



RESEARCH PAPER

Use of Bio-polymeric Dye from *Butea monosperma* (Palash Gond) Resin for Sustainable Textiles cotton, linen and silk Using Tie-Dye Technique

Rehmania Aman

PhD Scholar, Department of Archaeology, University of Peshawar, Peshawar, KPK, Pakistan

Corresponding Author: Rehmaniaaman786@gmail.com

ABSTRACT

This research paper examines how to extract natural dye from *Butea monosperma* (Palash Gond) and by using it for making fascinating fabric patterns through tie-dye techniques. The textile industry needs to evolve better ways to colour fabrics that do not harm the environment by use of Bio-polymeric dye. Natural dyes from plants offer a safe choice instead of chemical dyes that pollute water. In this research, mixed method research is used which integrates both qualitative and quantitative research which effectively address the research objectives. Aqueous method have been used to record how Palash resin works when applied on cotton, linen, and silk using traditional tie-dye technique like marbling, Nui shibori, and binding techniques. The findings reveal that Palash resin creates warm colours ranging from reddish pink to orange with clear pattern lines because the resin is naturally sticky and thick. Textile artists and small craft businesses can make use of natural dye to make special fabric products that customers' value for being traditional and environmentally friendly.

Keywords Natural Dye, Tie-Dye Technique, Sustainable Textiles, Palash Resin, Fabric Design

Introduction

The textile industry in this era is facing various problems which include how to colour the fabrics. Most of factories make use of synthetic dyes made up from chemicals. These dyes contaminate the water killing aquatic flora and fauna. The release of this coloured wastewater without scientific treatment occasions damage to the environment. (Kant, 2012). Studies unveil that textile industry annually emits three billion tons of harmful gases by dyeing and finishing processes thereby causing extensive environmental hazards. (Pizzicato et al., 2023). Huge amount of water and energy is consumed in the dyeing process as around 12 to 15 % of chemicals used in textile factories drain out even without sticking to the fabric. (Chung, 2016). This waste dye directly goes into rivers and streams.

Butea monosperma, a specie of trees grows in South Asia especially India, Pakistan, and Bangladesh. It has many local names including *Palash Gond*, Flame of the Forest, or *Dhak*. It has bright orange-red flowers which bloom during spring. This tree produces a sticky substance called resin or gum. For hundreds of years, local people used this resin in making medicine and colouring fabrics fig.1 (Pandey, 2016). Its resin contains natural colour substances that give shades of pink , orange, and reddish pink (Negi et al., 2023). Unlike flower petals that require crushing and soaking, the resin of this tree contains special

sticky properties which naturally help attach colour to the fabric without extra-use of chemicals. It thus helps discount the cost of dyeing.



Fig 1. Palash Gond For Natural Dyeing

Tie-dye is an ancient method used for dyeing fabric by tying, folding, or twisting before adding colour. The tied parts resist the dye and maintain their original colour, creating patterns. Many cultures have practiced tie-dye for thousands of years. In India, people call it *Bandhani*. In Japan, they call it *Shibori* (Wada et al., 2012). In both traditions, craftspeople produce different but beautiful patterns by carefully tying the fabric in many ways. Each tie-dye technique produces different pattern shapes. Some patterns give the look of circles, others like lines or stars etcetra. The beauty of tie-dye emanates from mixing careful planning with natural unpredictability. Thus no two pieces ever look facsimile of one another.

This research aims to bring together the natural plant dye methods and the traditional tie-dye techniques for creating environment-friendly textile designs. This study tests how Palash resin works as a dye on three types of commonly used fabric. Cotton is made from the plant fibers. The linen comes from flax plants while the silk from silkworm cocoons. Each fabric takes colour differently because of its structure. It further examines what patterns emerge, how strong the colours can be, and whether they fade away quickly. This knowledge may help textile artists, fashion designers, and craft businesses to make products that are both beautiful and good for the environment.

Literature Review

Traditional Tie-Dye Techniques

Tie-dye exists in many countries and cultures across the globe. In India, *Bandhani* technique involves pinching small portions of fabric and tying them tightly with thread. Workers use their fingernails to lift up tiny points of fabric while dyeing. The tied areas resist dye and create small dots or circles. Different regions in India have their own local patterns. Gujarat and Rajasthan states are famous for *Bandhani* work (Talib et al., 2024). Names of patterns are descriptive of their appearance. *Bundi* means small dots with dark centers. *Leheriya* produces diagonal wave patterns. Each pattern depicts cultural meaning and is used for specific occasion like weddings or festivals.

Japanese *Shibori* techniques offer more variety on how to manipulate fabric. *Kanoko Shibori* makes use of thread binding to create dot patterns. *Itajime Shibori* involves folding fabric accordion-style and clamping it between carved wooden blocks. It gives birth to geometric patterns with straight lines and repeated shapes. *Arashi Shibori* wraps fabric diagonally around a pole and scrunches it before dyeing. It creates diagonal rain streaks. *Kumo Shibori* produces patterns that look like spider webs through special pleating and binding. *Nui Shibori* apply the sewing stitches that get pulled tight to gather the fabric (Wada

et al., 2012). Each technique requires different skills and produces unique visual effects. Fashion designers today combine these old techniques with modern designs.

Natural Dyes from Plants

Prior to the invention of chemical dyes during the 1800s, all fabric colours used to come from natural sources (Subramanian Senthilkannan Muthu, 2023) Plants would provide most of colours. Parts of different plants give different colours. Roots often give colours like red or brown. Leaves may give green or yellow while the Bark brown or black. Flowers also provide so many colours depending on the species of the plants. People would extract colour by boiling plant materials in water (Samanta & Agarwal, 2009). The colour would dissolve into the water creating dye liquid. Fabric soaked in this liquid would absorb the colour. However, natural dyes face number of challenges. Many natural colours fade quickly in sunlight or wash out. They also produce softer and less brighter colours than chemical dyes.

Several researchers have studied *Butea monosperma* flowers and resin. Substances contained in the flowers are called flavonoids that create colour. Research works of scientists reveal that they have duly identified specific colour compounds including butein, butrin, and iso-butrin (Negi et al., 2023). The compounds so found relate to a family of plant chemicals which produce yellow, orange, and red colours. Scientists have found the same colour compounds including sticky substances called tannins from the resin of the tree trunk. Tannins help the colours stick to fabric naturally. The resin thus acts as colorant as well as fixing agent. It was established by research conducted by (Sinha et al., 2012) that *Butea monosperma* flowers successfully dye cotton and other fabrics via optimized extraction methods. Work of Mayusoh (2015) showed that natural dyes from various plant sources including sappanwood, red cabbage, basil, and mango help create beautiful tie-dye patterns on fabric. As regards the colours' range from light yellow to deep orange-red, it fully depends upon how much plant material is used and how long the fabric soaks in the dye.

Improving Natural Dye Performance

There is a problem with natural dyes that they do not last long on fabric. The colour fades away after washing or exposure to sunlight. To fix this problem, dyers make use of mordants i.e a substance that helps dye stick better to fabric (Samanta & Agarwal, 2009). Included in the list of traditional mordants are mineral salts such as alum. Alum is aluminum salt that helps bridge gap between dye molecules and fabric fibers. Colours become brighter and last longer when fabric is treated with alum before dyeing. But mineral mordants may pollute water (Benli, 2024). To deal with this issue, what scientists do is that they explore plant-based mordants which work effectively without being hazardous to the environment. In this respect, pomegranate peels, tea leaves, and certain tree barks are found to contain natural tannins that act as mordants.

Different Fabrics Take Colour Differently

Since cotton, linen, and silk have different structures, therefore, each of them accepts dye differently. Cotton fiber, being almost a pure plant cellulose has got a twisted ribbon-like shape. Waxy coating on fiber surface has to be removed before dyeing through a prescribed process: namely, scouring in which washing soda and hot water are used to remove wax, oils, and dirt (Samanta & Agarwal, 2009). After scouring, cotton becomes more easily dye-absorber. At the same time, it needs mordants' help to hold natural dyes. Mordanting cotton is a two-step process: firstly, fabric is soaked in a tannin bath; and secondly, it is soaked in alum solution. This technique makes it quite easy to attach the dye to fabric firmly.

Linen is by-product of flax plant stems. Its fibers are longer and stiffer than that of cotton. Besides cellulose, linen contains more plant materials including substances known as lignin and pectin. Owing to these extra-materials, it is hard to dye linen as compared to cotton because it requires stronger scouring treatment to expose the fiber surface. Fabric needs longer time in the dye bath to absorb colour evenly. Linen does have certain thick spots along each fiber known as nodes. The nodes take dye first and stronger than other parts. It though gives an interesting pattern effect, yet linen gives less even colour overall.

Silk is altogether different from cotton and linen for being a protein fiber and not a plant fiber. Silkworms make silk from protein in their bodies. Silk's protein structure gives it many sites where dye can attach. Silk needs no two-step tannin and alum treatment. Mordant can directly attach to the silk proteins (Samanta & Agarwal, 2009). Other general attribute of silk is that it takes colour more easily producing brighter and stronger colours than that of cotton or linen.

Environmental Benefits of Natural Dyes

Synthetic dyes have serious environmental implications. Around 60 to 70 % of textile dyes are related to a type known as azo dyes which contain chemical structures that are resistant to easily break down in nature (Chung, 2016). Molecules of these dyes, when their wastewater is released by factories into rivers, remain alive for longer time. These dyes make the water coloured thereby preventing sunlight from reaching underwater aquatic fauna and flora. As result, water plants' growth gets affected and entire water ecosystem gets endangered. Scientists have further noticed that some of chemical dyes, during their breaking down process, emit toxic substances. These toxins may become cause of cancer and other health problems for humans as well as animals.

Contrarily, natural dyes completely end up into harmless substances. The release of natural dye water is into the environment in inconsequential as bacteria and other microorganisms digest it. Molecules of these dyes decompose into minor organic materials which are not fatal to any living thing (Pizzicato et al., 2023). Tests applied to measure water pollution use certain standards, namely: BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand). These tests mathematically work out quantity of contaminating and pollutive elements in water. As regards chemical dye wastewater, it has got very high COD numbers, that is to say, it contains substances which are resistant to natural break down. Natural dye wastewater has lower numbers of COD, hence liable to natural break down with ease.

Collection of Palash resin in no way harms the trees. Workers tap the trees from the trunks where sticky resin is oozing out and they gather it. It is rather similar to that of collecting rubber or maple syrup. It does not at all adversely affect the natural growth of trees. The use of dyes made from material obtainable from plants, which can naturally grow back or regrow every year, is far better than the use of oil-based chemical dyes (Dey et al., 2025). Oil is a limited resource and it may eventually run out. Plants regrow each season. Growing trees helps remove carbon dioxide from the air and reduce climate change (Pizzicato et al., 2023). Production of chemical dyes requires high temperatures and creates pollution. Extraction of natural dyes uses much less energy and produces less rather nominal pollution.

Material and Methods

The nature of this research is mixed method research which integrates both qualitative and quantitative research which effectively address the research objectives. The purposive sampling technique is used. Simple methods have been used to watch and record how Palash resin works when applied fabrics like cotton, linen and silk using traditional tie-

dye patterns like marbling, Nui shibori, and binding techniques. These materials are documented through photographs, experiments and detailed descriptions.

Extracting Colour from Palash Resin

To get colour from Palash is not an uneasy task. It starts with gathering the resin from the trees. Resin appears as reddish-brown sticky substance on trunk of tree. Workers scrape off the dried resin pieces. These pieces are cleansed by removing bark, dirt or other impurities. Thereafter, resin is crushed into smaller pieces and consequently, it may be ground into powder form (Mall et al., 2016). To break resin into small pieces helps the colour dissolve easily into water as these small pieces have more surface area touching the water, hence easy to liquify.

The crushed resin is added to water and heated in order to extract dye (fig 2). Demonstrated that there occurs maximum extraction at temperatures between 70 and 80 degrees Celsius. This is not boiling but only hot. Mixture needs to be heated for about 45 minutes to one hour. Water should be stirred occasionally during heating. Colour substances dissolve from the resin into water. Gradually, water changes from clear to pinkish or reddish-brown. As and when heating is complete, the mixture is filtered to remove solid pieces or residue (Pandey, 2016). Liquid is poured through fine cloth or fine strainer to separate coloured water from the debris. The filtered liquid is thus dye bath ready to use.

Quantity of resin used in heating process is an indicator regarding strength of colour. More amount of resin creates darker colours. Less amount of resin gives lighter shades. For obtaining strong colours, typical ratio is 50 grams of crushed resin pieces to 500 millilitres of water. This ratio is adjustable to get colour depth on need-basis. The quantity of resin used to make dye acts as adjuster of colour strength. More resin creates darker and more intense colours. To brighten the orange tone, alum powder is added to the dye bath. One teaspoon alum powder per one litre dye bath can work well. Alum not only makes the colour vivid but helps the colour stick to the fabric with ease.



Fig 2. Extracting dye from palash gond

Preparing Fabric for Dyeing

It is essential to prepare all fabric before tie-dyeing. It is necessary to give a thorough wash to cotton and linen in order to remove factory treatments. Unused fabric has starch or sizing that hampers the absorption of dye. These coatings are removed through scouring. For scouring cotton or linen, fabric is washed in very hot water with washing soda (fig 3). (Samanta & Agarwal, 2009). For a gallon of clean water, two tablespoons full of washing soda are more than enough. Soak the fabric for about 30 minutes. Then rinse the fabric thoroughly with clean water. When fabric is felt clean and slightly rough but not slippery or smooth, it is ready to go for next dyeing step.

Gentler treatment is required for silk. Silk is degummed to remove sericin gum coating. Fill in a large pot with clean water and add to it mild soap or silk detergent. Heat it

to about 90 degrees Celsius. Put the silk into hot soapy water. Let it simmer for about 30 to 60 minutes. Stir it occasionally but handle it gently to avoid damage to delicate fibers. Water will get cloudy when the gum is dissolved. After degumming, rinse the fabric progressively in cooler water until the water runs clear. When silk gives softer feeling and shining look, it is ready for further dyeing step.

As and when scouring or degumming is completely done, if stronger colour is desired, the fabric should be treated with mordant. For cotton or linen, make tannin bath first. Tea, oak, galls or pomegranate peel may provide quality tannin (Shahid-ul-Islam et al., 2018). Boil tannin source in clean water for 30 minutes. Strain out solid pieces. Put scoured or degummed fabric into the tannin water and soak it for several hours or overnight. After that, make alum bath. Dissolve alum powder in warm water. Use alum equivalent to about 15 percent of the fabric weight. Soak tannin-treated fabric in alum water for one hour. As regards silk, it needs alum bath alone as the silk does not need tannin pre-treatment. After complete mordanting, rinse the fabric and squeeze out the excess water. The fabric is now ready for tying and dyeing.



Fig 3 Scouring and mordanting the Fabric

Results and Discussion

The main findings reveal that Palash resin creates warm colours ranging from reddish pink to orange with clear pattern lines because the resin is naturally sticky and thick. Different patterns are created on fabrics by using different tie dye techniques and each technique has given a different shapes and designs.

Tie-Dye Techniques and Pattern Creation

Marbling technique is employed to create organic (fig. 4) and vein-like patterns that give the look of natural stone. To apply this technique, the fabric is randomly crumpled into a loose ball. Rubber bands or string are wrapped around the ball in different directions. (Mayusoh, 2015). More random crumpling helps produce more organic patterns. During dyeing process, the dye seeps into folds creating irregular lines and shapes. Tightly compressed crumpled areas stay lighter. Loosely folded areas take more dye and become darker. Marbling suits dyeing of large pieces of fabric such as scarves or wall hangings where an over-all pattern is the befitting one without regular repetition.

Nui Shibori apply the sewing stitches (fig. 5) that get pulled tight to gather the fabric (Wada et al., 2012). That creates circular patterns radiating from a center point. Fabric is laid flat on a table. It is pinched at a point where the center of spiral is desired. That specific point is twisted but rest of fabric is held in place. Twisting is kept on until the entire fabric turns into a flat spiral disk. The spiral is secured with string or rubber bands crossing through the center like the spokes of a wheel. During dyeing, the tight center resists the dye and remains light coloured and the dye flows along and sticks to the twisted folds creating sunburst or spiral galaxy patterns. Colour is strongest at the outer edge and it gradually lightens towards the center. As respects the pattern, it fully depends upon how the fabric is

sewing and what shape are used. Squares produce grid patterns. Triangles create diamond patterns.

Binding technique is so unique as it creates dots and circles. Dyer pick ups small points of fabric and wraps them tightly with thread (Talib et al., 2024). The tighter the wraps, the better the resist effect. For larger circles, more fabric is gathered. For smaller dots, less fabric is gathered. Patterns can be produced by spacing the tied points evenly or randomly. In traditional Indian *Bandhani* dyeing (fig. 6), this technique is applied to create intricate dot patterns that cover up the entire fabric. Though this process is time-consuming, yet it creates fascinating results. After dyeing, when the threads are untied, each tied point becomes a perfect circle with soft colour gradation from the center outward.



Fig 4. Marbling technique on linen fabric



Fig 5. Nui Shibori with spiral Technique On Silk Duppatta



Fig 6. Binding Technique (Bandhani) On Cotton Fabric

The Dyeing Process

Once the fabric is tied, it is ready for dyeing. Heat the Palash resin dye bath to about 70 degrees Celsius. The utensil size and amount of dye bath should be large enough so that the tied fabric can move freely therein. The tied fabric should be wetted thoroughly with plain water before dipping it into the dye. This would help the dye penetrate evenly. The tied fabric needs to be lowered down into the hot dye bath ensuring that all parts of fabric must come under the liquid. Keep the heat steady. It must not at all be boiled vigorously as it can cause damage to the fragile fibres and may even cause uneven dyeing.

For obtaining strong colours, soak the fabric for duration between 45 minutes to one hour (Pranta & Rahaman, 2024). During dyeing stage, the dyer may occasionally move the fabric around gently ensuring even dye penetration. If a small dab of salt is added to the dye bath, it can help the colour soak better (Mayusoh, 2015). For this purpose, one tablespoon of salt per liter of dye works well. The Palash resin dye has inherent thickness owing to its own sticky substances. For tie-dye, this natural thickness is much helpful. Thick dye does not easily percolate into tightly tied areas. As result, very clear and sharp lines between dyed and undyed sections are created on fabric. If the dye is thin watery, it it causes seepage everywhere thereby making fuzzy pattern edges.

After when the dyeing time is complete, the fabric is removed from dye bath. It should not be untied forthwith but it must be rinsed in cool water to remove excess or extra dye. Rinsing must continue until the water runs clear. Thereafter, the strings are untied and clamps removed. The fabric is unfolded with care and caution to unveil the patterns. The opened fabric is once again rinsed in cool water. For final rinsing, one may add a small amount of vinegar to the water. Remove the fabric from the dye bath. Do not untie it immediately. Rinse the tied fabric in cool water that will help set the colours. One cup of vinegar per one gallon of water is recommended as a well workable ratio. When rinsing is complete, fabric must be hanged to dry in the sunlight, Strong sun is, however, fatal as it may cause fading of colours while fabric is still wet.



Fig 7. Dyeing fabrics of cotton, linen and silk

Understanding Pattern Results

The Palash resin dye does have very special attributes and characteristic in terms of creation of patterns on fabric. For its thickness and sticky nature, resin dye produces halo effect around tied areas. The halo appears in the form of a gradual colour change from dark to light. It occurs so because it can penetrate up to a very short distance into the compressed fabric. The very center of tied area remains either untouched as white or very lightly coloured. The colour gradually deepens outward. This natural gradation gives the tie-dye

patterns a unique organic and hand-made quality. This is not possible to produce such fragile colour blending with any machine printing.

Colours that are obtainable from Palash resin range between yellow-orange and orange deep rust-red (Negi et al., 2023). The exactness of colours hinges on number of factors. More amount of resin gives darker colours. Addition of alum helps produce brighter colours. Original colour of fabric also matters to a sufficient extent. Palash resin dye on white fabric gives bright and clear look. The colours appear more earthy and subdued if Palash resin dye is applied on natural and unbleached fabric. Different fabrics reveal effect of colour dye and tone of colour differently. Silk takes the strongest but vivid colours, Cotton gives medium-strength colours. Linen produces lightest but subtle colours. Palash resin dye is unique in this respect that it creates different aesthetic effect on each type of fabric.

The Palash resin tie-dye has uniqueness in its line quality. The reason is that owing to its thickness and sticky nature, it prevents bleeding and blurring. When it is compared to other synthetic dyes, which are thin and watery, it stands out clearly that that thin dyes seep into tightly tied areas thereby producing fizzy edges but the natural thickness of Palash resin dye helps keep it where it should be. That is why it creates professional- looking results for novice. The patterns create very sharp contrast between coloured and white areas. This specific quality of resin makes geometric patterns strikingly striking. This is the speciality of this particular natural dye.

Making Colours Last Longer

Natural dyes face two major durability challenges: washing and light exposure. During wash, some colour of naturally dyed fabric washes out. With usual washes, the colour becomes lighter and lighter. Exposure of naturally dyed fabric to sunlight has the fading effect on the colour. Strong sun affects colour molecules. Colour of fabric hanged behind bright windows or worn outside fades faster than the fabric kept in shade. These are genuine issues, which are manageable through care and treatment.

Mordanting is a distinct technique to improve upon durability of colours. Treatment of fabric with alum before dyeing, it has been discussed hereinbefore, helps colour last longer (Samanta & Agarwal, 2009). Alum creates connectivity between dye molecules and fabric fibers and such bond is stronger than dye alone. Fabric mordanted with alum can better withstand the fading effects of several washes. For better results, natural materials can serve as good mordants (Benli, 2024). Tannins contained in pomegranate peel help fix colours. Tea is another natural mordant. These plant-based mordants are fully safe for environment

Environmental and Social Benefits

Use of natural dyes is contra-pollutive in many ways. Dyeing process per se releases less contaminated water as the natural dye water contains plant material and simple mineral salts. Bacteria in rivers and soil can easily offset the effects of these substances (Pizzicato et al., 2023). But chemical dye water contains compounds which are resistant to break down. These compounds are fatal to the environment and cause long-term damage. It is scientifically proved that even very small amount of chemical dyes contain toxic material which are injurious to aquatic flora and fauna. (Chung, 2016). Natural dyes have got no such toxicity issue.

To gather Palash resin is no threat whatever to sustainability of forestry as trees are not subjected to any cut down. The trees continue their growth uninterruptedly producing flowers and resin in every season year after year (Coelho et al., 2023). It gives an economic incentive to local communities to keep their forests healthy for earning from the sale of resin. They thus protect the forests instead of cutting them down for other purposes. Even

this encourages them to grow more trees which absorb carbon dioxide from the air. This helps fight against climate change. By way of using plant-based dyes instead of petroleum-based chemical dyes, too much dependence on oil is automatically reduced as oil is a limited resource and its extraction and refining produces pollution, besides its depletion.

Natural dye crafts serve as income generation source for denizens of rural areas. Small-scale dyers and textile artists can conveniently work from home with aid of simple, cheap and easily available equipment (Mall et al., 2016). This helps create job opportunities in areas where factory employment is non-available. As regards the worth of handmade tie-dye products, they sell at higher prices as compared to the mass-produced fabrics. Customers' trend is to pay more attention and value to the unique patterns including environmental benefits. Artisans can thus earn fair income, in addition to preserving age-old traditional skills. Teaching tie-dye methods and techniques to the youth will help keep the cultural knowledge alive (Talib et al., 2024). Some institutions offer training programmes on combination of traditional tie-dye methods with modern business skills.

Market Opportunities and Product Development

Consumers' interest in environment-friendly products is an ever growing trend. There is a tendency among the people that they want to know where do the products come from and how are they made. Natural dye textiles perfectly fit this general trend. They have a clear story: each dye comes from a specific plant, techniques are traditional, and process avoids toxic chemicals. This story serves as value addition as customers feel good to buy products that are traditional crafts, besides being friendly to environmental health. They show more willingness to pay higher prices for these benefits.

Tie-dye products can help fill a good number of market segments. Items like scarves and table runners have appealing value to everyday customers. Other elaborate products such as clothing or decorative textiles target premium markets. No two tie-dye pieces can have exact similarity. This unique attribute of tie-dye products fascinates the customers who want to have something new, and special but traditional and not mass-produced. Owing to this tradition-ridden public demand, the fashion designers have changed their marketing techniques and business outlook to align them with public trend and they have thus begun amalgamation of natural tie-dye products to their collections (Xiaohua, 2016). They have now come to laud and realise the real value and worth of organic, aesthetic and sustainability credentials of natural tie-dye products as modern tool of marketability. Some designers have even combined the tie-dye with embroidery or printing for fascinating visual effect and interest.

It is a principle of marketability that quality of products constitutes a determinant for success. Although customers may compromise colour variation as part of natural dye charm, yet they demand and expect good construction and reasonable durability. Attention to the nitty-gritty matters a lot: neat stitching, proper finishing, and clearly indicated washing instructions help build customers' trust. Care guidance, if offered, further helps customers maintain their purchases. In this regard, easy-to-understand instructions respecting gentle washing and avoiding direct sun may extend product life. Impressive packaging vitally enhances the perceived value. General and very simple items give a real feel of speciality when nicely presented.

Marketing has special emphasis upon environmental and cultural aspects. Photographs must depict natural materials and handwork process. Stories of success about the artisans, who have created the products, create emotional attachments (Subramanian Senthilkannan Muthu, 2023). The role of social media platforms in showcasing tie-dye patterns is important as the visuals are naturally attractive. Each piece should be individually photographed to highlight its unique pattern. Online sales make it easy for small-scale producers to reach out the customers globally. Craft fairs and local markets

provide face-to-face sales opportunities where artisans can explain their process directly to the interested buyers.

Conclusion

This research makes it out that *Butea monosperma* resin provides an efficacious natural dye to create tie-dye patterns on cotton, linen and silk fabrics. Colours obtainable from this resin range between yellow-orange and deep red-brown. Other quality of it is that its thickness helps create clear pattern lines which do not blur. This aspect of resin renders it especially fit and appropriate for applicability and creation of geometric tie-dye techniques which require sharp edges and vivid contrast. It is further found that sticky nature of this resin helps the colours fasten to the fabric fibers. It has the direct effect of reducing the need for use of any other additional fixing chemicals.

Response of different fabrics to Palash dye is found distinct and different. As regards silk, it most readily accepts the colours and produces strongest and brightest shades. Cotton is found to be taking medium-strength colours. However, its pre-treatment with tannin and alum helps produce best results. Linen reveals more subtle and earthy tones and needs longer dyeing time. Each fabric type has its own distinct aesthetic effect giving the designers options for number of applications. From these attributes and distinctions, it stands out conspicuously that the application of dye prepared from this resin demands deliberate selection or choice of fabric to achieve desired results.

Traditional tie-dye techniques which Indians and Japanese adopt work better with Palash resin dye. Marbling is adopted to create organic flowering patterns. Spiral technique is employed to produce circular sunburst designs. Nui Shibori technique makes it easy to produce geometric shapes. As regards binding technique, it creates dots and circles of any size with much ease. Each technique requires distinct and specific skills.

From environmental point of view, natural dyes have substantial benefits. These dyes break down completely without producing toxicity. Resin is gathered without slightly harming or cutting down the trees. It fully supports forest conservation. The environmental advantages are quite in line with ever growing consumers demand for sustainable products.

From economic perspective, lot of opportunities are created for small-scale producers and artisans. Since customers value handmade quality, unique patterns and environmental friendliness, that is why natural tie-dye products can command premium prices in appropriate markets. Effective marketing techniques and tools help communicate these values through various means such as storytelling, visual presentation and craft fairs. Even online sales platforms can expand market reach beyond local areas. Natural dye crafts can help provide meaningful income while preserving cultural traditions and supporting environmental goals.

Recommendations

By creating database in respect of regional dye plants, their colour ranges, changing trends and ever-growing public demands, artisans can be enabled to access diverse colour options. Combination of various colours is another area of preparing fresh dye colour schemes which might help produce new colours or improve durability. Focus of research ought to be on identifying those plants that grow easily and require no intensive cultivation intricacies.

Training programmes must be so designed as to combine traditional techniques with modern business skills. It does not suffice to merely teach tie-dye methods. Artisans need instructive material in product photography, online marketing, pricing strategies, and customer service. These programmes need to include hands-on craft training and practical

business education. To prepare participants for commercial success, a well-thought comprehensive approach can work well. Craft Organizations and Business Development Groups, through coordination and collaboration, can jointly deliver integrated trainings.

Since older practitioners are ageing rapidly, therefore, it is must to preserve the traditional knowledge through proper documentation for posterity. Most of skilled artisans have inherited these skills and knowledge from their ancestors through hands-on training and toiling efforts. Their hands and minds are repository of this knowledge. These skills are very likely to vanish, if not documented in time. Preservation of this knowledge is easily achievable through video recordings, written instructions, booklets, and apprenticeship programmes. Focal point of this mission has to be on less common techniques and regional variations. It is high time to set up accessible archives which will help posterity learn from past masters.

Natural dye adoption is a hot cake if government takes a policy decision to support it by offering training subsidies including equipment grants enabling the artisans to start natural dye businesses, Tax incentivization such as concessions or exemptions and even tax holidays on occasions of festivities for environment-friendly textile production would help make natural dyes economically more competitive (Pranta & Rahaman, 2024). Government institutions like schools and hospitals should, as a matter of policy, prefer natural dye textiles in their routine and essential official purchases. Policy, if pursued on these lines, will help create market encouraging production. International cooperation sharing successful policy models would help multiple countries develop their natural dye sectors.

Building bridges between artisan communities and fashion designers can help create mutual benefits. Designers have better opportunities of access to unique, sustainable materials and authentic traditional techniques. Artisans may thus be able to gain exposure to new markets and design perspectives. These collaborations need to be so structured as to ensure fair compensation and proper credit for traditional knowledge. Design Schools should incorporate natural dye projects into their curricula, introducing students to these techniques early in their careers. These connections help natural dye crafts evolve while maintaining rather strengthening their cultural roots and preserving traditional knowledge for posterity.

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