



Preservation characteristics and restoration core technology of palm leaf manuscripts in Potala Palace

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Abstract

There are the richest collections of palm leaf manuscripts in Potala Palace of Tibet in China; they represent very precious cultural heritage with both literature and research value. The study reported in this paper has selected the original palm leaf manuscripts and the photocopies of palm leaf manuscripts in Potala Palace as investigation objects randomly. The investigation of damage status focuses on both media (palm leaves) and handwriting. Results show 11 kinds of deterioration of palm leaf manuscripts. They can be divided into three categories based on the frequency and destructiveness of deterioration: major, minor and occasional deterioration. The purpose of grading is to take targeted measures according to the degree of damage. Restoration and preservation of palm leaf manuscripts in the Potala Palace are relatively complicated because of minimal research on the restoration of palm leaf manuscripts. There are few stable and mature restoration methods that would be used for damaged manuscripts. It is very important to find out the most suitable method for seriously damaged palm leaves before making a restoration plan in order to prioritize appropriately and facilitate long-term preservation and utilization. This study analyzes and demonstrates the feasibility of the restoration techniques for the most damaged, thus laying a foundation for comprehensive practices of the preservation and restoration of the palm leaves in the Potala Palace.

Keywords Potala Palace · Tibet · Palm leaf manuscripts · Preservation characteristics · Preservation and restoration

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Introduction

Potala Palace is known as “the treasure house of Tibetan history, culture, and art” for its unique architecture and numerous cultural relics. As the political and cultural center in Tibet, there are nearly 40,000 volumes of precious ancient books in Chinese, Tibetan, Manchu, Mongolian, Sanskrit and other languages in the Potala Palace, covering all forms of Tibetan ancient books. Palm leaf manuscripts from ancient India and other places are one of their special collections. The palm leaf manuscript gets its name because of its carrier material—palm leaf, and its contents are primarily Buddhist scriptures. Many palm leaf manuscripts in Potala Palace are important Sanskrit origin texts. Most of them are over 700 years old, the oldest being over 1000 years old. They have extremely high literature and research value and represent a significant component in world cultural heritage. In 2006, local government embarked on a project to protect the Tibetan Sanskrit palm leaf manuscripts. All the palm leaf manuscripts in Potala Palace have been registered and cataloged, and all of them are digitized.

The Department of Potala Palace Management is responsible for collecting and caring for the collections. It was founded in 1988, by the Tibet Autonomous Region Cultural Heritage Administration. The Cultural Heritage Research Section within the Department of Potala Palace Management is responsible for the preservation and restoration of the collections. In 2009, the storage environment for palm leaf manuscripts was improved, and they were moved to a special ventilated room with protection against light, fire and theft.

The palm leaf manuscripts storage room on the ground building, and it is surrounded by walls without windows and illuminated by lamps without UV emission. According to Standard for the Repository of Ancient Books and Special Collection of Library, the recommended temperature for storage room is between 16 and 22 °C, and the relative humidity is between 45 and 60%. The temperature in the Potala Palace storage room is between 18 and 22 °C all year, and the relative humidity is kept at 45–50%. In addition, there are alarm systems, monitoring equipment and fire-fighting equipment. There is no air-conditioning system in the storage room because the air quality in Lhasa is clean, and there is almost no air pollution.

The Potala Palace palm leaf manuscripts are wrapped in three layers, namely acid-free paper (Potala Palace staff believe that wrapping palm leaf manuscripts with acid-free paper will provide moisture protection), silk (silk is specially soaked with Tibetan medicine and protects against insects) and yellow cotton cloth (yellow cotton cloth can prevent dust). Then, the manuscripts are bound tightly with wrapping tape to fix the manuscripts and prevent palm leaves from scattering or rubbing against each other. Finally, the manuscripts are placed in between two wooden boards slightly larger than the manuscripts. In addition, customized camphor wood boxes are used for storage.

Despite these preservation measures some manuscripts are inevitably aging and deteriorating. Therefore, it is necessary to investigate the preservation status of manuscripts and take adequate measures to prevent manuscripts from further

deterioration. This research is not based on pre-existing assessments. Based on the investigation of the status of palm leaf manuscripts in Potala Palace, this research analyzes the frequency and degree of deterioration and divides the deterioration into three types: major, minor and occasional deterioration. This paper focuses on demonstrating the feasibility of the repair technology for major deterioration, providing a foundation for the comprehensive preservation and restoration of palm leaf manuscripts in Potala Palace.

Literature review

There is a body of literature that has discussed the deterioration of palm leaf manuscripts. Gupta (1974) categorized the causes of deterioration as physical and chemical damage, improper storage and other factors. Prajapati (1995) mentioned that climatic factors, pollution factors and biological damage were the factors causing damage to palm leaf manuscripts. Joshi (1995) pointed out that palm leaf was very susceptible to deterioration caused by temperature, relative humidity and biodegradation. Dean (1999) observed that palm leaf manuscripts were susceptible to damage (insect staining, splitting and cleavage and mechanical damage) over time. Sah (2002a, b) considered the degradation of palm leaf manuscripts and conservation practices. He found that insect attacks caused most damage, and microorganisms attacked the surface and even the whole leaf structure. They summarized the main causes of deterioration but did not undertake a comprehensive investigation. Subsequently, Takagi et al. (2006) investigated the palm leaf manuscripts in the Asa Archives in Kathmandu, Nepal, and detailed their preservation. For instance, as rodents are prevalent in Nepal, the palm leaf manuscript was generally kept in a small plastic bag, and the top was closed with a string for protection against rodents. Rachman (2018) identified the deterioration phenomena of palm leaf manuscripts kept at the Royal Library of Puro Mangkunegaran, Surakarta. His research found that the palm leaf manuscripts at the Royal Library of Puro Mangkunegaran, Surakarta, were stable but exhibited insect damage, discoloration and mold. There are also many studies about the restoration of palm leaf manuscripts. Pandit Rao et al. (1992) described the method of consolidation and preservation of palm leaf manuscripts by using a mixture of fungicide and 10% polyvinyl acetate. Takagi et al. (2006) explained how stains on the surface of the palm leaf manuscripts were cleaned with cotton swabs with a mixture of ethanol and filtered water, and tears were repaired using Japanese paper. Dashrath Patidar et al. (2016) detailed the different types of indigenous material used to preserve the manuscripts and summarized their effectiveness.

Previous research does not provide a holistic overview or classification of the deterioration of and damage to palm leaf manuscripts. In addition, there is little research in this field undertaken in China. Therefore, it is relatively complicated to carry out the restoration and preservation of palm leaf manuscripts in the Potala Palace. A survey of the deterioration characteristics of palm leaf manuscripts in the Potala Palace was conducted by us. This paper analyzed and identified the major,

minor and occasional deterioration of the manuscripts and applied different restoration methods according to the deterioration types.

Materials and methods

Materials

Over time, palm leaf manuscripts will deteriorate due to natural aging of materials, environmental factors and manual damage. As there are so many palm leaf manuscripts in Potala Palace a representative sample had to be taken. Based on the investigation of these sample manuscripts, conclusions can be drawn about the overall preservation of palm leaf manuscripts in Potala Palace and their deterioration.

Random sampling was used to reduce the interference of human factors and increase the representativeness of the selection. Manuscripts were selected from different places, different collection times and different languages for investigation. The sample consisted of four original manuscripts and six photocopied manuscripts. The investigation codes of the four original palm leaf manuscripts are N1, N2, N3 and N4, and the six palm leaf manuscripts photocopies are P1, P2, P3, P4, P5 and P6. They are all written in Sanskrit, except N1 manuscripts have seven lines of text, P4 has ten lines of text, P6 has six lines of text, and the rest are seven lines of text per page.

In order to get an in-depth understanding of the palm leaf manuscripts in Potala Palace, the different deterioration of the originals and the photocopies were counted and analyzed. The types of major deterioration were categorized according to the frequency and degree of deterioration.

Methods

1. pH test

The pH test with a portable pH meter (HANNA HI8424) was used to measure the pH value on the surface of manuscripts to avoid taking samples of the original material.

2. Classification of damage

As there is no standard for classifying the deterioration of palm leaf manuscripts in China, the paper damage classification standard of archives and books industry is chosen for reference, because of the similarities. The analysis of the condition of Potala Palace manuscripts was based on DA/T 64.1-2017 (2017): Specifications for Rescue and Restoration of Paper Archives Part 1: The Grading of Damage, WH/T 24-2006 (2006): Standard for the repository of ancient books and special collection of library, WW/T 0026-2010 (2010): Classification and Legends of Diseases of Paper Collection, and WW/T 0003-2007 (2007): Classification and Symbol

Table 1 Classification of damage grades of archives

Damage grade	Extremely serious (which includes one of the following situations)	Severe (which includes one of the following situations)	Moderate (which includes one of the following situations)	Slight (which includes one of the following situations)
Deterioration				
Acidification	pH ≤ 4.0	4.0 < pH ≤ 5.0	5.0 < pH ≤ 5.5	5.5 < pH ≤ 6.5
Mold	Area > 30%	20% < area ≤ 30%	5% < area ≤ 20%	Area ≤ 5%
Wormhole or rodent attack	Area > 30%	20% < area ≤ 30%	5% < area ≤ 20%	Area ≤ 5%
Stain	Area > 60%	20% < area ≤ 60%	5% < area ≤ 20%	Area ≤ 5%
Damage and fragmentation	Area > 40%	20% < area ≤ 40%	5% < area ≤ 20%	Area ≤ 5%
Conglutination	Area > 50%	20% < area ≤ 50%	5% < area ≤ 20%	Area ≤ 5%
Fracture	–	Paper crease is irregular, resulting in damaged paper or illegible handwriting	25% < area ≤ 50%	Area ≤ 25%
Ink diffusing or feathering	Seriously affect the reading of archives	It is hard to read	Basic readability	It almost does not affect the reading
Ink fading	Seriously affect the reading of archives	It is hard to read	Basic readability	It almost does not affect the reading

The phenomenon is that manuscripts are stuck together due to moisture, dust, mold, long-term extrusion, and other reasons

The color of ink spreads around, which leads to the illegibility of handwriting and affects reading

The phenomenon is that the chromaticity of manuscript handwriting pigment decreases and gradually blurs due to various reasons, which affects reading

Illustration of the Diseases of Unearthed (Bamboo, Wood and Lacquer) Artifacts on Museum Collection (Table 1). Excel was used to record and count the data collected.

Status of palm leaf manuscripts in Potala Palace

Four original palm leaf manuscripts

1. Manuscript N1

The palm leaf manuscript is written in Sanskrit, which has eight lines. Text is difficult to read. This manuscript is severely damaged (Fig. 1); its length and width cannot be measured. The surface of the palm leaf manuscript has some clay stuck to the manuscript after encountering the urine of rats, which could lead to extremely severe conglutination. The major deterioration of manuscript N1 is stain, conglutination, damage and fragmentation (Table 2). The stained area of this manuscript takes up over 60%, and the conglutination area is more than 50%. According to Table 1, the manuscript shows extremely serious damage. The leaves of the manuscript are broken into many fragments, which cannot be picked up.

2. Manuscript N2

The manuscript N2 is also written in Sanskrit and has seven lines. The length of the manuscript cannot be measured due to severe damage. The single leaf width is 3.65 cm, and weight is 2.64 g. The pH value of the manuscript surface is 6.11, which is slightly acidified. The manuscript's major deterioration includes stain, conglutination, wormhole, mold and ink fading (Table 2). The stained area of manuscript N2 takes up over 20%, and the text is covered and unreadable. According to Table 1, this manuscript is in the category of severe damage.

3. Manuscript N3

Fig. 1 Palm leaf manuscripts are conglutinated and damaged.



Table 2 Condition of the original palm leaf manuscripts in Potala Palace

Code	pH	Deterioration	Damage grade
N1	6.15	Stain, conglutination, damage and fragmentation, mold, rodent attack, dusty, stain of rodent urine	Extremely serious damage
N2	6.11	Stain, conglutination, wormholes, mold, ink fading, ink diffusing or feathering	Severe damage
N3	4.60	Frayed out, wormhole	Severe damage
N4	5.10	Wormhole, frayed out, stain, hole fraying	Moderate damage

The manuscript N3 is written in Sanskrit and also has seven lines. The size of a single leaf is 31.3 cm (length) *6 cm (width), and the weight is 2.49 g. The pH value of the manuscript surface is 4.60, which is seriously acidified. According to Table 1, this manuscript is severely damaged. However, from the appearance, manuscript N3 has only slight frayed out and wormhole (Table 2).

4. Manuscript N4

The manuscript is written in Sanskrit with seven lines, and the text is legible. The pH value of the back surface is 5.10, which is moderately acidified. The major deterioration of manuscript N4 is due to wormhole, frayed out and stain (Table 2). The manuscript shows moderate damage (Table 1).

Six palm leaf manuscripts photocopies

These were copies of six manuscripts from Volume 21 and Volume 27 of the *Tibet Autonomous Region Collection of palm leaf manuscripts photocopies*. The deterioration types were identified page by page. The major deterioration included frayed out, stains, damage and fragmentation, fracture and ink fading. See Table 3 for details.

Eighty leaves of manuscript P1 had frayed out, 21 leaves with ink stains, rust stains and water stains. Fractures were found on fifteen leaves in different degrees, according to Table 1, among which six leaves were slight, seven leaves moderate and two leaves severe. The manuscript P1 was severely damaged, and the major deterioration involved frayed out, stain, fracture and damage.

Table 3 Deterioration of the palm leaf manuscripts photocopies in Potala Palace

Deterioration	Statistics of deterioration leaves					
	P1	P2	P3	P4	P5	P6
Frayed out	80	0	10	4	1	7
Stain	21	5	3	3	2	9
Damage and fragmentation	8	2	6	9	4	4
Ink fading	3	2	8	1	5	4
Fracture	15	1	2	2	1	1
Crease	6	1	0	3	0	2
Rodent attack, wormholes and mold	0	1	6	2	0	2
Hole fraying	0	0	0	2	3	5
Staining from fire	1	2	0	1	1	0
Ink diffusing or feathering	1	1	0	0	0	0
Total	135	15	35	27	17	34

The hole in the palm manuscript is used to fasten the manuscript with a string. Over time, the string rubs against the hole and causes it to deform

Manuscripts P2, P3 and P4, were in good condition, only slightly damaged according to Table 1. The major deterioration are were stains, fragmentation and ink fading. According to Table 1, manuscript P5 and P6 were moderately damaged. The major deterioration of manuscript P5 included frayed out, ink fading and fragmentation, while the major deterioration of manuscript P6 were stains and frayed out.

Excel software was used to convert the data in Table 3 into Fig. 2 to show the highest frequency of deterioration.

Analysis of the types of deterioration Potala Palace manuscripts

According to the damage grade of palm leaf manuscripts in Potala Palace (Table 2) and the statistical results of deterioration frequency (Fig. 2), a classification standard was developed to identify the types of deteriorated manuscripts, after careful consideration and discussion (see Table 4).

Eleven types of deterioration of palm leaf manuscripts are divided into three categories: major, minor and occasional. Three types of deterioration would be introduced in detail in the following content. In addition, the influence and concrete manifestation of deterioration on manuscripts and the causes would be discussed and analyzed.

Major deterioration

This category refers to the deterioration that frequently occurs in palm leaf manuscripts, which poses significant risk to the manuscripts’ sustainability. This type of deterioration requires close observation and regular monitoring.

1. Frayed out

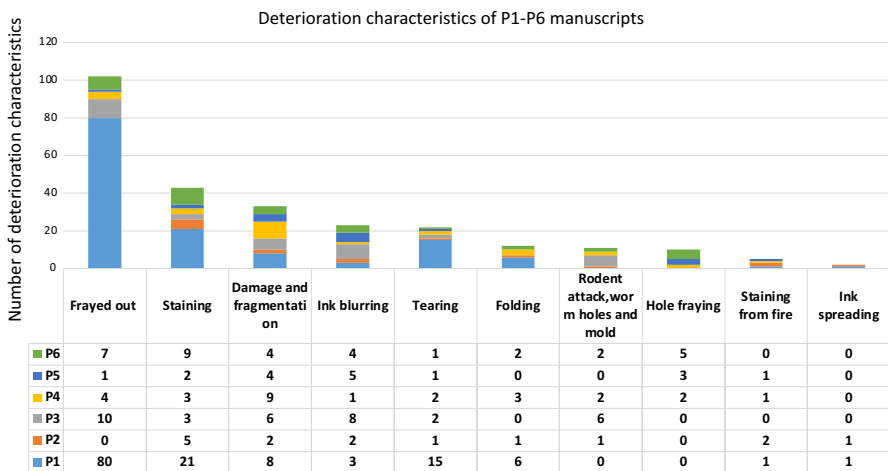


Fig. 2 Deterioration frequency of the palm leaf manuscripts photocopies in Potala Palace.

Table 4 Deterioration types of manuscripts in Potala Palace

Deterioration types	Influence on manuscripts	Method
Major deterioration	The high frequency of occurrence has a great influence on palm leaf manuscripts and even directly threatens the life of manuscripts	Carry out the necessary restoration of palm leaf manuscripts
Minor deterioration	The general frequency of appearance is relatively high, which has a little influence on palm leaf manuscripts and will not endanger the life of the manuscripts	Strengthen preservation measures to maintain the status quo of manuscripts and prevent from further deterioration
Occasional deterioration	The low frequency of occurrence has an uncertain influence on palm leaf manuscripts, sometimes large and sometimes small	Focus on analyzing the causes of deterioration, and improve the condition of storage

Fig. 3 Frayed out palm leaves**Fig. 4** Ink Stain on the palm leaf manuscript

Frayed out is the most common deterioration of palm leaf manuscripts. The main reasons are long-term wear and tear, resulting in the separation of the leaf fiber at the edge into filaments.

There are three original manuscripts showing different degrees of frayed out (Fig. 3). Among the six photocopies of palm leaf manuscripts, 102 leaves have frayed out at the edge of the manuscripts, more than half of the area damaged accounted for 15% of the total. The results of this investigation show that the frayed palm leaf manuscripts are the most common and serious deterioration, has to be noticed.

2. Staining

The other important finding was that staining is the second most common deterioration after frayed out. The stains on palm leaf manuscripts cover up the text and cause serious conglutination of palm leaf manuscripts. Four palm leaf manuscripts had a variety of stains, including water stains (33%), ink stains (16%), rust stains (5%) and unknown stains (46%) (Fig. 4).

3. Damage and fragmentation

The current study found that damage and fragmentation usually occur at the edge of the palm leaf manuscripts, and a few seriously damaged palm leaf manuscripts were largely incomplete. Under the influence of external factors, the loss is caused by an external force after the palm leaf manuscripts material is aging or acidified and becomes brittle.

Several leaves of the N1 manuscripts had severe damage and loss on their edges. Thirty-three leaves were damaged in the six photocopies, P1 and P4 have more missing edges, and P2 has a slight missing edge.

4. Ink fading

The handwriting deterioration of the ten palm leaf manuscripts investigated in this study is mainly ink fading and ink diffusing or feathering, with fading (92%) the most common handwriting deterioration. The water absorption of the surface of palm leaf manuscripts is slight, the combination of ink and the palm leaf is not firm, and the handwriting is scraped off easily. Therefore, the friction between the palm leaf manuscripts or the cracking of the manuscript surface can easily lead to the blurring of the writing, which reduces the legibility of the text content of the manuscripts.

5. Fracture

The palm leaf manuscripts will be damaged after being squeezed by an external force, so they need to be carefully stored. If the damage is not reinforced in time, palm leaf manuscripts' condition will worsen, affecting the integrity and readability of contents. Among the six photocopies of palm leaf manuscripts, there were fractures in different degrees, among which 9% were severe, 52% were moderate and, 39% were slight (Fig. 5).

6. Biological attack

Palm leaves are organic material, which is easily attacked by mold, pests and rodents. The insects include booklice, termites, silverfish, cockroaches and moths. Mice are the most frequent type of rodent. These pests and the development of mold growth on the manuscripts have led to pollution, damage, acidification and conglutination of the manuscripts.

Fig. 5 The palm leaf manuscript is fractured



7. Conglutination

Almost all of the leaves of manuscript N1 were conglutinated together, which was very serious. Part of the leaves of manuscripts N2 was conglutinated. This was due to inappropriate storage, the glue component in the ink, and the long-term effects of high humidity, dust, insect and mold secretions. The leaves were conglutinated, which causes consolidation into blocks and form “the bricks of the palm leaf manuscripts.”

Minor deterioration

Minor deterioration means that the frequency of occurrence is lower than that of major deterioration. The damage grade is moderate, which has little influence on the long-term preservation and utilization of palm leaf manuscripts. For minor deterioration that does not endanger the life span of palm leaf manuscripts, it is only necessary to maintain the status quo and strengthen the preservation measures to prevent further deterioration, without any other restoration work on the manuscripts.

1. Hole fraying

Similar to paper books, palm leaf manuscripts need to be bound with string through holes. Usually, holes are punched in the palm leaf and then used to connect the individual leaves with a white cotton string passed through.

Generally, the long palm leaf manuscript has two holes, while the short ones have only one hole. The number of holes is determined by the length of the palm leaf manuscript. Hole fraying means that holes are often worn by string during long-time reading and utilization, resulting in deformation of hole shape.

2. Crease

The creases of palm leaf manuscripts are similar to archives and books formed by an external force. According to the investigation, the creases of palm leaf manuscripts are slight at present. However, once the crease develops, the manuscript will be damaged. Therefore, although creases are currently minor and uncommon, special attention should be paid to avoid the creases getting worse during future storage.

Occasional deterioration

Occasional deterioration refers to the low frequency of occurrence, which occurs only under certain particular circumstances. So long as it does not affect the readability of the contents of the palm leaf manuscripts, it does not require remedial action. It is necessary to discuss the causes of occasional deterioration in order to avoid them in future preservation strategies.

1. Staining from fire

Staining from fire means that the local color of palm leaf manuscripts turns dark brown, which seriously affects the legibility of the text. There are many reasons for this staining, which may be due to smoke or aging of materials. There-

fore, the preservation environment of palm leaf manuscripts should be kept clean and free of air pollution.

2. Ink diffusing or feathering

The ink diffusing or feathering is mainly caused by water-soluble ink, which indicates that the surface of the palm leaf manuscript was once wet. During the process of preservation, palm leaf manuscripts should be kept dry and not exposed to moisture.

Discussion of main deterioration repair technologies

The most critical work in preserving and restoring palm leaf manuscripts is to stop the deterioration of the manuscript and restore the major and serious damage. However, according to the literature review, as we know, there is little discussion about manually restoring other deterioration, so there is very little best practice to follow. In view of the preciousness and fragility of the palm leaf manuscripts, the Potala Palace has not yet undertaken any restoration. Before embarking on any restoration strategy, Potala Palace needs to carry out an in-depth study of the causes of deterioration and analyze the existing research on the manual restoration of palm leaf manuscript.

Frayed out and fracture: repair and reinforcement

Sah (2002) proposed that the palm leaf manuscript fracture could be repaired using silk gauze, chiffon or tissue paper, along with acrylic rubber adhesive, acrylic emulsion adhesive or starch paste. As for the frayed palm leaves of the edge of manuscripts, traditionally in Thailand, lacquer is brushed on the leaf edges (Agrawal 1984). However, the lacquer will harden the edge of the palm leaf, the blade's edge, and the paint will fall off and contaminate the manuscript so plant gum should be used instead. A flame would be used to scorch the palm leaf edges in Sri Lanka (Sah 2002). Agrawal (1984) has proposed that acrylic emulsion could be applied to strengthen the edge fiber at the palm leaf manuscripts. There were also some collections that use hand-made paper to repair frayed out palm leaves at the edge of manuscripts (Joshi 1989).

There are three ways to repair the missing edge of palm leaf. The first method is to repair the edge with palm leaf material. The National Cultural Heritage Preservation Research Center of India adopted the edge lap method and uses polyvinyl acetate emulsion for bonding (Agrawal 1984). The British Library adopted the method of inlaying, cutting the palm leaves into the same shape at the missing parts, bonding them with resin wood adhesive. The second one is to repair with hand-made paper. Both the National Cultural Heritage Conservation Research Center of India and the British Library used Japanese paper, and wheat starch paste to repair the breaks in palm leaf manuscripts (Lawson 1987). The third is to use bark to repair. Nichols (2004) explained that the Boston Museum of Art in the USA had used the inner white bark of mulberry trees to repair the palm leaves, with good effect. In addition, a pulp repair machine is used to repair the missing part of the palm leaf manuscripts in batches, and the impact needs further discussion.

To repair broken leaves, hand-made paper, silk laminates or gauze were usually used, dyed and cut into strips, and then pasted, and strengthened with adhesives such as paste, methylcellulose and fish glue (Lyu Xiaofang 2020). Some palm leaf manuscripts were repaired with stitches or pressure-sensitive tape. These are nonstandard repair methods that would change the appearance of the manuscript. Repair damaged manuscripts need adhesives, but the adhesive effect of starch or fish paste is limited, unless it is high polymer adhesive, but the latter may affect or remain in palm leaves.

Ink fading: re-inking

Two writing systems are used in palm leaf manuscripts. One involves use of a stylus to engrave the letter first, then to color with ink, and the other is to write with fluid inks and a quill pen. The writing type depends on type of leaves. A stylus was used to write Tala leaves, while a quill pen is used to write Sritala leaves (Sahoo Jyotshna 2016). Engraving is mainly popular in South India. First, it is engraved with stylus and then colored with insect-repellent essential oils such as citronella oil and lamp-black (Kumar 2009). Using a quill pen and other tools to write on the surface of leaves is common in North India.

Sah (2002) explained that re-inking could be used to increase the legibility of text, and 5% solution of cellulose acetate could also be used for reinforcement. Researchers select the method of repair in accordance with the degree of deterioration. In addition to re-inking, Agrawal (1984) pointed out that 2% soluble nylon ethanol solution could be used as an ink preservation coating on the surface of palm leaves, which could enhance handwriting and prevent the ink color from falling off.

In conclusion, scholars in India, Britain and the USA have studied the reinforcement of handwriting on palm leaf manuscripts. Despite this, the restoration and preservation of palm leaf manuscripts in the Potala Palace are still quite complicated, because there are a large number of palm leaf manuscripts here, they are different in terms of ages, ink and writing tools (such as a stylus or quill pen). The influence of reinforcing agents on palm leaf manuscripts needs further discussion. There is no research on the ink reinforcement of palm leaf manuscripts in China. However, the research on paper handwriting reinforcement is relatively mature, and there are many successful experiences to learn from.

In recent years, digital handwriting restoration technology has developed rapidly. Digital handwriting is repaired by image enhancement, image segmentation and binarization technology, and it can achieve good results.

Stain: cleaning

The dust and stain on the surface of palm leaf manuscripts should be first cleaned with a soft brush or cloth. The stains which are difficult to remove and affect the utilization of the manuscripts need to be cleaned with distilled water or organic solvent.

At present, engraved palm leaf manuscripts are generally wiped and cleaned with a soft cloth or brush dipped in distilled water. If there is handwriting on the surface

of palm leaves, a first consideration must be whether the ink is soluble in water and if so, an alternative cleaning agent used.

The British Museum used trichloroethane for cleaning; Gupta (1974) also suggested cleaning the palm leaf manuscripts with a mixture of alcohol and distilled water in the ratio of 3:2 with a soft cloth. The use of these organic solvents is still being explored, and their impact on palm leaf manuscripts needs further study. Paper cleaning technology has been used and tested over time. Therefore, the paper cleaning technology can be fully used for reference and applied to clean palm leaves.

Wormhole and mold: pest and mold control strategies

Traditional deworming measures in Southeast Asian countries, such as India, use various natural plants to prevent insects and bacteria. Essential oils such as citronella oil (lemongrass oil), cedar oil, clove oil, camphor oil and eucalyptus oil can effectively repel insects. Plant seeds can also kill insects and resist bacteria effectively. For example, the powder of *Annona squamosa* seeds can kill insects. Thymol was contained in Ajowan seeds, a natural compound with insecticidal and antibacterial properties with good insecticidal and antibacterial effects (Sharma 2018). In addition, the wooden planks are made of neem wood which can ward off termites; leaves of neem, turmeric, black pepper and garlic can be used as an insect repellent (Dashrath Patidar 2016).

In addition to the natural insect repellents mentioned above, synthetic chemical insecticides have been widely used by various collecting agencies in recent decades. To disinfect storerooms and conduct large-scale insecticidal sterilization, chemical synthetic fumigants such as thymol, *p*-dichlorobenzene, carbon tetrachloride and trichloroethane can be used (Sah 2002a, b). Mold on the upper part of the palm leaves can be wiped off with cotton swabs dipped in ethanol (Agrawal 1984).

In recent years, the archival departments and cultural relics departments in China have applied low-oxygen controlled atmosphere technology to prevent insects and mold infestation of archives, ancient books and wooden cultural relics. The practice shows good results. Therefore, this technology has strong practicability, and its application can be extended to pest control of palm leaf manuscripts.

Conglutination: Mounting

Das (1987) gave an overview of the preservation and restoration of manuscripts in the National Library, Kolkata. The library separated palm leaves by humidification or by hot liquid paraffin heated to 70–80 °C, and then the wax was cleared with acetone. It was also possible to separate the stuck palm leaves by putting them into hot water at 60 degrees and adding 5–10% glycerol in the water. Alternatively, the palm leaves were treated with hot steam, softened water-soluble substances with steam and separated the adhered leaves (Joshi 1995). The method of soaking palm leaves in liquid for separation of the adhered leaves is easy to deform the leaves. The liquid will remain in the leaves, which may have a bad influence on it in the future.

Conclusion

Palm leaf manuscripts are among the most precious ancient books in the world. As for the precious and fragile cultural heritage of palm leaf manuscripts, it is necessary to investigate its deterioration accurately. The purpose of assigning grades is to take targeted measures for different damaged objects. For major deterioration, if it threatens the life of manuscripts, mature and safe repair methods should be adopted for restoration as soon as possible. For minor deterioration and occasional deterioration, the primary purpose should be to maintain the stability of the manuscripts, which can be preserved by improving the environment and equipment to avoid excessive intervention and treatment so as to realize optimized the long-term preservation and inheritance of palm leaf manuscripts.

The purpose of restoring palm leaf manuscripts is to prolong their life as much as possible. However, if inappropriate repair methods are adopted, manuscripts will be damaged further. At present, the method and technology of manual restoration of palm leaf manuscripts are still immature both in China and elsewhere and are still in the exploratory stage. On the other hand, internationally there are some good practices, theory and experience. It is necessary to fully understand the feasibility, scope of application and potential risks of each restoration technology, material and make clear which are ready to be applied, and which are still experimental. Reduce the risk caused by the uncertainty of restoration work and ensure that the repair methods, materials and processes have no adverse impact on the palm leaves. Restoring the original appearance of the palm leaf manuscript is the fundamental goal of the implementation of restoration technology.

The present study makes a preliminary classification of deterioration, based on analysis of the Potala Palace palm leaf manuscripts. Future research will explore the classification strategy and further refine the deterioration types. This could include for instance a hierarchical protection model and the palm leaf manuscripts can be divided into five grades according to the degree of deterioration. Such a classification system can clarify the prioritization of restoration actions so the most damage manuscripts are restored first.

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