



Morphological and Phenotypic Variability of Olive Varieties (*Olea europaea sativa* L.) in Algeria : Implications for Cultivation in Semi-Arid Regions

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Abstract: The olive tree (*Olea europaea* L.) exhibits considerable genetic diversity, while environmental factors such as soil and microclimate contribute to phenotypic variation among varieties. This study evaluated the phenotypic and morphological characteristics of six olive varieties : Azeradj, Frontoio, Neb Djemel, Limli, Sigoise, and Chemlal cultivated under the semi-arid conditions of Bordj Bou Arréridj, Algeria. The objective was to characterize key morphological traits, including leaf, flower, and fruit characteristics, following the guidelines of the International Olive Council. The results showed that all varieties exhibited medium vegetative growth and elliptical-lanceolate leaves, with a floral formula of $Z(4S) + (4P) + (2E) + 1C$. Significant differences were observed among the varieties, particularly in tree width, trunk or main branch thickness, and leaf dimensions. Frontoio and Chemlal exhibited the highest numbers of flowers per branch and higher fruit-setting rates, indicating greater reproductive potential. Fruit size also varied among varieties, with Azeradj and Sigoise producing the largest fruits, whereas Chemlal produced the smallest. These differences may be associated with varietal characteristics and environmental conditions, particularly water availability. Overall, Frontoio and Chemlal showed superior reproductive characteristics under the study conditions. The findings highlight the importance of appropriate irrigation and soil management practices for improving olive productivity in semi-arid regions.

Key words: Olive tree, variety, characterization, behaviour, semi-arid.

The olive tree (*Olea europaea sativa* L.) exhibits significant polymorphism, which can be influenced by environmental factors such as soil and microclimate, leading to both phenotypic and genotypic variations (Ouazzani *et al.*, 1995; Belaj *et al.*, 2001). This genetic diversity is largely attributed to the tree's longevity, historical significance, and unique pollination processes. Olive cultivation dates back to ancient times, and its spread was facilitated by human activities, with the tree becoming deeply embedded in Mediterranean cultures (Abdessemed, 2017; Green, 2002). In Algeria, the olive tree is one of the most important fruit species, with a significant number of varieties grown, due to its social, economic, and environmental value. It is characterized by opposite leaves, fleshy fruits, and a trunk that is smooth and grey in youth, becoming rough and tortuous as the tree matures (Barranco *et al.*, 2000; Villa, 2003). The olive fruit is fleshy, ovoid, and changes from green to black when ripe, with size variations across different varieties (Saad, 2009). Olive cultivation is widespread, especially in the northern regions, where the tree adapts to various bioclimatic conditions (Achour, 1995). Olive farming is the most widespread fruit cultivation in the country, with approximately 34,739,080 trees covering 5.72% of the usable agricultural area (UAA) (Oreggia and Marinelli, 2018). Bordj Bou Arréridj ranks fourth in terms of the area dedicated to olive cultivation, with 27,457 hectares and 2,534,710 trees (DSA, 2021).

The aim of this study is to assess the phenotypic and morphological characteristics of six olive tree varieties: *Azeradj*, *Frontoio*, *Neb Djemel*, *Limli*, *Sigoise*, and *Chemlal*, grown in the El Annasser region of Bordj Bou Arréridj. By focusing on key tree organs, including leaves, inflorescences, and fruits, the study follows the International Olive Council's (IOC, 1997) guidelines. The objective is to analyze the variability among the different varieties and evaluate their potential for cultivation in the region, considering both their vegetative growth and fruiting characteristics.

Material and Methods

The soils in the study area range from shallow to deep, are well-drained, and have a silty to silty-clay texture. They are calcareous in nature, with a pH of 7.9, an organic matter

content of 3.5%, and an electrical conductivity of 1 dS m⁻¹. Phosphorus (P) levels are very high, while potassium (K) levels are low, with an average total nitrogen value. The soil is suitable for olive cultivation. The climate is typical of the Mediterranean region, characterized by hot, dry summers and mild, wet winters.

This study investigates the olive-growing heritage of the El Annasser region, situated in the center of Bordj Bou Arréridj, by examining six commonly cultivated olive tree varieties: *Azeradj*, *Frontoio*, *Neb Djemel*, *Limli*, *Sigoise*, and *Chemlal*. The aim is to perform a phenotypic and morphological characterization of these varieties, focusing on the traits that make certain varieties stand out in terms of growth and fruiting. The research specifically targets 19 years old trees, tracking their growth cycle from bud break to fruiting. Using a completely randomized design, four trees from each variety were selected, resulting in a sample of 24 trees for study.

The methodology followed in this research is based on both phenotypic and morphological assessments, referencing the variety catalog by Mendil and Sebai (2006) and the global catalog of olive varieties to guide the evaluation. This approach was designed to provide a deeper understanding of the particular behaviors of the selected varieties in terms of growth, fruiting, and other key characteristics. For phenotypic characteristics: Measurements were taken to assess the general appearance of the tree, trunk thickness, tree height, number of main branch, tree width, and the thickness of the carpenters.

The number of carpenters (main branches) was determined by counting the main branch involved in processing each tree during data collection. This variable was recorded as the total number of main branch assigned to each tree and used for statistical analysis. The timber thickness was measured for each tree using a measuring tape and recorded in millimetres (mm). Tree height was measured for each tree from the base of the trunk to the highest point of the canopy, the measurements were recorded in metres (m). The measured thickness was used as one of the study variables for statistical analysis. The canopy of each tree was measured by determining the average canopy diameter. Two perpendicular canopy diameters were measured using a measuring tape, and the

Table 1. Mean values of trunk thickness, tree height, and number of main branches in six olive varieties

	Azeradj	Frontoio	Neb Djemel	Limli	Sigoise	Chemlal
Tree height (cm)	228.60	234.38	225.25	204.0	207.10	220.45
Trunk thickness (mm)	37.60	42.28	43.25	28.38	32.58	40.0
Number of main branch	2.5	3.0	2.25	2.25	2.0	2.4

average of the two measurements was recorded in meters (m). The morphological analysis involved measuring the length and width of the leaves (cm), leaf length/width ratio, leaf surface area (cm²), flower characteristics (such as the number of flowers per cluster and per branch), the number of olives per branch, fruit setting rate, and the growth of the olives trees. This comprehensive study aims to shed light on the growth and fruiting dynamics of these varieties and how they may contribute to olive cultivation in the region.

Results and Discussion

Phenotypic Characteristics

Tree height, trunk thickness and number of main branch: The majority of the tested varieties have tree heights between 161.08 cm and 234.38 cm. Regarding trunk thickness, we observed that the Limli trunk was the thinnest (28.38 cm) and the Frontoio trunk the thickest (42.28 cm). As for the number of main branches, most varieties had between 2 and 4 (Table 1). Statistical analysis indicated that there were no significant differences among the varieties with respect to trunk thickness, tree height, and number of main branches ($p = 0.25$, $p = 0.16$ and $p = 0.10$ respectively), as all p -values exceeded both the 5% and 1% significance levels. These parameters appear to be relatively consistent across the studied olive tree varieties.

Tree width and main branch: Statistical analysis revealed significant differences among the varieties with respect to tree width and main branch thickness ($p = 0.02$), indicating significance at the 5% level ($p < 0.05$), but not at the 1% level ($p > 0.01$) (Fig. 1 and 2). This suggests that these parameters vary considerably between the studied olive tree varieties, potentially influencing their overall growth patterns and structural characteristics.

The analysis of tree width among the studied olive varieties reveals that *Neb Djemel* has the largest canopy, measuring 273.75 cm, while *Sigoise* records the smallest width at 166.10 cm. The remaining varieties exhibit intermediate values: *Frontoio* (257.25 cm), *Azeradj* (240.55 cm), *Chemlal* (234.58 cm), and *Limli* (171.88 cm), demonstrating variation in tree expansion patterns (Fig. 1).

Regarding main branch thickness, *Neb Djemel* records the greatest value at 19.78 cm, followed closely by *Frontoio* (19.41 cm) and *Chemlal* (17.52 cm). Conversely, *Sigoise* has the smallest main branch thickness at 10.81 cm. The remaining varieties, *Azeradj* (15.39 cm) and *Limli* (14.10 cm), present moderate values, indicating structural differences in branch development among the studied olive trees (Fig. 2).

Leaf morphological traits: The results of the analysis of variance reveal very highly significant

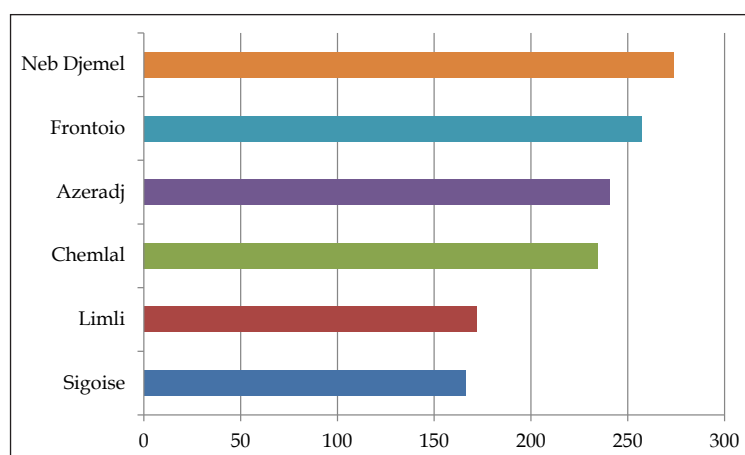


Fig. 1. Comparative analysis of tree width of six olive tree varieties differences.

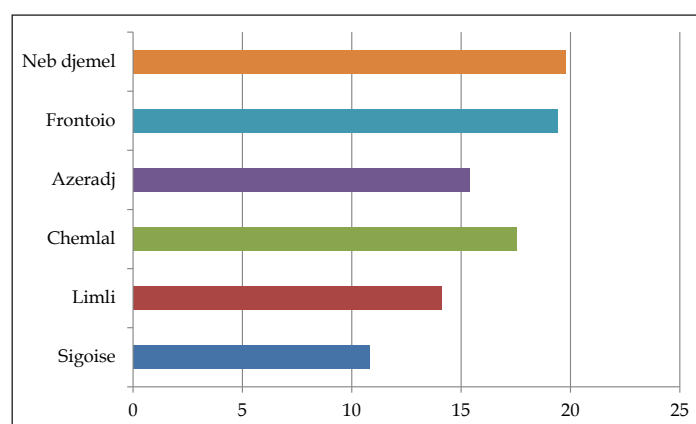


Fig. 2. Comparative analysis of main branch thickness of six olive tree varieties differences.

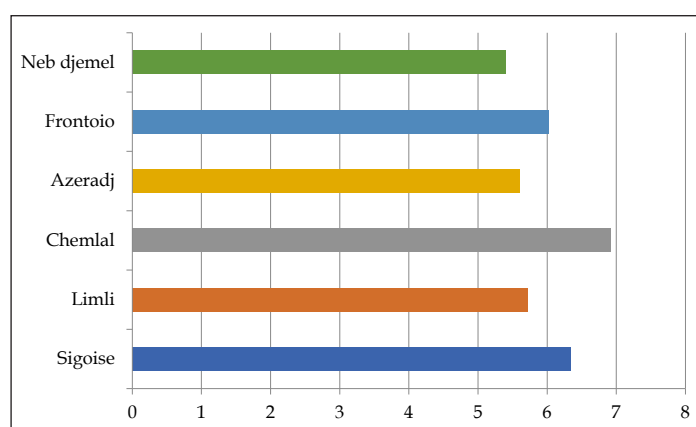


Fig. 3. Comparative analysis of leaf length (cm) of six olive tree varieties.

differences between the varieties tested for the leaf length trait. The greatest length is recorded in the Chemlal variety (6.92 cm), whereas Neb Djemel is the one that recorded the lowest value (5.40 cm). The varieties Sigoise, Frontoio, Limli, and Azeradj have intermediate values, which are respectively (6.34 cm), (6.02 cm), (5.72 cm), and (5.60 cm) (Fig. 3). The leaves of the varieties studied have slightly shorter average lengths compared to the leaves of the Chemlal variety.

The analysis of variance showed very highly significant differences among the varieties for this character ($p < 0.001$). The largest width is recorded by the Sigoise (1.28 cm) and Chemlal (1.27 cm) varieties, whereas the lowest value is recorded for Azeradj (1.14 cm). The Frontoio, Limli, and Neb Djemel varieties present average values of 1.22 cm, 1.21 cm, and 1.15 cm, respectively (Fig. 4).

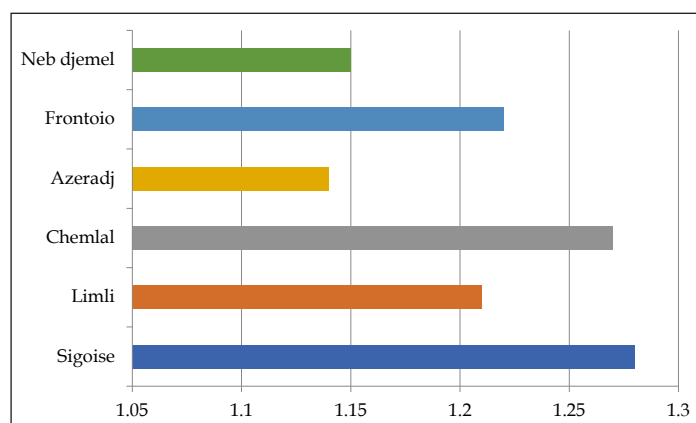


Fig. 4. Comparative analysis of leaf width (cm) of six olive tree varieties.

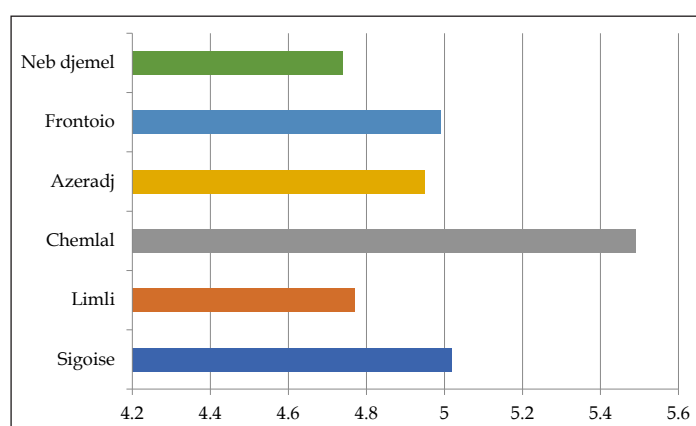


Fig. 5. Comparative analysis of the length-width ratio of leaves of six olive tree varieties.

The results of the analysis of variance reveal highly significant differences between varieties for this character ($Pr = 0.05$). The LF/IF ratio determines the shape of the leaves, which is elliptical, elliptical-lanceolate, or lanceolate. The varieties Chemlal, Sigoise, Frontoio, Azeradj, and Limli recorded values of 5.49, 5.02, 4.99, 4.95 and 4.77 respectively. The lowest value is recorded by the variety Neb Djemel with 4.74. The Chemlal variety is characterized by a dominance of the lanceolate elliptical shape. The leaves of the Sigoise, Frontoio, Azeradj, Limli, and Neb Djemel varieties have the same shape as the Chemlal variety (Fig. 5).

The difference between the varieties is highly significant ($Pr < 0.00$) for the leaf area parameter. The results showed that the largest leaf area is recorded in the varieties Chemlal and Frontoio with 5.35 cm² and 5.05 cm², respectively, whereas Neb Djemel has the lowest leaf area with 3.79 cm². The other varieties, Sigoise, Limli, and Azeradj, have leaf areas of 4.82 cm², 4.39 cm², and 3.94 cm², respectively. The leaf area varies depending on

the variety, climatic conditions, and leaf size (Fig. 6).

Characteristics of the flower: The floral characteristics of the studied varieties, as determined from the observation of qualitative traits, are presented as follows:

Azeradj: Floral formula: Z: (4S) + (5P) + (2E) + 1C, Color of petals: White

Frontoio: Floral formula: Z: (4S) + (4P) + (2E) + 1C, Color of petals: White

Neb Djemel: Floral formula: Z: (4S) + (4P) + (2E) + 1C, Color of petals: White center/light green side

Limli: Floral formula: Z: (4S) + (4P) + (2E) + 1C, Color of petals: White center/light yellow-green side

Sigoise: Floral formula: Z: (4S) + (4P) + (2E) + 1C, Color of petals: White

Chemlal: Floral formula: Z: (4S) + (4P) + (2E) + 1C, Color of petals: White center/light yellow-green side

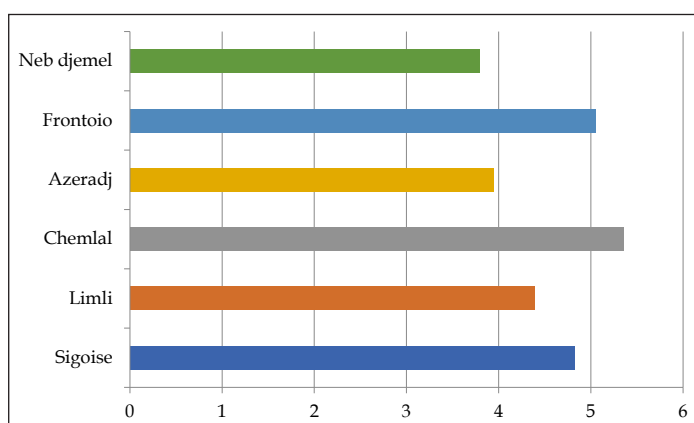


Fig. 6. Comparative analysis of leaf area (cm²) of six olive tree varieties.

Table 2. Comparative analysis of the average number of olives per branch across six olive tree varieties

Variety	Chemlal	Sigoise	Limli	Neb Djemel	Frontoio	Azeradj
Average (%)	14.75	5.25	12.25	5.75	19.0	7.25

Table 3. Comparative study of the average fruit setting rate across six olive tree varieties

Variety	Azeradj	Frontoio	Neb Djemel	Limli	Sigoise	Chemlal
Average (%)	3.88	5.57	3.20	4.47	3.11	5.14

Characteristics of the Fruit

Number of olives per branch: The results of the analysis of variance reveal non-significant differences between the varieties for the olive number trait. The highest olive number average is recorded by the Frontoio and Chemlal varieties with 19 and 14.75, while the lowest average is recorded by the Sigoise variety with only 5.25 (Table 2). The low yields observed for the Sigoise variety are linked to a lack of water and therefore to water stress which can impact flower formation through pistillate abortions. These floral anomalies, which occur approximately one month before anthesis, can also be the consequence of a low mineral diet (Badr and Hartman, 1971).

Fruit setting rate: The analysis of variance showed that the fruit-setting rate did not differ significantly among the varieties, as the probability value ($p = 0.49$) exceeded the 5% significance level ($p > 0.05$). Overall, the fruit setting rate is relatively low, not exceeding 8%. The highest rates are recorded by the Frontoio and Chemlal varieties, with rates of 5.57% and 5.14%, respectively. In contrast, the Sigoise variety has the lowest rate at 3.11%. The remaining varieties: Azeradj, Limli, and Neb

Djemel, show intermediate values of 3.88%, 4.47%, and 3.20%, respectively. This suggests that fruit setting is generally low across all varieties, with environmental conditions likely influencing the observed rates.

Olive growth: The results of the analysis of variance revealed highly significant differences among the varieties for this character ($p=0.001$; $p\leq 0.01$), specifically for fruit size. The fruit enlargement curve begins with a slow growth rate, followed by a faster growth rate. The Azeradj (1.6 cm) and Sigoise (1.4 cm) varieties have the largest fruit sizes, while the Chemlal variety shows the smallest fruit size, with an average of 1 cm. Other varieties exhibit intermediate fruit sizes: Neb Djemel (1.21 cm), Limli (1.05 cm), and Frontoio (1.07 cm). These findings demonstrate significant variation in fruit size across the varieties, with Chemlal exhibiting notably smaller fruits compared to the others. This is in contrast to Boukhari's (2014) study, which reported larger fruits for the Chemlal variety in the M'kira region. The discrepancies are likely due to varying environmental conditions that can significantly affect fruit development, such as temperature, water availability, and soil fertility (Fig. 7).

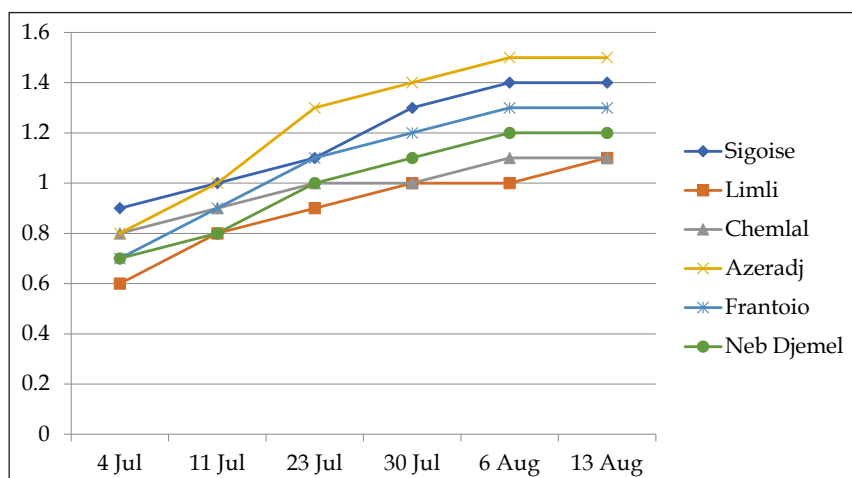


Fig. 7. Comprehensive analysis of the enlargement and growth patterns of olives across different olive tree varieties, with emphasis on fruit size development.

Correlation Analysis of Vegetative Growth, Morphological, and Fruit Production Traits

Strong positive correlations among vegetative traits such as tree height, trunk thickness (+0.65), and tree width (+0.45). Leaf traits are even more closely related, with leaf length and leaf width (+0.75), leaf length and leaf area (+0.90), and leaf width and leaf area (+0.85). In contrast, the length/width ratio is negatively correlated with these traits (-0.50 with leaf length and -0.70 with leaf area), meaning larger leaves are less elongated.

Reproductive traits are also interconnected. Flowers per inflorescence is strongly correlated with flowers per branch (+0.80), while flowers per branch is moderately correlated with olives per branch (+0.60). Fruit setting rate shows moderate positive correlations with traits like tree height (+0.50), leaf length (+0.50), and flowers per branch (+0.50), suggesting that better growth supports better reproduction.

Fruit size is positively correlated with most vegetative traits, such as tree width (+0.70), leaf area (+0.70), and trunk thickness (+0.50). However, it has a strong negative correlation with olives per branch (-0.70), indicating a trade-off between fruit size and number, where higher yield is associated with smaller fruits.

Conclusions

This study examined six olive tree varieties (Azeradj, Frontoio, Neb Djemel, Limli, Sigoise, and Chemlal) under the semi-arid climatic conditions of Bordj Bou Arréridj. The results revealed significant phenotypic and morphological variability among the studied varieties, particularly in tree width, carpellary (branch reproductive structure) thickness, and leaf characteristics. Similar variability in olive cultivars under contrasting environments has been widely reported in Mediterranean studies (Barranco and Rallo, 2000; IOC, 2011). While traits such as tree height, trunk thickness, and number of carpels showed relatively limited variation, the observed differences in tree width and carpellary thickness especially in Neb Djemel indicate a diverse growth behavior among genotypes, likely reflecting genetic differentiation and adaptation responses (Rugini and Lavee, 2014).

In terms of reproductive performance, Frontoio and Chemlal exhibited the highest

number of flowers per branch and the most favorable fruit set rates. However, fruit set remained generally low across all varieties, which may be attributed to environmental constraints such as water stress, high evapotranspiration, and irregular rainfall typical of semi-arid regions (Fernández, 2014; Lavee, 2010). Fruit size also varied significantly, with Azeradj and Sigoise producing larger fruits, while Chemlal showed smaller fruit size, suggesting that both genetic factors and environmental limitations influence fruit development and final yield (IOC, 2011).

Overall, Frontoio and Chemlal appear to be the most promising cultivars for cultivation in this region, due to their relatively higher flowering intensity, better fruit setting potential, and favorable vegetative characteristics such as larger leaf area, which can enhance photosynthetic capacity. Nevertheless, the study emphasizes that water stress remains a major limiting factor affecting productivity. Improving irrigation management and soil moisture conservation practices is therefore essential to optimize olive tree performance in semi-arid environments (Fernández and Moreno, 2015; Barranco *et al.*, 2017). Further research focusing on irrigation scheduling and soil management strategies is recommended to enhance yield stability and adaptability of these cultivars.

Conflict of Interest

The authors have no conflicts of interest to declare.

Author's contribution

Conceptualization, supervision and methodology by BF, collected, analyzed data collection and laboratory analyses by KC and DM. All authors reviewed and checked the manuscript, and authors approved the final version

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