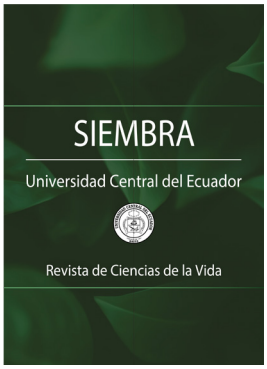
Optimization of staking in intraspecific varieties of Hypericum spp. for export

Optimización del tutoreo en variedades intraespecíficas de Hypericum spp. para exportación



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Abstract

The study aimed to analyze how the use of staking influences the production of cut flowers of three varieties of *Hypericum* spp. A randomized complete block design with split plots was used, where the main plots represented management with and without staking, and the subplots included three varieties of *Hypericum* spp. (Vulcano, Rubí, and Code V71), distributed across four blocks, with 10 plants per block as the experimental unit. Regarding the variable of stem lodging, Vulcano presented an average of 2.5 stems per plant. The number of induced axillary buds in the three varieties was not affected by staking. The estimation of Leaf Area Index [LAI] placed V71 with the best index of 0.66, with no influence of the use or absence of tutoring meshes. The straightness of stems was observed in Rubí and V71, showing a tendency for straight stem growth while Vulcano, due to its growth habit, presented various curvatures in the stem. Regarding the number of berries, Rubí exhibited up to 60 % of stems with more than 12 berries, indicating outstanding quality for commercialization. The marketable stems for Rubí and V71 were 140 and 136 stems m^{-2}, respectively, demonstrating their yield potential compared to Vulcano. In contrast, for non-marketable stems, the V71 variety exhibited a higher quantity, with an average of 49.25 stems m^{-2}. Nevertheless, staking is recommended only for the Vulcano variety due to its lower performance. These results underscore the importance of studying and applying staking specifically according to the characteristics of each Hypericum spp. variety intended for export.

***Keywords*:** export flowers, Hypericum management, cut flowers, floriculture production, berries for floriculture.

Resumen

El objetivo del estudio fue analizar cómo el uso de tutoreo influye en la obtención de flores de corte de *Hypericum* spp. Se empleó un diseño de bloques completos al azar con parcelas divididas, donde las parcelas principales representaron el manejo con y sin tutoreo, y las subparcelas incluyeron tres variedades de *Hypericum* spp. (Vulcano, Rubí y Código V71), distribuidas en cuatro bloques, con diez plantas/bloque como unidad experimental. En relación con la variable de acame de tallos, Vulca-

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no presentó una media de 2,5 tallos por planta. El número de yemas axilares inducidas en las tres variedades no se vio afectado por el tutoreo. La estimación del IAF ubicó a V71 con el mejor índice de 0,66, sin que el uso o no de mallas tutoras tuviera influencia en esta variable. La rectitud de tallos se observó en Rubí y V71, con disposición a un crecimiento de tallos rectos, mientras que Vulcano, debido a su hábito de crecimiento, presentó diversas curvaturas en los tallos. En cuanto al número de bayas, Rubí exhibió hasta el 60 % de tallos con más de 12 bayas, indicando una calidad destacada para la comercialización. Los tallos comerciables de Rubí y V71 fueron de 140,63 y 136,13 tallos m^{-2}, respectivamente, y demostraron su potencial de rendimiento en comparación con Vulcano. En contraste, en el caso de tallos no comerciales, la variedad V71 exhibe una mayor cantidad con un promedio de 49,25 tallos m^{-2}. No obstante, se recomienda aplicar el tutoreo únicamente en la variedad Vulcano debido a su rendimiento más bajo. Estos resultados demuestran la relevancia de estudiar y aplicar el tutoreo de manera específica según las características de cada variedad de *Hypericum* spp. destinada a la exportación.

Palabras clave: flor de exportación, manejo de hipérico, flor de corte, producción florícola, bayas para floricultura.

1. Introduction

The crop *Hypericum* spp. was once considered an agricultural crop with great growth potential in the country due to its floral characteristics. The wide diversity of berry colors is particularly appealing to both national and international markets (Merino Pacheco, 2004). It is important to diversify this species because various cultivars are needed to meet the growing market demand for colourful berries. This includes incorporating varieties with berries in colour such as red, black, green, and others (Kerr & Harun, 2007).

There are different growth habits within the genus *Hypericum* spp. due to its wide variety of species, which have different stem dispositions including erect, semi-erect, decumbent, and creeping types. These qualities are relevant for crop management because they influence the production of stems that meet the market's demanding standards (Slusarski et al., 2007). For crop management is important to recognize the varieties that tend to grow erect without the need of a growing support which is determined by monitoring the weight and the number of berries per stem to avoid premature overturn. This and adverse climate conditions, such as rain and strong wind currents, can disrupt the correct growth of the stems in open field (Nürk et al., 2013).

The process of flower production in the country are varied, from the ones done at open field to the ones done within greenhouses. They depend on the type of crop and the final flower production. One of the main characteristics of cut flowers is having an erect and strong stem, which is why staking is implemented for cut flowers such as carnations, lilies, and others. The importance of this input has not been emphasized on the management of *Hypericum* spp. but in certain varieties prone to lodging, each stem must be guided through a prefabricated or woven grid (Verdugo et al., 2007). The correct distribution of the stems and an adequate exposition to light create the ideal conditions for a uniform stem growth in cut flowers. Any deficiency can lead to developmental delays and a decline in product quality (Fraccinetti et al., 2008).

Thus, the use of staking mesh enhances stem development in *Hypericum* spp. by the end of the crop cycle, ensuring compliance with market standards. These standards require erect or semi-erect stems measuring 60 to 70 cm in length, with at least eight mature berries for export. Therefore, any variety or code undergoing validation for mass production must meet these requirements (Sarango, 2006).

On the other hand, the use of staking mesh increases production costs and the demand for manual labor, particularly for tasks such as properly guiding the stems. Additionally, the mesh presents challenges for workers during harvest, as inserting pruning shears through the mesh to cut stems at the basal zone is difficult and requires expertise, ultimately reducing the number of stems cut per unit of time (Verdugo et al., 2007). Given this scenario, the objective is to evaluate the effect of staking mesh on three intraspecific varieties of *Hypericum* spp. in the production of cut flowers for export.

2. Materials and Methods

The experiment was located at FLORANDES FARMS, in the parish of Puembo-Quito, Ecuador. The experimental design consisted of randomized complete block design [RCBD] with split-plot design. The big parcel was used for the management with and without staking, and three varieties of *Hypericum* spp. (Vulcano, Rubi and Code V71) in the sub parcels with four blocks and ten plants per block as experimental unit.

Seedlings were obtained in trays using a peat-based substrate, utilizing apical cuttings from mother plants. After two weeks in acclimatation phase, fertilization and phytosanitary controls were started. During the fifth week the seedlings were transplanted in the field.

The crop was planted in one-meter-wide raised beds with a staggered spacing of 20 x 20 cm, arranged in four rows per bed, totaling 28 plants per square meter. Drip fertigation was used.

At 21 days after transplanting [DAT], apical pruning was performed, leaving two pairs of leaves in plants of approximately 20cm high. From the fifth week after transplanting [WAT], the sprouts with little growth were removed, leaving seven sprouts per plant. The staking mesh was placed as well (20 x 20 cm per grid, according to the treatment) at 40 cm from the base of the plants.

Starting at 49 DAT, the photoperiod was artificially extended for 6 additional hours daily using artificial light with light-emitting diodes [LEDs] starting at 23h for 9 weeks until observing the induction of uniform flowering. Starting at 56 DAT, the lateral buds of the productive stems were removed. The harvest started at 140 DAT when the berries were completely formed and had uniform color.

Complementary activities were carried out during the development of the crop such as weeding, fertilization, and phytosanitary control. The evaluation was performed during the entire crop cycle and at the end with the harvested stems.

2.1. Evaluations in the field

- **Stem lodging:** in each plot the stems with a tendency to lodge were counted per plant. (Figure 1).

Figure 1. Stems prone to lodging in the cultivation of *Hypericum* spp.

- **Number of axillar buds (active) per stem:** every two weeks starting at 60 DAT, the axillar buds with more than 5cm were counted.
- **Leaf Area Index [LAI]:** a digital camera was used for the quantification of plant traits like leaf area (Baker et al., 1996; Campillo et al., 2008; Lati et al., 2011; Lukina et al., 1999) and leaf senescence (Adamsen et al., 1999; Ide & Oguma J., 2010). The application BreedPix 1.0 (Casadesús y Villegas, 2014) was used to measure other traits. For this, photographs of each plot were taken prior to harvest, all of them taken at 2 meters high. The area was delimited before the images were inserted into the software. Subsequently, the percentage within the green range was obtained, and the remaining area was considered as uncovered surface.

With the measurement of *green area [GA] - green fraction [GF]*, we can estimate the proportion of green pixels with respect to the total number of pixels of an image. This is a reliable estimate of plant cover (Lukina et al., 1999). The estimates are based on the average color of the entire image, in various units related to 'greenness' or in the fraction of pixels classified as green canopy in relation to the total number of pixels in the image.

2.2. Evaluations in harvested stems

- **Stem straightness:** observations were made from the top view with a straight base line and six different kinds of stem curvatures were defined (Sierra de Grado et al., 1999) (Figure 2).

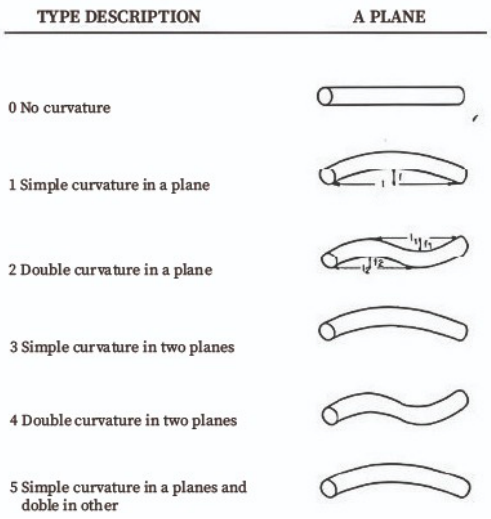

Figure 2. Types of stem curvature.

- **Number of berries per stem:** during post-harvest, the standardization of cut stems was done after counting the number of berries, separating the tender berries from the mature ones, and classified with the help of the ordinal scale based on parameters established by the International Union for the Protection of New Varieties of Plants [UPOV] in the section of *Hypericum* spp. (Table 1).

Table 1. Quality scales according to the number and size of *Hypericum* spp. berries.

Score	Berries	
	Number	**Size**
1	Very low ≤ 4 berries	Small ≤ 0.6 cm
2	Low ≤ 6 berries	Small ≤ 0.6 cm
3	Medium 6 - 8 berries	Medium 0.6 – 0.8 cm
4	High 9 – 12 berries	Big ≥ 0.8 cm
5	Very high ≥ 12 berries	Big ≥ 0.8 cm

Source: Dutfield (2011); Sarango (2006)

- **Number of marketable stems m^{-2}:** during post-harvest the number of stems obtained were counted and categorized based on quality parameters (Table 2).

Table 2. Quality scale according to the number of berries and stem length for *Hypericum* spp.

Quality	Parameters	
	Number of berries (matured)	**Stem length**
Exportable	≥ 8 berries	60 – 70 cm
National	5 – 7 berries	50 – 60 cm

- **Number of discarded stems m^{-2}:** the stems that did not reach desirable characteristics were counted and considered as waste, among them, those that are immature, small or had some damage (Table 3).

Table 3. Scale for stem classification of *Hypericum* spp., national trade.

Quality	Parameters	
	Number of berries (matured)	**Stem length**
Waste	4 berries	≤ 50 cm

- **Yield:** To calculate the yield, the data obtained was extrapolated to one hectare (10,000 m^2) considering that the useful area is 6,000 m^2 (planting beds of 1 m and pathways of 0.5 m wide), totalizing 168,000 plants ha^{-1} with an average of seven stems of production per plant, reaching a total of 1'176,000 stems ha^{-1}. The respective calculation in percentage ha^{-1} was carried out in base on the number of exportable stems and the estimated waste in the present study.

2.3. Statistical Analysis

The software Infostat (2004) was used for the statistical analysis. Initially, the assumptions of normality and homogeneity of variance were demonstrated (Balzarini et al., 2012), verifying that there were no anomalous data or lost plots. Subsequently, with the determination of the ADEVA, the influence of the independent variables on the dependent variables was evaluated, as well as morphological characteristics, and the distinct quality parameters that were the subject of this study. DMS tests adjusted to the 5% of reliability were carried out to obtain the significance ranges and the difference between treatments.

In the case of qualitative variables, a frequency distribution was performed to identify the highest percentage of occurrence for the different scales.

3. Results and Discusion

3.1. Field Evaluations

For the variables: stem lodging, number of axillary buds, and LAI, the subplot was significant, while the plot (with and without staking) was not significant.

Vulcano with and without staking presented a higher number of stems with tendency to lodging, while in the second significance range, the Rubi variety with and without staking presented the lowest value for this variable, resulting in a variety with high productive potential of straight stems (Figure 3a). For the comparison of mean values of the number of axillary buds, three significance ranges were identified. It can be inferred that independently of the use or no use of tutoring, the emergence of the number of buds is a characteristic of each variety. On the other hand, the code V71 presented high tendency of bud generation during the crop cycle (10.65 buds per stem) in comparison to the other two varieties (Rubi: 7.15 and Vulcano: 3.12 buds per stem) (Figure 3b). For the leaf area index, three significance ranges were identified placing the V71 code in the first place with an average of 0.66, Rubi in the second place with an average of 0.57, and Vulcano in the last place with an average of 0.48 (Figure 3c).

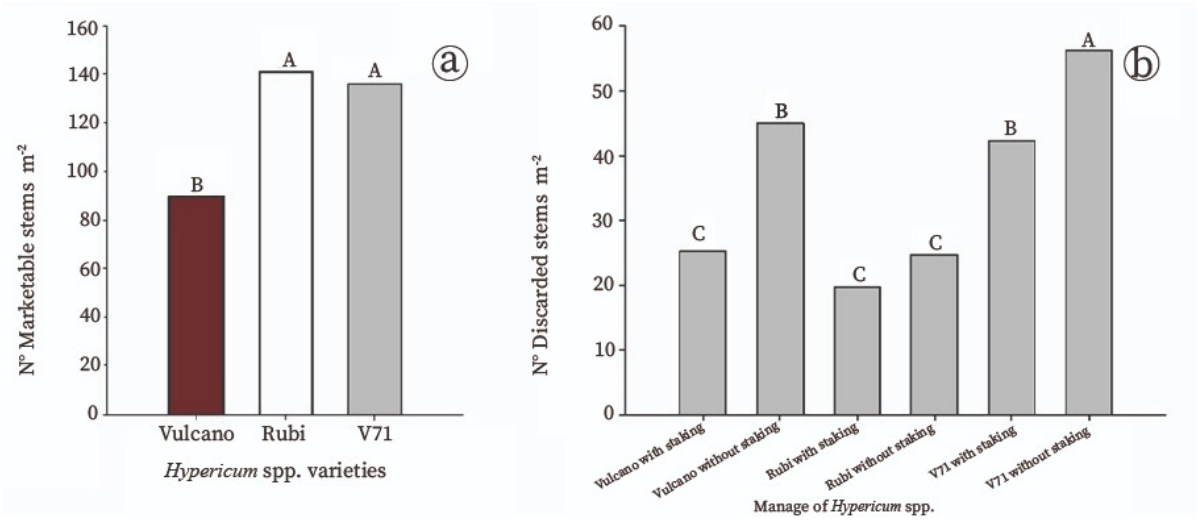

Figure 3. Stem lodging per plant (a), Number of axillary buds per stem (b) and leaf area index (c) in the cultivation of *Hypericum* spp., with and without staking.*

* Means followed by the same letter in the vertical are not significantly different at the 5% level according to the DMS test.

In this study, the intraspecific difference of the studied varieties of *Hypericum* spp. was evidenced due to their physiological and morphological characteristics. Therefore, the sprouting and uniform stem growth in *Hypericum* spp. responds to several factors such as genetics, nutrition, plantation density, among others (Salas Sanjuán et al., 2010).

Stem lodging decreases the quality of the stems and induce the growth of axillary buds in certain varieties. On that account, placing staking meshes and removing axillary buds turn out to be appropriate management techniques and favor apical dominance. *Hypericum* spp. is a plant that present weak apical dominance which allows faster growth and dense axillary buds during the crop cycle (Nagarathna et al., 2010). Thus, the removal of axillary buds is a priority activity in the management of the crop because the growth of axillary buds retains nutrients which are assimilated for the growth and maturation of the berries, directly influencing the quality of the exportable-type stem production (Jiménez Mariña, 2015).

On the other hand, apical dominance is influenced by biosynthesis and concentration of auxins and cytokines in the plant. Cytokines are plant-growth hormones involved in lateral branching (Nordström et al., 2004). The interaction between cytokines and auxins triggers a hormonal balance triggering different physiological responses (Dun et al., 2006). At low auxin levels, there are high levels of cytokines available which causes the initiation of lateral sprouting (Nagarathna et al., 2009). The synthesis and concentration of phytohormones in plants depend on the plant's genetics and it is expressed in distinct growth and development events, participating in the regulation of multiple physiological processes (Cruz Aguilar et al., 2007) as it was observed during the present study where the response to the appearance of axillary buds was different among varieties.

The interaction between genetics and environmental elements is decisive for the formation of lateral buds because this varietal characteristic directly affects in the decision-making process for the genetic improvement, and it is a decisive variable to establish whether the variety enters intensive production processes. Therefore, the removal of lateral buds could generate an additional value to the production costs.

The varietal influence was also observed in the number, size and disposition of the foliage, which determines the LAI, a parameter that allows the estimation of the photosynthetic capacity of plant material and directly influences the accumulation of plant biomass, which, at the end of the cycle, will translate into the variety's performance or yield (Fernández Gálvez et al., 2021), and must also reach high quality standards for commercial production (Macías et al., 2008).

In this study, the use of the staking mesh did not have any significant influence in the number of lodging stems per plant, number of axillary buds per stem or LAI. However, for those varieties with a tendency to lodging, with greater berry weight, in areas with high wind presence, the staking mesh allows for the correct direction of stem growth with better foliage distribution m^{-2}, improving light interception and with that greater photosynthetic efficiency in plants to obtain more uniform yields (Jerez Mompie et al., 2016; Quevedo García et al., 2015).

3.2. Evaluations in harvested stems

For stem straightness, in the Vulcano variety, with the use of staking mesh, stems with scale 6 predominated, while without staking, scale 1 predominated (50 %) (Figure 4a). In the Rubi variety, both with and without staking, scale 1 predominated with 90 % and 50 %, respectively (Figure 4b). On the other hand, the V71 code, with and without staking, showed percentages of up to 90 % in scale 1 (Figure 4c).

Based on the quality scale, according to the number and size of the berries of *Hypericum* spp. in the varieties Rubi and V71, with and without staking, the scales 5 and 4 predominated respectively, which represents a high number of berries (Figures 4e-f). On the contrary, a diversification of all scales was observed in the treatments with Vulcano with and without staking (Figure 4d).

Based on the obtained results from these variables, it can be inferred that the variety Vulcano does not require staking to keep their stems straight because the use of the staking mesh did not correct their growth direction due to the physical characteristics of the stems, degree of lignification and growing habit (Guzmán Cárdenas, 2019). Meanwhile, Rubi and V71, with and without staking, showed to have high potential to stand upright, and they got straight stems which is an essential requirement for exportation (Castrillón Gallardo, 2012). Obtaining straight stems without the use of staking mesh is a favorable characteristic at the moment of determining production costs because it directly influences on the material to be used and the manual labor for its establishment.

Regarding the number of berries, the Rubi and V71 varieties, with or without staking, successfully fulfi-

lled the quality standards for exportation with more than nine berries per stem as mentioned by Afonso Dorta (2000). The weight and the number of berries per stem, and the growth habit of the stem can determine the requirement or not of the staking mesh.

The formation of a different number of berries with varying sizes in *Hypericum* spp. depends on genetic makeup, with each variety's potential being a key determinant for these variables. Additionally, nutrition is one of the most important factors for the growth, development, and production of cut flowers. However, this aspect in ornamental flowers is very limited and contradictory (Dole & Wilkins, 2005; Sonneveld & Voogt, 2009). Considering that nutritional recommendations should be specified for each variety due to their genetic variability, the correct nutrient supply during the phenological stages of the crop allow taking advantage of the high potential of the plant (Ortega-Blu et al., 2006).

When analyzing the number of marketable stems, some differences were observed between the Rubi and V71 varieties because the averages obtained were 140.63 and 136.13 marketable stems m^{-2} respectively (Figure 5a). On the other hand, the interaction was significant for discarded stems m^{-2} , the variety V71 without staking is placed in the first range with 56.25 discarded stems m^{-2}, followed by the treatments: Vulcano without staking (45 discarded stems m^{-2}) and V71 with staking in the second range (42.25 discarded stems m^{-2}) (Figure 5b).

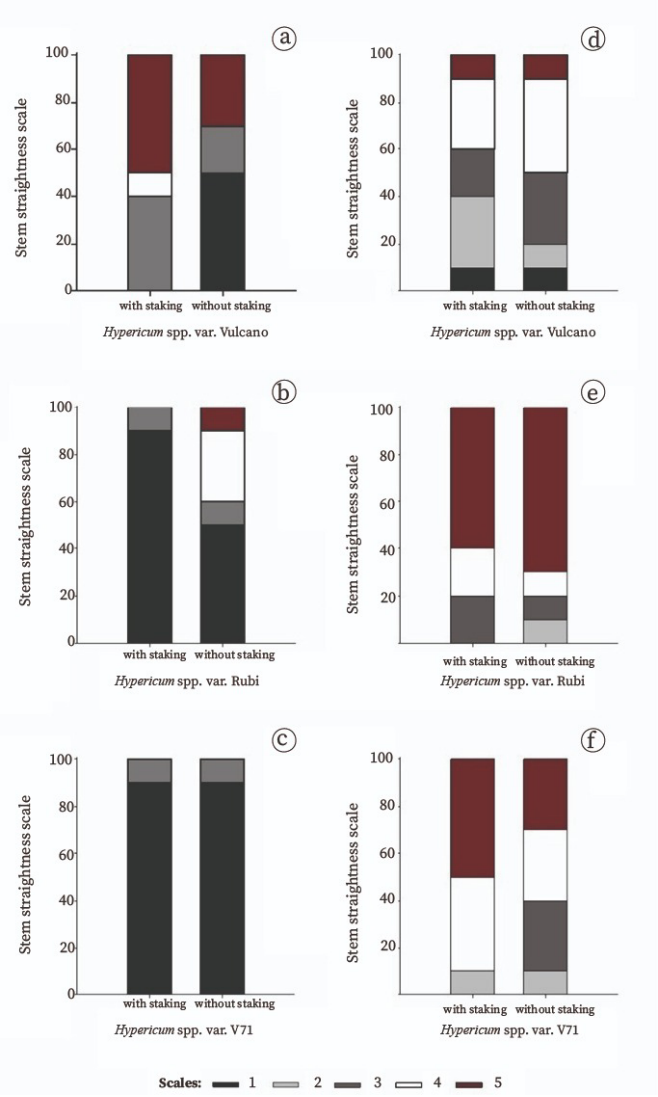

Figure 4. Frequency distribution based on berry number scales of *Hypericum* spp., with and without staking, Vulcano (a and d), Rubí (b and e) and V71 (c and f).

The varieties Rubi and V71, with or without staking, got statistically the highest number of marketable stems m^{-2}, being marketable or exportable stems all the stems that fulfill the quality characteristics such as: minimum stem length of 55 cm to 70 cm, uniform, without twists, complete and healthy leaves, without physical damage

in the sepals, and considering that the fruit (berry) of *Hypericum* spp. is commercialized. The berries must have sizes larger than 8 mm, with a number per stem higher to 9, and with defined colors, plus no presence of pests (Sarango, 2006).

On the other hand, the results showed that some stems did not fulfill the characteristics for the market. However, the use of the staking mesh reduced the number of discarded stems, mainly in the varieties V71 and Vulcano. It is important to consider that the use of the staking mesh represents an additional cost for the crop management of cut flowers. This costs plus the installation bring with it expenses on pambil poles, rope, galvanized wire and stakes to improve support in the field (Sierra Cárdenas, et al., 2013).

Another factor associated to the increase in discarded stems m^{-2} may be the homogeneous management among all the varieties in the application of artificial light (18 hours per week). Since the crop cycle of each variety is different, the cycle of Vulcano has 18 weeks, Rubi has 20 weeks and V71 has between 20-21 weeks, which makes a detailed phenological study of each variety essential to find the best growth conditions.

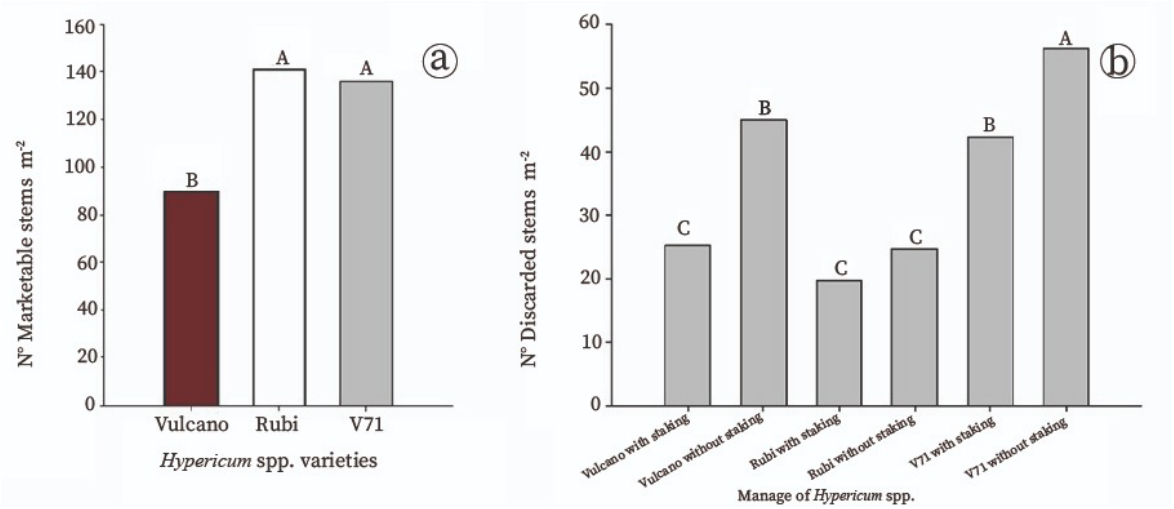

Figure 5. Marketable stems (a) and stems (b) in the cultivation of *Hypericum* spp., with and without staking.*
* Means followed by the same letter in the vertical are not significantly different at the 5% level according to the DMS test.

Analyzing the yield, it was observed that the variety Vulcano had a high percentage of discarded stems and a low percentage of marketable stems. On the contrary, the variety V71 with a high percentage of discarded stems had a high percentage of marketable stems. Thus, V71 and Rubi presented a good yield (Figure 6).

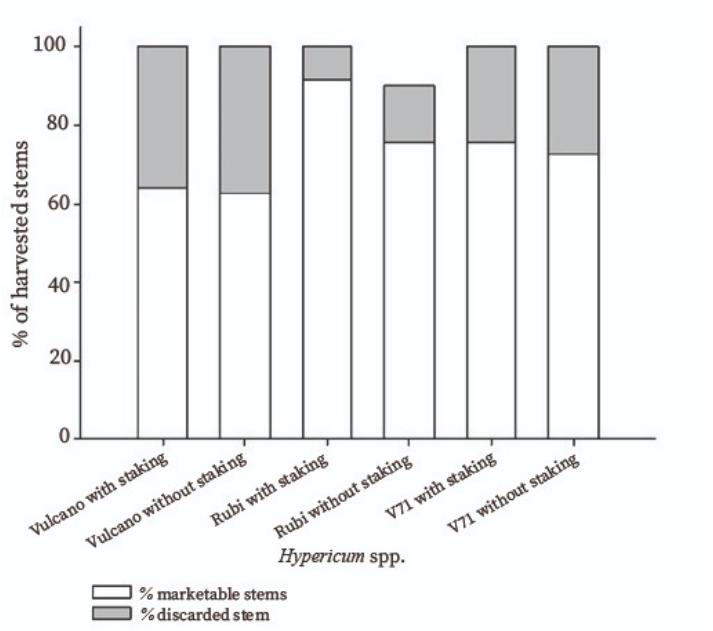

Figure 6. Performance of each variety of *Hypericum* spp., with and without staking.

The productivity of each variety results from an appropriate interaction between genetic and environmental factors such as water, light, temperature, fertilization and cultural practices. All of these factors are considered as essential for growth and development (Arce et al., 2017). On the other hand, the nutrition study is one of the most fundamental factors for the development of flowers. The nutritional requirements for each variety must be known because these determine profitable and uniform productivity as well as the quality of the product (Rueda-Luna et al., 2016). In terms of performance (yield) and efficiency, a high number of discarded stems show deficiencies at some stage in the production process.

4. Conclusions

This study demonstrated the varietal influence on most of the variables studied: stem lodging, number of buds, leaf area index, stem straightness, number of berries per stem, and marketable stems. These are inherent characteristics of each variety, as they result from intraspecific crosses.

The variable that showed significance in variable interaction and management was the quantity of discarded stems. A significant increase in the quantity of discarded stems was observed when the staking mesh was not used, especially in the varieties of Vulcano and V71. This indicates that the use of staking mesh can be an efficient practice in these varieties, and it is essential for the V71 variety that, even though its specific characteristics, show a high number of marketable stems which results in an overall positive performance.

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Contributor roles

- Jaime Andres Yanascual Paillacho: conceptualization, investigation, methodology, resources, writing – original draft
- María Yumbla-Orbes: conceptualization, methodology, validation, supervision, writing – review & editing.

Ethical Implications

Ethics approval not applicable.

Conflict of Interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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