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Evaluation of the role of aluminium sulfate of potash ($KAl(SO_4)_2 \cdot 12H_2O$) in improving the dyeing properties and colour fastness of wool and cotton/viscose blends

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تقييم دور كبريتات الألمنيوم والبوتاسيوم (الشبّة) في تحسين خصائص الصباغة وثبات اللون للأقمشة الصوفية ومزائج القطن/الفسكوز

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Abstract:
Dyeing with natural plants is a sustainable and environmentally friendly method compared to chemical dyes, which cause environmental pollution and consume large amounts of energy and harmful chemicals. This project aims to study the possibility of using natural plants, such as cloves, olive leaves, and indigo, to dye cotton and wool fabrics as a sustainable and environmentally friendly alternative to chemical dyes. This research evaluated the effect of aluminum potassium sulfate (alum) as a stabilizer on the color fastness of fabrics dyed with plant products, by conducting light exposure, washing, and dry and wet rubbing tests. The experiment included three main techniques: dyeing without a stabilizer, using a stabilizer before dyeing, and using a stabilizer after dyeing. The results showed that cloves and olive leaves achieved excellent results and high stability to light, washing, and dry and wet rubbing. Lightfastness results after exposure to sunlight for 80 and 100 hours showed readings of 7 and 8 on the blue wool color index for both cloves and olive leaves, respectively, and 4/5 and 5 on the gray color index for each, respectively. Indigo powder, however, did not produce positive results, with weak readings of 2/3 on the gray color index and 2 on the blue wool standard index. The results were similar in the wash fastness test, with the exception of blue indigo, which achieved better results in the wash test than the light test, while the dry rub test achieved better results than the wet rubbing test.
The study concluded that natural dyes such as cloves and olive leaves achieve excellent results in terms of color fastness, light resistance, and washing, even without the use of chemical stabilizers. They produce stable colors that are stable to light, washing, dry rubbing, and wet rubbing, which are among the most important criteria for measuring textile product quality and are considered a safe alternative. It is natural for industrial dyes to cause huge environmental pollution.

Keywords: Blue wool scale, Dry and wet rubbing, Grey scale, Light and wash Fastness and Mordant.

الملخص
تعد الصباغة بالنباتات الطبيعية وسيلة مستدامة وصديقة للبيئة مقارنةً بالأصباغ الكيميائية التي تتسبب في تلوث البيئة وتستهلك كميات كبيرة من الطاقة والمواد الكيميائية الضارة. يهدف هذا المشروع إلى دراسة إمكانية استخدام النباتات الطبيعية، مثل القرنفل وأوراق الزيتون والنيلة الزرقاء، في صباغة الأقمشة القطنية والصوفية كبديل مستدام وصديق للبيئة للأصباغ الكيميائية. تم في هذا البحث تقييم تأثير مادة كبريتات بوتاس الالمونيوم (الشبّ) كمثبت على ثبات اللون للأقمشة المصبوغة بمنتجات نباتية، بإجراء اختبارات التعرض للضوء، والغسيل، والحك الجاف والرطب. شملت التجربة ثلاث تقنيات رئيسية: الصباغة بدون مثبت، استخدام المثبت قبل الصباغة، واستخدام المثبت بعد الصباغة.
أظهرت النتائج أن نبات القرنفل وأوراق الزيتون سجلا نتائج ممتازة وثباتية عالية للضوء والغسيل والحك الجاف والرطب حيث أظهرت نتائج الثبات للضوء بعد تعرضها لأشعة الشمس 80 ساعة و100 ساعة بقراءات 7 و 8 في دليل الصوف

الأزرق لقياس التغير في اللون في كل من القرنفل وأوراق الزيتون على التوالي، وما يعادل 5/4 و5 في الدليل الرمادي لقياس التغير في اللون في كل منهما على التوالي، أما مسحوق النيلة فلم يعطي نتائج ايجابية بقراءات ضعيفة تدنت الى 3/2 في الدليل الرمادي للتغير في اللون و 2 في دليل الصوف الأزرق القياسي وكانت النتائج متقاربة في اختبار الثبات للغسيل ، باستثناء النيلة الزرقاء التي سجلت نتائج في اختبار الغسيل أفضل من اختبار الضوء، في حين أن اختبار الحك الجاف سجل نتائج أفضل من الحك الرطب .
خلصت الدراسة الى أن الأصباغ الطبيعية مثل القرنفل وأوراق الزيتون تحقق نتائج ممتازة من حيث ثبات اللون ومقاومة الضوء والغسيل، حتى بدون استخدام المثبتات الكيميائية وتعطي ألوان ثابتة ومستقرة للضوء والغسيل والحك الجاف والرطب، والتي تعتبر من أهم المعايير التي تقاس بها جودة المنتج النسيجي وتعتبر بديل امن وطبيعي للأصباغ الصناعية التي تسبب تلوثا ضخما للبيئة.

الكلمات المفتاحية: دليل الصوف الأزرق، الحك الجاف والرطب، الدليل الرمادي، اختبار الضوء والغسيل.

Introduction:

Colours are basic compounds utilized in different businesses counting materials, printing, beauty care products, and nourishment, to confer color to substrates. Colours can be characterized as chromophoric substances with a capacity to connected chemically or physically with substrates, driving to particular assimilation of particular wavelengths of light and coming about in a show of color. (Kowalska, J.*et al*, 2021)

. From the early utilize of normal sources to present day amalgamation of complex natural compounds, the ponder of colors includes a wide extend of disciplines, each contributing to the understanding of coloration, fabric science, and human imagination. After the discovery of synthetic dyes in 1856, the natural dyes have become less important than before, due to the low cost of synthetic dyes, and dyestuff. In the twentieth century, the use of synthetic dyes were massive, estimated at around 10,000,000,00 tons per annum. Recently, it has been noted that the industry related to synthetic dyes, including production and application release huge amount of wastes, and has negative impact on the environment. (ado, et al 2014). Natural dyes have regained popularity in recent years because of their environmental friendliness, accessibility, cost, non-toxicity, and sustainability. As a result, natural dyes are becoming more and more well-liked as superior substitutes for synthetic dyes. With a wide variety of plant species with different colors and characteristics that may be utilized in the textile, printing, cosmetics, and food sectors (Alegbe, E and Uthman T, 2024). The utilization of natural dyes poses no environmental concerns regarding waste disposal and results in organically colored textiles. Since ancient times, dyes have been sourced from natural materials. Today, the resurgence of sustainable, plant-based dyes has become a growing global demand across various industries (Ragab & Hassabo 2021). The durability and intensity of these natural dyes can be significantly improved through the application of stabilizing agents, such as metal salts, which enhance their affinity to textile fibers and reduce solubility during usage and laundering processes (Jothi, D. 2008).

Materials and Methods

1- Extraction of Natural dyes

These experiment, two different fibers were chosen, wool and cotton mixed with viscose. The experiments were focused on dyeing theses fibers with selected natural dyes (olive leaves, cloves and indigo). The materials were collected from Bosleem market and Industrial Research Center in Tajoura. The experiments were conducted in an aqueous solutions to obtain a dye extracts of each plant weighing 20 g per 200 ml of water, to ensure obtaining the color, Then these quantities were boiled to boiling point for 15 minutes (Talib *et.al*, 2023) and the samples were kept inside the dye solution after that for at least 12 hours to ensure absorption of the largest amount of dye molecules in the fabric. (Repon *et al. (2024)* also indicated that boiling at moderate temperatures improves dye extraction and preserves its properties. In this study, a slight modification was made by using different plants (indigo, cloves, and olive leaves) as substitutes for turmeric and hibiscus, to expand the scope of experiments.

2- Pre-Mordanting

9×9 cm cotton and wool fabrics were soaked in a solution of 2 g of alum per 100 ml of water. The fabrics were boiled in this solution for 4 minutes and then left to stand for 12 hours to ensure complete saturation with the stabilizer. Ozdemir (2023) points out the importance of pre-treating fabrics with a stabilizer before dyeing to improve absorbency and increase fastness, using alum as the primary stabilizer. However, this study differs from Ozdemir's approach in reducing the boiling time to only 4 minutes, rather than the recommended longer time, to avoid fiber damage and achieve higher efficiency.

3- Dyeing Process

After treating the fabrics with the fixative, they were immersed in the prepared dye solutions. The dye contained 10 g of each plant in 200 ml of water. The fabrics were boiled in the solution for 4 minutes and then left to cool in the solution for 12 hours. According to (Tegegne et al., 2024), With longer dyeing durations, the depth or

intensity of color (K/S value) progressively increases until the dye absorption process reaches its equilibrium point, (Uddin, M. G. 2015) also confirmed the effectiveness of dyeing natural fabrics in the same way using plants such as saffron, as this method enhanced color distribution and absorption. The modification made in this study is the use of indigo and olive leaves as new dye sources.

4- Post-Mordanting

After dyeing, some fabrics underwent a post-fixation process with an alum solution to improve color fastness. The fabrics were soaked in the solution for 12 hours without heating. (Ozdemir, 2023) demonstrated that post-fixation enhances color fastness to external factors such as washing and light, supporting the use of this step as part of the methods. The difference in this study is the use of only alum instead of synthetic fixatives to ensure the simplicity of the method and reduce costs.

Note: The methods derived from previous studies have been modified to suit the plants and materials used in this research. These modifications included reducing the boiling time during the initial fixation and applying new plant species as natural dye sources, while maintaining the basic principles proven effective in the aforementioned studies.

5- Control of experiment

In this experiment, samples of cotton mixed with viscose and wool were dyed without adding any fixative at all to compare it with other results (fixing before dyeing, fixing after dyeing).

Figure (1) Weigh 10 g of each of the experimental samples (olive leaves/cloves/indigo).

Olive leaves extraction **Cloves extraction**

Alum Solution **Indigo extraction**

Figure (2) Dye extraction process for plant products (cloves, olive leaves, indigo powder, alum).

Figure (3) Fixing the experimental samples in the net and dyeing the experimental samples in dye solutions**.**

Figure (4) Preparation of wool and cotton blend samples for light testing, accompanied by the standard blue wool guide.

Figure (5) Exposing the experimental samples to daylight.

Results and Discussions

1- Results of Light Fastness

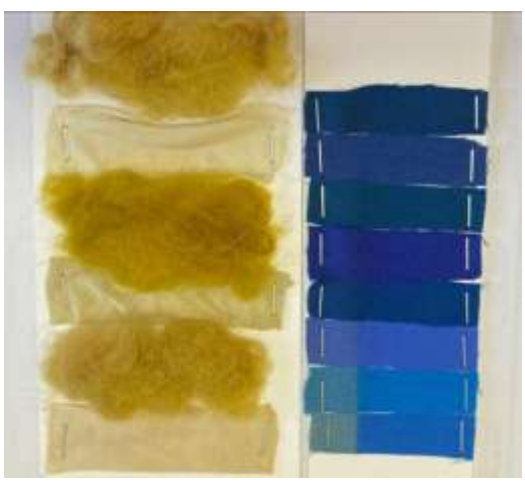
An experiment on dyeing cloves after exposure to light for 80 hours demonstrated high color fastness, even without the addition of a mordant (control). The control sample yielded readings of 7 on the standard blue wool index and 4/5 on the gray index for measuring color change (ISO 105 A02). The experimental sample, in which the dye was fixed before dyeing, yielded an excellent result when compared to the standard blue wool index, which is considered a color change index. When compared to the standard gray index for measuring color change, it yielded a reading of 5, the best reading on the gray index for color change. The results of the dye fixation experiment after dyeing showed the same results as before dyeing, confirming that the dye fixation process yields similar or close results whether fixed before or after dyeing.

The results of this experiment are similar to the study by Moniruzzaman et al. (2018) On color fastness to light: The study showed similar results to this experiment, with blue wool index readings ranging from 6-7, and gray color change index giving 4-5, indicating that the fixing process either before or after dyeing results in good color fastness. The difference is that the standard blue wool index showed a higher reading (8) compared to the study

(6-7), indicating that cloves as a natural dye may provide higher color fastness compared to the tea used. The gray index of color change: Despite the great similarity in results, this experiment showed the best reading (5) when using fixation, which reflects greater effectiveness in resisting color change. Therefore, the experiment appears consistent with the study in the efficiency of the fixation process, with a slight superiority of clove dye in color fastness, Figure (6). When the clove samples were exposed to light for a period of 100 hours, the results did not change significantly, as the results in the control sample recorded a reading of 7 in the blue wool and 4/5 in the gray index of color change. In the fixation experiment before and after dyeing, the results were similar, as it recorded 8 in the standard blue wool index and 5 in the gray index of color change. This fastness is due to the presence of tannin in the cloves in a high percentage, which is considered to have high stability in dyeing. (Ahmed, W. 2016) as shown in Figure (7).

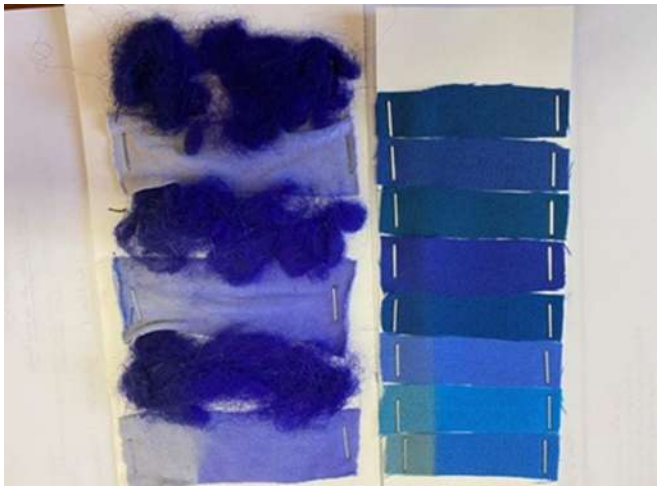
The olive dyeing experiment after exposure to sunlight for approximately 80 hours showed excellent results even without adding a fixative (control), as the readings in the control sample were at the standard blue wool index 7 and at the gray index for measuring color change 4/5 (ISO 105 A02). As for the experimental sample in which the dye was fixed before dyeing, when compared to the standard blue wool index, it gave a result of 8. This is considered a high result. When compared to the standard gray index for measuring color change, it gave a reading of 5, which is the highest result in the standard gray index. The results of fixing the dye after dyeing gave excellent results, similar to those before dyeing or close to those before and after dyeing. This is consistent with the study conducted by Yılmaz, Bahtiyari (2020), where 6 fixatives were used. The experiment concluded that olives dye with high stability even without the use of fixatives, Figure (6). When the olive samples were further exposed to sunlight for a period of up to 100 hours, they did not There is no significant change in the results as your eye witness recorded 7 in the standard blue wool index and 4/5 in the gray color change index and in fixation before and after dyeing it gave 8 in the standard blue index and 5 in the gray color change index which are the best results and are considered conclusive and excellent results. Figure (7). (Ahmed, W. 2016) explained that tannin, which is present in olives, plays a major role in improving color fastness to light and washing, which is consistent with the research results.

The indigo dyeing experiment after exposure to light for 80 hours showed low stability even without adding a fixative (control) as the readings were 2 in the control sample at the blue wool index and 2 at the gray index to measure the change in color (ISO 105 A02). As for the experimental sample in which fixation was carried out before dyeing, it gave a score of 3 when compared to the standard blue wool index, while when compared to the standard gray index to measure the change in color, it gave a reading of 2/3. As for the results of the fixation experiment after dyeing, they gave very low results as it was at the standard blue wool index 1, which is the lowest score in the blue index, while for the gray index to measure the change in color, it was close to 1/2. These are considered very low scores, as shown in Figure (6), because fabrics and fibers are usually dyed with indigo dye using reduction or temporary dissolution methods (instantaneous), then removing the effect of the solvent to fix the dye. In this study, the indigo dyeing process was carried out in the same way as olive. And cloves, and this explains the results of indigo that are less good than the previous ones, as olive leaves and cloves contain tannin, which fixes the dye more effectively, and this is confirmed by Chavan, R (2015) in the necessity of using reducing materials such as sodium hydroxide and then exposing the fabric to air until it oxidizes, giving the blue color. However, when the indigo samples were exposed to sunlight for a period of up to 100 hours, the results were lower compared to 80 hours, as the readings were recorded for the control sample and fixation before dyeing, close degrees at the blue index and the gray index, as the results were at the standard blue wool index 2, and at the gray index for measuring the change in color, the result was 1/2, while when fixing after dyeing, the result was 1 at the standard blue wool index and 1 at the gray index for measuring the color, as shown in Figure (7).



Olives Leaves

Cloves



Indigo

Figure (6) Results of exposing the experimental samples and the standard blue wool guide to daylight for 80 hours

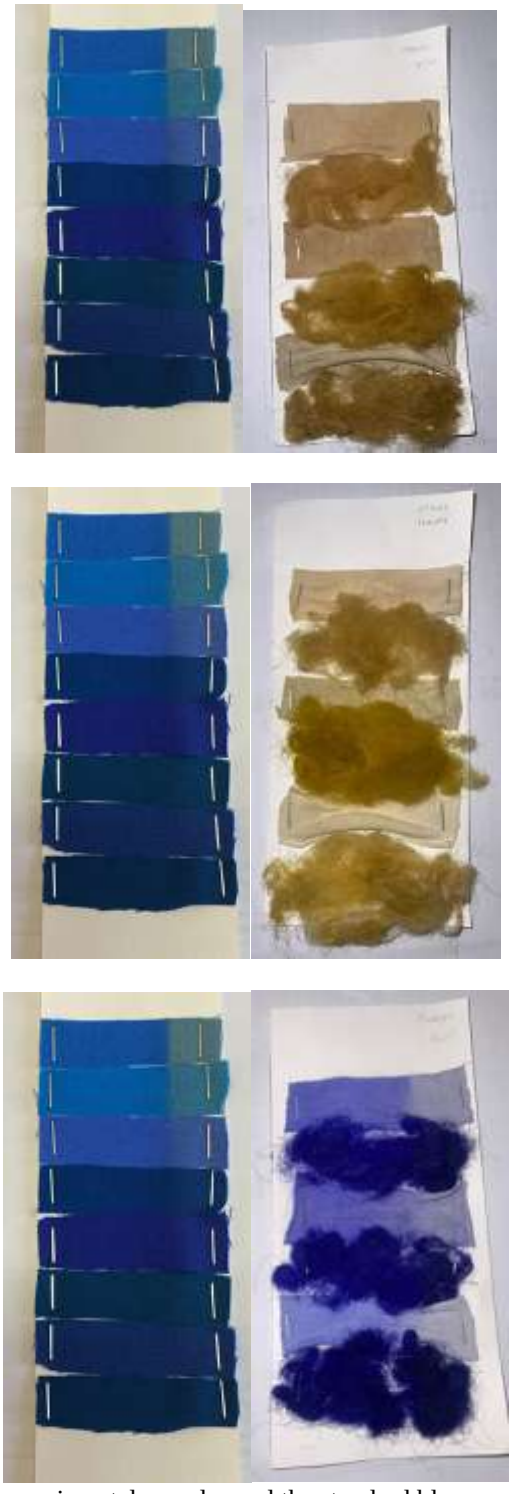


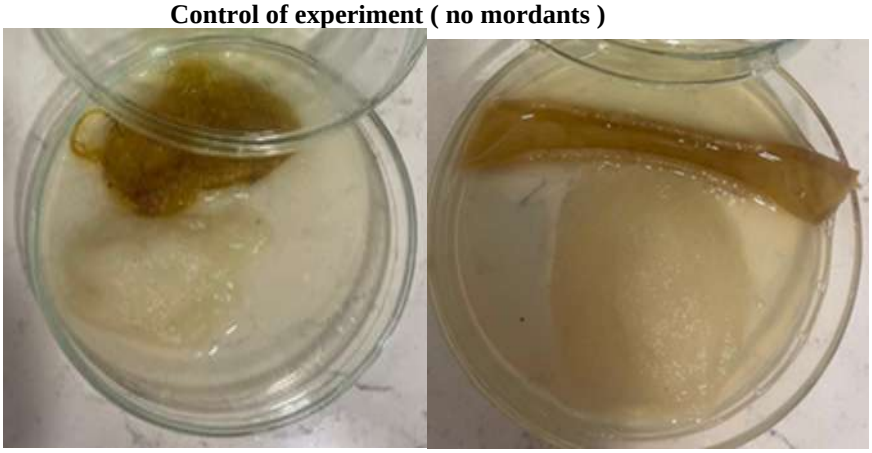
Figure (7) Results of exposing the experimental samples and the standard blue wool guide to daylight for 100 hours**.**

2- Results of Wash Fastness

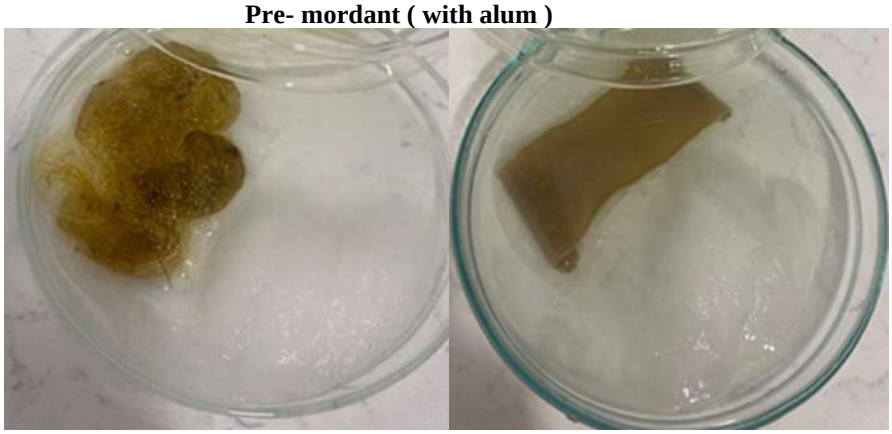
The clove washing experiment showed excellent results after washing and soaking it in soap and water for an hour, as the result without adding (the control) for me was 4/5, and the same was true for me for dye fixation before dyeing and after dyeing, as the results were of high quality in three stages.(Yameen, et al., 2023) obtained similar results when dyeing wool fibers with cloves using a microwave, as it gave results of 5 for each of the change in light, washing, and dry rubbing, while the results of wet rubbing were 4 in the gray index for rubbing, Figure (8). In terms of olive washing experiment also showed excellent quality of natural cotton compared to the

cloves results. The results were 5 for the gray staining index even without adding (control). However, when dyeing before dye fixation, the result was 3/4 for the gray staining index. When dyeing after dye fixation, the result was 5, which is a very excellent result. This is due to the fact that cloves and olive leaves contain tannin. (Ahmed,W.2016) indicated that the presence of tannin contributes significantly to improving color fastness to washing, Figure (9). The indigo washing experiment showed good quality even without adding (control). The gray index for mottling was 5, while in dyeing before dye fixation it was 2/3, and in dyeing after dye fixation the result was 3. These are considered acceptable results compared to the results of exposure to ISO 105-X12: 2016. Figure (10)

Control of experiment (no mordants)

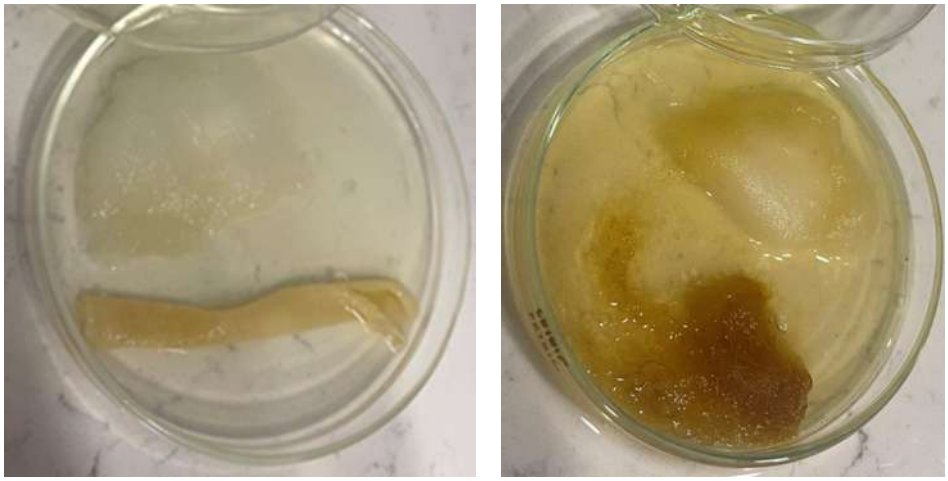


Pre- mordant (with alum)

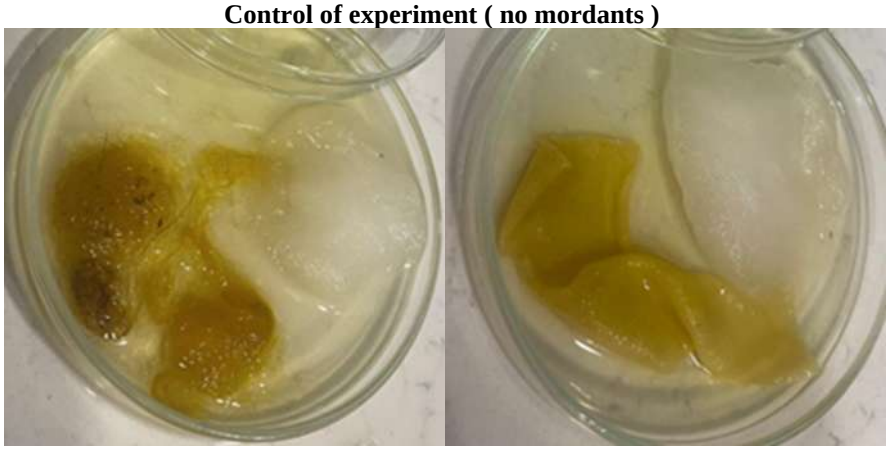


Post- mordant (with alum)

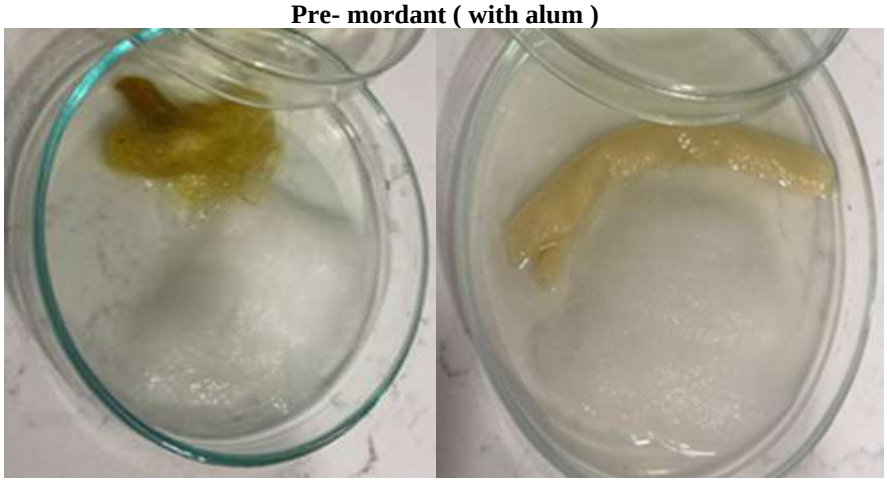
Figure (8) Wash Fastness results of Cloves.



Control of experiment (no mordants)

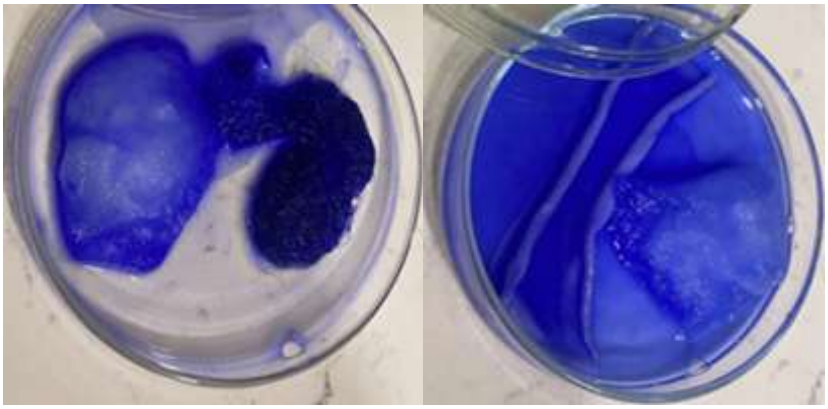


Pre- mordant (with alum)

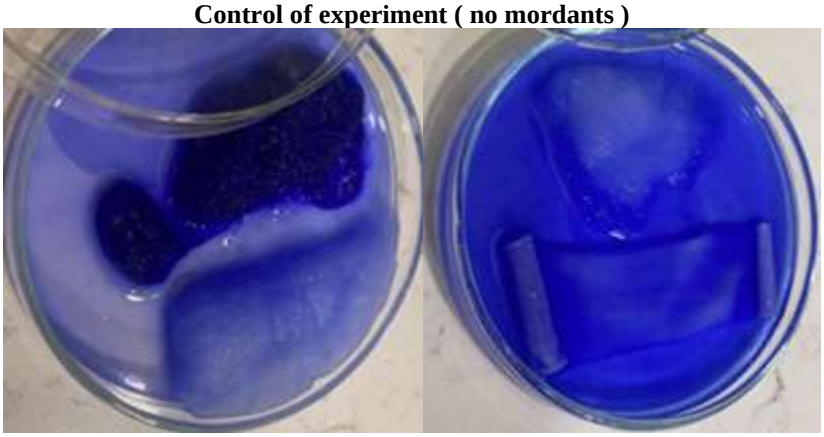


Post- mordant (with alum)

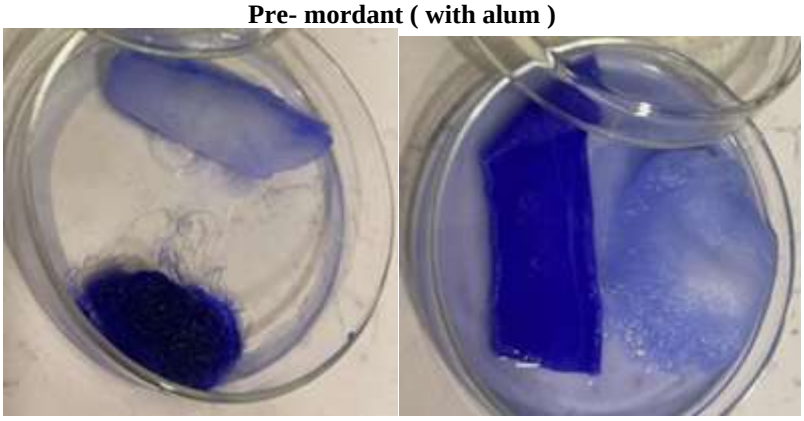
Figure (9) Wash Fastness results of Olive leaves**.**



Control of experiment (no mordants)



Pre- mordant (with alum)



Post- mordant (with alum)

Figure (10) Wash Fastness results of Indigo.

3- Results of Dry and Wet Rubbing

The dry and wet rubbing experiment of cloves using standard fabric from the Industrial Research Center showed relatively good results for each type of fabric when rubbing dry, as for wool at the gray index of spotting it was 3/4, while for cotton it was 4, which is considered better quality than wool. When dyeing before fixing the dye, the wool was 3 and for cotton 4, and when fixing the dye after the dyeing process, the cotton was 4 and the wool was 3/4, and here we note that the cotton was of better quality than wool. When carrying out the wet rubbing experiment, the result was (control) at the gray index of spotting for wool 2/3 and for cotton 4/5, and in fixing the dye before dyeing for wool 2 and for cotton also 2, and in dyeing after fixing the dye for cotton it was 2 and for wool 3, and the percentage of spotting in wet rubbing is considered higher than dry (ISO 105-X12: 2016) Figure (11). Olives also showed using a standard fabric. When rubbing dry, the results were reasonably excellent, as without adding a (control) at the gray index of spotting in wool and cotton, the result was the same, which was 3. However, when fixing the dye before dyeing, the cotton was 3/4 and the wool 3. When fixing the dye after dyeing, the wool and cotton had the same result, 4. When rubbing wet, without even adding a (control) at the gray index of spotting in wool and cotton 3. Fixing the dye before dyeing was 2/3, and fixing the dye after dyeing was 4/5. We note that in this test, the quality of both wool and cotton was close, Figure (12). The results of dry and wet

rubbing of indigo when using a standard fabric using the gray indicator for staining without even adding a (control) for wool and cotton 2 and when fixing the dye before dyeing for wool 3/4 and cotton 3 and when dyeing after fixing the dye were 1/2 for wool and 2 for cotton, but when experimenting with wet rubbing, the results were without even adding a (control) for the gray indicator for staining for wool 1/2 and for cotton 1 and when fixing the dye before dyeing, the result was in cotton 1 and wool 2 and in dyeing after fixing the dye for the gray indicator for staining for wool 3 and for cotton 1. From here we note that wet rubbing of indigo in cotton was of poorer quality than wool and even more than dry rubbing and this defect is also due to the method of dyeing indigo (ISO 105-F01: 2001), Figure (13).

Control (no mordant)

Pre- mordant (with alum)

Post- mordant (with alum)

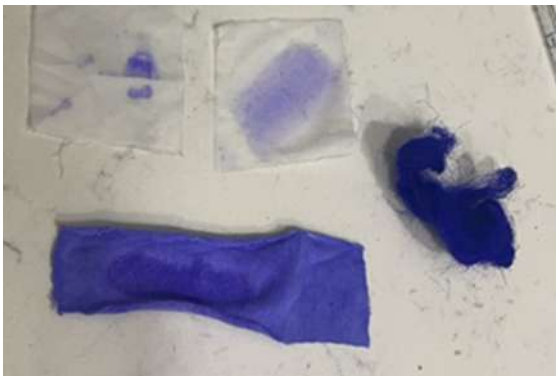
Figure (11) Rubbing test of clove samples compared to standard cotton fabric

Control (no mordant)

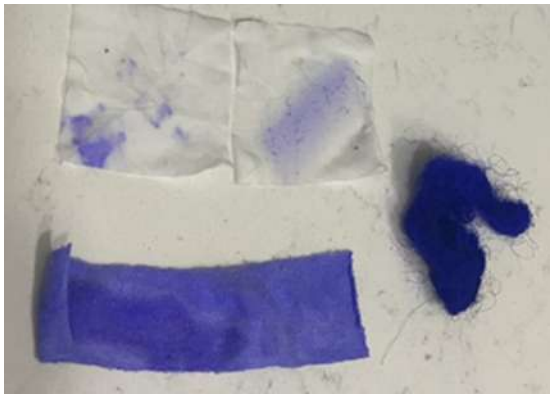
Pre- mordant (with alum)

Post- mordant (with alum)

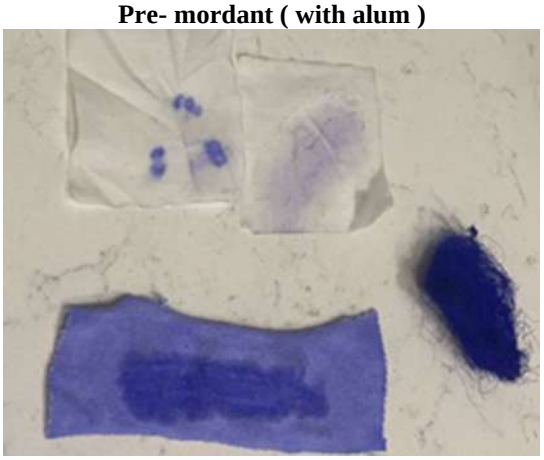
Figure (12) Rubbing test of Olive leaves samples compared to standard cotton fabric.



Control (no mordant)



Pre- mordant (with alum)



Post- mordant (with alum)

Figure (13) Rubbing test of Indigo samples compared to standard cotton fabric

Conclusions and Recommendations:

The study concluded that using natural plants such as cloves and olive leaves in dyeing cotton and wool fabrics achieves excellent results in terms of color fastness, light resistance, and washing resistance, even without the use of chemical stabilizers. These plants outperformed indigo, which performed poorly, due to the different nature of the dye and its fixation mechanism. The results confirmed that the tannin found in plants such as olives and cloves plays a vital role in improving color fastness. Experiments also demonstrated that using aluminum sulfate of potash (alum) as a stabilizer before or after dyeing enhances color fastness, making it an ideal choice for natural and environmentally friendly dyeing. The study recommends Expanding experiments on the use of natural plants in fabric dyeing, improving their fastness and quality, as they are an ideal alternative to synthetic dyes, it is also important to Conduct studies on the stabilization of water-insoluble natural dyes, such as indigo blue, to improve their results using reducing agents to ensure color retention, also using natural stabilizers such as aluminum potassium sulfate (alum) and iron chloride to enhance color fastness and reduce negative environmental impact. Eventually, applying these findings at the industrial production level to promote environmentally friendly dyeing and achieve sustainability in the textile industry.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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