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Multidimensional Assessment of Hybrid Rose Cultivars: From Ornamental Features to Bioactive Compounds

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Abstract

Roses are used in Landscaping, pharmaceutical industry and cosmetic manufacturing. Hybrid rose fall under the Rosa hybrida category, and they're really significant both economically and genetically. These beautiful cut flowers come from the crossbreeding of Hybrid Perpetual and Tea rose. Roses tend to react differently in new environments. So, it's important to look into which varieties perform best for the specific area being studied if we want to commercialize them. So, in this study, we looked at eight different Hybrid rose cultivars, including Eye Paint, Fragrant Plum, Midas Touch, Elina, Ana Marie Trechslin, Morstylo, Bora Bora, and Broceliande, to see how they perform in the Potwar region's climate. We assessed various traits, including growth, flowering, and even some pharmaceutical characteristics, to find the best variety for this area. Our findings showed that Elina and Bora Bora are standout performers, showing good plant height, plenty of branches, fewer prickles, lots of flowers, longer vase life, and higher levels of total phenolics, ascorbic acid, and total flavanols. On the flip side, the cultivars Eye Paint and Morstylo didn't do as well.

1. Introduction

Flowers have a wonderful way of helping us express ourselves. They symbolize love, celebrate important moments, and convey a variety of feelings (Usman *et al.*, 2014). Rose (*Rosa hybrida*) is a group that comes from the Rosaceae family (Nybom *et al.*, 2004) are truly remarkable, as they also carry significant economic value due to their delightful fragrance, stunning flowers, and a variety of medicinal and aesthetic applications. Often referred to as the 'Queen of flowers' (Marriott, 2003). The genus Rosa, part of the Rosaceae family, includes around 200 to 350 recognized species and an impressive 18,000 to 30,000 cultivars (Takahashi, N. 2024).

Rosa hybrida is categorized into five primary groups: Hybrid Tea Rose (HT Rose), Floribunda, Polyantha, Miniature, and Climber. Among these, hybrid tea roses (*Rosa hybrida*) are particularly significant as cut flowers, appreciated for their economic value and genetic variety. These HT roses result from the crossbreeding of Hybrid Perpetual and Tea rose (Soujanya *et al.*, 2018). Roses possess a fundamental set of chromosomes (2n=7) and can exhibit various polyploid variations (2n=7x8) as a result of hybridization and polyploidy (Zhang *et al.*, 2013).

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Roses are incredibly important in the perfume industry, as they are key ingredients for producing attar, perfumes, rose water, and essential rose oil (Lavid *et al.*, 2002). The delightful scent of the flower comes from a blend of different low molecular mass and volatile compounds (Guterman *et al.*, 2002). The France is popular for producing the rose syrup, which is most of time made from rose petals extract. In cosmetic industry rose hip oil also used which is prepared by rose hips. Rose hips (fruit of rose flower) are rich in pectin, tannins, vitamins, sugars, phenolic compounds, sugars, fruit acids volatile oils bioflavonoids, carotenoids, organic acids, tocopherol, amino acids, and minerals (Kazaz, Baydar, & Erbas, 2009; Bakhsh *et al.*, 2020).

In Pakistan, approximately 9,000 acres are devoted to cultivating beautiful flowers such as roses, gladiolus, tuberoses, and jasmine, resulting in an impressive yield of about 10 to 12 thousand tons (Riaz *et al.*, 2007). Pakistan has the potential to grow flowers throughout the year, which could help satisfy the needs of international markets, especially in Gulf countries like the United Arab Emirates (UAE) and the Kingdom of Saudi Arabia (KSA), along with Russia and Europe (Aftab, Shabbier, & Mehmood, 2007). Regions such as Pattoki, Chakwal, Hyderabad, and Islamabad are particularly renowned for their cut rose production. This transition towards cut flower farming may inspire farmers to shift from conventional agricultural practices to more innovative methods, focusing on high-value floriculture crops (Ahmad *et al.*, 2010).

It's important to recognize that cut roses often have a relatively short vase life. One significant factor contributing to this is the blockage of xylem vessels, which restricts the water supply to the flowers (Rezvanypour & Osfoori, 2011). This reduction in lifespan can be affected by several elements, including the presence of bacteria and the physiological response of the stems or cuttings (Ichimura, Taguchi, & Norikoshi, 2006). A well-known way to extend the vase life of cut flowers is by using silver nitrate ($AgNO_3$). This not only helps to preserve the flowers but also acts as an inhibitor of ethylene binding. Research indicates that treating roses with $AgNO_3$ can significantly enhance their vase life (Elgimabi, 2011). Furthermore, antimicrobial compounds may contribute to the prolonged longevity of flowers (Bleeksma & Doorn, 2003). Adding citric acid can enhance the lifespan of cut roses by lowering the pH of the vase solution and managing the growth of microbes that may be present (Nowak, Rudnicki, & Duncan, 1990). Furthermore, aluminum sulfate has been noted to extend vase life and enhance water relations and postharvest quality due to its antimicrobial properties (Edrisi, 2003). However, it's essential to keep in mind that aluminum sulfate is not particularly effective in absorbing solutions or promoting water flow (Knee, 2000). Other antimicrobial alternatives, such as $CuSO_4$ or 8-HQC, have demonstrated better efficiency as compared to aluminum sulfate (Tiwari & Singh, 2002).

2. Materials and Methods

2.1. Cultivars and location

The research was conducted at the University Research Farm in Koont (Dist. Chakwal), which is part of Pir Mehr Ali Shah Arid Agriculture University in Rawalpindi (PMAS-AAUR), Pakistan. This study took place in the Potwar plateau, situated between Latitude 32˚ 10' to 34˚ 9' N and Longitude 71˚ 10' to 73˚ 55' E, within the Rawalpindi division of the Punjab province (i.e. semi-arid climate). The climate in this area changes monthly. For this research, various Hybrid Rose cultivars were utilized, including Eye Paint (V1), Fragrant Plum (V2), Midas Touch (V3), Elina (V4), Ana Marie Trechslin (V5), Morstylo (V6), Bora Bora (V7), and Broceliande (V8), to assess different morphological, economic, and pharmaceutical traits (Table 1 and Figure 1).

2.2 Data collection for Morphological traits

We gathered data on different traits, such as plant height, which we measured from the bottom to the top with a measuring tape. For assessing stem girth, we carefully used a Vernier caliper at the base of the plant. We manually counted the branches, particularly focusing on those that were one year old. Additionally, we counted the number of prickles within a 10 cm^2 area on the branch, which we did after measuring about 3-4 buds from the base.

2.3 Data collection for economical values

The economic value of flowers was assessed based on the quantity of flowers and their weight for scent extraction. This involved counting the number of flowers per plant by hand, measuring the fresh and dry weight of the flowers using a digital weighing balance, determining the diameter of flower buds with a digital Vernier caliper, and evaluating the vase life of the flowers at room temperature. For the vase life assessment, various treatments of silver nitrate ($AgNO_3$) at concentrations of T1(10ppm), T2(20ppm), and T3(30ppm) were used, with distilled water serving as the control.

2.4 Data collection for pharmaceutical traits

We carefully measured three key pharmaceutical traits: phenol content, ascorbic acid, and flavanol content.

To determine the total phenol contents, we followed the protocol from Baba & Malik (2015). We took 200µl of rose petals extract and mixed it with 2.8 ml of distilled water, then added 0.5 ml of Folin-Ciocalteu reagent (a mixture of phosphomolybdic and phosphotungstic acids) and mixed it for 3 minutes. A 20% sodium carbonate solution was prepared, now we added 2 ml of it to the sample, allowing it to place in the dark for about an hour. We then noted the absorbance at 650 nm. The Total Phenolic Content (TPC) was calculated using the formula;

$$\text{TPC}\left({}^{\text{mg of GAE}}/_{\text{100 ml}}\right)=\frac{\text{Sample absorbance}+0.058}{0.102}$$

For ascorbic acid, we adhered to the method outlined by Nawaz *et al.* (2019). We ground 5g of fresh flower petals with 5 ml of 1% HCl and centrifuged the mixture at 10,000 rpm for 10 minutes. The supernatant (0.3 ml) was combined with 2.7 ml of distilled water, and we measured the absorbance at 243 nm using a spectrophotometer. All samples were collected in triplicate. The Ascorbic Acid content (AA) was calculated using the formula;

$$\text{AA}\left({}^{\text{mg}}/_{\text{100 ml}}\right)=\frac{\text{Sample absorbance}\times 10}{0.293}$$

To determine total flavanols, we used Neu's reagent solution following the method of Miliauskas *et al.* (2004). The flower petals were dried in the shade at room temperature, and the air-dried samples were powdered. We measured the absorbance of the extract at 410 nm on the spectrophotometer, expressing flavanols as mg rutin equivalent (mg RE g^{-1} DW). Again, all samples were collected in triplicate. The Total Flavanol Content (TFC) was calculated using the formula;

$$\text{TFC}\left({}^{\text{mg of quercetin}}/_{\text{100 g of petals}}\right)=\frac{\text{Sample absorbance}+0.01}{0.024}$$

For statistical analysis, the experiment was conducted using a Randomized Complete Block Design (RCBD). The collected data was analyzed statistically with the help of software Statistics 8.1, and means were separated through analysis of variance (ANOVA), as referenced from Steel, Torrie, & Bostan (1997).

Figure 1. Utilized eight different cultivars of hybrid roses: a) Ana Marie Trechslin, b) Bora Bora, c) Eye Paint, d) Fragrant Plum, e) Morstylo, f) Elina, g) Midas Touch, and h) Broceliande.

Table 1. Characteristics of selected Rose Cultivars

Cultivars	Parentage and year	Characteristics
Ana Marie Trechslin	Sutter"s Gold× (Demain x Peace) 1968	This is a modern, large-flowered hybrid tea rose that boasts a beautiful, deep orange-pink color and is known for its ability to flower repeatedly.
Bora Bora	Rosen-Tantau/Tantau 1998	This is a hybrid tea rose with double flowers and a soft, fruity scent. It features high-centered blooms and will flower again, maintaining that pleasant fruity aroma.
Eye Paint	MACyeleve × Picasso 1969	This is a modern cluster-flowered Floribunda rose with a beautiful red blend and a white center. It blooms repeatedly and has a gentle fragrance.
Fragrant Plum	Shocking Blue× [Blue Nile × (Ivory Tower x Angel face)] 1990	This lovely Grandiflora flower in a beautiful mauve shade is modern and large, blooming multiple times and filling the air with a delightful fruity fragrance.
Morstylo	Local selection	The Modern Floribunda features a stunning solitary bloom with a beautiful blend of red and creamy white, and it continues to produce flowers throughout the season.
Elina	Nana Mouskouri × Lolita 1984	This modern flower is a large hybrid tea variety, featuring a lovely light-yellow color that resembles lemon white. It blooms repeatedly and has a subtle fragrance that adds to its charm.
Midas Touch	Brandy × Freisensohne 1992	This beautiful flower is a modern, large-flowered hybrid tea variety. It boasts a deep yellow color and is known for its repeat flowering and strong fragrance, which makes it truly delightful.
Broceliande	Bred by Michel Adam (France) 2000	The Hybrid Tea rose features a large, solitary bloom adorned with beautiful red and white stripes. It offers repeat flowering and exudes a strong, delightful fragrance.

3. Results

3.1 Morphological traits

Crop plant height is affected by genetic factors and environmental conditions. Our analysis of various *Rosa hybrida* cultivars showed significant height variation ($p \leq 0.0008$) among them, as shown in Table 2. The Midas Touch cultivar was the tallest at 54.1 cm, and the 'Elina' cultivar also showed impressive height (Figure 2A). This height variation may result from cultivar differences or environmental factors. Key environmental influences include temperature, humidity, light interception, and day length. Roses grow best at temperatures between 24°C and 26°C; higher temperatures or light levels can stress the plants, prompting them to produce hydrogen peroxide as a coping mechanism. However, excessive temperature and light can negatively impact flower production and plant height, According to Khan *et al.* (2019), factors such as variety, temperature, crop management, and environmental conditions determine plant height.

The thickness of the stem is really important for how strong the plant is, how well it stores energy from photosynthesis, and even how it affects the quality of cut flowers. When we looked at the data, there weren't any significant differences between the different types of roses (Table 2). The Ana Marie Trechslin variety had the biggest stem thickness (Figure 2B). We think that might play a role in stem thickness since roses are C_3 plants, which need plenty of light to grow well. More light can boost the levels of Rubisco and generate more synthases that get stored in the stem, leading to a thicker stem overall. Ramzan *et al.* (2014)

Table 2. ANOVA results for attributes under study

Attributes		Sources	DF	SS	MS	F-Value	P-Value	Significance
1.	Plant Height	Treatment	7	430.715	61.5307	7.43	0.0008	Yes
		Error	14	115.862	8.2759			
2.	Stem Girth	Treatment	7	188.759	26.9656	1.97	0.1323	No
		Error	14	191.382	13.6701			
3.	Number of Branches/ Plant	Treatment	7	124.387	17.7696	5.98	0.0023	Yes
		Error	14	41.590	2.9707			
4.	Prickles	Treatment	7	640.596	91.5137	28.24	<0.0001	Yes
		Error	14	45.369	3.2406			
5.	Number of Flowers	Treatment	7	124.653	17.8076	9.63	0.0002	Yes
		Error	14	25.901	1.8501			
6.	Flowers Fresh Weight	Treatment	7	1061.38	151.626	14.77	<0.0001	Yes
		Error	14	143.67	10.262			
7.	Flowers Dry Weight	Treatment	7	22.0655	3.15221	6.72	0.0013	Yes
		Error	14	6.5648	0.46891			
8.	Flower Bud Diameter	Treatment	7	30.3745	4.33922	5.93	0.0024	Yes
		Error	14	10.2426	0.73161			
9.	Flower Vase Life-To	Variety	7	8.9583	1.2798	2.42	0.0759	No
		Error	14	7.4167	0.5298			
10.	T1: $AgNO_3$ 10ppm	VARIETY	7	26.6667	3.80952	10.49	0.0001	YES
		ERROR	14	5.0833	0.36310			
11.	T2: $AgNO_3$ 20ppm	VARIETY	7	65.8333	9.40476	17.17	<0.0001	Yes
		ERROR	14	7.6667	0.54762			
12.	T3: $AgNO_3$ 30ppm	VARIETY	7	109.958	15.7083	27.78	<0.0001	Yes
		ERROR	14	7.917	0.5655			
13.	Phenolic Contents	TREATMENT	7	728.939	104.134	243	<0.0001	Yes
		ERROR	16	6.852	0.428			
14.	Ascorbic Acid	TREATMENT	7	2266.58	323.798	342	<0.0001	Yes
		ERROR	16	15.14	0.946			
15.	Total Flavanols	TREATMENT	7	1384.03	197.718	934	<0.0001	Yes
		ERROR	16	3.39	0.212			

pointed out that sunlight is a major factor affecting the growth of rose plants. Similarly, Naing *et al.* (2016) highlighted that light is crucial for the stem thickness of roses.

There's a noticeable difference in how many branches each plant cultivar has ($p \leq 0.0023$) (Table 2). The Elina cultivar really stands out, boasting the highest branch count compared to the others (Figure 2C). This pattern is pretty clear across all cultivars when it comes to branch numbers. Plus, it seems like plants tend to grow more branches when they get more light. Khan *et al.* (2019) found that branch counts can be affected by higher temperatures. On top of that, Shahrin *et al.* (2015) mentioned that the variations in branch counts among cultivars might be linked to their genetic backgrounds. Tarannum & Naik (2014) also pointed out that branch numbers are connected to the thickness of the stem.

The peri clinical chimera is characterized by an epidermis that has undergone a mutation to become thornless, while internally it contains genetically thorny components. Consequently, it fundamentally comprises thorns. The results revealed a notable difference in the number of prickles per 10 cm² area of branch across cultivars ($p \leq 0.0000$) (Table 2). Among the cultivars, Eye Paint had the highest number of prickles at 22.48 per 10 cm² area, significantly outpacing the others, with Morstylo and Ana Marie Trechslin following behind (Figure 2D). The variation in prickles per 10 cm² could be influenced by either genetic traits or environmental factors. Factors like temperature shock, freezing, soil conditions, and genetics play a role in the number of prickles (Gitonga *et al.*, 2014).

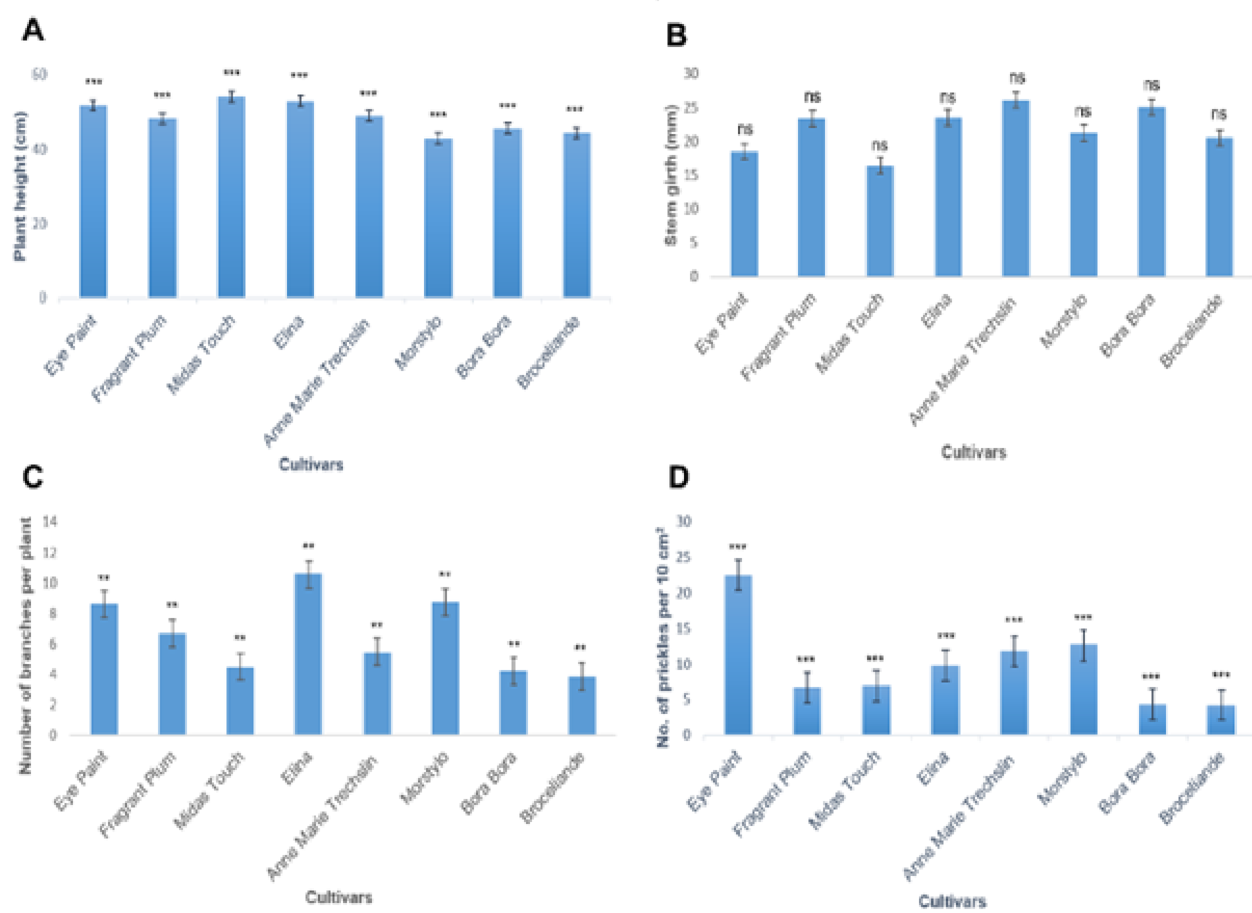

Figure 2. Morphological attributes of cultivars: a) the average plant height measured in (cm), b) the average stem girth (mm), c) the average number of branches per plant, d) the average number of prickles(cm^2).

Economically values traits

Rose plants are cultivated for their economic value, which includes factors like the number, weight, and size of the flowers. There was a notable variation in the number of flowers across different cultivars ($p \leq 0.0002$) (Table 2). The Eye Paint cultivar stood out with the highest flower count at 9.2, making it significantly more dominant than the others (Figure 3A). This variation in flower quantity is largely influenced by the number of branches and the overall plant structure, but genetics play a crucial role as well. Abd-Elrahim and Osman (2017) noted that an increase in morphological traits, such as the number of branches and leaves, can boost photosynthesis, leading to a higher flower production. Additionally, they found that the number of flowers per plant tends to decrease as temperatures rise in July (Ramzan *et al.* 2014).

The fresh flower weight among all cultivars showed considerable variation ($p \leq 0.0000$) (Table 2), with the Elina cultivar having the highest fresh flower weight at 30.1 g, which stands out significantly compared to the other cultivars. On the other hand, the Eye Paint cultivar exhibited the lowest fresh weight at 6.04 g (Figure 3B). This difference may be influenced by factors such as the plant's water uptake and the accumulation of water in vacuoles, or it could be related to environmental conditions. Bieleski (1993) noted that the fresh weight ratio is indicative of petal expansion in flowers due to water uptake. Additionally, Dolatkhahi *et al.* (2013) pointed out that light also plays a role in affecting both the fresh and dry weight of flowers.

The dry weight of flowers showed significant variation between different cultivars ($p \leq 0.0013$) (Table 2). The Bora Bora cultivar exhibited the highest dry flower weight at 4.045

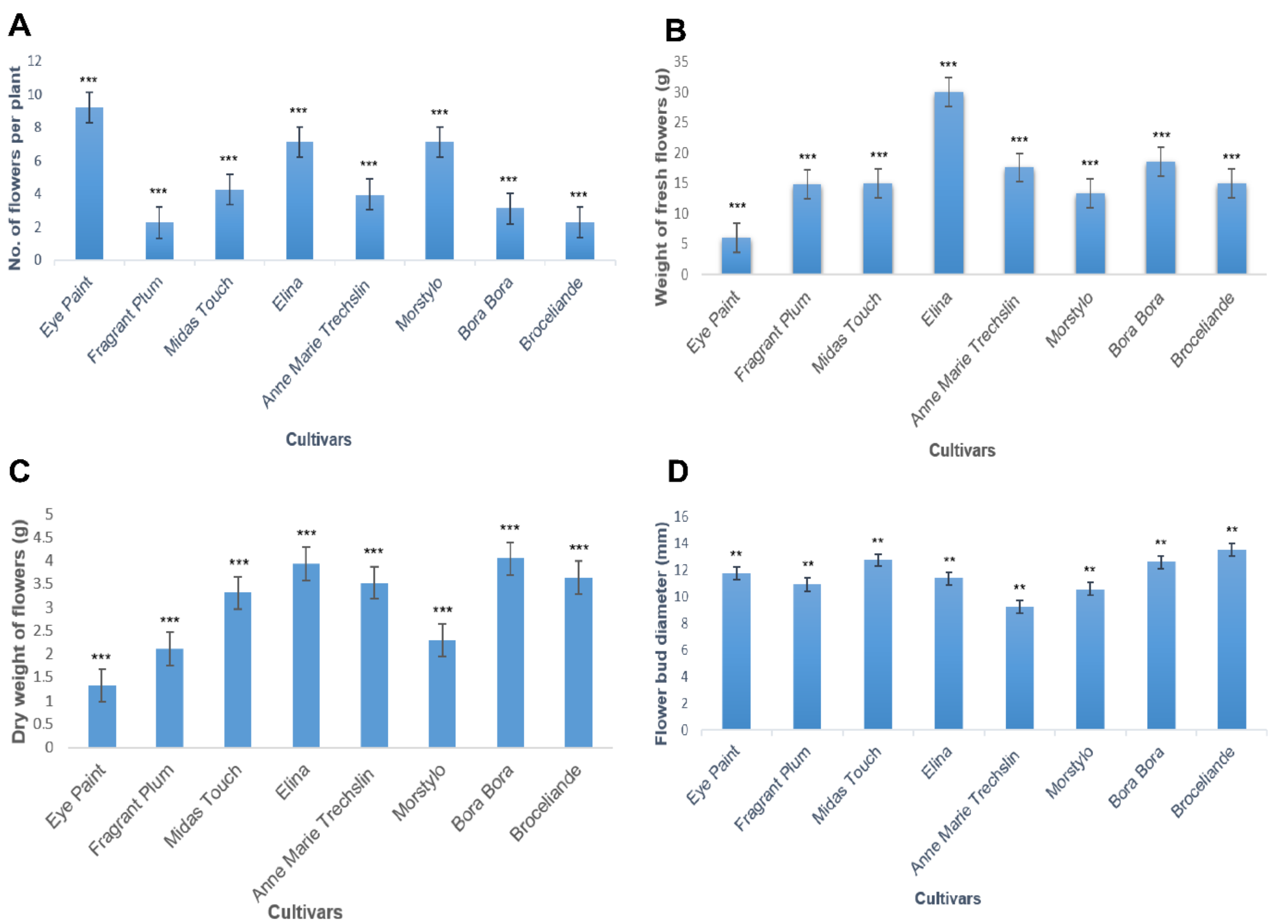

Figure 3. Presented the average values of various economic traits: a) the average number of flowers per plant, b) the average weight of fresh flowers (g), c) the average dry weight of flowers (g), d) the average diameter of flower buds (mm).

g (Figure 3C). Schmitzer *et al.* (2010) highlighted the crucial role of cell expansion and water accumulation in vacuoles for the development of rose flowers. As flowers transition from buds to partially or fully open stages, petal dry weight tends to increase, and similarly, water content rises from the bud stage to the later developmental phases.

The size of flower buds varied quite a bit among different cultivars, as shown in Table 2. The Broceliande cultivar had the biggest buds, reaching 13.5 mm, while the smallest were from the Ana Marie Trechslin at just 9.2 mm (Figure 3D). This difference in bud size can be traced back to the plant's genetics. Typically, plants that come from different hybridizations show traits from their parent plants, as noted by Abd-Elrahim & Osman (2017).

The vase life of cut roses was improved by utilizing various concentrations of Silver Nitrate ($AgNO_3$). The results indicated that different cultivars respond differently to these concentrations. The most effective concentration was found to be 30ppm of $AgNO_3$, where the Elina cultivar achieved the longest vase life of 10.67 days, followed by Ana Marie Trechslin and Midas Touch with vase lives of 9 and 7.3 days, respectively. Conversely, the Morstylo cultivar exhibited the shortest vase life of 3.33 days at the same concentration of 30ppm $AgNO_3$.

The cultivars Morstylo and Broceliande demonstrated the longest vase life at a concentration of 20ppm $AgNO_3$ in T2, compared to other treatments. For the cultivars Elina and Ana Marie Trechslin (V5), the maximum vase life recorded was 8.33 days, while the minimum vase life of 3.67 days was observed in the cultivar Fragrant Plum at the same 20ppm solution. In treatments T1 and To, no significant results were detected (Table 2). The cultivar Elina exhibited a maximum vase life of 5.67 days in a 10ppm $AgNO_3$ solution, whereas the lowest vase life in this concentration was noted in the cultivars Eye Paint and Morstylo. Interestingly, cultivars Morstylo and Eye Paint performed better in the control solution than in the 10ppm $AgNO_3$, showing values of 3 days and 2.5 days respectively (Figure 4A). This could be attributed to the internal processes of the flowers interacting with the solution. The solution seems to reduce ethylene production or deactivate microbial activity, which helps to prolong the freshness of the flowers.Similarly, Elgimabi (2011) documented comparable findings, noting that Silver Nitrate ($AgNO_3$) inhibits the action of ethylene in plant tissues. The treatment with $AgNO_3$ diminishes the ethylene output in cut flowers and provides antimicrobial benefits compared to the control. Butt (2005) also noted that silver nitrate ($AgNO_3$) significantly impacts the biosynthetic cycle in plants. The ethylene produced through the application of silver nitrate has been shown to affect the protoplast within the cells. The production of ethylene from silver nitrate appears to play a role in the differentiation and regeneration of developmental processes. The application of varying doses of silver nitrate ($AgNO_3$) yielded positive results in enhancing stem and leaf size; however, the overall length of the plantlets remained shorter due to insufficient cell enlargement despite increased cell multiplication (Khalid *et al.*, 1991; Taylor *et al.*, 1994).

3.3 Pharmaceutical traits

The pharmaceutical properties of rose plants, such as their phenolic, ascorbic acid, and Flavonols contents, plays a crucial role in the medicine industry. Beyond their beautiful rose color, these plants also house bioactive compounds including pigments and effective antioxidants (Garz'on *et al.*, 2009). The chemical analysis revealed significant variation in total phenolic contents among different cultivars (Table 2), with the maximum recorded at 24.07 mg in the Bora Bora cultivar. Conversely, the lowest total phenolic content measured at 7.74 mg GAE per100 ml was found in the Fragrant plum cultivar (Figure 4B). This variation may stem from the climatic conditions where the plants were cultivated, with mild influences from the specific cultivars used (Czyzowska *et al.*, 2015). Additionally, the levels of acidic and bound phenols in rose petals tend to rise during the early stages of flower development (Sood *et al.*, 2006).

The rich presence of vitamins, organic acids, and the delightful flavor of rose makes it a highly valued dietary supplement. The results from chemical analysis revealed that the levels of ascorbic acid varied significantly among different cultivars (Table 2), with the Elina cultivar showing the highest concentration of ascorbic acid at 50.92 mg/100 ml, followed closely by Bora Bora and Eye Paint (Figure 4C). It's important to note that the content of vitamin C is influenced by both genetic factors and environmental conditions, including climate and soil quality. Research has shown that prolonged rainy seasons during the growing period can lead to a decrease in vitamin C levels. Additionally, plants at higher altitudes benefit from greater light exposure, which can enhance the vitamin C content in

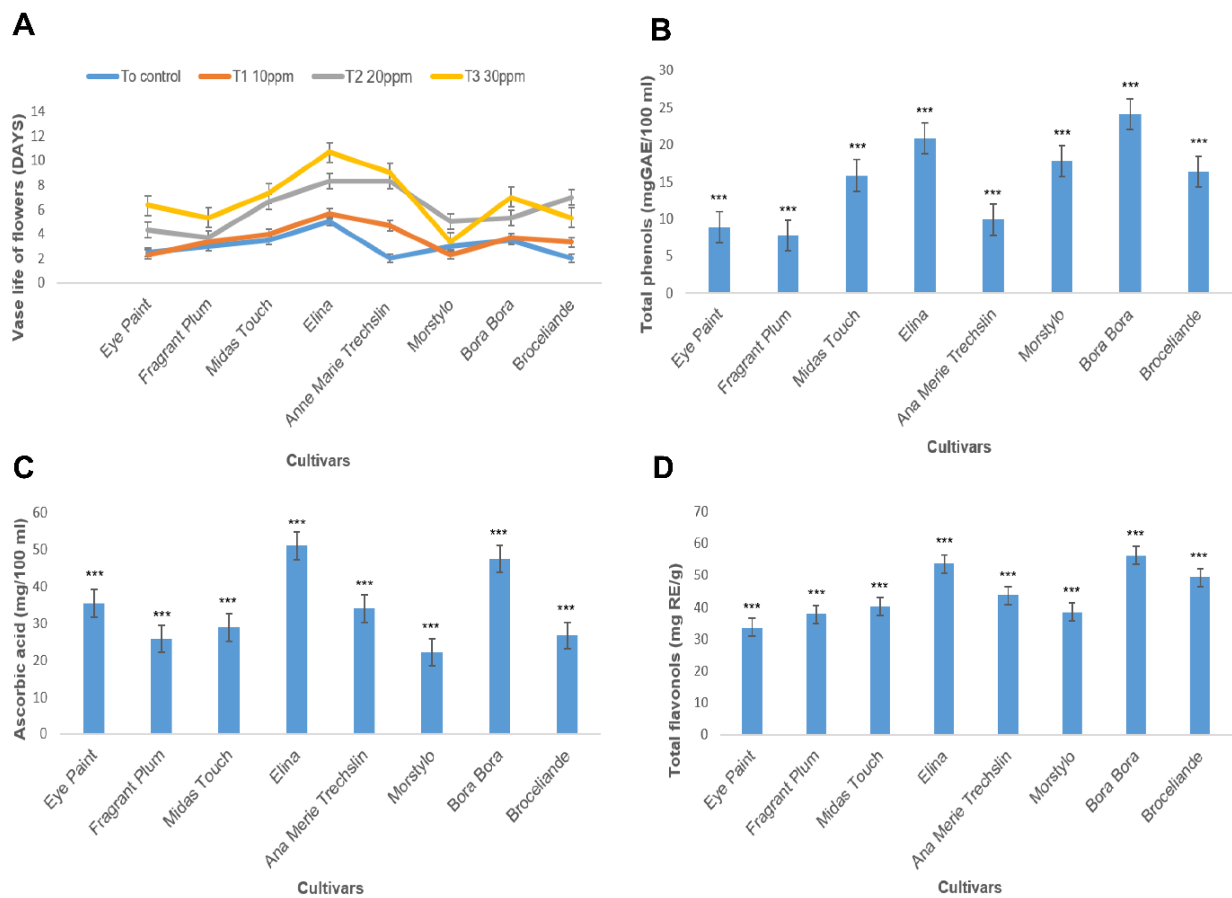

Figure 4. Illustrated the mean values of pharmaceutical traits, a) Mean values for vase life of flowers where all three treatments are presented with different colors of line, b) Mean values for total phenols (mg per 100ml), c) Mean values for ascorbic acid (mg per 100ml), d) Mean values for total Flavonol (mg per gram).

their fruits. Conversely, insufficient phosphorus or an excess of potassium in the soil can result in lower vitamin C levels.

The content of total Flavonols varied across all cultivars (Table 2), with the highest amount found in the Bora Bora cultivar (56.23 mg), followed closely by Elina and Broceliande. The lowest total Flavonols content was noted in Eye Paint (Figure 4D). According to Martínez-Lüscher *et al.* (2014), regulatory and synthetic genes that are involved in Flavonols biosynthesis are significantly activated by UV-B rays from sunlight, which leads to an increase in Flavonols contents when exposed to UV-B radiation (Matus, 2016). The total Flavonols content in flowers showed a rise during the early stages of flowering, followed by a decline as the flowers reached the half and fully open phases (Sood *et al.*, 2006). Flavonols degradation can take place in various plant organs due to different environmental and developmental factors; this is often connected to changes in vacuoles that reduce the stability of the pigments, resulting in chemical degradation or making them more susceptible to breakdown by enzymes like peroxidases and b-glucosidases that are found in the vacuoles (Oren-Shamir, 2009).

4. Conclusion

Roses are such a lovely aspect of nature, and it's fascinating how their ability to adapt can change based on their growing conditions. It's essential to explore how various cultivars can flourish in different environments. In this study, we focused on eight Hybrid rose cultivars: Eye Paint, Fragrant Plum, Midas Touch, Elina, Ana Marie Trechslin, Morstylo, Bora Bora, and Broceliande, to evaluate their growth, yield, and health benefits within the climatic context of the Potwar region. Our results revealed that the

Elina and Bora Bora cultivars truly excelled in several aspects, including plant height, branch quantity, fewer prickles, more blossoms, longer vase life, and higher concentrations of total phenolics, ascorbic acid, and total Flavonols when compared to the others in the semi-arid climate. Conversely, Eye Paint and Morstylo didn't quite meet the same level of performance.

5. Funding

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6. Acknowledgment

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7. Conflict of Interest

The authors declare no conflict of interest.

8. Authors' Contribution

Furqan Ahmed and Ishfaq Ahmad Hafiz designed the study, Furqan Ahmed and Muhammad Zeeshan Mola Bakhsh carried out the experiments, Furqan Ahmed and Shujaat Hussain analyzed the data. Ishfaq Ahmad Hafiz and Shujaat Hussain critically reviewed the article.

9. SDGs Addressed

This study aligns with the United Nations Sustainable Development Goals (SDGs) 12 and 15 by promoting sustainable production of ornamental and medicinal plants and supporting biodiversity conservation. Additionally, it contributes to SDG 3 (Good Health and Well-being) through the identification of rose cultivars rich in bioactive compounds with potential pharmaceutical and cosmetic applications.

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