Study on character association and path analysis in Korarima (*Aframomum corrorima* (Braun) Jansen) germplasms at Jimma Southwestern, Ethiopia

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ABSTRACT

In Ethiopia, the spice Korarima is one of the most important cash crops. The Jimma agricultural research institute recently gathered a large number of Korarima genotypes from Ethiopia's key growing regions to analyze genetic variations between genotypes and produce varieties. However, no characterization or genetic variability research has begun in these kororima collections. Thus, character association and path coefficient analysis was performed on twenty-five Korarima germplasm samples collected from various agro-ecological regions of Ethiopia to estimate the extent of correlation between characters at the phenotypic and genotypic levels, and compare the direct and indirect effects of the characters on yield. Each incomplete block has a $5 \times 5$ simple lattice design with two replications and five accessions in Jimma agricultural research center during the 2020 main cropping season. Nine plants were planted in each plot, with a row and plant spacing of 1.8 m. The genotypes were grown under Sesbania shade trees. At both the genotypic and phenotypic levels of significance, yield per plant had a positive and significant relationship with the total tiller, bearing tiller, number of leaves per stem, number of capsules per plant, the weight of fresh capsule, and length of dry capsule, indicating the possibility of correlated response to selection. The number of capsules per plant had the greatest direct effect on yield, according to genotypic path analysis. This proves that the correlation is real and that direct selection using these features will be quite effective. The diameter of the dry capsule, total tiller, dry capsule weight, and fresh capsule length all have a direct positive effect on yield. Varietal, environmental, and edaphic elements, as well as management practices, might all contribute to the variation. The findings might help with future breeding and quality-improvement efforts.

1. Introduction

Korarima [*Aframomum corrorima* (Braun) P.C.M. Jansen] is a monocotyledonous, perennial, and aromatic herbaceous plant belonging to the Zingiberaceae family. The Korarima's chromosomes were found to be quite small, with a diploid number of $2n = 1.48 = 2x$ [1,2]. A subterranean rhizome, a pseudo-stem, and a faux leaf make up the plant. It has multiple wide leaves and resembles Elettaria species morphologically. A mature Korarima plant can grow to be up to 1–2 m tall. It sets seed and continues to develop after 3–5 years, depending on the planting materials utilized.

Korarima is an Ethiopian spice and medicinal plant that is endemic to the country. It is sometimes known as Ethiopian cardamom or false cardamom and is an Ethiopian and Eritrean spice prepared from the plant's seeds (usually dried) [3, 4]. Western Ethiopia, southern Sudan, western Uganda, and Tanzania are home to the plant [5]. It is widely spread in southern and western Ethiopia, according to [6], provinces of Kafa, Gamo Gofa, Debub Omo, Sidamo, Illubabor, and Wollega. Outside of these places, it is grown near Lake Tana and Gelemso, as well as in Eritrea.

Even if the plant is less well-known and farmed in industrialized nations, well-documented information on plant genetic resources may be accessible [7, 8]. Despite the availability of large gene pools, the function of wild germplasm in improving cultivated plants is relatively restricted. Although Ethiopia is a key international center of origin and/or genetic diversity for many important domesticated food plants, the conservation and usage of Ethiopian germplasm have not been completely utilized [8, 9, 10, 11, 12].

According to the Ethiopian Agricultural Research Organization, the economic returns obtained from Korarima (yields per ha) were substantially higher than food grains grown in the key Korarima growing
administrative zones [13]. Data on the quantity and nature of character interrelationships, according to [14], contribute to the construction of effective multiple trait selection schemes by allowing for direct and indirect selection of component characteristics. Plant breeding and genetic resource conservation are heavily influenced by the assessment of genetic diversity in crops. It is especially effective in crops that have not been well researched. For the successful selection of individual genotypes to be employed as parents in hybridization programs or to develop as varieties, knowledge of the crop nature, extent, and distribution of genetic diversity are essential. The number of populations necessary to conserve genetic diversity within a species depends on the measure of diversity and its pattern of partition within and among populations [2, 15]. A huge number of korerima genotypes were recently gathered from the main growing locations of Ethiopia by the Jimma agricultural research center to examine genetic variances across genotypes and so produce varieties. In Ethiopia, there is a scarcity of data on character association and path coefficient analysis of the korarima plant.

The correlation coefficient can be used to determine the relative contribution of component characteristics to yield. Furthermore, because of an overestimation or underestimating of a component character's relationship with other characters, the correlation between grain yield and that character might be deceptive. As a result, yield components influence ultimate yield both directly and indirectly. Thus, breaking down overall association into direct and indirect impacts would provide a more accurate picture of the connection. The path coefficient, a typical partial regression coefficient, defines the cause-and-effect connection and assesses the proportional importance of each variable [2, 16]. Therefore, correlation in combination with path coefficient analysis will be an important tool to find out the association and quantify the direct and indirect influence of one character upon another [2, 17]. However, characterization and genetic variability study has not started in these collections of korerima. Therefore, the objective of this work was to determine the degree of correlation between characters at the phenotypic and genotypic levels and to assess the traits' direct and indirect effects on yield.

2. Materials and methods

The field experiment was conducted at Jimma agricultural research center during the 2020 main cropping season. The area is among the most conducive production areas for *Aframomum coramina* in Ethiopia and thus, the accessions were expected to fully express their genetic potential for the trait under consideration. The main cropping season of Korarima is *Meher* (June–October). The soil type of the experimental area is Eutric Nitosol (reddish-brown) with a pH of around 5.2. The area receives a mean annual rainfall of 1536 mm with a maximum and minimum temperature of 25.9°C and 11.2°C, respectively [18]. The study used 25 established Ethiopian Korarima germplasm accessions that were five years old, as well as a local check. The germplasm accessions for Korarima were obtained from reliable and representative sites. The germplasm accessions were collected from the major growing regions of the Jimma area. The experiment was performed on plants that were grown in a 5 × 5 basic lattice design arrangement with two replications and five accessions each incomplete block. Nine plants were planted in each plot, with a row and plant spacing of 1.8 m. The genotypes were grown in the shadow of Sesbania trees.

The following data were acquired from five plants chosen at random from each plot. Using mean values from these samples, the performance of each germplasm accession for the factors under consideration was assessed. Plant height (cm), number of tillers per plant, number of bearing tillers per plant, intermodal length (cm), number of leaves per stem, leaf area (cm²), number of capsules per plant, and yield per plant are all taken into consideration. Twenty-five capsules were taken from each of five randomly selected plants of plots to determine the weight of a single capsule (g), the length of the single capsule (cm), and the diameter of the single capsule (cm) both at the fresh and dry base. The process of [19] was used to extract essential oils and oleoresins, while the process of [14] was used to determine the dry matter, total ash, crude fiber, and crude fat content on a percent basis [20].

To establish the importance of variance across samples, the obtained data were analyzed using the General Linear Model procedure of Statistical Analysis Systems (SAS, [21]) version 9.2. At a 5% probability level, the samples' means were compared using the Least Significant Difference (LSD) test. The small letters a to z were used to separate the treatment means that showed significant differences. To evaluate the validity of the data, Bartlett's test for homogeneity of variance was performed using Minitab 15 (Minitab version 15, Minitab Inc., State College, PA, USA) statistical software, and data transformation was performed for those who failed the test. Following retransformation, the mean values of converted data were presented.

2.1. Correlation analysis

2.1.1. Phenotypic and genotypic correction coefficient analysis

The phenotypic correlation (rp), which is the observable correlation between two variables that include both genes and environmental factors, was calculated using the formula proposed by [22, 23]. Thus, the phenotypic and genotypic correlation coefficients were estimated using the formula suggested by Johnson et al. [22] and Singh and Chaudhury [24] respectively.

\[ r_p = \frac{P_{covxy}}{\sqrt{V_{px} \cdot V_{py}}} \]  
(1)

\[ r_g = \frac{P_{covxy}}{V_{gy}} \]  
(2)

where, \( r_p = \) Phenotypic correlation coefficient.  
\( r_g = \) Genotypic correlation coefficient.  
\( P_{covxy} = \) Phenotypic covariance between variables x and y.  
\( V_{px} = \) Genotypic variance for variable x.  
\( V_{py} = \) Genotypic variance for variable y.  
\( V_{gy} = \) Genotypic variance for variable y.

2.1.2. Path coefficient analysis

Path coefficient analysis was used to calculate the direct and indirect effects of yield-related features on yield/plot. According to [21, 22], the analysis was carried out using the method proposed by [17]. Thus, Path coefficient analysis was estimated for morphological traits following the method described by Dewey and Lu [17]. The following was the formula:

\[ r_{ij} = P_{ij} + \sum r_{ik}p_{kj} \]  
(3)

where: \( r_{ij} = \) Mutual association between the independent character (i) and dependent character (j) as measured by the correlation coefficient.

\[ P_{ij} = \text{Component of direct effects of the independent character (i) on dependent character (j) as measured by the path coefficient and} \]  
\[ \sum r_{ik}p_{kj} = \text{Summation of components of the indirect effect of a given independent character (i) on the given dependent character (j) via all other independent character k).} \]

The residual effect was determined as described in Dewey and Lu [17]. Residual effect estimated by the formula

\[ \sqrt{1 - R^2} \]  
(4)

where: \( R^2 = \Sigma p_{ij} r_{ij} \)

\[ p_{ij} = \text{Component of direct effects of the independent character (i) on dependent character (j) as measured by the path coefficient.} \]
Table 1. Genotypic correlation (Above the diagonal) and phenotypic (Below the diagonal) coefficients of 18 characters of 25 korarima accessions studied at JARC 2020.

| Traits      | PH   | TT   | BT   | NLPS | NCPP | LA   | WFC  | LFC  | DFC  | WDC  | LDC  | DDC  | VOC  | OC   | %ASH | CRFAT | YPP |
|-------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| PH          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| TT          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| BT          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| NLPS        |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| NCPP        |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| LA          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| WFC         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| LFC         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| DFC         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| WDC         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| LDC         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| DDC         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| VOC         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| OC          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| %ASH        |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| CRFAT       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| YPP         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |

3. Results and discussions

3.1. Correlation of yields with other traits

Genotypic and phenotypic correlation coefficients for yield and related variables are presented in Table 1. At both the phenotypic and genotypic levels, total tiller, bearing tiller, number of leaves per stem, number of capsules per plant, the weight of fresh capsule, and length of the dry capsule were all positively and substantially linked with yield per plant (Table 1). Furthermore, at the genotypic level solely, the length of the fresh capsule was positively and significantly linked with yield per plant. The probability of a related response to selection is indicated by the positive connotation of pairs of features.

On the other hand, oleoresin and crude fat content demonstrated a negative and substantial relationship with yield per plant at both the phenotypic and genotypic levels, indicating that those attributes could not be improved simultaneously (Table 1). Biparental mating, diallel selective mating, and mutation breeding could be utilized to improve these features by breaking undesired linkages. At both the genotypic and phenotypic levels, yield per plant was not substantially associated with the other variables (Table 1).

In line with the current finding [25], reported a positive and substantial link between tiller per plant and yield per plant, as well as a negative association between crude fiber content and yield in turmeric. Similarly [26, 27], in fenugreek found that pod per plant and pod length had a positive connection with yield per plant. Likewise [28], found a substantial and positive relationship between the number of capsules per plant and the yield per plant. They found a negative association of capsule length with yield per plant in sesame, but a positive correlation of oil content with yield per plant, which contradicts this conclusion.

3.2. Correlations among other characters

Plant height had a positive and substantial association with practically all capsule features at the genotypic and phenotypic levels, including capsule weight, length, and diameter on a fresh and dry basis. Total tiller was likewise linked to bearing tiller, the number of leaves per stem, and the number of capsules per plant in a favorable and significant way. The number of capsules per plant and the length of the dry capsule were both strongly connected with the number of capsules per plant and the length of the dry capsule. Furthermore, the number of leaves per stem was found to have a strong and positive relationship with the number of capsules per plant. The length of a fresh capsule, its diameter, the percent ash content are all positively and strongly connected with the weight of a fresh capsule. Because these attributes have a positive and strong relationship, selection can develop them all at the same time.

In cardamom, the number of tillers per plant and the number of bearing tillers per plant exhibited a positive and substantial association with the number of capsules per plant, according to the findings of [29]. The relationship between plant heights and the number of capsules per plant, on the other hand, was not significant. They also found a substantial and positive relationship between the total number of tillers per plant and the fresh weight of capsules per plant. The fresh weight of capsules per plant was positively connected with the number of bearing tillers per plant and the plant's height, although the correlation was not significant.

In line with our findings [30], found that essential oil content had a negative genotypic connection with seed production and 1000 seed weight in black cumin. They also discovered a negative link between oil concentration and plant height, which contradicted their previous findings. In India, however, plant height was found to have a substantial positive relationship with rhizome yield in turmeric, contradicting this finding [2, 31]. Total tiller and bearing tillers were adversely and significantly linked with oleoresin and crude fat content in terms of negative correlation. Aside from the number of leaves per stem with
Table 2. Estimates of direct (bold diagonal) and indirect effect (off-diagonal) at the genotypic level of different characters on yield of Zizania latifolia at JAMC 2020.

| Trait | PH | TT | BT | NLPS | LA | DDC | DCF | WDC | LDC | VOC | OC | %ASH | CRFAT% | Residual effect |
|-------|----|----|----|------|----|-----|-----|-----|-----|-----|----|-----|--------|----------------|
| PH    | -0.08 | 0.013 | 0.002 | 0.012 | 0.004 | 0.003 | 0.002 | 0.002 | 0.001 | 0.013 | 0.002 | 0.014 | 0.017 | 0.197 |
| TT    | -0.146 | 0.47 | -0.013 | 0.029 | -0.037 | 0.502 | 0.005 | -0.099 | -0.075 | 0.077 | -0.119 | 0.133 | 0.006 | 0.016 |
| BT    | 0.001 | -0.02 | 0.065 | 0.029 | -0.065 | 0.005 | 0.002 | 0.001 | 0.003 | 0.002 | 0.001 | 0.003 | 0.004 | 0.016 |
| NLPS  | 0.011 | 0.033 | 0.009 | 0.693 | 0.014 | 0.009 | 0.002 | 0.001 | 0.003 | 0.002 | 0.001 | 0.003 | 0.004 | 0.016 |
| LA    | 0.01 | 0.012 | 0.012 | 0.005 | 0.006 | 0.005 | 0.002 | 0.001 | 0.003 | 0.002 | 0.001 | 0.003 | 0.004 | 0.016 |
| DDC   | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |
| DCF   | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |
| WDC   | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |
| LDC   | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |
| VOC   | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |
| OC    | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |
| %ASH  | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |
| CRFAT%| 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.016 |

Residual effect 0.197, ** Significant at probability level of 0.05 (r = 0.505) respectively. PH: plant height, TT: total tiller, BT: bearing tiller, NLPS: number of leaves per stem, LA: leaf area, diameter of the dry capsule, DDC: length of dry capsule, DCF: weight of dry capsule, VOC: volatile oil content, OC: oleoresin content, %ASH: percent ash content, CRFAT%: crude fat percentage.

Volatile oil and oleoresin content, there is a negative and substantial association between the number of capsules per plant with oleoresin and crude fat content.

3.3. Path coefficient analysis

To divide the correlation coefficients into direct and indirect effects, path coefficient analysis was used. Direct and indirect effects of component attributes on yield per plant are presented in Table 2. The largest and most favorable direct effect on yield was the number of capsules per plant, which exhibited a strong and positive association with production (1.104) (Table 2). This explains why the connection implies a good and real link, as well as successful direct selection through these features. The dry capsule’s diameter demonstrated a positive direct effect. It had a positive correlation coefficient with yield, while the indirect effects via other features were generally negative and insignificant.

As a result, the direct influence accounted for the majority of the favorable relationship it had with yield. Directly, the weight of the dry capsule and the overall tiller had a good effect. The direct effects had the same magnitudes as the genotypic correlation coefficients. This proves that the correlation is accurate in describing the true relationship. The length of the fresh capsule, which was associated with yield in a favorable and significant way, had a beneficial direct influence. Direct effects of oleoresin concentration, crude fiber, and crude fat were beneficial. They exhibited a negative genotypic connection with yield. They had largely detrimental indirect effects on other characters. As a result, their negative correlation coefficient with yield was primarily owing to their indirect influence, implying that limited simultaneous selection should be used to mitigate the unfavorable indirect effect. Inconsistent with this conclusion [32, 33, 34], also claimed that capsules per plant had the most direct positive influence on yield. Furthermore, the number of tillers and rhizomes per plant had a positive and substantial direct effect on yield [35].

The diameter of the new capsule and its weight both showed detrimental direct impacts. These traits demonstrated a positive genotypic connection with yield. Most of the other qualities had negligible indirect impacts. As a result, the genotypic associations with yield were primarily owing to direct influences. The amount of volatile oil in the capsule and the length of the dry capsule both showed negative direct effects on yield, but their correlation coefficients were positive, and the indirect effects via other features were largely favorable.

As a result of their indirect impacts, they had a link with yield. The direct effects of leaf area and ash were negative, as were the correlation coefficients of these variables with yield, while the indirect impacts via other features were mainly negative. As a result, the yield correlation they had was due to indirect influences. The number of leaves per stem has a direct negative effect on the number of leaves per stem. The number of leaves per stem has a positive genotypic correlation, and the indirect effect via most of the other features is minimal, implying that the correlation with yield is attributable to a direct effect. Similarly [36, 37], reported that the leaves per brush were positively correlated with phenotypic characteristics in turmeric and Cymbopogon winterianus, respectively.

The path analysis revealed a residual value of 0.197, indicating that the characters in the path analysis expressed 80.3 percent of the variability in yield.

4. Conclusion

The following conclusion may be drawn from the current study: both genotypic and phenotypic levels, as well as characteristics, were associated with pure seed and exhibited a positive and substantial connection. Yield per plant had a positive and significant relationship with total tiller, bearing tiller, number of leaves per stem, number of capsules per plant, weight of fresh capsule, and length of dry capsule at both the genotypic and phenotypic levels of significance, indicating the possibility of
correlated response to selection. The number of capsules per plant had the largest direct influence on yield, according to genotypic path analysis. This proves that the correlation is real and that direct selection using these features will be quite effective. Furthermore, the diameter of the dry capsule, total tiller, dry capsule weight, and fresh capsule length all has a direct favorable effect on yield. As a result, both the genotypic and phenotypic levels, practically all characteristics and path analyses indicated a positive and substantial connection. Generally, there is variability in physical and biochemical parameters among korarima samples in the study area. The variation may be due to varietal, environmental, edaphic factors and management practices. The findings might help with future breeding and quality improvement initiatives.

**Declarations**

**Author contribution statement**

Simegn Kinifu: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.  
Tamirat Wato: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.  
Tilahun Negash: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data included in article/supplementary material/referenced in article.

**Declaration of interests statement**

The authors declare no conflict of interest.

**Additional information**

No additional information is available for this paper.

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