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Use of plants as dyes: A case study of the use of pre-mordanting method to dye cotton fabric with extracts from *Allium burdickii*

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ABSTRACT
Some of the synthetic dyes and mordants are harmful to the environment. The aim of this research was to study the dyeing of cotton fabric using extracts from wild leek (*Allium burdickii*). The bark of mango tree was used as a mordant. The pre-mordanting method was used and four treatments were investigated with respect to exhaustion of the dye. These were: temperature, time, pH and concentration of mordant. Dye exhaustion for 27 experiments was investigated by comparing the relationship between the independent and dependent variables. The regression model obtained from the interactions was significant with an R^2 value of 0.611. The effect of pH was insignificant while all the other three variables significantly influenced exhaustion of dye. The optimised conditions for temperature, time and concentration of mordant were: 60^0C, 90 minutes and 28.18% owf, respectively. The fabrics showed acceptable fastness properties ranging from 2/3-4/5 (fair to very good), 1.2-4 (slightly considerable to noticeable) and 4-5 (very good to excellent) for wash, perspiration and rubbing fastness, respectively.

Key words: *Allium burdickii*, dyeing conditions, mango bark, pre-mordant

RÉSUMÉ
Certains colorants synthétiques et mordants sont nocifs pour l'environnement. Le but de cette recherche était d'étudier la teinture de tissus de coton à l'aide d'extraits de poireau sauvage (*Allium burdickii)*. L'écorce du manguier était le mordant utilisé et la méthode de pré-mordançage a été adoptée. En ce qui concerne l'épuisement de la teinture, quatre paramètres ont été évalués à savoir: la température, le temps, le pH et la concentration de mordant. L'épuisement de la teinture de 27 expériences a été étudié en comparant la relation entre les variables indépendantes et dépendantes. Le modèle de régression obtenu à partir des interactions était significatif avec une valeur R^2 de 0,611. L'effet du pH était insignifiant alors que toutes les trois autres variables influençaient de façon significative l'épuisement du colorant. Les conditions optimales de température, de temps et de concentration de mordant étaient respectivement de: 60^0C, 90 minutes et 28, 18% owf. Les tissus ont montré des propriétés de solidité acceptables allant de 2/3-4/5 (acceptable à très bon), 1,2-4 (légèrement remarquable à remarquable) et 4-5 (très bon à excellent) respectivement pour le lavage, la transpiration et la solidité au frottement.

Mots clés: *Allium burdickii*, conditions de teinture, écorce du manguier, pré-mordant

INTRODUCTION

Dyeing is an ancient art which predates written records. Its practice can be traced back to the Bronze Age era, where primitive techniques of dyeing included sticking plants to fabric then rubbing the crushed pigments onto clothes (Cordon, 2007; Ado, 2014). These practices have since transformed to the use of machinery and synthetic dyes. However, production and application of synthetic dyes and mordant have some associated disadvantages. It is these concerns, coupled with the dynamics of modern day developments that have revived consumer interest in natural dyes. In Africa, the art of dyeing with natural dyes is gradually getting perfected (Jansen, 2005; Kamel, 2005, 2009; Wanyama, 2011). In Uganda, available natural dyes are usually utilized in the dyeing of mats, ropes and other home based craft materials. According to Pan (2003) and Kar (2008), the idea of producing natural dyes with lower particular cost entails the use of cheap agricultural by-products such as waste tree bark from the timber industry, renewable sources and various plant parts from abundant natural sources like plant, animals and insects. Dyeing manifests at any

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stage of textile manufacturing either on loose fibre, intermediate forms such as sliver, yarn and fabric or towards the end of the manufacturing cycle which includes garments and finished articles. During the course of mordanting (whether dyeing natural or synthetic fibres), it is essential to constantly monitor process parameters at all phases, in order to ensure proper feedback on the effectiveness of the control algorithm, and the response of the system to the changes in dye bath parameters. The aim of this research was to investigate the effect of various dyeing conditions on exhaustion of pre-mordanted cotton fabrics, using *Allium burdickii* plant extract, with mango tree bark as a mordant.

Experimental

The materials used in this study included cotton fabric and extracts from *Allium burdickii* plant and mango tree bark. In this research, the pre-mordanting approach was adopted. Considering four factors: dyeing temperature (X_1), time (X_2), pH (X_3) and concentration of mordant (X_4), at three levels within these factors, the experiment had a total of 27 treatment combinations. Dyeing temperature was varied from 60^{0}C to 100^{0}C, time from 60 to 90 minutes, pH 4 to 7 and concentration of mordant 10% to 50% (% owf). The dye exhuastion and color fastness were monitored for the 27 experiments.

RESULTS AND DISCUSSION

Dye exhaustion. As discussed in the experimental section, dye exhaustion (Y1) was monitored during the experiments. The relationship obtained was as given in the equation below:

$$Y_1 = -537 + 10.88X_1 + 5.27X_2 + 2.86X_4 - 0.0383X_1^2 - 0.0506X_4^2 - 0.0741X_1 \times X_2$$

The results indicated that the regression model generated was statistically significant with a correlation coefficient (R^2) of 0.611. Temperature (X_1) was the major factor that contributed highly to the percentage exhaustion of dye. Its increase led to an increase in percentage exhaustion by over 10.88%. The effect of pH in this research work was insignificant.

Effect of temperature on dye exhaustion. As noted in Equation 1, an increase in temperature led to an increase in pecentage exhaustion by about 10.9%. A further increase in temperature beyond 60^{0}C however inversely affected dye exhaustion (Fig.1). However for the 27 observations, most of the fabrics (Fig. 2) adsorbed dye molecules with a percentage exhaustion ranging from 50 to 90.4%. This indicates that this paricular extract had acceptable substantivity for cotton fabrics when dyed at temperatures between 60 to 100^{0}C. At particular temperatures however, percentage exhaustion decreased from 60 to 80^{0}C, then generally increased up to 100^{0}C. Experiments that were executed at 80 and 100^{0}C presented the same trend in variation of increasing then decreasing exhaustion from one run order to another. The lowest exhaustion of -288. 6, -110.1 and -42.1% observed in runs 24, 14 and 9 implies that at those particular dyeing conditions, primary exhaustion took place however the dye fiber bonding was low. The combined effects of temperature and time as shown in Fig. 3 demonstrated a reduction in mean percentage exhaustion by 0.074% as temperature decreases with increase in time.

Temperature is a factor that has a role in destabilizing anthocyanin molecular structure. At higher temperatures, hydrolyzation of the dye structure

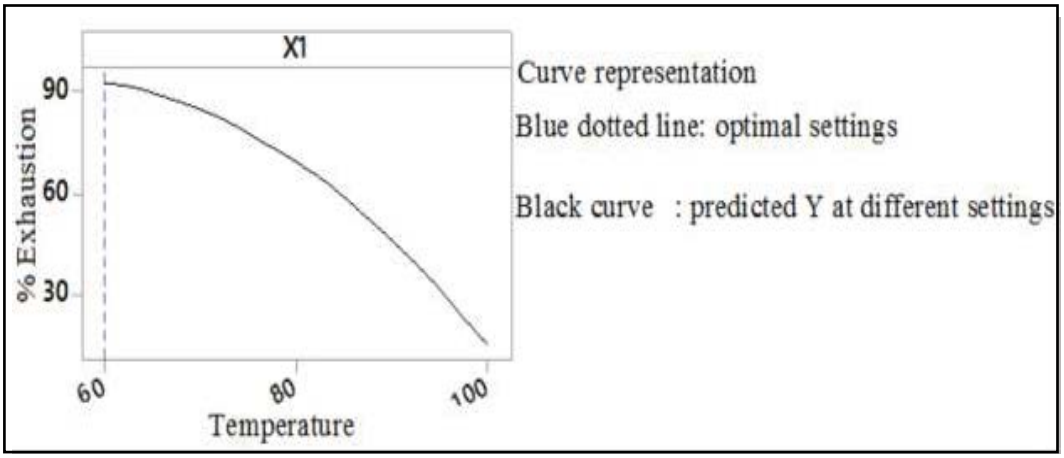

Figure 1: Effect of Tenperature on dye exhaustion

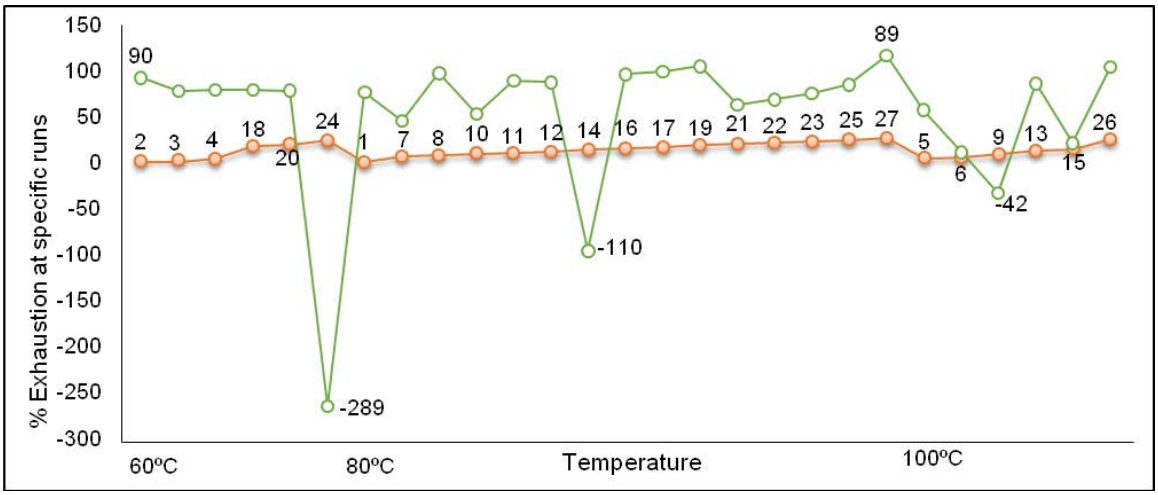

Figure 2: Effects of specific temperature on dye exhaustion

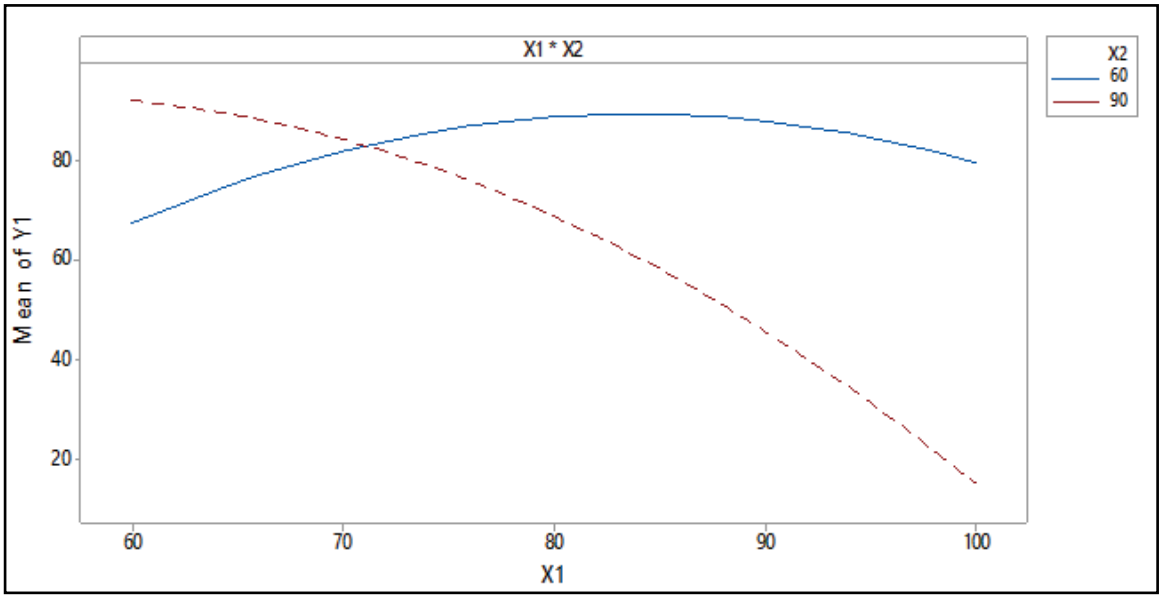

Figure 3: Combined effect of temperature and time on dye exhaustion

(Ju, 2003; Laleh, 2006) occurs which in turn leads to greater destruction of anthocayanin and extraction of excess components. This eventually leads to the reduction in percentage exhaustion.

Influence of time on dye exhaustion

The blue dotted line in Fig. 4 represents the optimal settings while the black line is the predicted Y at different settings, respectively. From Equation 1 and Figure 4, it was observed that an increase in time from 60 to 90 miunutes gradually increased the transfer of dye molecules from the dye bath onto the cotton fabric by 5.27%. The dyeing time which is related to the rate of dyeing is greatly influenced by varying factors such as the degree of dye aggregation in aqueous solution, the rate of diffusion either in aqueoous solution or within the fibre itself, substantivity of the dye, dyeing temperature and pH of the dye bath.

At specific dyeing time (Fig. 5), percentage exhaustion decreased when dyeing was carried out for 60 minutes. However, increasing the dyeing time from 75 minutes to 90 minutes, led to an increase in exhaustion. This is because all the chromophores were fully extracted. Natural dyes usually need

longer extraction time and since exhaustion of dye is a function of time, this implies that as time is increased, rate of exhaustion increases with decrease in the rate of dyeing. This suggests that the longer stirring time for this particular dye enabled absorption of dye molecules into the fiber until equilibrium was attained at 90 minutes which was the best time of extraction. These results relate with Broadbent (2001) who established that increase in time increased the percentage exhaustion of dye (Broadbent, 2001).

Effect of concentration of mordant on dye exhaustion. Various shades were obtained when cotton fabrics were pre-mordanted with extracts from mango tree bark. During mordanting, the dye demonstrated an intial increase in equilibrium exhaustion by 2.86% from 10% o.w.f. up to an optimal concentration of 28.18% o.w.f, beyond which the pecentage dye uptake reduced by 0.05% (Fig.6). In pre-mordanting, the fabric is first mordanted and then dyed. Therefore the reduction of exhaustion with increase in concentration of mordants beyond 28.18% o.w.f could have been due to the aggregation of the extracted molecules caused by reduction in extract solubility (Ali, 2011). This therefore led to its precipitation thus difficulty of penetration of dye molecules into the fabric during dyeing.

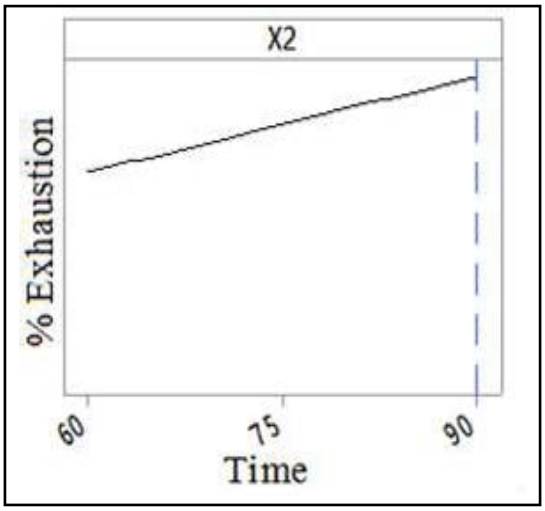

Figure 4: Effect of time on dye exhaustion

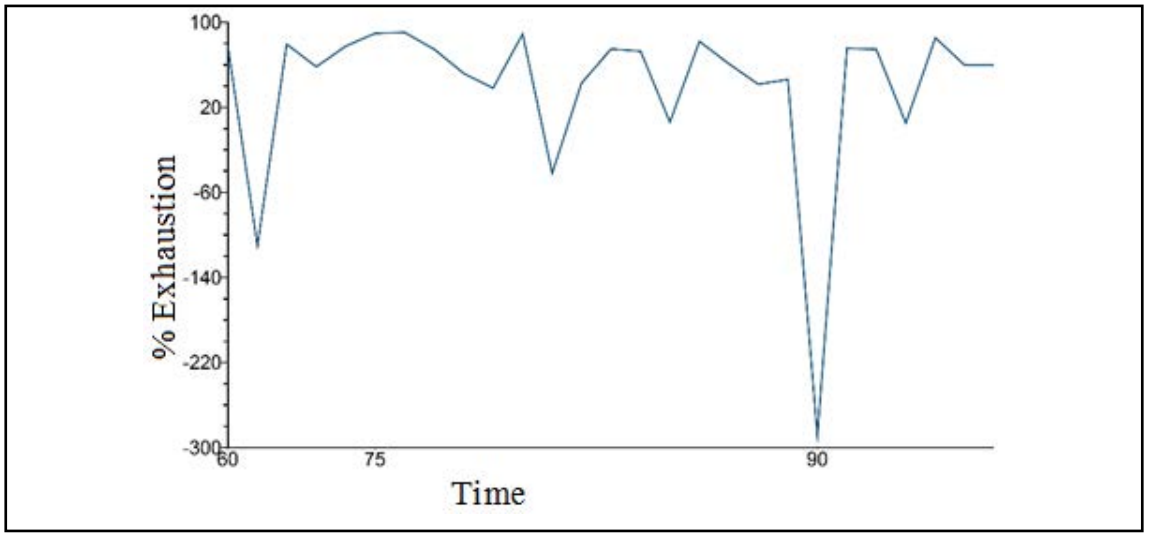

Figure 5: Effect of time on percentage exhaustion

Analysis of fastness properties. To investigate the effect of the four parameters (dyeing temperature, time, pH and concentration of mordant) during pre-mordanting dyeing of cotton fabrics with *Allium burdickii* extract, fastness to rubbing, washing and perspiration was investigated. Parameters used in this investigation were colour change (CC) and colour staining (CS) to washing, dry and wet rubbing fastness while for perspiration, only staining of the fabric was considered. Results are given in Figure 7.

From the results, CS and CC to dry rubbing presented the best results amongst all the fastness properties (Figure 7). These were rated 4.5-5 (very good to excellent). The fastness rating of the dyed cotton fabrics for CC and CS was from 1.2-5 (fair to excellent), 1.2-4.5 (fair to very good) and 2-4.5 (fairly good to very good) for CC and CS to washing respectively and 2.3-4 (considerable to noticeable) and 1.2-4 (slightly considerable to noticeable) for alkaline and acidic perspiration, respectively.

The good fastness properties of cotton fabric dyed with *Allium burdickii* bulb extract is attributed to the fact that these dye contains tannin, which may help in covalent bond formation with fibre thus good fixation on the fibrous material. Moreover, these tannins, having a phenolic structure, can form metal chelation with different mordants, and as a result improve wash fastness.

CONCLUSION

Plant extracts from *Allium burdickii* and mango bark (as the mordant), were used to dye cotton fabric using the pre-mordanting method. Dyeing temperature significantly effected dye exhaustion, while the

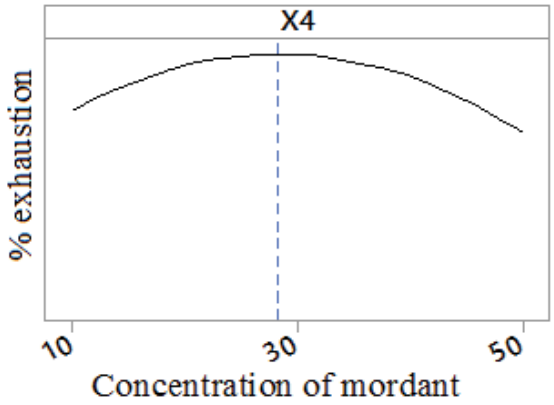

Figure 6: Effect of concentration of mordant on dyeability

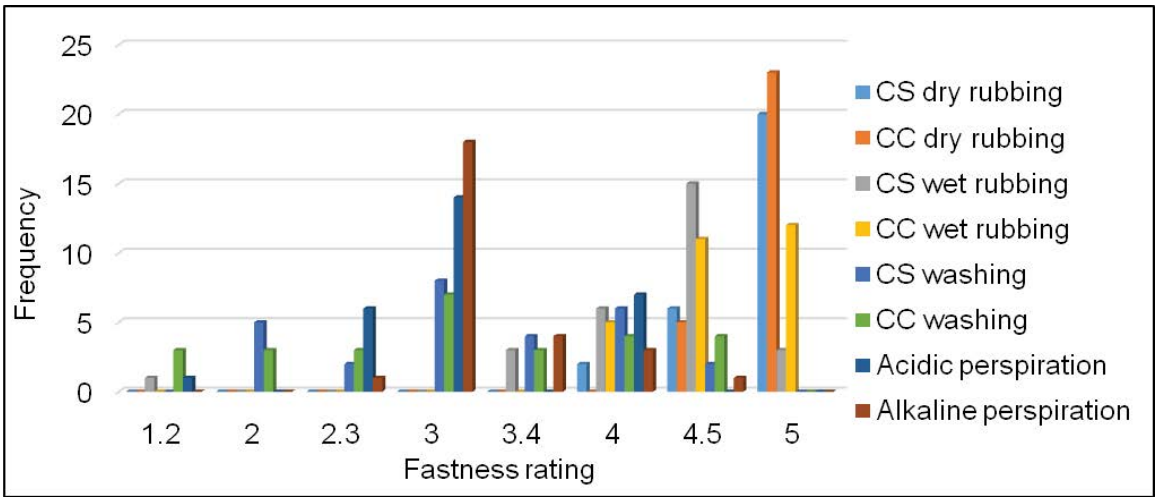

Figure 7: Fastness properties for pre- mordanted cotton fabrics

effect of pH was insignificant. The optimised conditions for temperature, time and concentration of mordant were: 60^0C, 90 minutes and 28.18% owf, respectively. The fabrics showed acceptable fastness properties ranging from 2/3-4/5 (fair to very good), 1.2-4 (slightly considerable to noticeable) and 4-5 (very good to excellent) for wash, perspiration and rubbing fastness, respectively. The *Allium burdickii* plant extracts and mango bark mordant can thus be utilised for dyeing cotton substrates.This research has provided insights for the utilization of locally sourced *Allium burdickii* plant for dye applications in textiles.

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STATEMENT OF NO CONFLICT OF INTEREST

We the authors of this paper hereby declare that there are no competing interests in this publication.

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