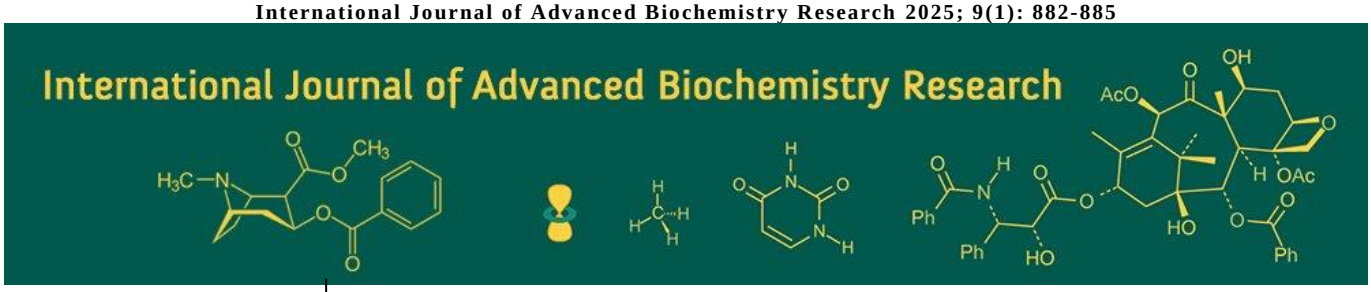

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Correlation between morphological parameters, yield attributes and corm rot incidence and severity in saffron (*Crocus sativus* L.): A two-year study (2022-2024)

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Abstract
The present study analyzed the correlation between morphological parameters, yield attributes, and the incidence and severity of corm rot in saffron (*Crocus sativus* L.) during the 2022-23 and 2023-24 growing seasons. Results revealed significant relationships among these variables. Morphological traits, including the number of corms sprouted, number of flowers per corm, number of leaves, leaf length, stigma length, and yield, exhibited strong negative correlations with the severity of corm rot, with correlation coefficients (r) ranging from -0.81 to -0.94 in 2022-23 and -0.56 to -0.94 in 2023-24. A significantly positive correlation was observed between the incidence and severity of corm rot (r = 0.97 and r = 0.96, respectively). The incidence of corm rot showed negative correlations with key morphological parameters, including stigma length (r = - 0.97, -0.93), number of leaves (r = -0.96, -0.86), and number of corms sprouted (r = -0.93, -0.95). Yield, number of flowers per corm, and leaf length also exhibited negative correlations with incidence (r ranging from -0.89 to -0.92). Conversely, positive correlations were observed between yield and morphological parameters such as number of corms sprouted, number of flowers per corm, number of leaves, leaf length, and stigma length (r values ranging from 0.85 to 0.98).

Keywords: Correlation, yield, morphological parameters, corm rot, microbial consortia

1. Introduction
Saffron (*Crocus sativus* L.), often referred to as "red gold," is one of the most valuable and economically significant spices in the world, renowned for its unique aroma, flavor, and medicinal properties. It is derived from the dried stigmas of the saffron flower and has been used for centuries in culinary, pharmaceutical, and cosmetic industries (Gresta *et al.*, 2008) [3, 4]. The global demand for saffron continues to rise due to its extensive applications in traditional and modern medicine, including its antioxidant, anticancer, and antidepressant properties (Moghaddasi, 2010) [10]. However, saffron production faces significant challenges, particularly from diseases such as corm rot, which is caused by fungal pathogens like *Fusarium* spp. and *Penicillium* spp. (Palmero *et al.*, 2012) [12]. Corm rot leads to substantial yield losses, affecting both the quantity and quality of saffron, thereby posing a threat to the livelihoods of farmers and the global saffron trade (Wani *et al.*, 2021) [14].
India is one of the major producers of saffron, with the Kashmir region contributing significantly to its cultivation. However, the productivity of saffron in India has declined over the years due to various biotic and abiotic stresses, with corm rot being a primary concern (Husaini *et al.*, 2010) [5]. To combat this pathogen, conventional methods such as the application of chemical fungicides have been widely employed. While these chemicals have shown efficacy in controlling fungal pathogens, their prolonged use has raised concerns due to their detrimental effects on the environment, human health, and the development of resistant pathogen strains (Damalas and Eleftherohorinos, 2011) [2]. The accumulation of chemical residues in soil and water, along with the disruption of beneficial microbial communities, has necessitated the exploration of sustainable alternatives for disease management.

In recent years, biological control agents (BCAs) have emerged as a promising and eco-friendly alternative to chemical fungicides. These beneficial microorganisms, including bacteria, fungi, and actinomycetes, suppress plant pathogens through various mechanisms such as competition, antibiosis, and induction of systemic resistance (Compant *et al*., 2005) [1]. Traditionally, single microbial strains were applied for disease control, but recent trends have shifted toward the use of microbial consortia—a combination of multiple beneficial microbes. Consortia offer enhanced disease suppression due to synergistic interactions among the microbes, leading to improved plant health and growth (Xu *et al*., 2011) [15]. Moreover, the application of microbial consortia has been shown to not only suppress pathogens but also improve morphological parameters such as root length, shoot height, and biomass, thereby enhancing overall crop productivity (Mishra *et al*., 2015) [9].

The use of microbial consortia in saffron cultivation holds immense potential for sustainable agriculture. By leveraging the synergistic effects of multiple microbes, it is possible to achieve effective disease management while promoting plant growth and reducing reliance on chemical inputs. This study aims to explore the efficacy of microbial consortia in controlling corm rot and improving the growth parameters of saffron, thereby contributing to the development of sustainable strategies for saffron production. The findings of this research could have significant implications for saffron cultivation in India and worldwide, offering a viable solution to the challenges posed by corm rot and chemical fungicides.

2. Materials and Methods

2.1 Field Trial Location and Experimental Design

A field trial was conducted during the 2022-23 and 2023-24 growing seasons in the saffron cultivation area of Kishtwar, Jammu, located in the northern region of India. Kishtwar is known for its ideal saffron-growing conditions, characterized by a temperate climate and well-drained, slightly alkaline soil. The trial was set up in a randomized block design (RBD), with three replicates per treatment. Each plot was approximately 4 m² in size, and saffron corms were planted at a spacing of 10 cm within rows and 15 cm between rows. The experimental treatments consisted of various biocontrol agents and a control group that received no treatment. These treatments were applied to assess their effectiveness in managing corm rot caused by soil-borne pathogens, primarily *Fusarium* spp., *Rhizoctonia* spp., and *Pythium* spp.

2.2 Data Collection

During the growing seasons, various parameters related to the incidence and severity of corm rot, as well as morphological characteristics of the saffron plants, were monitored and recorded. The disease incidence was assessed by counting the number of infected corms relative to the total number of corms planted, and severity was rated based on visual symptoms of corm rot according to a standard disease severity scale.

Morphological parameters were also recorded, including the number of corms sprouted, number of flowers per corm, number of leaves, leaf length, stigma length, and final yield (in grams per plot). These measurements were recorded at the time of flowering and at harvest to capture the effects of the treatments on plant development.

2.3 Statistical analysis

Data were analyzed using standard statistical methods. Descriptive statistics and correlation coefficients were calculated using RStudio (R version 4.0.2). The summary function was used to obtain descriptive statistics, while Pearson's correlation coefficients were computed using the cor() function.

3. Results

3.1 Correlation of morphological parameters with yield Attributes, incidence, and severity of corm rot of saffron (2022-23)

Correlation analysis was conducted to evaluate the relationship between morphological parameters, yield attributes, and the incidence and severity of corm rot in saffron during the 2022- 23 growing season (Fig. 3.1). The results revealed significant associations among these variables. Morphological parameters, including the number of corms sprouted, number of flowers per corm, number of leaves, length of leaves, stigma length, and yield, exhibited a significantly negative correlation with the severity of corm rot. The correlation coefficients (r) for these parameters were -0.92, -0.81, -0.93, -0.81, -0.88, and -0.94, respectively. In contrast, the incidence of corm rot showed a significantly positive correlation with severity (r = 0.97).

Similarly, the incidence of corm rot was negatively correlated with key morphological parameters. Stigma length, number of leaves, and number of corms sprouted demonstrated strong negative correlations with incidence, with correlation coefficients of -0.97, -0.96, and -0.93, respectively. Yield, number of flowers per corm, and length of leaves also showed negative correlations with incidence, with r values of -0.92, -0.90, and -0.89, respectively. Furthermore, a significantly positive correlation was observed between severity and incidence (r = 0.97).

Additionally, morphological parameters such as the number of corms sprouted, number of flowers per corm, number of leaves, length of leaves, and stigma length were positively correlated with yield. The correlation coefficients for these parameters were 0.85, 0.94, 0.95, 0.96, and 0.92, respectively, indicating that improvements in these growth attributes contribute to higher saffron yields.

3.2 Correlation of morphological parameters with yield attributes, incidence, and severity of corm rot of saffron (2023-24)

The correlation analysis for the 2023-24 growing season further confirmed the relationships observed in the previous year (Fig. 3.2). Morphological parameters, including the number of corms sprouted, number of flowers per corm, number of leaves, length of leaves, stigma length, and yield, exhibited significantly negative correlations with the severity of corm rot. The correlation coefficients (r) for these parameters were -0.94, -0.88, -0.81, -0.56, -0.92, and -0.88, respectively. The incidence of corm rot again showed a significantly positive correlation with severity (r = 0.96).

The incidence of corm rot was also negatively correlated with key morphological parameters. The number of corms sprouted, stigma length, and number of flowers per corm demonstrated strong negative correlations with incidence, with r values of -0.95, -0.93, and -0.92, respectively. Yield, number of leaves, and length of leaves also showed negative correlations with incidence, with r values of -0.89, -0.86, and -0.66, respectively. A significantly positive correlation

was again observed between severity and incidence (r = 0.96).

Moreover, morphological parameters such as the number of corms sprouted, number of flowers per corm, number of leaves, length of leaves, and stigma length were positively correlated with yield. The correlation coefficients for these parameters were 0.89, 0.98, 0.95, 0.75, and 0.90, respectively, reinforcing the importance of these growth attributes in enhancing saffron productivity.

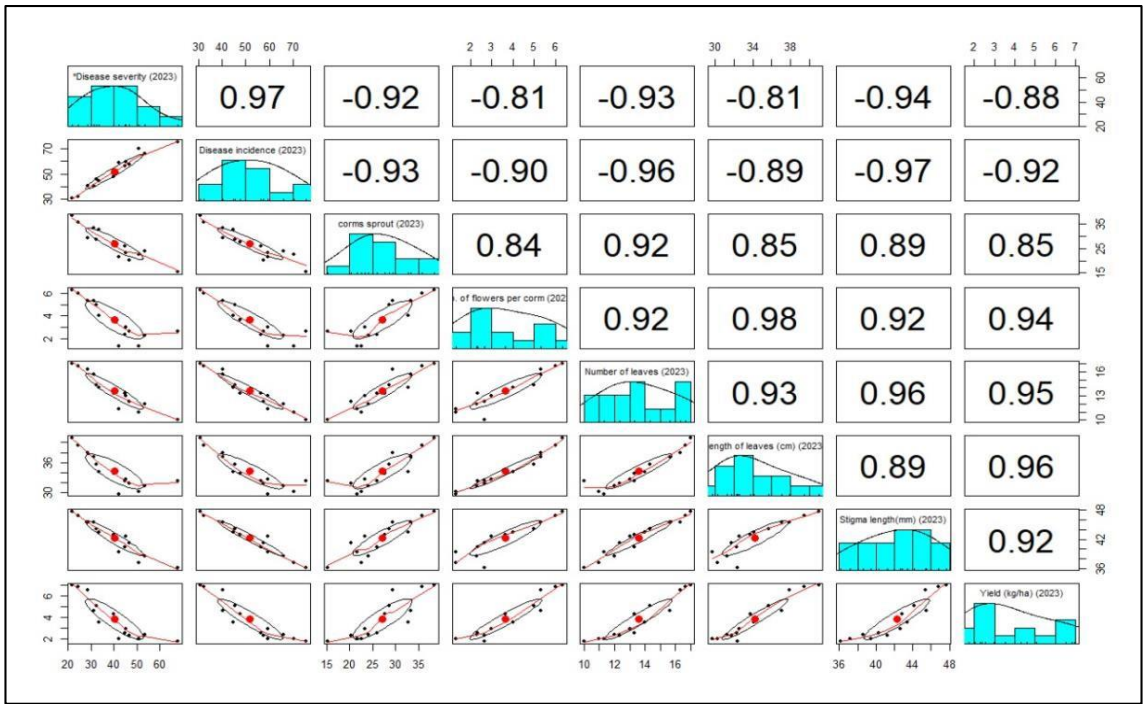

Fig 1: Correlation matrix of growth parameter with incidence, severity and yield (2022-23)

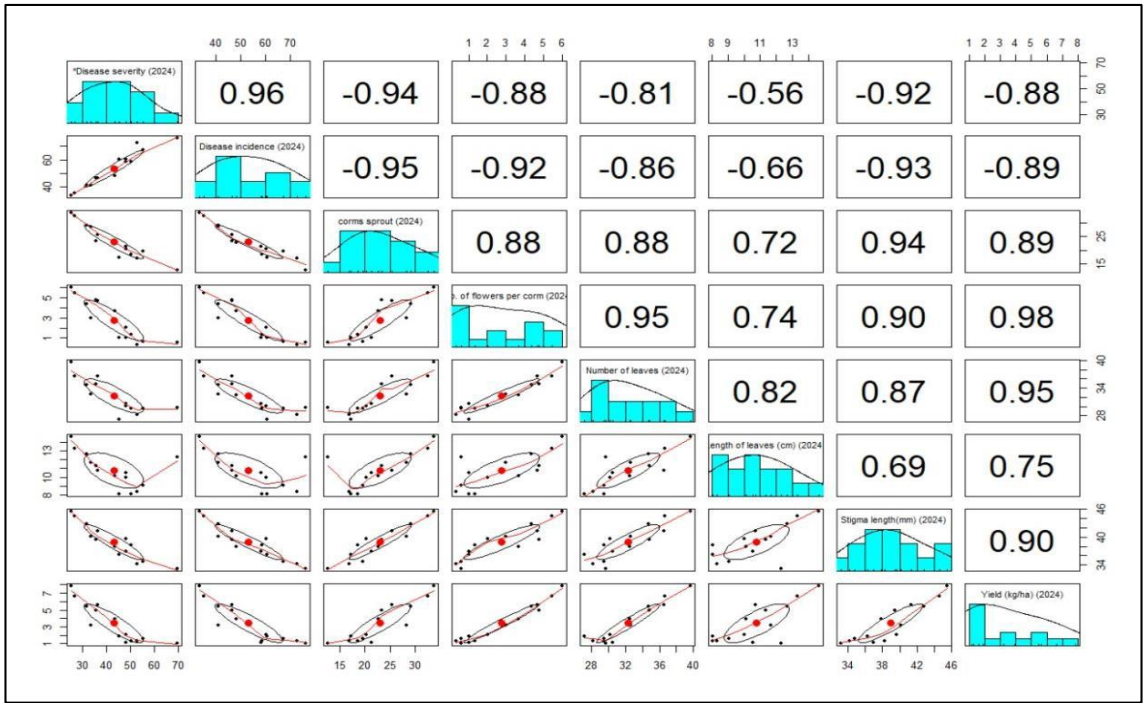

Fig 2: Correlation matrix of growth parameter with incidence, severity and yield (2023-24)

4. Discussion

The correlation analysis conducted over the 2022-23 and 2023-24 growing seasons provides valuable insights into the relationships between morphological parameters, yield attributes, and the incidence and severity of corm rot in saffron. The results highlight consistent patterns across both years, underscoring the significant impact of corm rot on saffron growth and productivity. These findings align with previous studies that have explored the effects of fungal diseases on saffron and other crops.

The strong negative correlations observed between morphological parameters (e.g., number of corms sprouted, number of flowers per corm, number of leaves, length of leaves, stigma length, and yield) and the severity of corm rot suggest that corm rot adversely affects saffron growth and development. For instance, the high negative correlation

coefficients (ranging from -0.81 to -0.94 in 2022-23 and -0.56 to -0.94 in 2023-24) indicate that as corm rot severity increases, there is a significant reduction in key growth attributes. Similar findings were reported by Kumar *et al*. (2020) [7], who found that corm rot caused by *Fusarium oxysporum* significantly reduced the number of sprouts and flowers in saffron, leading to lower yields. Additionally, Husaini *et al*. (2010) [5] observed that fungal pathogens impair nutrient uptake and physiological processes, resulting in stunted growth and reduced flower production in saffron.

Similarly, the incidence of corm rot showed strong negative correlations with morphological parameters such as stigma length, number of leaves, and number of corms sprouted. The correlation coefficients for these relationships were consistently high (ranging from -0.93 to -0.97 in 2022-23 and -0.92 to -0.95 in 2023-24), indicating that higher disease incidence is associated with poorer plant growth. This is consistent with the findings of Mir *et al*. (2015) [8], who reported that saffron plants infected with corm rot exhibited fewer leaves and shorter stigma lengths, which directly impacted yield and quality. The negative correlation between stigma length and corm rot incidence is particularly noteworthy, as stigma length is a key determinant of saffron quality and market value (Gresta *et al*., 2008) [3, 4].

The significantly positive correlation between corm rot severity and incidence (r = 0.97 in 2022-23 and r = 0.96 in 2023-24) indicates that as the disease becomes more widespread, its severity also increases. This relationship underscores the importance of early disease detection and management to prevent the spread and escalation of corm rot. Sharma *et al*. (2019) [13] also reported a similar positive correlation between disease incidence and severity in saffron, emphasizing the need for integrated disease management strategies, including the use of disease-free planting material and fungicide application.

The positive correlations between morphological parameters (e.g., number of corms sprouted, number of flowers per corm, number of leaves, length of leaves, and stigma length) and yield highlight the importance of these growth attributes in enhancing saffron productivity. The high correlation coefficients (ranging from 0.85 to 0.96 in 2022-23 and 0.75 to 0.98 in 2023-24) suggest that improvements in these parameters directly contribute to higher yields. This finding is supported by Koul and Farooq (2002) [6], who demonstrated that healthy corm development and robust leaf growth are critical for maximizing saffron yield. Similarly, Nehvi *et al*. (2007) [11] found that increasing the number of flowers per corm and stigma length significantly improved saffron productivity. The consistency of the results across the two growing seasons (2022-23 and 2023-24) strengthens the reliability of the findings. The repeated observation of strong negative correlations between morphological parameters and corm rot severity/incidence, as well as the positive correlations between morphological parameters and yield, suggests that these relationships are robust and not merely coincidental. This consistency also highlights the persistent threat posed by corm rot to saffron cultivation and the need for long-term strategies to manage this disease.

5. Conclusion

The correlation analysis over the 2022-23 and 2023-24 growing seasons revealed consistent relationships between morphological parameters, yield attributes, and corm rot in saffron. Key traits such as the number of corms sprouted, flowers per corm, leaves, leaf length, and stigma length showed strong negative correlations with corm rot severity and incidence, while positively correlating with yield. These findings highlight the importance of robust plant growth in reducing disease susceptibility and enhancing productivity. Optimizing these morphological traits through improved cultivation practices or breeding could effectively mitigate corm rot and boost saffron yields.

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