

## Analysis of the growth and morpho-physiological performance of three cultivars of Colombian quinoa grown under a greenhouse

*Análise do crescimento e desempenho morfofisiológico de três cultivares de quinoa colombiana cultivadas em casa de vegetação*

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### ABSTRACT

Quinoa (Amaranthaceae) is a native pseudo-cereal produced throughout the South American zone, where it is used in the preparation of food and as a promising alternative for the colonization of edaphoclimatic areas affected by anthropic and natural factors. Among the main problems that affect crop production, we can include those related to growth, development and production, generated by limitations of adaptability of new cultivars in specific areas. For this reason, this research intended to analyze the growth and morpho-physiological behavior of the cultivars of quinoa Blanca Soracá (BS), Blanca Jericó (BT), and Tunkahuan (T). The study was carried out in the greenhouse of the Faculty of Agricultural Sciences of the Cauca University (Colombia) located at 1880 m a.s.l. The analysis, allowed to recognize that the three cultivars of quinoa, show different times of phenological development, until harvest ( $138.25 \pm 2.3$  and  $161 \pm 1.1$  days). The number of leaves, the height of plants, and the number of branches show adjustment of sigmoidal regression equations ( $R^2$  0.99 - 0.98) for the cultivars BJ and T, while total chlorophyll content was adjusted to cubic behavior ( $R^2$  0.90 - 0.89). The cultivars of quinoa express productive behaviors that are associated with early and late cycles, showing differences in the production and weight of seeds.

**KEYWORDS:** chlorophyll, morphology, phenology, cultivars.

### RESUMO

Quinoa (Amaranthaceae) é um pseudo-cereal nativo produzido em toda a zona sul-americana, onde é utilizada como alimento e alternativa promissora para o cultivo em áreas edafoclimáticas afetadas por fatores antrópicos e naturais. Entre os principais problemas que afetam a produção agrícola, inclui-se aqueles relacionados ao crescimento, desenvolvimento e produção, gerados por limitações de adaptabilidade de novas cultivares em áreas específicas. Por este motivo, esta pesquisa teve como objetivo analisar o crescimento e o comportamento morfológico das cultivares de quinoa Blanca Soracá (BS), Blanca Jericó (BT) e Tunkahuan (T). O estudo foi realizado na estufa da Faculdade de Ciências Agrárias da Universidade de Cauca (Colômbia) a 1880 m.a.n.m A análise permitiu reconhecer que as três cultivares de quinoa apresentam diferentes épocas de desenvolvimento fenológico até a colheita ( $138,25 \pm 2,3$  e  $161 \pm 1,1$  dias). O número de folhas, a altura das plantas e o número de ramos mostram ajuste às equações de regressão sigmoidal ( $R^2$  0,99 - 0,98) para as cultivares BJ e T, enquanto o teor de clorofila total foi ajustado para comportamento cúbica ( $R^2$  0,90 - 0,89). As cultivares de quinoa expressam comportamentos produtivos associados a ciclos precoces e tardios, mostrando diferenças na produção e peso das sementes.

**PALAVRAS-CHAVE:** clorofila, morfologia, fenologia, cultivares.

### INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is a species belonging to the Amaranthaceae family. It is originally from the Andean zone, mainly from Bolivia, Ecuador, Peru, and Colombia; now, it has been expanded to different parts of European, Asian, and North American countries. This plant has been recognized for its adaptability to extreme climate and soil conditions, mainly at soil salinity, significant

temperature changes, and low rainfall. Currently, Colombia is one of the countries with the highest interest in the production of this renowned pseudo-cereal (GARCÍA-PARRA & PLAZAS-LEGUIZAMÓN 2018). Due to this, the grain is positioned as a promising crop of agroecological interest, as well as its importance in compositional and agro-industrial characteristics, which allow it to elaborate functional foods (MARADINI et al. 2015), foods of great value for diet development plans.

According to the Ministry of Agriculture and Rural Development of Colombia, the production of this pseudo-cereal, it does not exceed 2550 hectares, throughout the national territory. It has production systems, which do not produce more than two t. ha<sup>-1</sup> (GUERRERO-LÓPEZ 2018). This production has huge disadvantages since farmers ignore the plant performance and the post-harvest characteristics of quinoa (GARCÍA-PARRA et al. 2018).

Thus, in the departments of Boyacá, Cauca, Nariño, and Cundinamarca, the varieties of quinoa are a problem for researchers and farmers, because, now, the production of quinoa is composed of plant materials, resulting from mixtures, which express various phenological physiological, productive and compositional performances. This composition brings disadvantages when post-harvest practices come and marketing.

Regarding what we have just mentioned, researches about the performance of different plant materials of quinoa, have started. Taking into account, the agro-ecological characteristics of some productive regions (2500-2800 m a.s.l.), as in the case of the department of Boyacá, where, currently, research is underway on the morphological characterization of numerous varieties of quinoa, as well as, the effect of fertilization on the physiological performance of these plants (INFANTE et al. 2018, GARCÍA-PARRA et al. 2019).

In the case of the department of Cauca, the development of quinoa cultivation has surpassed the agro-industrial expectations, according to school and commercial diet programs. Cauca is the pioneer department in training producers and strategic alliances with research centers, universities, and companies of the public and private sector (GUERRERO-LÓPEZ 2018). However, the weaknesses of production systems throughout the national territory have been the use of varieties and the knowledge of the performance of materials concerning edaphoclimatic conditions.

For this reason, the growth of plants is an integral and explanatory variable, which allows us to understand the shape, function, and performance of plants in certain climatic conditions. This variable is displayed through the increase in the cells' mass, tissues and organs, being activated the metabolism, which determines physiological processes, mainly, the production of chlorophyll, phytohormones and some secondary pigments that are synthesized as attraction or protection agents before other organisms (MELO ORTIZ 2016).

The analysis of plant growth is a response of environmental characteristics respect to a specific time sequence. It becomes an indispensable aspect of knowledge for the development of agronomic practices that can strengthen and optimize the needs and demands of producers, marketers, and consumers (CASIERRA-POSADA et al. 2007). In this sense, the growth curves allow us to know the development models of a plant, being variations according to the species and the given conditions of climate and soil. Thus, this type of methodology facilitates the evaluation of the number of leaves, length of stems, number of branches, and chlorophyll contents through chronological time sequence.

Besides, the morphological aspects are one of the main tools, which allow describing the observable features of the plants, being the visual identification the tool of characterization of the species, around colors, shapes, sizes, and types of inflorescences (RUIZ HERNANDEZ et al. 2013).

In that order, it is necessary to evaluate the morpho-physiological performance of three cultivars of quinoa (*Chenopodium quinoa* Willd). Blanca Soracá (BS), Blanca Jericó (BJ), and Tunkahuan (T). These cultivars are under controlled conditions, being these the main productive alternatives for Colombia's central zone and the study object for plant breeding effort programs.

## MATERIAL AND METHODS

In the present assay, the morph physiological growth and development of three cultivars of quinoa (*Chenopodium quinoa* Willd.), cultivated under greenhouse conditions, were evaluated. The cultivars evaluated were Blanca Soracá (BS), Blanca Jericó (BJ), and Tunkahuan (T) and obtained from the Germplasm Laboratory of the Gobernación de Boyacá-Colombia. The study was conducted in the greenhouse of the Faculty of Agriculture Sciences of the Cauca University (Colombia), located at 1880 m a.s.l., with coordinates 2° 28'14.06" N and 76° 33' 01.23" W. The average temperature is 20 °C. For each one of the cultivars, four seeds were planted in plastic containers of the organic substrate with a capacity of 5

Kg (Table 1). After 15 days of germination, the plant with the best characters of vigor and health was selected, while the rest were eliminated. The measurements were made until the harvest of each one of the repetitions, through non-destructive tests.

Table 1. Chemical characteristics of experimental soil.

Component	
pH	6.9
Organic matter (%)	21.19
CEC (cmol/Kg)	55.27
Ca (cmol/Kg)	38.1
Mg (cmol/Kg)	8.87
K (cmol/Kg)	11.12
Na (cmol/Kg)	0.98
P (mg/Kg)	569
Fe (mg/Kg)	87.8
Mn (mg/Kg)	14.1
Zn (mg/Kg)	8.7
Cu (mg/Kg)	9.8
B (mg/Kg)	2.1
S (mg/Kg)	189

### Phenological development

The phenological development of the plants allowed to evaluate each one of the cultivars concerning their early growth in important vegetative and reproductive phases. Thus, variables such as germination days, 2, 6, and 8 true leaves, as well as 50% of flowering, milky grain, pasty grain, and days to harvest, were determined by evaluating the time from sowing to each one of the phases mentioned above. For this, the BBCH scale proposed by SOSA-ZUNIGA et al. (2017) was used. The qualitative evaluation of leaves, stems, and panicles was done using photographic documentation when the grain was milky according to the method described by INFANTE et al. (2018).

### Number of leaves, branches, and height of plants

The number of leaves was counted manually eight days after the appearance of four pairs of true leaves and until the milky grain phase, where the senescence and fall of the leaves exceeded 60% of the leaves registered in the last count. The number of branches was counted at the time of their appearance and until the complete formation of the panicle, determined as secondary structures protruding from the secondary stem. The height's measurement of the plants allowed to evaluate their behavior concerning time, which was determined from 21 days after germination, using a rigid-flex meter from the base of the stem to the terminal bud of the main stem.

### Chlorophyll content

The chlorophyll content was taken with portable chlorophyll meter (SPAD 502plus, Minolta corporation, Osaka, Japan), where the measurement was made at the time of arrival of each one of the phenological phases evaluated in the phenological development for each one of the cultivars.

### Seed Production

The weight for the productivity per plant and the weight of 1000 seeds, was done by using a high digital precision balance and cultivating each one of the plants that were put to dry at 30 °C in an oven for 4 days, and later collected seeds from the third middle of the panicle.

### Experiment design and statistics

The test was organized using a completely randomized design of three treatments, with twenty repetitions for a total of 60 experimental units. The normality of the data was carried out using the Shapiro-Wilk test and homogeneity using the Levene test. For the analysis of variance (ANOVA), the Tukey test was used ( $p < 0.05$ ). The statistical program used was IBM-SPSS statistics version 23.0. (IBM Corporation, New York, USA). The growth parameters were determined using the sigmoidal mathematical model, three parameters with Sigmaplot version 12.0 (Systat Software, Inc). The parameterization of this model was carried out according to what AGUILAR et al. (2012) indicated.

## RESULTS AND DISCUSSION

### Phenological behavior of quinoa

In the three cultivars studied, statistical differences were found for all the phenological phases (Table 2). In the case of the BS cultivar, it was found that precocity occurs at harvest days, due to flower formation occurred in less time compared to the other varieties. For the BJ cultivar, the formation of true leaves did not generate significant differences with the cultivar T. Nevertheless, in the reproductive phases, there was a postponement in the formation of each one of them, which label it as a medium precocity cultivar. The cultivar T took more time at the time of germination, as well as in days 2, 4, 6, and 8 true leaves, while, in the case of the reproductive phases, it needed more time to get days to harvest.

Table 2. Phenological performance in days after cultivation for three cultivars of quinoa (*C. quinoa* Willd.) cultivated under controlled conditions.

Cultivar	Tg	T2t	T6t	T8t	T50f	Tmg	Tpg	Th
BS	5±0.5 <sup>c</sup>	9.25±0.5 <sup>c</sup>	16.25±0.5 <sup>b</sup>	18.25±0.5 <sup>b</sup>	52.25±0.9 <sup>c</sup>	102.5±1.9 <sup>a</sup>	119.75±1.2 <sup>b</sup>	138.25±2.3 <sup>b</sup>
BJ	5.75±0.5 <sup>ab</sup>	9.75±0.5 <sup>ab</sup>	16.5±0.5 <sup>b</sup>	18.75±0.5 <sup>ab</sup>	61±1.4 <sup>a</sup>	91±1.4 <sup>b</sup>	112.5±1.7 <sup>c</sup>	150.75±7 <sup>b</sup>
T	6.5±0.5 <sup>a</sup>	11±0.8 <sup>a</sup>	19±0.8 <sup>a</sup>	19.5±0.5 <sup>a</sup>	57.75±1.7 <sup>b</sup>	77.75±0.5 <sup>c</sup>	132.25±2 <sup>a</sup>	161±1.1 <sup>a</sup>

Tg = Time to germination; T2t = Time to two true leaves; T6t = Time to six true leaves; T8t = Time to eight true leaves; T50f = Time at 50% Flowering; Tmg = Time to milky grains; Tpg = Time to pasty grain; Th = Time to harvest. ± Standard deviation. Different letters in the same column indicate significant differences according to the Tukey test ( $p \leq 0.05$ ).

The results displayed that the precocity capacity of the three cultivars is connected to genetic aspects and environmental characteristics; meanwhile, the germination speed is changing, depending on the cultivar of quinoa. According to BOIS et al. (2006), an essential factor in the germination time is the hardness of the seed bark and the presence of secondary metabolites such as saponins. These can postpone this process; conversely, other varieties present phytohormones as the cytokines and gibberellins. These are present in a higher proportion, and that induce germination in a short time.

Also, according to YANG et al. (2016) the vegetative growth of quinoa, is linked to the induction of cell division and elongation, which are stimulated by the enzymes' synthesis that promotes the production of apical and lateral meristems, giving rise to different organs such as leaves and branches. However, conditions, similar to, hydric and nutritional status, which along with other elements, like nitrogen and phosphorus favor the production of structural biomass, which determines the architecture, and distribution of structures such as, leaves and branches during growth and development (NOULAS et al. 2017). It agrees with the results obtained cultivating BS, which expressed, higher vegetative capacity, as an effect of the accelerated presence of leaves and secondary structures as ramifications, which makes it an accelerated material of biomass production according to PODKÓWKA et al. (2018) given its early growth characteristics at 2, 6 and 8 true leaves.

According to CHRISTIANSEN et al. (2010), factors such as temperature, solar radiation, and the expression of phytohormones are induction markers of the reproductive phases and particularly of flowering in *C. quinoa*. These data are in the same line, with the achieved by REGUERA et al. (2018) who found that the time from cultivation to flowering varies between 50 and 100 days, being strongly influenced, by the edaphoclimatic conditions of subtropical and seasonal zones, resulting in early expressions for the Titicaca cultivar. Also, MELO ORTIZ (2016) reported that the BS variety has a faster development until the flowering days, while after cultivated, it reached this stage at 47 days; this agrees with the data obtained for the evaluated crops.

Days with milky grains and pasty grains are crucial to obtain post-harvest and agro-industrial quality seeds. According to RAMZANI et al. (2017), the growth and development stages of the seeds are the expression of the assimilated translocation from the source organs to the landfills. Consequently, aspects such as the size and proximal compounds presence favor the selection of varieties in specific territories. Thus, MADRID et al. (2018) affirm that the edaphoclimatic conditions are determinant factors in the precocity characteristics of the quinoa varieties; however, this is connected to the genetic base, that is, closely related to the factors mentioned above, and that generates the ecophysiological stabilization of quinoa.

### Analysis of growth and development

The calculated data were adjusted with precision from the observed data, and explained through the regression equation, showing that the degree of association, between time (X-axis) and the parameter evaluated (Y-axis), determines the behavior trend. For this case, the cultivars, number of leaves, plant

height, number of branches, and total chlorophyll content showed a monomodal tendency with  $R^2$  between 89% and 99% and sigmoidal and quadratic adjustment behaviors.

### Number of leaves

For the BS, BJ and T cultivars, the regression function that was more adjusted, it was the cubic behavior. On the other hand, the data of coefficient determination ( $R^2$ ) was oscillating between 0.98 and 0.99, very close to the unit. The lowest value of  $R^2$  was registered for cultivar BS. For all cases, the regression analysis presented highly significant results ( $p < 0.05$ ) in the evaluated functions. Based on the information, it can be inferred that, among the evaluated cultivars, BS is the one with the highest production of leaves with monomodal behavior, also expressing the highest average number of leaves in days before entering the milky-grained phase (Figure 1).

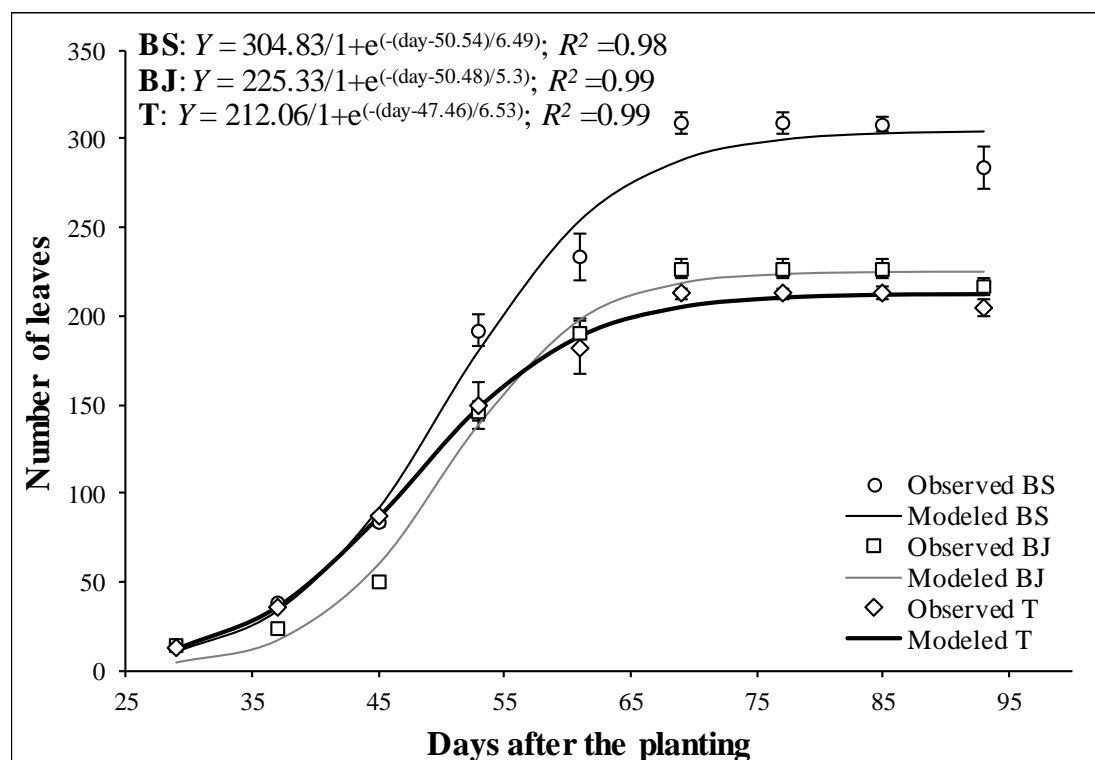


Figure 1. The performance of the number of leaves in days after cultivation for three cultivars of quinoa (*C. quinoa* Willd.).

The number of leaves, during the phenological development of quinoa plants, is a variable and determinant aspect, in the capture of solar energy (GARCÍA-PARRA et al. 2019) because in the leaves, it is transformed into chemical energy and it is used for the development of genetic, physiological and metabolic activities. However, the characteristics and availability of elements in the soil, are influential in the production of leaves, mainly, the presence of nitrogen (N), which participates in the structural construction of chlorophyll, and in the photosynthetic activity of the leaves (GEREN 2015).

Agreeing with BASCUÑÁN-GODOY et al. (2018a), different varieties of quinoa can adapt to low contents of soil elements; however, some varieties express the best foliar development under conditions of nitrogen unavailability, since they find significant differences compared to Chilean varieties. These data agree with what was obtained, while BS presented the highest number of leaves structures during the entire production cycle compared to BJ and T.

### Height of the plants

The dynamics of the longitudinal growth of the plants, in each one of the cultivars of quinoa, was evaluated by the depending height variable (Y-axis) and the independent variable of physiological time or time after cultivation in days (X-axis). Based on the regression curve, the best adjustment was presented in the sigmoidal analysis with an  $R^2$  of 0.99 for all cultivars. When observing the height of the plants throughout the productive development, it was found that the growth of the cultivars BS, BJ, and T, have the same tendency (Figure 2). Likewise, these presented the peak of growth at 85 days with  $148.7 \pm 0.95$  cm,  $141 \pm 0.81$  cm, and  $146 \pm 0.81$  cm, respectively. From the formation of grain (milky and pasty grain), there was a slight decrease in the vertical length of the stem.

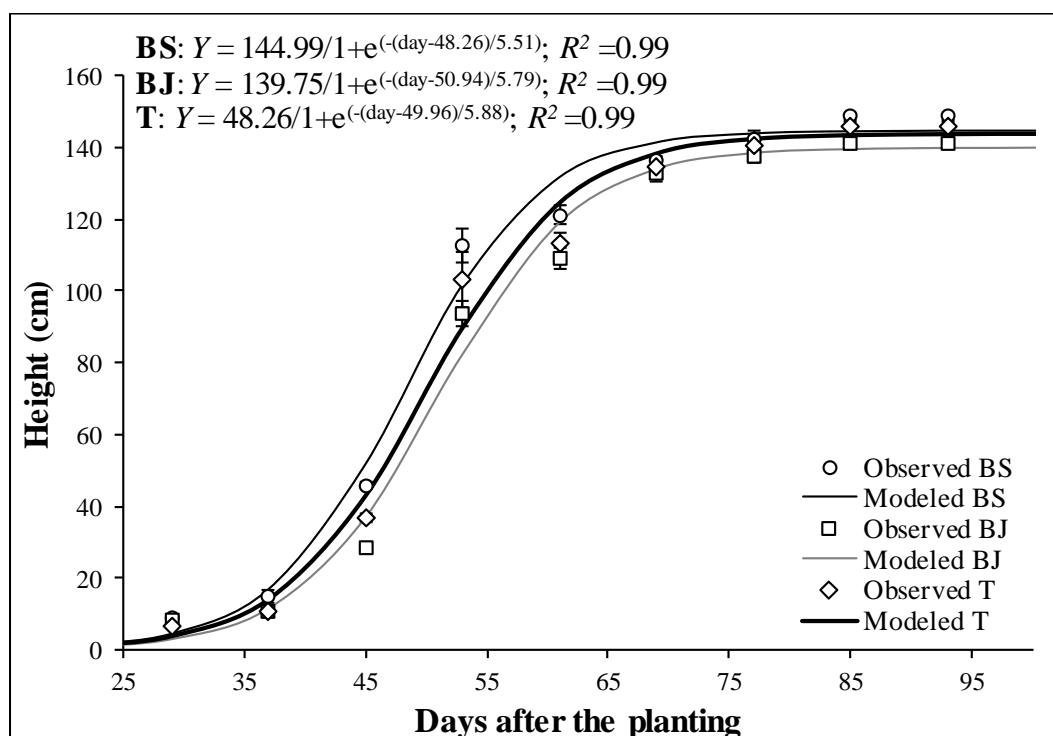


Figure 2. The performance plant height for three cultivars of quinoa (*C. quinoa* Willd.) over time.

Aspects such as the quinoa plant growth are connected to genetic and environmental factors. For this reason, evaluating the physiological behavior of plants under controlled conditions becomes an important activity. According to GARCÍA-PARRA et al. (2019), the vertical length of the stem allows determining the leaves and branches distributions, as well as, the panicle morphology and the architecture of the floral glomeruli and grain.

According to the results obtained in the study, there is evidence of a significant increase in growth in the three evaluated cultivars of quinoa. As stated by MARSCHNER (2014), it is a consequence of the nutrients translocation from the soil to the interior of the root and its transformation into important substances for cell division and elongation, besides the increase in metabolic activities, which are developed in the leaves and that are transported to all the structures of the plant. However, the reduction in stem length in the days close to harvest is manifested, as the loss of cell turgidity and therefore reduction of tissue stiffness; while the vacuoles represent about 40% of the cell mass, which is affected by the expression of acetylene (ISSA et al. 2019).

Furthermore, characteristics such as the height in varieties of *C. quinoa* is an essential factor of genetic and productive selectivity, as reported by MELO ORTIZ (2016), it shows advantages at the time of competition to solar radiation with aerial species, as well as, greater ease in the development of management and harvesting practices.

#### Number of branches

The branches quantity and disposition in the different cultivars of the *C. quinoa* species is a genetic factor, which is connected, not only to the stem architecture but also to the structure and form of the panicle, since, it determines the floral glomerulus and the grain disposition. Based on the obtained data, we found that the modeling adjustment was sigmoidal with  $R^2$  of 0.99, which evidences a significant increase of these structures through the time. Thus, BS remained as the cultivar with a greater number of branches throughout the vegetative and reproductive phases, getting at the end of the productive cycle  $33.25 \pm 2$  branches. At the same time, BJ and T displayed  $27 \pm 0.81$  and  $26.2 \pm 0.95$ , respectively (Figure 3).

In the same line of thought of HUSSAIN et al. (2018), not all the varieties of quinoa demonstrate structures with branches. This aspect illustrates panicle architecture and structure. Nonetheless, some varieties show compact inflorescence with branches, which display crude inflorescence structures, that in most of the cases present a set fruit. Still, it does not stand out interest at the harvest time.

Also, BHARGAVA et al. (2007) highlight that branches in this species are structures of crude genetic. These structures allow the proliferation of seeds, as well as the easy distribution of the leaves for the capture of solar radiation and the aeration of the panicle, mainly in times of rain and high relative humidity. This prevents the easy germination of the grains before harvesting. Thus LESJAK & CALDERINI (2017) state that

there is a close relationship between the number of branches, the height of the plant, and the number of leaves.

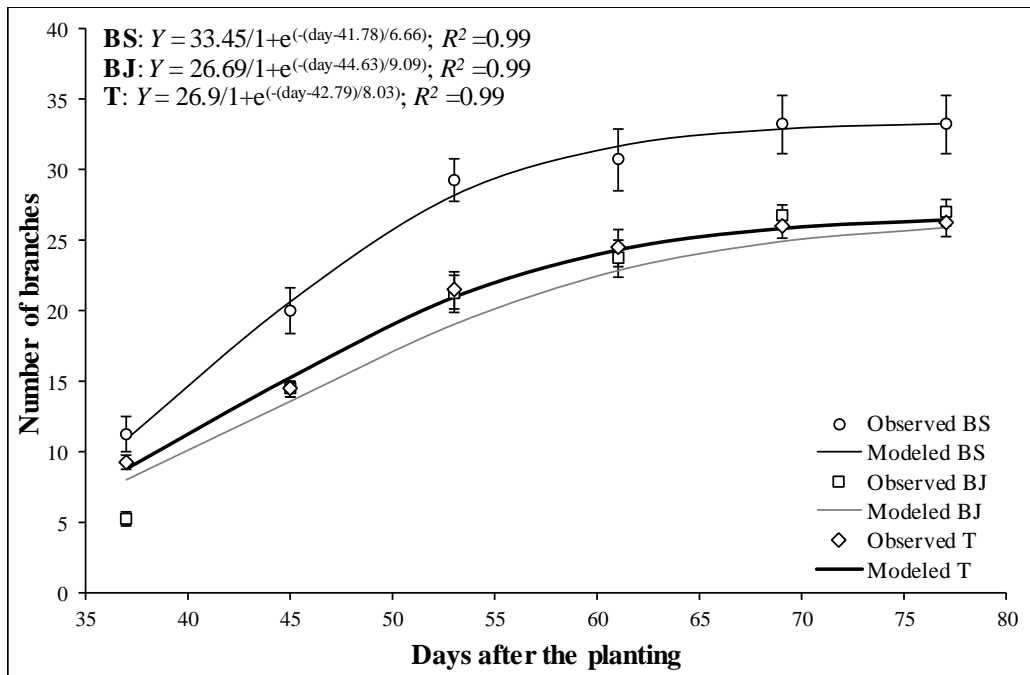


Figure 3. The performance of the number of branches in three cultivars of quinoa (*C. quinoa* Willd.) plants, throughout the time.

### Chlorophyll content

The total content of chlorophyll showed changes during the phenological development, while it increased gradually, for the case of the three varieties, from the eight true leaves. At the time of milky grains arrival, the highest values were presented; BS obtained  $71.5 \pm 1.73$  SPAD; while the values for BJ and T were 66 and  $68 \pm 0.95$  SPAD respectively. However, it is possible to observe in Figure 4 that in the time to harvest, (Th), chlorophyll production decreases, which is in line with the cubic regression model and generates an adjustment of  $R^2$  between 0.89 and 0.9 for all cultivars (Figure 4).

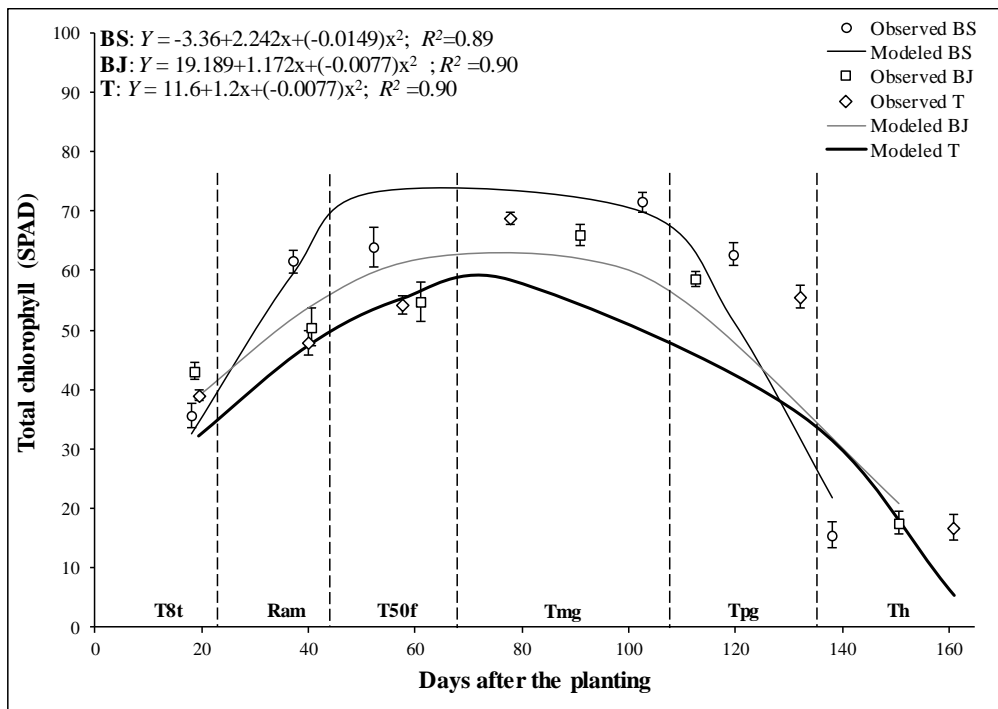


Figure 4. Model of total chlorophyll content in three cultivars of *C. quinoa* in the phenological phases. T8t = time of 8 true leaves; Ram = branch time; T50f = 50% flowering time; Tmg = Time to milky grain; Tpg = Time to pasty grain; Th = Time to harvest.

According to RICCARDI et al. (2014), the total chlorophyll content in amaranth plants is directly related to the concentration of pigments, the reflection on the surface of the leaf, the diffraction of light within the mesophyll and the distribution of chlorophyll in the evaluated leaf area. For this reason, water availability, nutritional status, and the variety of quinoa determine the contents of chlorophyll pigments.

The cultivar of quinoa BS has become a plant material of adaptive interest in different parts of the world (MELO ORTIZ 2016), while together with the foliar area production capacity and the precocity of productive development, this presents high contents of total chlorophyll. Thus, BASCUÑÁN-GODOY et al. (2018b) state that along with the CO<sub>2</sub> intake, this contributes to the development of photosynthesis and transformation of assimilates that determine the characteristics of the compositional seed.

### Productivity and weight of seeds

The quinoa crop production and productivity are essential factors in marketing plans, which makes that a fundamental objective in the production systems of this species. According to Figure 5 (A), significant differences were found in the seeds per plant production. At the same time, the cultivar T was the one with best seed productivity ( $44 \pm 2.9$  g) compared to BS and BJ, which had the productivity of  $33.5 \pm 1.7$  and  $23.8 \pm 3.5$  g, respectively. However, for the weight of 1000 seeds, cultivar BS expressed the best value ( $2.7 \pm 0.1$ ), finding significant differences with T ( $1.6 \pm 0.2$ ) and R ( $2.05 \pm 0.05$ ) (B).

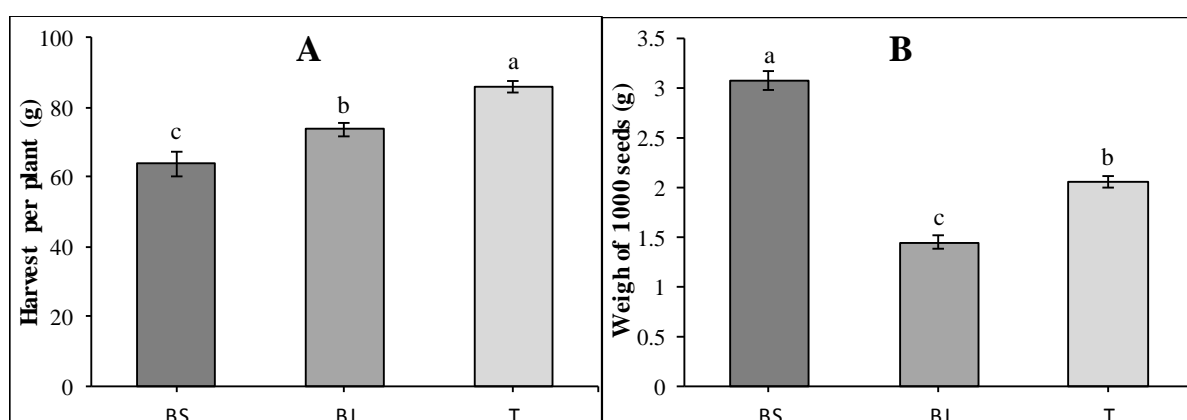


Figure 5. A: Quinoa seeds production for plant B: Weigh of 1000 seeds for the evaluated cultivars. The vertical bars indicate the deviation standard.

Grain production is the most important aspect of agricultural production systems, due to, it reflects morphological, physiological, and metabolic expressions of plants because they express the genetic characteristics and the fieldwork development. According to MELO ORTIZ (2016) cultivars of Colombian origin, express higher production rates than the average of commercial varieties, in line with the results obtained in the test, allowing them to be recognized as production alternatives in tropical, subtropical and seasonal conditions.

However, although BS represented the cultivar with the lowest production index, the characteristics of an abundant number of leaves and a high chlorophyll content allowed it to express significant weights per seed compared to the other cultivars. These results determine BS as an early cultivar with good an outstanding weight of seed, while the BJ is above the production average (BASCUÑÁN-GODOY et al. 2018b) and the T with high production indexes and medium to high seed weights (MELO ORTIZ 2016), in line with what was obtained in the study.

### Morphological characteristics

The morphological evaluation also allows recognizing the differences between the cultivars, the ecotypes of quinoa in an easier way, and the effect of climate and soil conditions on the structure and architecture of the plant. Regarding figure 6, it is possible to demonstrate the morphological characteristics that differ in each one of the plant materials studied. Thus, all the cultivars evaluated showed leaves with slightly to strongly serrated edges in a helical and green alternate arrangement. Besides, the stems showed corrugated angular shape, with purple pigmentations for T; yellow and pink for BJ, while BS has generalized green colorations. On the other hand, all the cultivars presented a compact panicle shape, with green, purple, and red colorations for BS, BJ, and T, respectively.

According to the Food and Agriculture Organization of the United Nations (FAO), the evaluation of the morphological characteristics of quinoa is one of the main tools for evaluating the adaptability strategies of the different varieties of quinoa. Since they express different behaviors according to climate and soil



conditions, and this is displayed in the nutritional and agro-industrial characteristics of seeds (APAZA et al. 2013).

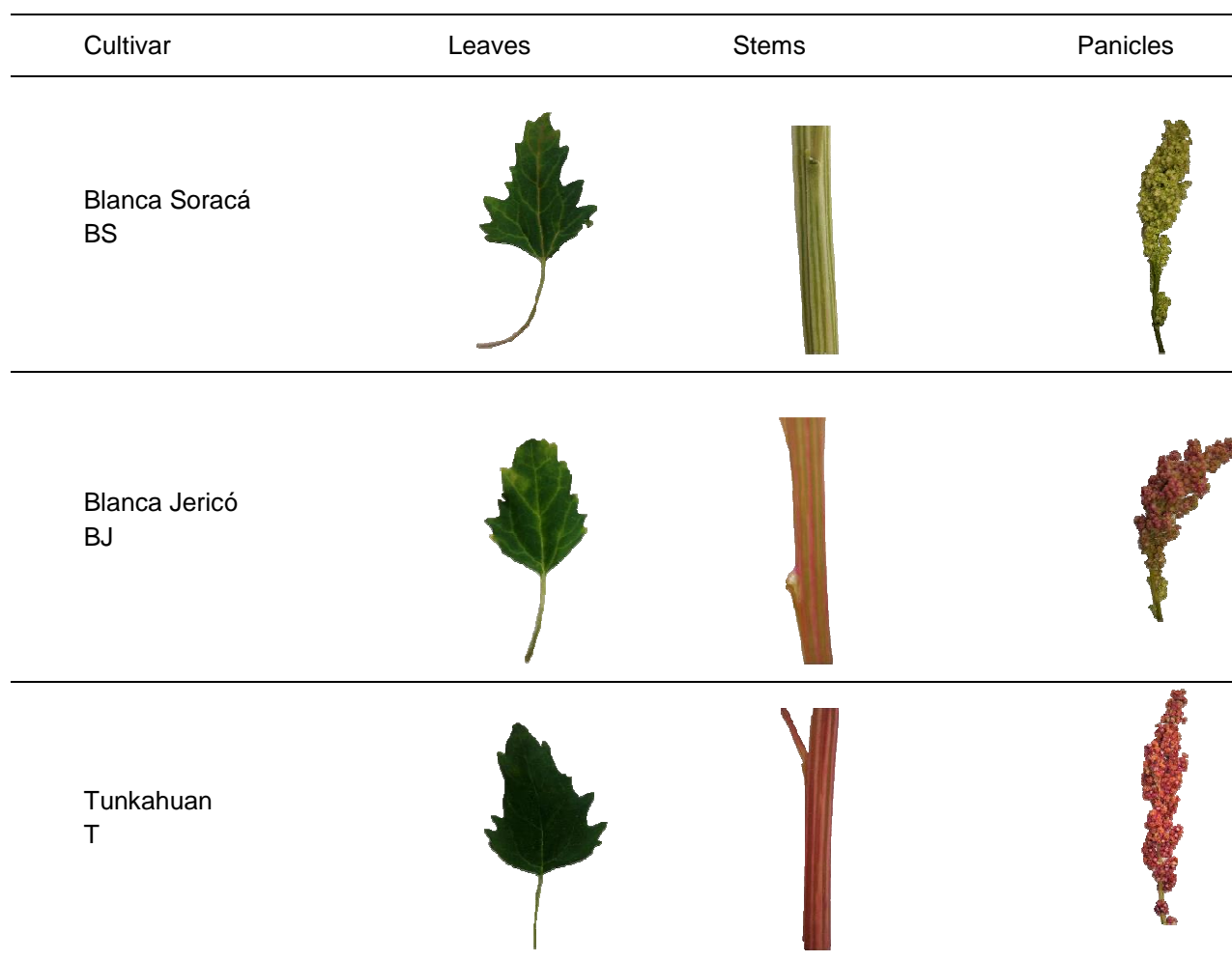


Figure 6. Morphology of leaves, stems, and panicles of three cultivars of Quinoa *C. quinoa* grown under greenhouse.

Cultivar BS expressed morphological characteristics similar to those reported by MELO ORTIZ (2016), which allows determining that the morphology of leaves, stems, and panicles are not changing in this cultivar, so seasonal to tropical conditions did not influence its phenotypic structure. As reported by BAZILE et al. (2014), quinoa cultivars such as BJ express diverse pigmentations according to edaphoclimatic conditions, which allows them to adapt more quickly.

Also, the cultivar T has become the cultivar of *C. quinoa* with the higher interest in different European countries. This is due to the striking reddish coloration that manifests at the level of the stems and panicles as a biological character. At the same time, aspects such as stress in plants, mainly the temperature and solar radiation, stimulate the production of metabolites such as anthocyanins or carotenes, which act as attractants in pollination stages (GONZÁLEZ et al. 2014).

## CONCLUSION

The growth and development behavior of the three-quinoa crops showed that there is variability in the productive expression associated with the genetic base. At the same time, the BS manifested an earlier growth under controlled conditions, in comparison to the BJ and R cultivars. This would encourage the evaluation of this crop under different agro-ecological conditions to evaluate its adaptive potential to the significant climate change in the tropical and subtropical zones.

Besides, it was determined that the BJ and T cultivars expressed similar behaviors in the production of leaves, the number of branches, and total chlorophyll content. In contrast, BS showed superiority in the variables above. However, T led the seed/plant performance. At the same time, BS was the best weight by the number of quinoa seeds, which determines the productive potential of each one of the plant materials, depending on their genetic base and the given agro-climate conditions.

Finally, it was determined that the morphological and pigmentation expression are connected to the varieties. Meanwhile, the T cultivar quinoa plants express colorations ranging from orange to red, while BS reflects colorations that are found throughout the range of green color.

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