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Growth of Ornamental Yellow Pepper Seedlings in Different Environments and Substrates

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ABSTRACT

Protected environment and substrate, as well as interaction between both, influence the formation of pepper seedlings and promote adequate plant growth. The present study evaluated different types of protected environments and substrate compositions in the initial growth of "Guaraci Cumari do Pará" pepper (*Capsicum chinense*) seedlings. The experiment was conducted in a completely randomized design, in a 4 x 5 factorial scheme (4 protected environments x 5 substrate compositions). Agricultural screenhouses with black polyethylene screens of 18% and 30% shading and agricultural greenhouses with polyethylene screens of 35% and 42-50% shading under the plastic film were used. In the environments, substrates 100% Carolina Soil® + 0% vermiculite, 80% Carolina Soil® + 20% vermiculite, 60% Carolina Soil® + 40% vermiculite; 40% Carolina Soil® + 60% vermiculite and 20% Carolina Soil® + 80% vermiculite were tested. The environment that provided higher growth for all substrates was with 35% shading, which increased seedling quality 2.9 times. In the 30% shading environment, better performance of the substrate (80% Carolina Soil® + 20% vermiculite) was observed, while in the 35% shading environment, better performance of the commercial substrate (100% Carolina Soil®) was observed, with greater plant height, stem diameter, number of leaves, and dry biomass. However, the 35% shading environment increased 2.4 times the quality of seedlings with the commercial substrate, regarding 40% Carolina Soil® + 60% vermiculite. Regarding seedling quality, the best substrate was the commercial substrate, i.e., 95% superior to 40% Carolina Soil® + 60% vermiculite in the average environment.

Introduction

Pepper cultivation has been growing over the years in Brazilian agribusiness (Costa et al., 2017). It has occurred in virtually all Brazilian states and is a source of income for family farming. Peppers can be used as an ornamental plant or consumed fresh or processed (Costa et al., 2020; Nascimento et al., 2021).

Crop productivity is influenced by the environment, solar radiation, and availability of water and inputs. In this context, a protected environment can improve production due to the control of environmental conditions of temperature, humidity, and water availability (Costa et al., 2017; Rao et al., 2023), and it can protect against bad weather. Protected environments can have various configurations, sizes, and structures, microclimate, shading, and

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irrigation, and allow cultivation more times a year (Costa et al., 2020). Thus, choosing the best type of protected environment and shading intensity will create environments favorable to healthy crop growth but dependent on the variety of cultivated plants (Rao et al., 2023).

Special care must be taken in the production of pepper seedlings. Seedling quality directly affects the development and production of the plant in the field (Costa et al., 2017). High-quality seedlings can adapt to the new environment when transplanted (Silva et al., 2019). The quality of seedlings will directly affect pepper productivity (Ramadani et al., 2016).

The growing environment can influence the morphological characteristics of seedlings (Costa et al., 2015b; Costa et al., 2017; Costa et al., 2020; Lima et al., 2017), as well as physiological and biochemical characteristics (Lekala et al., 2019), and the type of substrate can provide more development of the root system and seedling nutrition (Nascimento et al., 2021). The substrates are composed of different materials, which can affect seedling development directly and indirectly (Ramadani et al., 2016).

Regarding *Piper hispidinervum*, popularly known as long-pepper, an improvement in seedling quality, greater height, diameter, and dry mass occurred when grown in a protected environment (Lima et al., 2017). The same was observed by Costa et al. (2015b) in the production of cherry tomato seedlings. Evaluating the mixture of substrates, Silva et al. (2019) and Nascimento et al. (2021) observed better development of pepper seedlings using the commercial substrate, while Costa et al. (2015a) verified more in pepper seedlings using 30% vermiculite and 70% bovine manure. Silva et al. (2019) observed variations in the characteristics evaluated in pepper and bell pepper with different substrates and raw material compositions.

Commercial substrates provide good plant development, as they have balanced physical and chemical characteristics to provide nutrients, retain moisture, and suitable temperature, but increase the cost of production (Silva et al., 2019). Therefore, the use of mixing substrates with other substrates or raw materials available on the property has been adopted by producers (Nadai et al., 2015).

Thus, the choice of substrate and cultivation environment is essential for pepper seedlings to grow properly. Research is necessary regarding the composition of the substrate and cultivation environments. Therefore, the present work aims to evaluate the growth of pepper plants in different protected environments and substrate compositions.

Materials and Methods

Location and characterization of the experimental area

The experiment with the "Guaraci Cumari do Pará" yellow pepper (*Capsicum chinense*) was conducted from March 17 to April 24, 2022, at the State University of Mato Grosso do Sul (UEMS), at the Cassilândia University Unit (UUC), located in the municipality of Cassilândia (latitude 19º07'21" S, longitude 51º43'15" W and altitude 516 m). According to the Köppen climate classification, the region has a tropical rainy climate (Aw) with a rainy summer and a dry winter.

Experimental design

The environment factor with four levels and the substrate factor with five levels were studied in a completely randomized design in a factorial scheme of 4 x 5 (four environments x five substrates), with six replications and four seedlings per plot. The protected environments studied were two screen houses and two agricultural greenhouses, designated as follows (Fig. 1):

G+S42-50%: greenhouse with low-density polyethylene film and thermo-reflective screen under 42/50% shading film: identical structure to G+S35% but with LuxiNet 42/50 aluminized thermo-reflective screen, mobile, under LDPE film.

G+S35%: greenhouse with low-density polyethylene film and heat-reflective screen under 35% shading film: agricultural greenhouse measuring 18.0 m x 8.0 m x 4.0 m (144 m^2), covered with low-density polyethylene film (PEBD) of 150 microns, light diffuser, anti-drip, zenith opening sealed with the white screen of 30%, with side and front screen of monofilament of 30% of shading. ALUMINET® 35% aluminized thermo-reflective screen ("I"), mobile, under the LDPE film; S30%: screenhouse with a black screen with 30% shading: a structure identical to S18% but with black monofilament screen and 30% shading; S18%: screenhouse with 18% shading black screen: 18.0 m x 8.0 m x 3.5 m (144 m^2) agricultural screen, closed at 45 degrees, with black monofilament screen with 18% shading.

In these growing environments, five different sub strate compositions were evaluated (S1, S2, S3, S 4 and S5), resulting from the use of commercial s ubstrates Carolina Soil® and vermiculite, designa ted as follows: S1 = 100% Carolina Soil®, S2 = 80 % Carolina Soil® + 20% Vermiculite; S3 = 60% C arolina Soil® + 40% Vermiculite; S4 = 40% Carol ina Soil® + 60% Vermiculite; S5 = 20% Carolina S oil® + 80% Vermiculite.

The commercial substrate Carolina Soil® was composed of sphagnum peat, expanded vermiculite, carbonized rice husk, and traces of NPK, dolomitic limestone, and agricultural gypsum.

Fig. 1. Enviroments: S18%: screenhouse with 18% shading; S30%: screenhouse with 30% shading; G+S35%: greenhouse + Aluminet® screen with 35% shading under the plastic film; G+S42-50%: greenhouse + Luxinet® screen with 42-50% shading under the plastic film.

Experimental conduction and data collection

Sowing was carried out in trays that had 128 cells. We planted one seed per cell (3.5 x 3.5 cm) on March 17, 2022. The seedlings were watered using a manual sprayer when necessary.

Forty days after sowing (DAS), plant height (HP, cm), stem diameter (SD, mm), number of leaves (NL), shoot dry mass (SDM, g), and root dry mass (RDM, g) were recorded. The height of the seedlings was measured using a graduated ruler, measuring the distance from the plant collar to the apex of the stem meristem. The shoot dry mass and the root dry mass were obtained after drying in an oven with forced air circulation at 65 °C for 72 h and measured on an analytical balance.

The total dry mass (TDM, g), the shoot dry mass and root dry mass rate, the seedling height and stem diameter rate, the root and total dry mass rate (RTR), and Dickson's quality index (DQI).

In the cultivation environments, photosynthetically active radiation (PAR) (μmol m^{-2} s^{-1}) was monitored with a portable digital pyranometer (Apogee®), every day at 9:30 am, MS time. The PAR data were compared in a randomized block design with nine replicates (each replicate was three consecutive days of collection).

Photosynthetically active radiation at 9:30 am, air temperature, relative humidity, and precipitation outside the environments (full sun) was 1785 μmol m^{-2} s^{-1}, 23.2 ºC, 58,55%, and 154 mm, respectively.

Statistical analysis

The statistical program Sisvar 5.3 (FERREIRA, 2010) was used, with the averages submitted to the F test and compared using Tukey's test ($p \leq 0.05$).

Results

The photosynthetically active radiation (PAR) incident in the environments was different according to the covering material. The lowest incidence of PAR was observed in the greenhouse environments with 35% shading and in the greenhouse with 42-50% shading (Fig. 2). The highest incidence of PAR was verified in the environment with an agricultural screen of 18% shading.

Regarding external PAR, the environments G+S35%, G+S42-50%, S30%, and S18% presented an average of 22.2, 26.4, 59.5, and 76.0%, respectively. The PAR of the S18% was 3.4 times greater than that of the G+S35% (Fig. 2).

Plant height, stem diameter, number of leaves, shoot dry mass, root dry mass, total dry mass, PH/SD ratio, SDM/TDM ratio, RDM/TDM ratio, and Dickson's quality index changed significantly in response to environment, substrate, and environment x substrate interaction (Table 1).

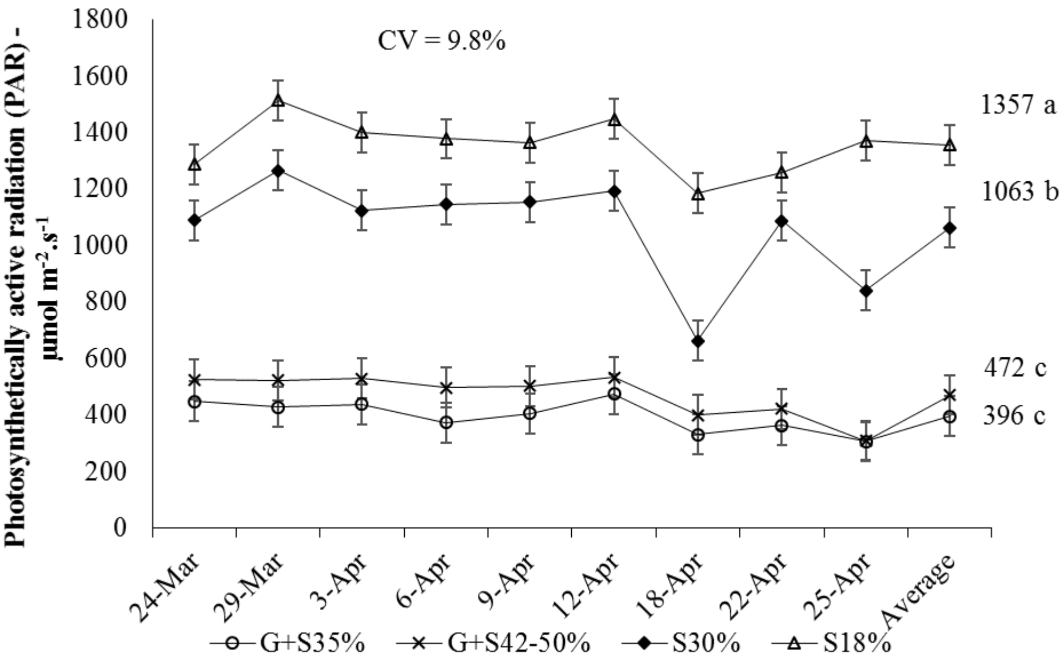

Fig. 2. Photosynthetically active radiation (PAR - μmol m^{-2} s^{-1}) in different environments from March 17 to April 25. Cassilândia, 2022.
Equal lowercase letters do not differ from each other at 5% probability according to Tukey's test. CV: coefficient of variation. S18%: screenhouse with 18% shading; S30%: screenhouse with 30% shading. G+S35%: greenhouse + Aluminet® screen with 35% shading under the plastic film. G+S42-50%: greenhouse + Luxinet® screen with 42-50% shading under the plastic film. Vertical bars correspond to standard error.

Table 1. Analysis of variance for variables plant height (PH), stem diameter (SD), number of leaves (NL), shoot dry mass (SDM), root dry mass (RDM), total dry mass (TDM), SDM/RDM ratio (RSR), PH/SD ratio (DHR), RDM/TDM ratio (RTR), and Dickson's quality index (DQI) of Guaraci Cumari do Pará yellow pepper seedlings in different protected environments and substrates. Cassilândia, 2022.

	HP	SD	LN	SDM	RDM
Environment (E)	43.0**	37.7**	68.2**	367.3**	262.6**
Substrates (S)	7.2**	14.4**	5.3**	57.3**	22.2**
A x S	4.4**	2.0*	4.2**	52.6**	19.1**
CV (%)	12.1	11.8	16.9	27.4	23.3
	TDM	**DHR**	**RSR**	**RTR**	**DQI**
Environment (E)	384.7**	1.7**	24.3**	28.0**	295.1**
Substrates (S)	47.0**	5.5**	8.6**	8.2**	32.4**
E x S	44.1**	2.5**	5.0**	5.2**	22.5**
CV (%)	23.3	11.4	21.5	9.8	23.8

ns = not significant, * significant at 1%; ** Significant at 5%. CV = coefficient of variation.

There was an increase of 18% in plant height for substrates S1 and S2 compared to S5. The G+S35% environment provided a 35% increase in seedling height, compared to the S18% environment. In the G+S35% environment, the plants in S1 were 39.8% larger than those in S4. The seedlings from the S1G+S35% treatment were 76.5% larger than those from the S5S18% treatment (Fig. 3A).

Regarding substrates S1, S2, and S3, a higher value of stem diameter was observed in environment G+S35%. Regarding substrate S5, the smallest stem diameter was observed in S18%. Regarding the G+S35% environment, there was a 35% increase in stem diameter compared to the S18% environment. The seedlings from the S1G+S35% treatment had stem diameters 64.3% larger than those of the S5S30% treatment (Fig. 3B).

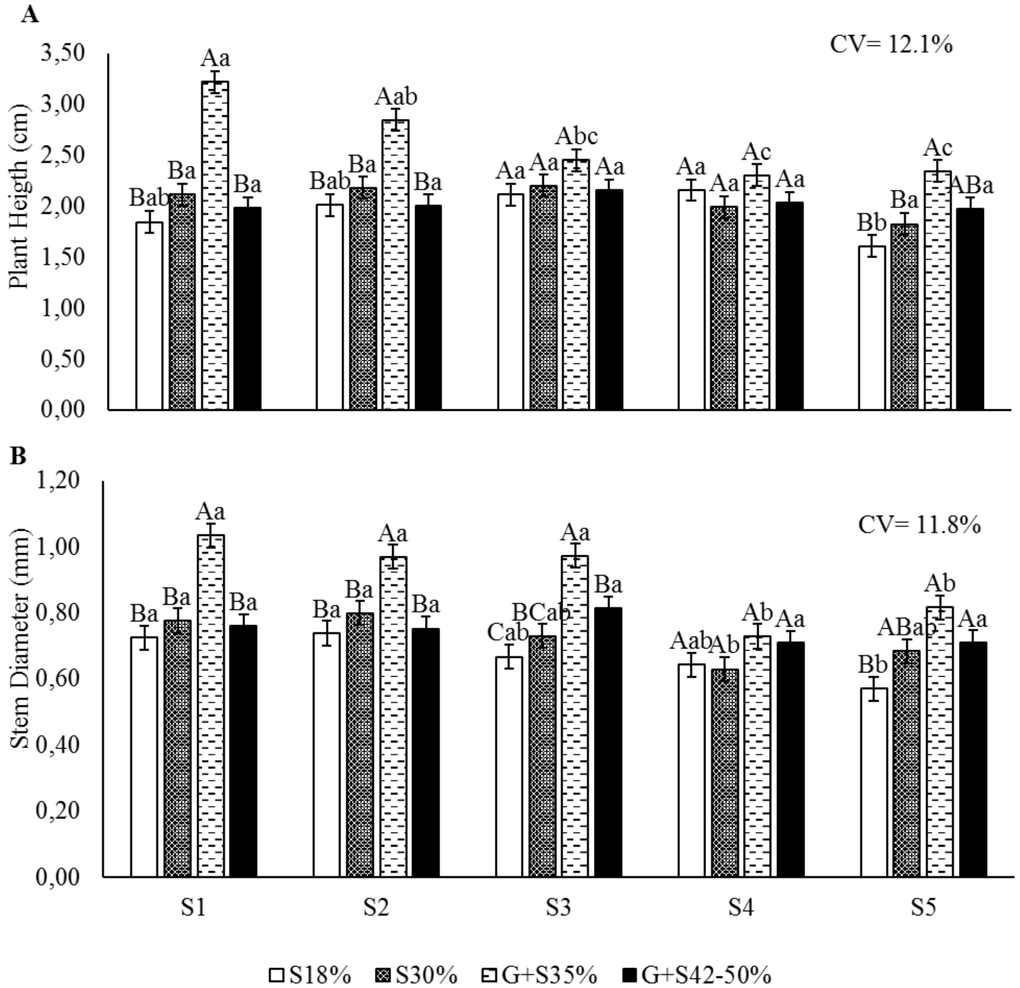

Fig. 3. Plant height (cm) (A) and stem diameter (mm) (B) of Guaraci Cumari do Pará yellow pepper seedlings (*Capsicum chinense*) in different environments and substrate compositions. Cassilândia, 2022.
Uppercase letters compare protected environments in the same substrate and lowercase letters compare substrates in the same envirionment. Similar letters do not differ from each other at 5% probability according to Tukey's test regarding each variable. CV: coefficient of variation. S18%: screenhouse with 18% shading. S30%: screenhouse with 30% shading. G+S35%: greenhouse + Aluminet® screen with 35% shading under the plastic film. G+S42-50%: greenhouse + Luxinet® screen with 42-50% shading under the plastic film. S1: 100% Carolina Soil®. S2: 80% Carolina Soil® + 20% vermiculite. S3: 60% Carolina Soil® + 40% vermiculite. S4: 40% Carolina Soil® + 60% vermiculite. S5: 20% Carolina Soil® + 80% vermiculite. Vertical bars correspond to standard error.

The highest number of green leaves was observed in substrates S1, S2, S3, S5, and the G+S35% environment. S30% and E35 environments caused the plants to have more leaves in substrate S1. There was a 71% increase in the number of green leaves in the G+S35% environment compared to the S18% environment. Substrate S1 provided 22% more leaves, compared to substrate S4 (Fig. 4A).

The relationship between height and stem diameter was higher in substrates S1 and S3 in environment G+S35%5 and S18%, respectively. Regarding the S18% environment, the highest RAD was observed in substrate S4. Regarding the G+S35% environment, the highest RAD was observed in substrates S1 and S2 (Fig. 4B).

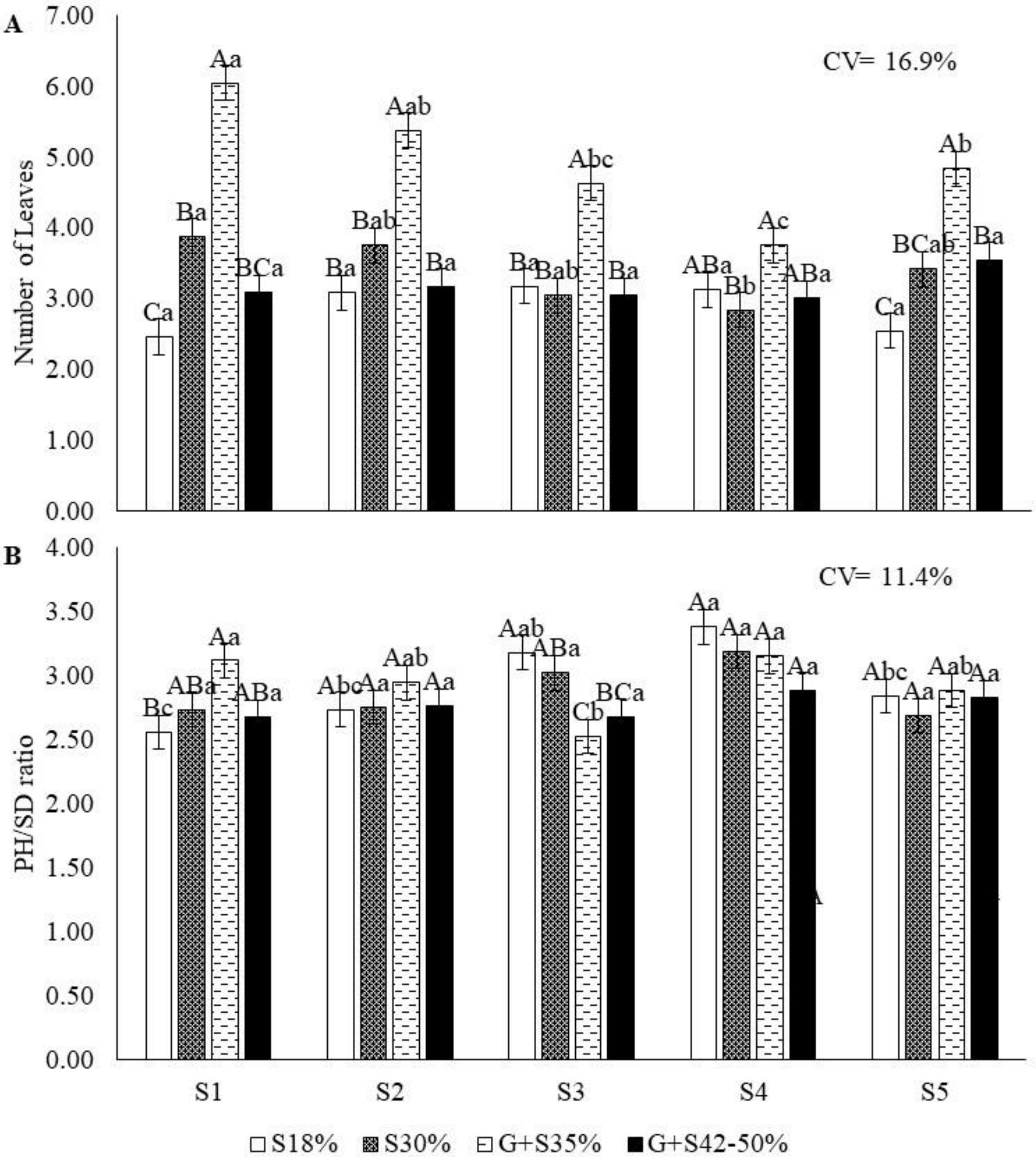

Fig. 4. Number of leaves (A) and the ratio between plant height and stem diameter (B) of Guaraci Cumari do Pará yellow pepper seedlings (*Capsicum chinense*) in different environments and substrate compositions. Cassilândia, 2022.

Uppercase letters compare protected environments in the same substrate and lowercase letters compare substrates in the same envirionment. Similar letters do not differ from each other at 5% probability according to Tukey's test for each variable. CV: coefficient of variation. S18%: screenhouse with 18% shading. S30%: screenhouse with 30% shading. G+S35%: greenhouse + Aluminet® screen with 35% shading under the plastic film. G+S42-50%: greenhouse + Luxinet® screen with 42-50% shading under the plastic film. S1: 100% Carolina Soil®. S2: 80% Carolina Soil® + 20% vermiculite. S3: 60% Carolina Soil® + 40% vermiculite. S4: 40% Carolina Soil® + 60% vermiculite. S5: 20% Carolina Soil® + 80% vermiculite. Vertical bars correspond to standard error.

Regarding the substrates, the highest dry biomass of shoots was observed in the G+S35% environment, with a dry biomass increase of 3.81 times (381%) for S1 concerning S4. Environment G+S35% provided 4.83 times (483%) more shoot dry mass than in environment S18%. Substrate S1 increased it 1.42 times (142%) compared to S5. The S1G+S35% interaction increased the shoot dry mass 20.76 times (2076%) compared to the S5S18% interaction (Fig. 5A).

Regarding the substrates, the highest dry mass of the root system was observed in the G+S35% environment, which increased 2.43 times (243%) compared to the S18% environment. In the G+S35% environment, the mass increment from S1 to S4 was 1.48 times (148%). Substrate S1 increased the root phytomass by 67% compared to substrate S5. The S1G+S35% interaction

increased 6.4 times (640%) the root dry mass compared to the S5S18% interaction (Fig. 5B).
Regarding the total dry mass in response to the substrates, the highest total dry mass was observed in the E35 environment. There was an increase in total dry mass of 356% for G+S35% compared to S18%. At G+S35%, the increase in dry mass of S1 concerning S4 was 2.65 times (265%). The S1G+S35% interaction increased 12.17 times (1217%) the total dry phytomass of plants in the S5S18% interaction (Fig. 5C).

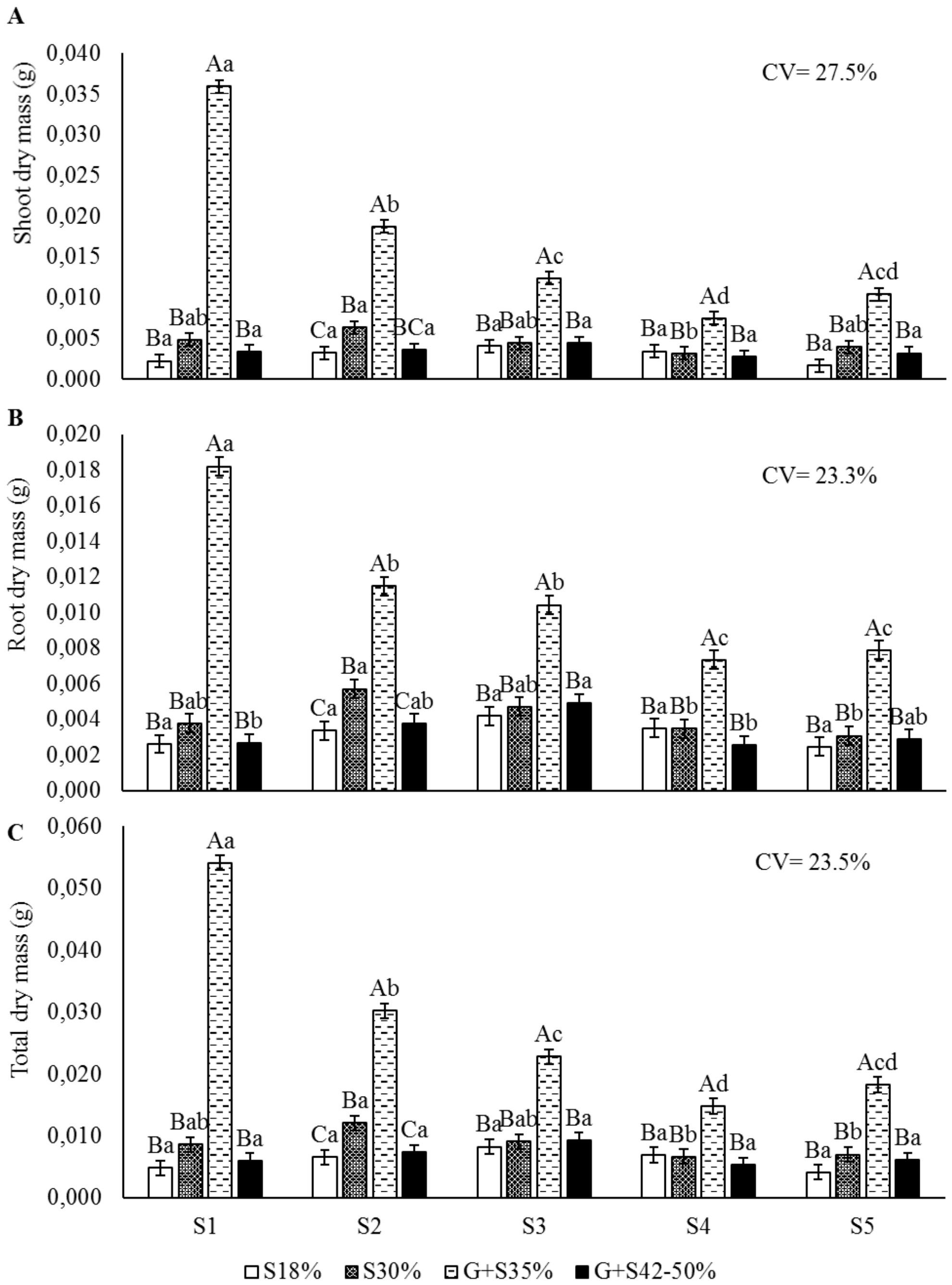

Fig. 5. Shoot dry mass (A), root system dry mass (B), and total dry mass (C) of Guaraci Cumari do Pará yellow pepper seedlings (*Capsicum chinense*) in different environments and substrate compositions. Cassilândia, 2022.

Uppercase letters compare protected environments in the same substrate and lowercase letters compare substrates in the same envirionment. Similar letters do not differ from each other at 5% probability according to Tukey's test for each variable. CV: coefficient of variation. S18%: screenhouse with 18% shading. S30%: screenhouse with 30% shading. G+S35%: greenhouse + Aluminet® screen with 35% shading under the plastic film. G+S42-50%: greenhouse

+ Luxinet® screen with 42-50% shading under the plastic film. S1: 100% Carolina Soil®. S2: 80% Carolina Soil® + 20% vermiculite. S3: 60% Carolina Soil® + 40% vermiculite. S4: 40% Carolina Soil® + 60% vermiculite. S5 = 20% Carolina Soil® + 80% vermiculite. Vertical bars correspond to standard error.

Regarding the substrates, the highest DQI occurred in response to the G+S35% environment. There was an increase in seedling quality by 2.93 times (293%) in response to G+S35% compared to S18%. At G+S35%, the increase in quality of S1 concerning S4 was 1.99 times (199%). Substrate S1 provided a 95% increase in quality compared to S4. The treatment S1G+S35% increased this trait 8.15 times (815%) the quality of seedlings in relation to the S5S18% interaction (Fig. 6).

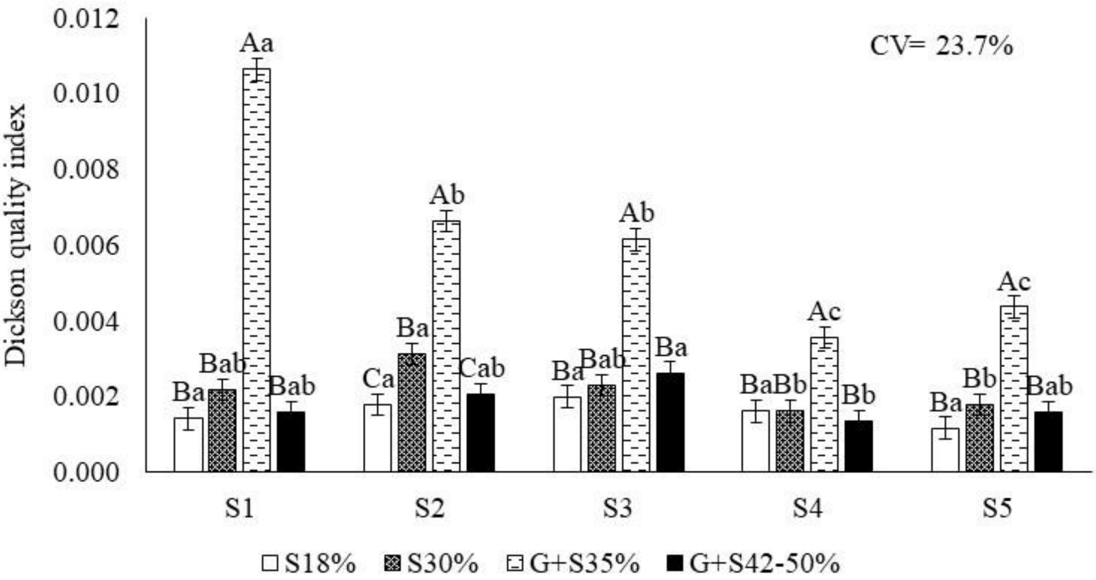

Fig. 6. Dickson's quality index Guaraci Cumari do Pará yellow pepper seedlings (*Capsicum chinense*) in different environments and substrate compositions. Cassilândia, 2022.

Uppercase letters compare protected environments in the same substrate and lowercase letters compare substrates in the same envirionment. Similar letters do not differ from each other at 5% probability according to Tukey's test. CV: coefficient of variation. S18%: screenhouse with 18% shading. S30%: screenhouse with 30% shading. G+S35%: greenhouse + Aluminet® screen with 35% shading under the plastic film. G+S42-50%: greenhouse + Luxinet® screen with 42-50% shading under the plastic film. S1: 100% Carolina Soil®. S2: 80% Carolina Soil® + 20% vermiculite. S3: 60% Carolina Soil® + 40% vermiculite. S4: 40% Carolina Soil® + 60% vermiculite. S5: 20% Carolina Soil® + 80% vermiculite. Vertical bars correspond to standard error.

Substrates S1 and S2 caused the highest RSR in the G+S35% environment. Substrate S5 had the lowest ratio in the T18 environment, while substrates S3 and S4 had no difference in their interaction with the environments. S18% and S30% environments showed no significant difference concerning the substrates for the RSR, while in the G+S35% and G+S42-50% environments, a higher RSR occurred in substrate S1. There was a 59% increase in the RSR in environment G+S35% compared to environment S18%. Substrate S1 increased the RSR by 37%, compared to the effect of S3 (Fig. 7A).

Substrates S1 and S5 had the highest RTR in the S18% environment, substrate S2 had the lowest RTR in the G+S35% environment, while substrates S3 and S4 did not show a significant difference concerning the different environments. Regarding the cultivation environments, the highest RTR occurred in response to the S18% environment. Also, the values were high with the use of the S5 substrate in the S30% environment, with the S4 substrate in the G+S35% environment, with the S3 and S4 substrates, and with the G+S42-50 environment and substrate S3 (Fig. 7B).

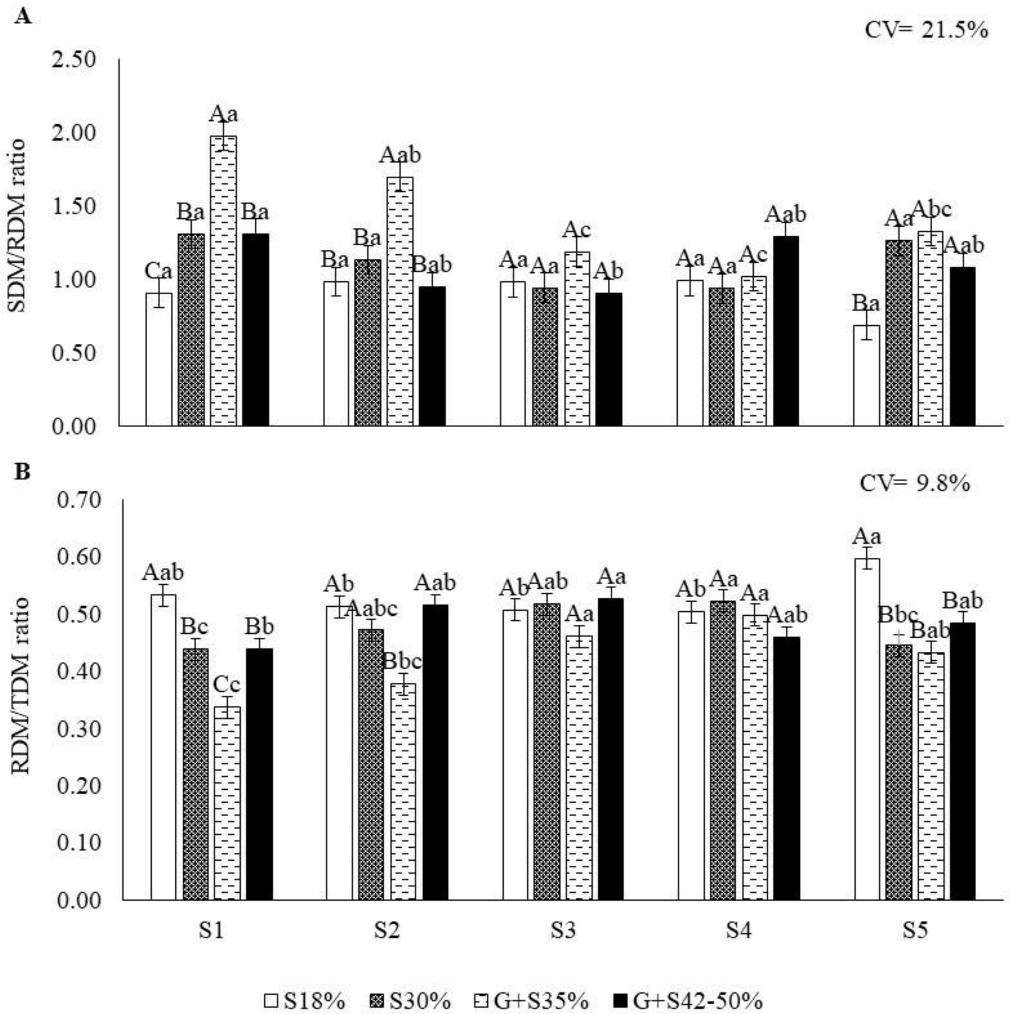

Fig. 7. Shoot dry mass and root dry mass (A), root and total dry mass (B) of Guaraci Cumari do Pará yellow pepper seedlings (*Capsicum chinense*) in different environments and substrate compositions. Cassilândia, 2022.

Uppercase letters compare protected environments in the same substrate and lowercase letters compare substrates in the same envirionment. Similar letters do not differ from each other at 5% probability according to Tukey's test for each variable. CV: coefficient of variation. S18%: screenhouse with 18% shading. S30%: screenhouse with 30% shading. G+S35%: greenhouse + Aluminet® screen with 35% shading under the plastic film. G+S42-50%: greenhouse + Luxinet® screen with 42-50% shading under the plastic film. S1: 100% Carolina Soil®. S2: 80% Carolina Soil® + 20% vermiculite. S3: 60% Carolina Soil® + 40% vermiculite. S4: 40% Carolina Soil® + 60% vermiculite. S5: 20% Carolina Soil® + 80% vermiculite. Vertical bars correspond to standard error.

Discussion

The lowest RFA enabled by the greenhouses provided better environmental conditions and favored the growth of pepper seedlings, and the highest RFA provided by the greenhouses (Paula et al., 2017; Silva et al., 2021; Moreira et al., 2021; Dantas et al., 2023), impaired the growth of this species at this stage of development.

The cultivation environment and the types of substrates used provided differences in plant growth, observed in seedling height, stem diameter, number of leaves, shoot dry mass, root system dry mass, total dry mass, and Dickson's quality index. Costa et al. (2020) and Costa et al. (2017) observed optimal pepper seedling growth in a shaded environment. On the other hand, Hassanien et al. (2022) did not observe any influence of shading on pepper growth (*Capsicum annuum* cv. 'Omega').

The substrate composition will directly influence plant growth by providing greater or lesser aeration, water retention, and nutrient availability (Nascimento et al., 2021). Vermiculite is a hydrated silicate of magnesium, aluminum, and iron. It has low density, capacity for cation exchange, and absorption of water and ions. It can help correct soil pH, increase porosity and aeration, and is highly recommended for seedling production (Pimenta et al., 2022). Commercial substrates, such as Carolina Soil® (S1), already have physical and chemical characteristics favorable to plant development.

In the present study, there was no significant influence of the commercial substrate mixture with vermiculite on the growth of pepper seedlings, except for substrate S5 (20% Carolina Soil® + 80% Vermiculite). In the T18 environment, the substrate caused shorter plant height and stem diameter but did not reduce dry mass production and Dickson's quality index. However, the highest values for plant height, number of leaves, dry mass, and Dickson's quality index were observed using the commercial substrate Carolina Soil® (treatment S1). Similarly, Ramadani et al. (2016) mixed peat and vermiculite in the production of pepper seedlings and observed that the best development of the seedlings occurred in response to adequate amounts of peat and less vermiculite.

The characteristics of plant height, stem diameter, dry mass, and Dickson's quality index are aspects of great importance in the production of high-quality seedlings (Costa et al., 2015b; Silva et al., 2019; Ramadani et al., 2016). The stem diameter can determine plant survival after transplantation, as it supports seedlings (Silva et al., 2019).

Costa et al. (2015a) observed that increasing the proportion of vermiculite in the substrate provided faster seedling emergence but did not influence the quality of pepper seedlings. Silva et al. (2019) verified a higher percentage of seedling emergence of yellow biquinho pepper (*Capsicum chinense*), chili pepper (*Capsicum frutescens*), and red and green pepper using the commercial substrate (Carolina Soil®). However, taller pepper yellow plants resulted from the mixture of substrates and the largest stem diameter when using the commercial substrate. The authors also observed a greater dry mass of shoots, roots, and total biomass when using the commercial substrate. Nascimento et al. (2021) observed a greater plant height of Cambuci pepper (*Capsicum baccatum* L. var. pendulum) when using a commercial substrate. A substrate composed of 100% peat caused taller pepper seedlings and a greater leaf area (Ramadani et al., 2016).

The substrate must provide plant nutrients and support the roots, regardless of origin. A commercial substrate provides nutrient availability and water absorption capacity in an environment conducive to plant development (Nascimento et al., 2021). The mixture of substrates alters the physical characteristics of granulometry, changing aeration, temperature, drainage, water retention, and chemical characteristics that may influence plant development (Nascimento et al., 2021).

Light is essential for plant growth, as it is directly related to metabolism, photosynthesis, and biological processes (Lima et al., 2017). Thus, a variation in the intensity of solar radiation influences the development of plants. In the present study, pepper seedlings developed better in the greenhouse environment with 35% shading.

Likewise, Costa et al. (2015b) observed better quality of cherry tomato seedlings grown in a protected environment due to its suitable temperature and humidity conditions. The greenhouse provided better radiation and seedlings with higher quality concerning the use of a screened environment.

The greenhouse environment with 35% shading provided a lower incidence of photosynthetically active radiation, greater plant height, stem diameter, number of leaves, dry mass, and Dickson's quality index, especially when using substrates S1 and S2.

Plant height, stem diameter, number of leaves, and dry mass were higher in pepper (Piper hispidinervum) when grown under 50% shading, compared to total sun exposure (Lima et al., 2017). For tomatoes, the environment with 50% shading improved plant growth parameters, such as plant height, number of branches, and dry biomass (Rao et al., 2023).

Grbic et al. (2016) observed an increase in the height of *Perilla frutescens* plants in a shaded environment, increasing it by 18% at 25% shading, but did not observe an increase in plant dry biomass. Lozano-Fernández et al. (2018) found a greater height of sweet pepper plants in a protected environment compared to the open field and a greater diameter in the open field environment. In pepper, the highest plant height, diameter, root volume, shoot dry mass, and Dickson's quality index were observed in an environment with 50% shading (Anjos et al., 2017).

These results, and those of the present study, may be due to the filtering of excess light by environments. Excess light can be harmful and cause photoinhibition, as the plant cannot use all the absorbed radiation (Lima et al., 2017). However, shading can result in thinner stems and

delay maturation (Lozano-Fernández et al., 2018).
Lima et al. (2017) observed that conditions of 30 and 50% shading provided an increase in chlorophyll a, b, and total chlorophyll content concerning total exposure to the sun, which may explain the increase in morphological characteristics. Excessive light, such as in an environment with total exposure to the sun, can accelerate the chlorophyll degradation process (Gonçalves, Santos Junior, 2005), while shaded environments can promote an increase in chlorophyll and carotenoid contents due to the process compensation (Lima et al., 2017). Lima et al. (2017) observed that conditions of 30 and 50% shading provided an increase in chlorophyll a, b, and total chlorophyll content concerning total exposure to the sun, which may explain the increase in morphological characteristics.
Another beneficial factor of shading is the increase in plant height, which can occur due to changes in the activation/inactivation of photoreceptors, allowing an increase in gibberellin production and more growth (Costa et al., 2020). Shaded environments increase plant apical dominance and lead to higher auxin transport, resulting in more cell elongation and taller plants (Rao et al., 2023).
Screens that filter light can bring qualitative gains and increase plant growth parameters (Amaro de Sales et al., 2021). The quality of light can potentially alter the physiological, biochemical, and growth processes of cultures, affecting the production and quality of the plants (Amaro de Sales et al., 2021; Lekala et al., 2019; Ntsoane et al., 2016).

Conclusion
The difference in light and substrate conditions p romoted changes in plant height, stem diameter, shoot, root, total dry mass, and Dikcson's quality index. The environment that provided the best c ulture development for all substrates was G+S35 %, increasing the quality 2.9 times. In the G+S35 % environment, S1 improved the seedling qualit y by two-fold, compared to the effect of S4 and S5 . Regarding seedling quality, the best substrate w as S1, and resulted in 95% superiority to S4 in th e average environment. The S1G+S35% improve d the seedling quality 8.2 times more than the eff ect of S2T18%.

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Conflict of Interest
The authors indicate no conflict of interest in this work.

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