ORIGINAL ARTICLE

Growth, yield and nutritional quality of Lagos spinach (*Celosia argentea* L.) as influenced by the density of goat weed (*Ageratum conyzoides* L.)

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Abstract

The benefits of Lagos spinach (*Celosia argentea* L.) as a medicinal plant and leafy vegetable encourage its production. However, goat weed (*Ageratum conyzoides* L.) is a common weed in the agroecological region where *C. argentea* thrives. Evaluation of the goat weed effect on *C. argentea* is necessary since the impact of crop-weed interaction varies with species and density. A screen-house study comprising a *C. argentea* plant with 0, 2, 4, 6, 8, and 10 goat weed plants per pot were laid out in a completely randomized design and replicated six times. The experimental treatments were equivalent to 0, 100, 200, 300, 400, and 500 goat weed plants per square meter. Growth parameters of *C. argentea,* such as plant height, number of leaves and number of branches, were recorded weekly. The study also analyzed weight, moisture, ash, lipid, dietary fiber, protein, and carbohydrate content of *C. argentea* after harvest. The results showed that all the goat weed densities negatively impacted the growth of *C. argentea.* However, 8 and 10 goat weed plants per pot seemed to have the greatest effect on the growth of *C. argentea*. The moisture content, ash, crude protein, and crude fiber of *C. argentea* were significantly reduced by 50–60%, 60–69%, 45–56%, and 42–54%, respectively, due to the goat weed densities, whereas the carbohydrate content increased. Hence, goat weed should be maintained at less than 100 plants per square meter to prevent quantitative and qualitative losses.

Keywords: *Celosia argentea*, goat weed, proximate composition, weed density

Introduction

Celosia argentea, originally from India, is commonly called "Lagos spinach" or "Sokoyokoto" in southwestern Nigeria. It is an erect, short-lived annual plant that belongs to the Amaranthaceae family (Law-Ogbomo and Ekunwe 2011; Adediran *et al.* 2015). It may be up to 150 cm in height with alternate leaves. The spikes are pink but later turn white when the seeds are mature. Seed propagation is the conventional method for producing *C. argentea*. The seeds are sown directly or transplanted after seedling emergence (Gbadamosi and Adeoluwa 2014; Ilodibia *et al.* 2016). The plant is a good source of protein, calcium, iron, and vitamins A, C, and E (Adegbaju *et al.* 2019). Hence, it is a nutritious leafy vegetable popularly cultivated in West Africa, where the leaves and the succulent shoots are used in preparing stews, sauces, and soups with other ingredients. *Celosia argentea* also serves as medicine to treat diabetes mellitus, dysentery, sores and menstruation problems (Makinde *et al.* 2016).

Production of *C. argentea* is possible in regions with a temperature range of 25 to 30°C and in well-drained, slightly acidic soils (Ayorinde *et al.* 2017). However, it is affected by weeds (Omovbude *et al.* 2016), rainfall (Nedunchezhiyan *et al.* 2020), and insect pests (Denloye *et al.* 2014). Oyekale (2014) reported a 94% reduction in the number of *C. argentea* stands in unweeded plots compared to weed-free plots.

Weeds generally compete with crop plants for water, nutrients, space and sunlight, thereby negatively affecting crop growth (Akadiri *et al*. 2017). However, there are reports that some weed species promoted crop growth (Baličević *et al*. 2014; Zohaib and Tasassum 2016). Bhandari and Sen (1979) showed that *Arnebia hispidissima* and *Borreria articularis* improved the growth and yield of pearl millet (*Pennisetum glaucum*) in India. Therefore, information on the effect of a crop's associated weed species is crucial for rational weed control decisions.

Goat weed (*Ageratum conyzoides* L.) is a common weed found in the tropics, where *C. argentea* also grows. It is an erect, herbaceous annual plant in the Asteraceae family. The plant is 30 to 80 cm in height, having fine white hairs and leaves with opposite phyllotaxy on its stems. As a mesophyte, the root system has a spread of approximately 8 cm and a shallow taproot (Kaur *et al*. 2012). Goat weed is dispersed by wind due to the presence of aristate pappus on its achene. Hence, it is a fast-spreading weed, making it a severe agricultural land invader (Kohli *et al*. 2012). Prolific seed production and allelopathy are goat weed strategies in out-competing native plants (Kaur *et al*. 2012).

A previous study showed that goat weed reduced the grain and the straw yield of rice (Kaur *et al*. 2012). Thus, it is crucial to investigate its effect on other associated crops. This study sought to identify the impact of goat weed densities on the growth, yield, and nutritional quality of *C. argentea*.

Materials and Methods

Experimental site

This study involved plant nursery and screen-house activities. The nursery and the screen-house used in this study were located at the Adekunle Ajasin University Akungba Akoko, Nigeria (7° 37'N, 5°44' E). The temperature and relative humidity (RH) in the screen-house during the trial were 22–35°C and 51–77% RH.

Collection of materials and preparation of potting media

Seeds of *C. argentea* and goat weed sourced from the Ondo State Agricultural Development Programme (ADP) Ikare-Akoko and Adekunle Ajasin University Teaching and Research Farm, Akungba-Akoko, respectively, were used for this study. The seeds were stored briefly in a paper bag and placed in a dry environment before planting. Also sourced was topsoil from 0 to 15 cm depth in fallowing farmland on the Adekunle Ajasin University Teaching and Research Farm, Akungba-Akoko. The soil collected was sandy loam. Table 1 shows the chemical properties of the soil used in this study. The soil was sieved, maintained at field capacity, and solarized for 2 weeks to deplete its weed seedbank. Nylon pots, 22 cm × 16 cm, measuring 200 cm^2 at the open end, were each filled with 10 kg soil and arranged in the screen-house.

Preparation of nursery beds for *Celosia argentea* and goat weed

To raise seedlings, *C. argentea* and goat weed seeds were sown on two separate beds measuring 1 m × 1 m each. Before sowing, the seeds were mixed with sand, and the mixtures were broadcast to facilitate uniform spread in the bed. Slight shade was made on the beds with thatch to reduce direct scorching of the sun. Also, watering was done every other day for the 2 weeks that the seedlings stayed in the nursery.

Transplanting of *Celosia argentea* and goat weed

Before transplanting, the beds were thoroughly watered to prevent root damage when removing the seedlings. Transplanting was done 2 weeks after sowing (WAS) at 2–3 leaf stage. It was done in the evening to reduce water loss through transpiration. *Celosia argentea* seedlings of uniform height were transplanted into the potting soil at the rate of one plant per pot. Goat weed seedlings were also transplanted into some of these pots at this time, according to the treatment plan.

Experimental treatment and design

The study included 0, 2, 4, 6, 8, and 10 goat weed plants per pot cohabiting with a stand of *C. argentea* as the treatments. Potted *C. argentea* plants without goat weed served as the control treatment. Based on the area of the pot used, the experimental treatments were equivalent to 0, 100, 200, 300, 400, and 500 goat weed

Table 1. Chemical properties of the potting soil

OC	OM	N	P	K	Na	Ca	Mg	EH^+	EAl^{3+}	CEC	pH	Sand	Clay	Slit
[%]			[$mg \cdot kg^{-1}$]	[$cmol \cdot kg^{-1}$]							[(1 : 2) H_2O]	[%]		
0.54	0.9	0.12	12.2	0.14	0.11	1.2	0.9	1.1	0.01	14.12	5.24	57	28	15

OC, OM, EH^+, EAl^{3+} and CEC represent organic carbon, organic matter, exchangeable hydrogen, exchangeable aluminium, and cation exchange capacity, respectively plants per square meter, respectively. The pots were arranged 1 m apart in the screen-house to prevent interaction. The experiment was laid out in a completely randomized design with six replications.

Data collection

The height and number of branches and leaves of *C. argentea* in each pot were recorded weekly. *C. argentea* plants attained commercial maturity at 8 WAS, when they were uprooted and analyzed for fresh and dry weights. Fresh samples of *C. argentea* were subjected to proximate analysis using three replicates per treatment, while the remaining three replicates were used to analyze the weights.

Proximate analysis

Samples of *C. argentea* from the treatments were subjected to proximate analysis in triplicate. The moisture content, ash, fat, dietary fiber, and protein contents were analyzed using 984.25, 942.05, 920.75, 978.10, and 988.05 methods of the Association of Official Analytical Chemists (AOAC 2012), respectively. For moisture content determination, samples were dried to a constant weight in an air-oven at 105°C. The ash was determined by placing samples in porcelain dishes in a muffle furnace at 600°C for 5 h. Soxhlet extraction was used to measure the fat content, and the dietary fiber content was determined by digesting the defatted samples with 0.26 N sulphuric acid and 0.23 N potassium hydroxide solutions. The total amount of nitrogen was determined using the micro-Kjeldahl method, and the protein content was estimated from the nitrogen present using 6.25 as the multiplying factor. The carbohydrate content was calculated by subtracting the sum of crude protein, crude fiber, ash, and lipid expressed from the total dry matter (Adegbaju *et al.* 2019).

Data analysis

The statistical analysis applied to the data obtained was Analysis of Variance (ANOVA), and the Duncan Multiple Range Test (DMRT) was used to separate the treatment means at 5% probability level. These were done using the SPSS Statistics 23 software (George and Mallery 2016).

Results

Effect of goat weed density on growth and yield of *Celosia argentea*

Goat weed density did not have a significant effect ($p < 0.05$) on the number of leaves, the number of branches, and the plant height of *C. argentea* at 2 weeks after transplanting (Fig. 1). In contrast, its effect was significant on the number of leaves and branches from 3 to 5 weeks after transplanting (WAT) and plant height at 4 and 5 WAT. Potted *C. argentea* plants with 8 and 10 goat weed plants resulted in a significantly reduced number of leaves from 3 to 5 WAT compared to the control. The cohabitation of 4, 6, 8, and 10 goat weeds with *C. argentea* resulted in a number of leaves that was not significantly different throughout the study.

The densities of goat weed evaluated in this study significantly ($p < 0.05$) reduced the number of *C. argentea* branches at 3 and 5 WAT compared to the control. The study showed that a density increase of 4 goat weed plants per pot resulted in a significantly reduced number of *C. argentea* branches at 5 WAT, except for goat weed density of 6 plants per pot that was comparable to 10 plants per pot. The *C. argentea* plants that cohabitated with 10 goat weed plants resulted in a reduced number of branches for 3 consecutive weeks.

The goat weed densities did not significantly ($p < 0.05$) affect the plant height of *C. argentea* until 4 WAT. However, a significant reduction in the plant height of *C. argentea* resulted from all goat weed densities at 4 and 5 WAT. Goat weed density of 10 plants per pot had the least plant height of *C. argentea* at 5 WAT. It was significantly less than goat weed densities of 2 and 4 plants per pot.

The goat weed densities significantly reduced the fresh weight of *C. argentea* by 49–68% at 5 WAT compared to the control (Fig. 2). Similarly, the goat weed densities of 4 and 10 plants per pot significantly reduced the dry weight of *C. argentea*. However, the goat weed densities resulted in *C. argentea* with comparable weights.

Effect of goat weed density on the nutritional quality of *Celosia argentea*

Goat weed density had a significant effect ($p < 0.05$) on the moisture, ash, crude protein, crude fiber, fat, and carbohydrate of *C. argentea* (Fig. 3). Goat weed at 4, 8, and 10 plants per pot significantly reduced the moisture content, ash, crude protein and crude fiber of *C. argentea* compared to the control. The moisture content, ash, crude protein and crude fiber of *C. argentea* was significantly reduced by 50–60, 60–69, 45–56, and 42–54%, respectively. In contrast, the carbohydrate content of *C. argentea* increased significantly ($p < 0.05$) at these goat weed densities, and 10 plants per pot had the highest carbohydrate content by a 54% increase.

The fat content of *C. argentea* was significantly decreased by 36 and 34% at goat weed densities of 4 and 10 plants per pot. However, it was comparable to the control at 2, 6, and 8 plants per pot. Goat weed densities of 2 and 6 plants per pot resulted in *C. argentea* with moisture, ash, crude protein, crude fiber, fat, and carbohydrate contents comparable to the control.

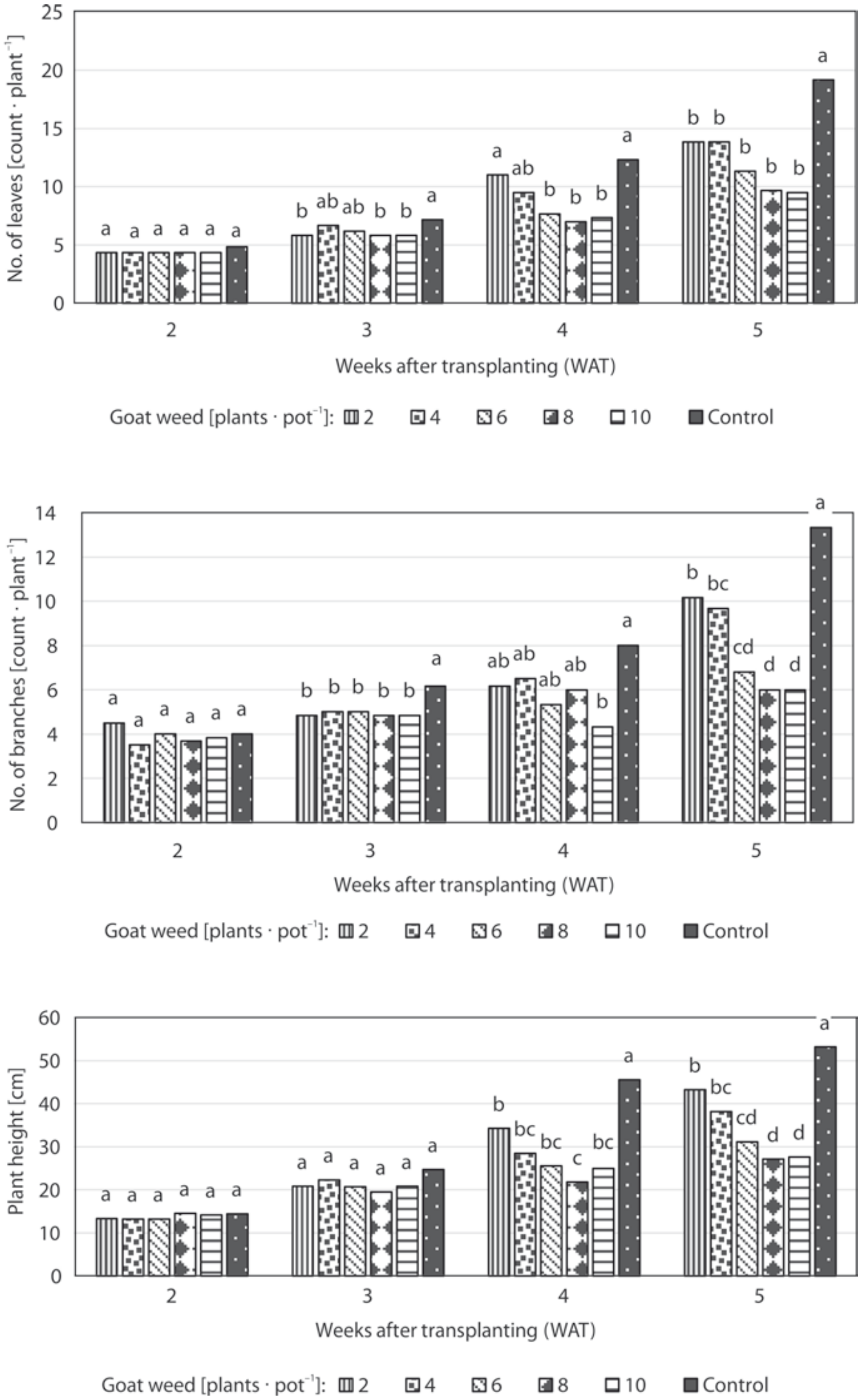

Fig. 1. Effect of goat weed density on the number of leaves, number of branches and plant height of *Celosia argentea*. Bars sharing the same letter are not significantly different, according to DMRT ($p = 0.05$)

Discussion

The growth of *C. argentea* that was not affected at the early stage of goat weed cohabitation and its reduction at the advanced stage suggest that the interference of goat weed at densities of 2, 4, 6, 8, and 10 plants per pot on the growth of *C. argentea* manifests itself over time. Similarly, Didon (2002) observed that the growth of barley (*Hordeum vulgare* L.) was not affected by the cohabitation of white mustard (*Sinapis alba* L.) until the tillering stage when growth reduction was apparent. The decrease in the growth of *C. argentea* at the later stage corroborates the report of Oyekale (2014) that the duration of weed interaction influences the growth of *C. argentea.*

The manifestation of interference caused by goat weed on the growth of *C. argentea* seems to set in early at high density. Hence, a longer duration of reduced *C. argentea* leaves resulted from the cohabitation of

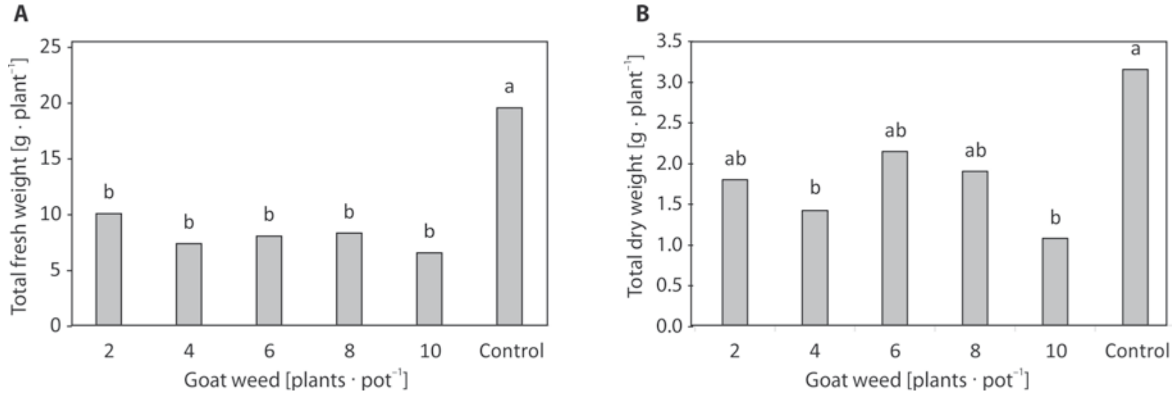

Fig. 2. Effect of goat weed density on the fresh (A) and dry (B) weight of *Celosia argentea* at 5 weeks after transplanting. Bars sharing the same letter are not significantly different, according to DMRT (p = 0.05)

8 and 10 goat weed plants per pot compared to lower densities. The study conducted by Oladokun (1978) showed that a nonlinear inverse relationship exists between the population density of some weed species and their weights. Therefore, weed population densities are capable of intraspecific competition that is not proportional. The reduction in the dry weight of *C. argentea* did not follow any trend, which suggests that the interspecific competition in *C. argentea* – goat weed interaction was influenced nonlinearly by the intraspecific competition of the goat weed densities.

The decline in the number of *C. argentea* leaves at commercial maturity indicates that goat weed densities of 2–10 plants per pot should not be allowed during the critical weed-free period of *C. argentea.* or the duration of the cohabitation of these densities should be shortened. In a previous study, Makinde *et al.* (2009) also observed a reduced number of *C. argentea* leaves in a cohabitation involving *C. argentea* and maize. The explanation for this is the greater competition for resources by companion plants at the advanced stage of growth.

During the study, visual assessment showed that increasing densities of goat weed reduced the amount of sunlight received by *C. argentea*. Shading promotes the accumulation of abscisic acid that represses branching (Yang and Li 2017). Hence, shading due to the interception of sunlight was responsible for the decline in the number of *C. argentea* branches and shorter plant heights at goat weed densities of 8 and 10 plants per pot compared to 2 and 4 plants per pot.

The negative impact of goat weed densities on the weight of *C. argentea* is due to reduced photosynthate resulting from sunlight interception and reduced water uptake. Similarly, Saberali and Mohammadi (2019) reported that the interception of sunlight due to high weed density resulted in less cowpea biomass than low weed density.

The moisture content of *C. argentea* that decreased due to goat weed density implies a propensity for dysfunctional maintenance of the protoplasmic content of the cells and flaccid plant form (Sharma *et al.* 2018). In contrast, a decrease in moisture content may increase the shelf life of *C. argentea* since microbial and chemical degradation is associated with high moisture content at post-harvest (Bal *et al.* 2011).

Ash is an inorganic constituent that cannot produce energy. The reduction in ash content of *C. argentea* caused by densities of goat weed indicated differential water uptake in the crop-weed situation compared to the weed-free situation. Bakker and Elbersen (2005) reported a direct relationship between a plant's ash content and its water uptake. The decline in the ash content of *C. argentea* corroborates previous studies that plants' coexistence causes competition for water (de Oliveira *et al.* 2018; Schappert *et al.* 2019). The reduced uptake of water in *C. argentea* – goat weed cohabitation was responsible for the decrease in the moisture content of *C. argentea*.

The decreased crude protein content of *C. argentea* indicates that its nitrogen content decreased since a positive correlation exists between nitrogen and protein (Asthir *et al.* 2017). Goat weed densities of 4, 8, and 10 plants per pot reduced the nitrogen uptake of *C. argentea* from the soil. The reduction of nitrogen uptake resulted from mitigated transpiration, an adaptive response to low moisture content (Basu 2016). The study conducted by Del Pozo *et al.* (2007) justifies this view, as it reported that transpiration and leaf nitrogen are positively correlated. Similarly, Dina and Klikoff (1973) discovered that the nitrogen content of big sagebrush (*Artemisia tridentata* Nutt.) decreased due to water stress.

Crude fiber assists the bowel movement when present in a sufficient amount in the human diet. It usually increases in plants with growth, and it indicates the woodiness of plants. The crude fiber content of *C. argentea* that decreased at goat weed densities of 4, 8, and 10 plants per pot further implies that the development of *C. argentea* was retarded by these weed densities.

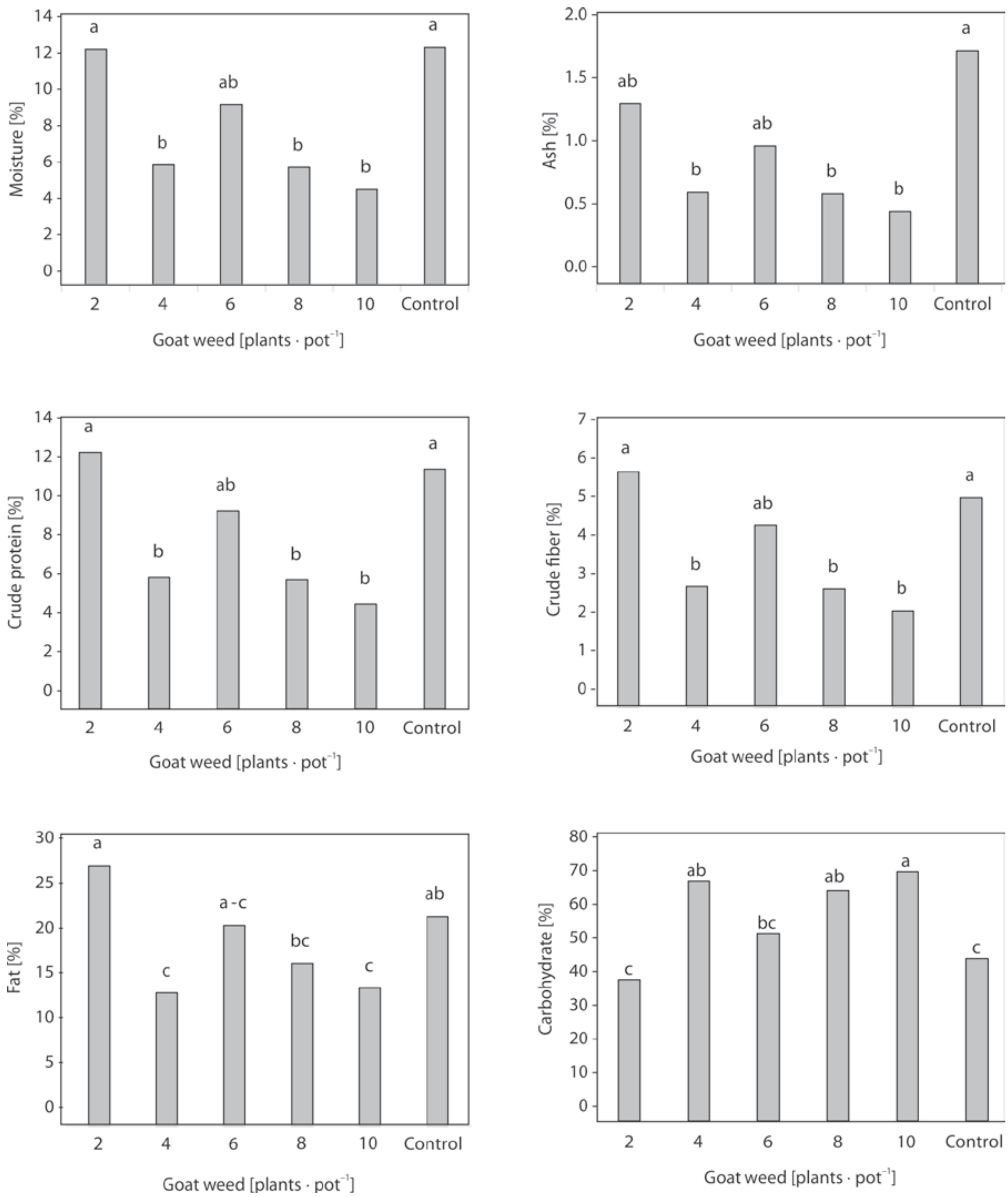

Fig. 3. Effect of goat weed density on the nutritional composition of *Celosia argentea* at 5 weeks after transplanting. Bars sharing the same letter are not significantly different, according to DMRT ($p = 0.05$)

The retarded growth of *C. argentea* by goat weed densities was responsible for the relative increase observed in its carbohydrate content compared to the control. This assertion relies on the fact that plant growth rate has an inverse correlation with carbohydrate content (Wang *et al*. 2010). Similarly, Dina and Klikoff (1973) reported that big sagebrush accumulates sugar due to retarded growth and water stress. Hence, *C. argentea,* which was unhindered in the control treatment, advanced the plant towards senescence faster, reducing its carbohydrate content. The carbohydrate content of *C. argentea* decreased because photosynthesis reduced as the plants approached senescence (Pandey *et al*. 2017).

Typically, green vegetables are sources of low fat. Therefore, the reduction of fat content by goat weed density makes the plant more suitable for managing health conditions like weight loss that requires low fat. Another positive side of goat weed cohabitation is that not all densities of this weed negatively impact the proximate nutritional value of *C. argentea.* This result suggests that the density of goat weed at some point could nullify its effects on the nutritional value of *C. argentea*. However, it may be challenging to determine the goat weed density that will not negatively impact *C. argentea* during production. Hence, the adoption of weed management is appropriate.

Conclusions

Goat weed reduced water uptake in *C. argentea* and caused sunlight interception. Its effect on the growth of *C. argentea* was more pronounced at high density. Goat weed density, ranging between 100–500 plants per square meter, negatively impacted the growth of *C. argentea*. Also, these densities altered the proximate nutritional value of *C. argentea*. Goat weed can reduce the yield of *C. argentea* and even modify the fitness of this vegetable for some specific uses. Hence, it is recommended that goat weed density should be maintained below 100 plants per square meter to prevent quantitative and qualitative losses.

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