: 175.
- Jahan, M.S., Ahsan, L., Noori, A. and Quaiyyum, M.A. (2008). Process for the production of dissolving pulp from *Trema orientalis* (Nalita) by prehydrolysis kraft and soda-ethylenediamine (EDA) process. *BioResearch* 3(3): 816-828.
- Jahan, M.S., Islam, M.K., Chowdhury, D.A.N, Moeiz, S.M.I and Arman, U. (2007): Pulping and papermaking properties of pati (*Typha*). *Industrial Crops and Products*, 26 (2007) 259–264.
- Kim C., Shin H and Choi H (2003): A phenetic analysis of *Typha* in Korea and far east Russia. *Aquatic Botany* 75 (2003) 33–43
- Jahan; M.S., Chowdhury, N. and Ni, Y. (2010): Effect of different locations on the morphological, chemical, Pulping and papermaking properties of *Trema orientalis* (Nalita). *Bioresource Technology* 10: 1892-1898.
- Kirci, H., Usta, M. and Eroglu, H. (1998): Soda-air pulping of *Phragmites reed*. The 5th Meeting of Pulp and Paper Industry of Balkan Countries, October, 7-9, Constanta, Mamaia, Romania.
- Madakadze, I.C., Masamvu, T.M., Radiotis, T., Li, J and Smith, D.L. (2010): Evaluation of Pulp and Paper Making Characteristics of Elephant grass (*Pennisetum purpureum* Shum) and Switchgrass (*Panicum virgatum* L.). *African Journal of Environmental Science and Technology*, Vol. 4(7): 465-470.
- Mark, M.C., Hogan, H. and Cleveland, C. (2010): Petenes Mangroves. *Encyclopedia of the Earth*. National Council of Science and Environment. Washington D.C.
- Marques, G., Rencoret, J., Gutiérrez, A., and Del Rio, J.C. (2010). Evaluation of the Chemical Composition of Different Non-Woody Plant Fibers Used for Pulp and Paper Manufacturing. *The Open Agriculture Journal*, 4, 93-101.
- Nieschlag, H.J., Nelson, G.H., Wolff, I.A. and Pardue, R.E. (1960): A search for new fiber crops. *Tappi J.* 43 (3), 193–201.
- O'Brien J. Paper demand continues to grow. *Paper Age*. 2006;122(6):1
- Rezig, S., Joauadi, M., Khoffi, F., Msahli, S. and Durand, B. (2016): Optimization of extraction process of *Typha* leaf fibres. *Indian Journal of Fibre and Textile Research*, 41(September): 242 – 248.
- Sabo, B. B., Karaye, A. K. And Badamasi, M. M. (2010): *Typha* Grass Militating against agricultural Productivity along Hadejia, Jigawa State, Nigeria. *Proceedings of the 21st Annual National Conference of Farm Management Association of Nigeria*, 11th - 14th October 2010. Pp 234-254.
- Sana, R., Mounir, J. and Slah, M. (2014): Study of Structure and Properties of Tunisian *Typha* Leaf Fibers. *IJERT*. 3(3): 539 – 546.
- Shakhes, J., Zeinaly, F., Marandi, M.A.B. and Saghafi, T. (2011): The effects of processing variables on the soda and soda-AQ pulping of kenaf bast fibre. *BioResources* 6 (4): 4626-4639.
- Singh, S., Dutt, D. and Tyagi, C.H. (2011): Complete characterization of Wheat straw (*Triticum aestivum* PBW-343 L. Emend. Fiori and Paol.) – A renewable source of fibre for pulp and paper making. *BioResources*, 6 (1): 154-177.
- Sotannde, O.A. and Oluwadare, A.O. (2014): Fibre and Elemental Contents of *Thaumatococcus daniellii* Stalk and its Implications as a Non-Wood Fibre Source. *International Journal of Applied Science and Technology*, Vol. 4 (1): 178 – 185.
- Tutus, A., Comlekcioglu, N., Karaman, S. and Alma, M.H. (2010): Chemical composition and fibre properties of *Crambe orientalis* and *C. tataria*. *Int. J. Agric. Biol.* 12 (2): 1814-9596.
- Udohitinah, J.S. and Oluwadare, A.O. (2011): Pulping properties of Kraft Pulp of Nigerian- Grown Kenaf (*Hibiscus cannabinus* L.). *BioResources* 6(1): 751-761.
- Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P. and Santas, R. (2004): Fiber dimensions, lignin and cellulose content of various plant materials and their suitability for paper production. *Ind. Crops Prod.* 19: 245–254.