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Article

The integration and transformative design research of plant dyeing techniques in Dong brocade with sustainable materials

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Abstract: Dong brocade, a fabric renowned for its intricate patterns and ethnic symbolism, has been woven by the Dong people for generations, showcasing their cultural significance. Traditional plant dyeing technology is one of the main aspects of Dong brocade but the documentation and understanding of this is still rather limited. With regard to the use of plant dye in Dong brocade, it is not as well explored as it should be since it has a traditional aspect. The main purpose is to investigate and apply the traditional plant dyeing technique to Dong brocade for the improvement of that sustainable concept and the preservation of cultural assets. Therefore, 121 Dong villagers were interviewed to elicit their awareness regarding prehistoric plant dyeing. By observing the dyeing conditions, this study provided accurate perception and learned how to differentiate between natural and synthetic mordants through ethnobotanical perception. The strategy is intended to integrate sustainable products into Dong brocade, employing orthogonal array development to find the right dyeing conditions for corresponding plant dyes. Research revealed that 8 genera of plants which include 7 species are used in dyeing Dong brocade. The findings presented in this work prove the effectiveness of the use of plant dyes in Dong brocade, showing its advantages with 30% of frequency and CI (Color Index) indices, 8% of them being cultural. 5 for ethnic cultural sustainment, developmental and bio-diversity reasons respectively. The unique integration between the traditional dyeing technique in Dong brocade and the utilization of sustainable resources is very promising for the improvement of identity enhancement and embodiment, and the preservation of the environment.

Keywords: plant dyeing techniques; Dong brocade; sustainable materials; integration and transformative design

1. Research background

The Dong cultural group's mothers have been passing down the brocade, which is renowned for its vibrant colors and intricate patterns, to their daughters for almost 2000 years. Considering many synthetic dyes are allergenic, mutagenic, and carcinogenic, sustainable dyes have become more and more important in textile dye applications. Natural dyes, which have been used since antiquity, can be classified into plant-based and animal-based sources. This categorization is significant because natural dyes are widely used in both traditional and industrial uses, demonstrating a rising concern for environmental sustainability. Understanding these categories aids in understanding the various sources and their importance in present dyeing processes. In chemical terms, there are natural dyes like mordant dyes (which are exclusively appropriate for use on mordanted materials) (Karabulut and Atav, 2020). Natural colors are derived from organic sources such as plant leaves (Pars and Karadag, 2024).

Further, dyes can be generated from dried animal parts (Pars and Karadag, 2023), including insects, and utilized to produce a wide range of colors (Pars, 2024). This more comprehensive perspective offers a deeper comprehension of the origins of natural colors. In recent years, natural dyes have been used in functional fibers too apart from textile products due to their various advantages. This development shows the potential of natural dyes, as well as their increasing application in today's textile industry to treat fabrics with special characteristics using eco-friendly techniques. Sustainable fibers, food items, medicine, product, handloom products, and leather products can be colored with sustainable colors (Singh et al., 2020). It is recognized as one of the most common natural dyes used today which is one of the early sustainable natural indigo known to people. It is derived from the plant species which synthesizes indigo including Indigofera tinctoria L. (Shi et al., 2020). Initially, these textiles were used by all age groups and were probably invented to support a significant part of cultural presence in the region and were intended to be worn during important occasions (Tamburini et al., 2020). Due to its insolubility in water, it is in organic form and it can be prepared in very small particles that can be put on supporting fibers these materials were used without using mordant it is both a pigment and dye: indigo blue. The results showed that a sufficient water source is obtained from the plants. In ancient times, a relatively large number of plants including those of the 300 species Indigofera have been employed to obtain blue (Tello-Burgos et al., 2021). Research and people have found that using sustainable natural dyes has a lot of attraction and potential for the textile industry has increasingly placed more emphasis on low-carbon, green, and sustainable regulations in recent years. To color both natural and synthetic textile materials, dye and synthetic pigments are widely utilized; Gong et al. (2020) suggested that it is one of the main sustainable pollution processes. With the need for low costs, easy availability, and durability, dyeing enterprises depend mainly on synthetic procedures these days. The textile sector uses two-thirds of the total world's synthetic dye and pigment supply, and annual use rises along with increasing textile consumption. The synthetic colors stay longer and are more radiant and process discharge control is made more difficult by the high chemical resistance (Lohtander et al., 2021).

1.1. Objective of the study

To resolve the gaps in integration and transformative design research of plant dyeing techniques, this study analyzes and examines the plant dying methods utilized in Dong brocade. It is required to maintain the cultural history, prove perspectives on innovation and skill within the distinctive textile tradition, and provide an in-depth comprehension of the procedures involved in developing Dong brocade by thoroughly investigating the traditional approaches.

1.2. Writing framework

Relevant articles are provided in stage 2. The methodology with data description and sample questions are determined in stage 3. In stage 4, the results are demonstrated. Discussions and conclusions are explored in stage 5.

2. Relevant articles

Two textile pieces from the Qing dynasty were examined by Li et al. (2020) to characterize the dyeing processes using the proper sustainable analysis. The outcomes demonstrated that *Gardenia jasminoides* Ellis was used to color the yellow silk thread, *Polygonum tinctorium* was used to dye the blue silk thread, and *Rhamnus davurica* pall, the plant that first appeared in ancient textiles was probably the source of the green silk thread. Alebeid et al. (2020) developed an inexpensive, sustainable technique for extracting natural dyes using henna leaves to enhance fiber/dye affinity and improve color intensity. The experiment used henna and acacia dyes on wool fibers within a variety of sustainable dying configurations. Luo et al. (2020) conducted an ethnobotanical examination on Sansui bamboo making. Participatory observations and interviews with key informants were two different ethnobotanical methodologies used in the study. To generate different designs, bamboo strips could be dyed with *Platycarya strobilacea* and *Rubia cordifolia*. Zhou et al. (2020) described the bioactive finishing method for wool fabric that was safe for the sustainable environment. It used the easy soaking method to remove garbage, or fallen leaves, rich in tannins from *Sapium sebiferum* L*,* known as Chinese tallow (CT). The results highlighted the superior antioxidant and ultraviolet (UV) defense properties of wool fiber treated with CT leaf extract. Liu et al. (2021) conducted dye research from prehistoric textiles using superior liquid chromatography paired with the mass spectrometric sensor and a detector made of diode arrays, which provides information on the history of plant-based dyes. Given the high *Porphyrophora* species amount in the clothes, it appeared as the early pastures civilization spread throughout the early periods of iron. Fiber optical reflectance spectroscopy has simplified the process of identifying and differentiating natural pigments and their mixtures on textiles. Eleven natural dyes with 4 different fiber types were subjected to the Kubelka–Munk transformation spectrum by Ding et al. (2021). The purple and green colors were discovered to be a combination of sappanwood and the dye indigo, respectively, and amur-cork tree and indigo. The natural dye from the flowers of *Spartium junceum* L. (SJL) was extracted for the study using sustainable cellulose (cotton) and protein (wool) fabric. The dye derived from SJL has been referred to as a mordant dye and it was more appropriate for dying wool materials, which has been demonstrated by Kovačević et al. (2021). Textile samples that were extracted were examined by Łucejko et al. (2021) using the mass spectrometric detector and diode array were features of high-performance liquid chromatography (HPLC). Through a combination of extraction techniques and focused analytical techniques, the investigators identified the madder-type dyestuffs used to color sensitive silk and gold crafts and woolen material with reddish-white and undyed stripes used for tents or sails. The molecular identification of the colors required the use of high-pressure liquid chromatography in combination with a mass spectrometry detector and a diode array is examined by Tamburini et al., (2022). Traditional Korean dyeing methods were used to preserve it and indigo, red, and orange were included. Ji et al. (2023) employed the water extract from *Phellodendron amurense* bark as a dye. By examining the color spectrum, color assessment, and dyeing properties of cotton materials, the most effective dyeing instances have been found. The outcomes showed that pH 5, pre-mordanting the liquid ratio, and the most

efficient dyeing techniques were determined by the mordant concentration, the dyeing procedure, temperature, and duration of the dyeing process. Ozdemir and Karadag (2023a) offered quantitative proof of Madder's market value. The study used numerical data to illustrate Madder's commercial potential. It has gained popularity in textile dyeing recently as it promotes the discharge of no hazardous chemicals into the environment. The objective suggested quantitative proof of Madder's market value. It used numerical data to illustrate Madder's commercial potential. It has gained popularity in textile dyeing recently as it promoted the discharge of no hazardous chemicals into the environment. Countries, manufacturers, and other stakeholders who care about the environment might assess the option after learning about its commercial viability. Ozdemir and Karadag (2023b) explored the potential resource of the Anatolian acorn (*Quercus ithaburensis* Decne) for many industries in Turkey and abroad. The acorn's distinctive color spectrum, fastness, and growers searched for a sustainable substitute often choose it because of its antimicrobial qualities. The development and monetization of the resource might have a significant influence on sustainability in Turkey and throughout the globe.

Research gap

The classification, extraction, and utilization of organic dyes in different materials are the primary research areas. There is an enormous amount of need to be discovered about the entire range of ways traditional dyeing methods could be standardized and expanded for modern, sustainable cloth manufacturing without harming the benefits of a sustainable environment and the cultural significance of natural dyes. By gathering traditional plant dyeing techniques, this research on Dong brocade covers resolves the gap. Through the integration of various procedures, it contributes to the framework for the manufacturing of sustainable materials that facilitate the protection of biodiversity, improve economic improvement, and protect cultural heritage.

3. Methodology

In this section, the research explores the research field, questions conducted on Dong village people, dyeing materials, and requirements to create dye for Dong brocade, and the laboratory experiments are also explored.

3.1. Description of field investigation

A random sample of 121 people from different Dong villages participated in semi-structured interviews. The participants were categorized based on five demographic data, such as age (25–85), gender (male–39 and female–82), experience in the work, income level, and marital status. The semi-structured interviews have four types led by an organization: flexibility, open-ended inquiries, and interactions. There are 20 various questions conducted on people with 7 category questions, which are shown in **Figure 1**, and sample questions in **Table 1**.

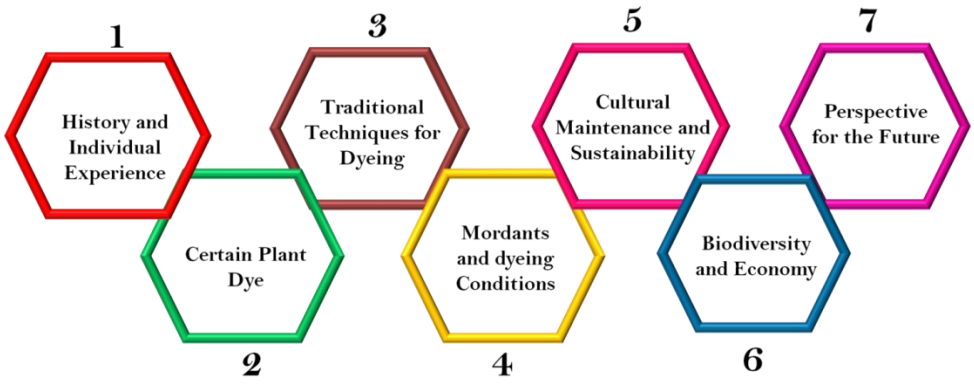

Figure 1. Various types of questions.

Table 1. Sample questions.

No. of Questions	Questions for Participants
1	What is your background and how are you involved with Dong brocade?
2	How long have you been employed and developing your Dong brocade skills?
3	Which species of plants are mostly utilized for dying?
4	Could you explain the traditional dyeing methods utilized in Dong brocade?
5	How do these plant dyeing techniques come to your attention? Did they come from generation to generation?
6	Which plants are mostly used for dying?
7	Could you describe how to dye with indigofera tinctoria in Dong brocade?
8	Do the hues generated by these dyes have any particular cultural or symbolic importance?
9	Which sustainable factors like temperature or duration are most suitable for dying?
10	Which kinds of mordants are employed throughout the dyeing process?
11	Have you observed any variations in dyeing quality or efficacy within natural and synthetic mordants?
12	How significant do you estimate the traditional plant dyes utilized in Dong brocade?
13	What are the advantages for sustainability and cultural heritage of employing natural plant dyes for Dong brocade?
14	When using natural plant dyes as compared to synthetic ones, are there any difficulties or issues that occur?
15	How was the local economy dependent on the usage of natural plant dyes?
16	Does the community have any initiatives focused on protecting and developing the plant species used for dyeing?
17	Is there a way that natural plant dyes could contribute to preserving a sustainable environment? In what way?
18	What modifications do you predict for plant dyeing and Dong brocade in the future?
19	What kind of materials would be useful to promote Dong Brocade's usage of natural plant dyes?
20	Would you like to anything more about your experience or observations about this domain?

3.2. Dyeing materials and requirements

Dong brocade cloth samples were employed in the dyeing experiments to preserve traditional weaving procedures. For traditional dyeing, 8 genera with 7 plant species have been taken. *Indigofera tinctoria* L. is prominent for its crucial contribution to the production of vibrant blue hues and various plant species like *Rubia cordifolia, Pogostemon cablin, Cinnamomum verum, Curcuma longa, Eucalyptus citriodora* and *Bauhinia purpurea* that are used in dying based on ethnobotanical research. Natural mordants such as tannin and metallic mordants such a alum, are used to improve the fabric's ability to preserve dyes and enhance the dyeing qualities.

Synthetic mordants like zinc sulphate and copper acetate were used as comparisons and it emerged that natural mordants performed superior.

3.3. Laboratory examinations

The dyeing process was performed in the laboratory, such as the extraction of dye from the plant, preparation of mordants, textile dyeing, assessing the quality, and observation of data. **Figure 2** and **Table 2** show the process for the preparation of dye and an orthogonal array of factors like pH temperature, and bath ratios were provided.

Table 2. Process of dye preparation.

Process	Steps	Requirements/ Materials	Specifications	Bath ratios (L: R)
Extraction of dye from the plant	Gather plant materials.	*Indigofera tinctoria* L.	pH (4.5–5.5) and temperature (60 °C to 90 °C)	1:10 to 1:20
	Prepare and extract dyes.	Water, heating sources, beakers, and vessels.		
	Monitor temperature and pH.	pH meter and thermometer		
Preparation of mordants	Quantify and mix the mordants.	Stirring rods, beakers, and scales.	The normal concentration of Alum (10–20 g/L)	1:20 to 1:30
	Sustain proper pH and temperature.	Heating source and water.		
Textile dyeing	Immerse Dong brocade samples in solutions.	Storage tanks of dyes, moderant solutions, and dye solutions.	pH (4.5–5.5) and temperature (60 °C to 90 °C)	1:10 to 1:20
	Sustain proper pH and temperature.	pH meter and thermometer		
	Rinse and dry the dyed fabric.	Hangers for drying and water		
Assessing the quality	Assess the fastness and intensity of the color.	Spectrophotometer	Absorption—particular color analysis wavelengths.	N/A
	Estimate efficiency of the moderant.		Compare both the mordants (natural and synthetic).	
Observation of data	Note the measurement of the observation.	Notebooks or data recording software	Note temperature, hue intensity, fastness, and pH tests.	N/A
	Data evaluation	Statistical software like SPSS	Identify ideal dyeing conditions and the efficacy of the mordant.	

Note: N/A stands for Not Applicable to procedures in which bath ratios have no beatings.

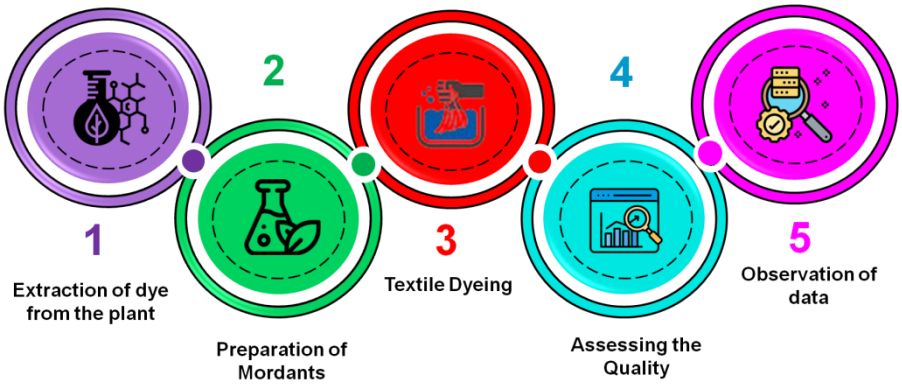

Figure 2. The preparation process of dye.

4. Results

In the identification of data from the tests, the research created an ethnobotanical record of the dye plants used by the Dong village peoples, based on a field examination of traditional plant dyes in the Dong brocade. To determine the most suitable dyeing conditions for particular plant dyes, an orthogonal array model was utilized. 7 plant species from 8 genera that are utilized for dyeing Dong brocade were determined during the research. The Dong brocade peoples primarily utilize the following plant parts to extract pigments from roots, stems, leaves, flowers, fruits, and peels. These components yield a variety of hues, including green, blue, yellow, white, red, orange, and black. In the Dong brocade, plant dyes are used to color foods, clothes, and nails, with a particular focus on textiles. The significance of *Indigofera tinctoria* L. for producing vibrant blue hues and its culture was emphasized.

4.1. Evaluation of tradition on plant dye

As qualitative indicators, the frequency measures have been utilized to evaluate the application potential of 7 different dye plant species. The frequency values of *Indigofera tinctoria*, *Rubia cordifolia, Pogostemon cablin, Cinnamomum verum, Curcuma longa, Eucalyptus citriodora, and Bauhinia purpurea* were demonstrated in **Table 3** and **Figure 3**. Given that these plants are the sources of the colors used as basic components in the clothes of the Dong brocade peoples, *Indigofera tinctoria* L. had the highest frequency value (30%) than other plant dyes.

Table 3. The Frequency value for 7 plant species.

Plant Species	Frequency Value
Indigofera tinctoria L.	30%
Rubia cordifolia L.	25%
Pogostemon cablin L.	10%
Cinnamomum verum L.	8%
Curcuma longa L.	12%
Eucalyptus citriodora L.	7%
Bauhinia purpurea L.	8%

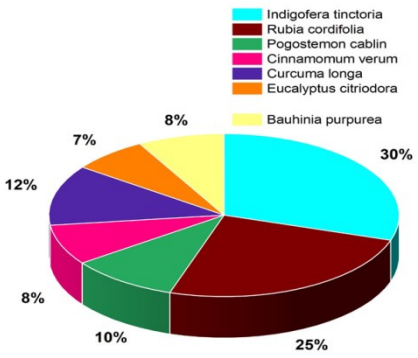

Figure 3. Plan species frequency values.

4.2. The traditional techniques of plant dyeing for cultural clothes

Cultural clothes dyeing is a prime representation of the Dong brocade people's traditional plant dyeing art and the cultural clothing of the Dong brocade people contains elements of plants. The cultural significance indexes (CI) of the traditional dye plants that are used for medicine and dyeing of 7 plant species are represented in **Table 4** and **Figure 4**. With the use of *Indigofera tinctoria*, the dye and CI values are more significant than other plant species.

Table 4. Use and CI values of plant species.

Plant Species	Dye	Medicine	CI
Indigofera tinctoria L.	9	1	8.5
Rubia cordifolia L.	8	7	6.2
Pogostemon cablin L.	7	8	6.0
Cinnamomum verum L.	6	8	5.0
Curcuma longa L.	9	9	7.8
Eucalyptus citriodora L.	7	8	5.5
Bauhinia purpurea L.	6	2	4.2

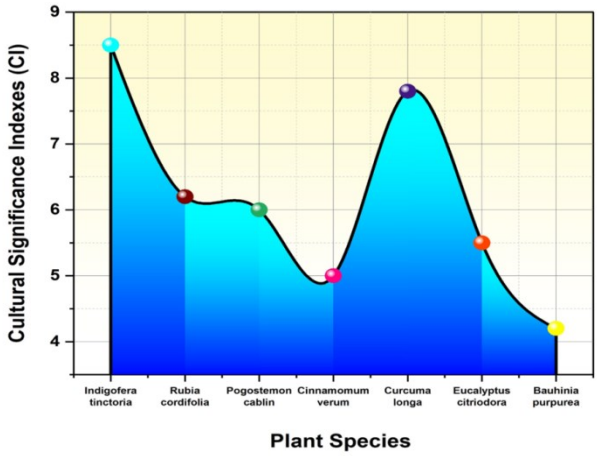

Figure 4. Cultural significance index (CI) for plant species.

4.3. Comparison phase

In this phase, the comparison among natural mordents (Bio-mordants) and synthetic mordents (Metallic mordants) was performed to show the effectiveness of the *Indigofera tinctoria* L. plant in Dong brocade clothes. **Table 5** illustrates the comparison between natural mordents and synthetic mordents. The variables like the lightness of the dyed clothes, red-green axis, and vibrant blue are explored and through the use of *Indigofera tinctoria* L., the vibrant blue color (30.00) is generated more efficiently.

Table 5. Comparison of natural mordents and synthetic mordents.

Mordants	Lightness of the Dyed Clothes	Red-green Axis	Vibrant Blue Hue
Bio-mordants			
Indigofera tinctoria	50.00	5.00	30.00
Tannin	65.20	4.10	12.30
Metallic mordants			
Alum	70.10	2.60	16.20
Zinc Sulphate	75.30	1.90	22.50
Copper Acetate	66.00	5.20	20.10

The qualities of dyed clothes were improved by the application of natural mordant solutions rather than synthetic mordants. As a result, there is considerable documentation showing the effectiveness of the traditional method of using *Indigofera tinctoria* L. for fabric dyeing, with enormous potential for feasible production.

5. Discussion and conclusion

5.1. Discussion

Plant dyes appear in a variety of forms and become more and more popular because of their benefits. There are 7 plant species, with 8 genera taken for the research. The study established the cultural and economic value of Dong brocade clothes by demonstrating the efficacy of traditional plant dyes, particularly *Indigofera tinctoria* L. plant and it produces vibrant blue hues when combined with bio-mordants. By comparing the frequency of *Indigofera tinctoria* L. with various dyeing plants for Dong brocade clothes, *Indigofera tinctoria* L. produces more frequency than the other dyeing plants. For dying, this study employs the *Indigofera tinctoria* L. plant, which produces vibrant blue hues for dyeing the Dong brocade clothes and it improved more in their performance of producing vibrant blue hues than other dyeing plants. The comparative phase demonstrated the improved dye quality obtained with natural mordents and synthetic mordents. The outcomes show the possibility of producing high-quality, sustainable dyes using traditional techniques and protecting cultural significance while serving the need of modern textile manufacturing in Dong brocade.

5.2. Conclusion

The varied designs and cultural significance of Dong brocade are established. The use of plant dyes in Dong brocade is not similarly explored as it should be given its historical heritage. By documenting and investigating the plant dyeing methods used in Dong brocade, this research intends to resolve the gap. To increase sustainable procedures and protect cultural heritage, the primary objective was to assess and integrate traditional plant dyeing techniques into Dong brocade. Semi-structured interviews were employed to collect data from 121 randomly selected individuals from different Dong villages. Plant species utilized for traditional dyeing were identified and documented through ethnobotanical research. For several plant dyes, the optimal dying conditions were found using an orthogonal array design. Seven plant species from eight genera were found to be utilized in the dyeing of Dong brocade. The

Indigofera tinctoria L. was emphasized for its cultural significance and important role in creating vibrant blue hues. The dyeing features of *Indigofera tinctoria* L. were found to be enhanced more by producing (30% frequency and CI with 8.5) natural mordants than synthetic ones. This study addresses a critical gap by extensively describing and analyzing the plant dying procedure used in Dong brocade, assuring the preservation of cultural heritage. The utilization of conventional plant dyes, namely *Indigofera tinctoria* L., is reliable with sustainable methodologies and fulfills the requirements of the Natural Organic Dye Standard (NODS). This highlights the need for environmentally conscious and culturally relevant techniques. It discovered that seven plant species are utilized in Dong brocade dyeing, with *Indigofera tinctoria* L. being particularly important for its brilliant blue hues and cultural significance. Natural mordants were discovered to improve dyeing qualities more efficiently than synthetic mordants, underlining the potential of traditional plant dyeing processes to protect cultural heritage and promote sustainability.

Limitation and future scope

The study could not accurately represent the Dong brocade heritage, since it was limited to the small number of participants and particular regions. It was not thoroughly examined the way various village's dyeing methods evolved. Future studies should investigate new plant species and dyeing procedures to improve the environmental impact and cultural importance of Dong brocade. Expanding research into both conventional and innovative mordants has the potential to increase dye quality while also supporting the preservation of cultural heritage and biodiversity.

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