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RESEARCH ARTICLE

Growth and yield performance of *Corchorus olitorius* under different population densities in a substrate-based hydroponics system

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ABSTRACT

Corchorus olitorius L. is a tropical vegetable grown for its culinary and medicinal attributes. However, its cultivation is at the subsistence level with little or no regard to optimal production population density. The performances of different population densities of *Corchorus olitorius* per 100 cm^2 in the hydroponics system were investigated. Seeds of *Corchorus olitorius* were planted in troughs at population densities: 10, 15, 20, 25, and 30 seeds per 100 cm^2 substrate-based hydroponics system. The experiment was laid out in a completely randomized design, replicated thrice in two cycles. Data were collected and analysed using descriptive statistics and ANOVA. Plants produced at a density of 10/100 cm^2 had the highest number of leaves (26 ± 0.9) and (42.6 ± 1.3), the highest proportion of tall plants above 30 cm (60.2 ± 2.1), (63.2±1.8) in the 1st and 2nd cycles respectively, which were significantly higher than the other treatments. However, in cycle 1, the shoot weight of plants above 30 cm was highest in population density of 15/100 cm^2 (18.4 ± 1.2 g), while in the 2nd cycle, the population density of 10/100 cm^2 had the highest shoot weight (28.0 ± 1.1 g). Hence the 10/100 cm^2 density is recommended as the optimal production population density for the cultivation of *Corchorous olitorius.*

Keywords: *Corchorous olitorius*, cocopeat substrate, hydroponics system, population density, vegetable production.

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INTRODUCTION

Vegetables are crops grown for their leaves, young shoots, and fruits for man's consumption worldwide (Ogwu et al., 2016). This act of vegetable cultivation and consumption is as old as life itself as they can be consumed raw or cooked with a mixture of other food classes due to their nutritional benefits (Ogunlade et al., 2011; Biswas, et al., 2022). However, in Africa, subsistence farmers continue to play a dominant role in the production of leafy vegetables. Unlike the developed nations of the world, vegetable production has contributed little or no input to the Nigerian Gross Domestic Production as the little produce could barely serve the large market demand in the country to talk of exporting (Iddrisu et al., 2020). This is a result of the lack of a mechanized system of vegetable production leaving vegetable production at the farmhand level, while attention is being centred on cereals and tubers (Thompson et al., 2011). In this present subsistence level of vegetable farming, depending on the environmental conditions of the locality, farmers rely solely on the inherent soil conditions with little or no input for the cultivation of leafy vegetables (Ogwu et al., 2016). As seeds of the vegetable are broadcastediced on open soil or raised in a nursery form with no regard for the population density, the plants are left to fate in survival by the fittest situation, while the fortunate ones to first outgrow the peers are thus harvested by the farmers for consumption.

Notable among the vegetables produced in Nigeria are tomato, cucurbits, alliums, chillies, amaranthus, *Telfera*, and *Corchorous* (Schreinemachers et al., 2018). *Corchorous olitorius* is an underutilised leafy vegetable which has several medicinal properties and nutritional benefits (Atalar, et al., 2023). The species is locally known by different names in Nigeria, it is called Ahihara by the Igbo, Ewedu by the Yoruba, and Malafiya by the Hausa (Ogunkanmi et al., 2010). The leaves of *Corchorous olitorius* possess high levels of iron, folate, protein, fibre, calcium, riboflavin, carotene, vitamin C and phenol (Abu-Khalaf et al., 2013) with low anti-nutrients, but zinc bioavailability is high (Akindahunsi & Salawu, 2005). However, the *Corchorous* production has received the least attention among others as the farmers tend to come across them accidentally in the field and monitor them until they reach the harvesting stage (Karki et al., 2022). As a consequence, coupled with other biotic and abiotic constraints, the growth and productivity of *Corchorous olitorius* in Nigeria remain sub-optimal.

Hydroponic production is the technique of growing plants in an environment devoid of soil with nutrients, water, and an inert medium which could be gravel, sand, pearlite, and cocopeat among others (Alfredo, 2018). Reports show that the use of hydroponic in the production of high-value fresh vegetables promotes higher nutritional quality due to the high accumulation of bioactive compounds; for instance, increased macro- and micronutrients and antioxidants were reported in hydroponics of tomatoes compared to the soil-based approach (Premuzic 1998, Alfredo, 2018). The hydroponics system has been fully advocated and used in developed countries for vegetable production. This system involves the production of crops in any substrate other than soil, for example, the cocopeat. This presents an alternative to the peasant soil system as reported for watermelon (Ossai et al., 2021) and gives room for the manipulation of the growth conditions. This study thus utilizes the hydroponics system in the cultivation of the much-neglected *Corchorous olitorius* by assessing the effect of population density on the growth and yield of the crop.

MATERIALS AND METHODS

Substrate preparation

Buffered cocopeat blocks were purchased from the Soilless Farmlab, Abeokuta. They were dissolved in water (30 litres of water per block) and the moistened cocopeat substrate was poured into a 4 kg capacity hydroponics trough with a dimension of 10 cm by 10 cm.

Experimental set-up

Seeds of *Corchorous olitorius* were planted in the troughs following the densities below as treatments;

1. 10 seeds per 100 cm^2
2. 15 seeds per 100 cm^2
3. 20 seeds per 100 cm^2
4. 25 seeds per 100 cm^2
5. 30 seeds per 100 cm^2

Experimental Design/cycle of set-up

The experiment was laid out in a completely randomized design, and replicated thrice. The experiment was carried out in two cycles (1 and 2) corresponding to the dry season (cycle 1: March) and the rainy season (cycle 2: May). Figure 1 shows the setup of the hydroponics system for the cultivation of *Corchorous olitorius.*

Figure 1. Hydroponics system used for the cultivation of *Corchorous olitorius*

Crop Husbandry

The plants were watered daily and once per week, 250 g of poultry manure was applied to each trough for the plant's nutrient uptake and growth.

Data Collection

Data were collected for the following parameters; the germination percentage (GP), plant height (PH), number of leaves (NOL), leaf Area (LA), percentage of plants above 30 cm high (in proportion to number planted per treatment), percentage of plants between 20 and 30 cm high, percentage of plants below 20 cm high, weight of plants above 30 cm high (in proportion to number planted per treatment), weight of plants between 20 and 30 cm high, weight of plants below 20 cm high

Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA), and significantly different treatment means were separated using Least Significance Differences (LSD) at a 5% level of significance.

RESULTS

Effect of different planting densities on the germination and growth parameters of Corchorous olitorus planted in a hydroponics system in dry and rainy seasons

Results obtained from analysis of variance revealed significant differences ($p < 0.05$) among the treatments in the parameters considered for the effect of different planting densities on the germination and growth parameters of *Corchorous olitorus* planted in a hydroponics system in dry and rainy seasons except for the germination percentage of the Corchorous seeds in the first cycle of planting seasons (Table 1). In the second cycle of planting, the plant population of 10 / 100 cm^2 had the highest germination percentage (97.0 ± 2.6%) which was not significantly different from the population of 15 /100 cm^2 (91.6 ± 2.6%) but was significantly higher than the other treatments with higher population density. In the 1st planting cycle, the height of the plants in the plant population of 10 / 100 cm^2 (39.0 ±1.0 cm) and the population of 15 per trough (37.4 ± 1.0 cm) were significantly different from each other ($p < 0.05$), but the former was significantly taller than the other treatments with higher population densities. However, in the second cycle, the plant height obtained in the population density of 10 / 100 cm^2 (49.7 ± 2.1 cm) was significantly taller than the other treatments.

In the 1st cycle, the number of leaves produced by the plants in population density of 10/100 cm^2 (26.0 ± 0.9) was not significantly different from the population density of 15/100 cm^2 (23.0 ± 0.92) Whereas, in the 2nd cycle of planting, the number of leaves produced in the population density of 10/100 cm^2 (42.0 ± 1.3) was significantly higher than the other treatments. On the area of leaves produced, the plants with a population density of 10/100 cm^2 (54.9 ± 3.9 cm^2) were the largest, nonetheless, it was only significantly larger than the leaf area obtained in the plant population density of 30/100 cm^2 (38.0 ± 3.9 cm^2). In the 2nd cycle of planting, the leaf area obtained in the population densities of 10/100 cm^2 (59.6 ± 2.9 cm^2), 15/100 cm^2 (47.7 ± 2.9 cm^2), and 20/100 cm^2 (51.7 ± 2.9 cm^2) were not significantly different, however, the leaf area obtained in the density of 10/100 cm^2 was significantly larger than that of 25/100 cm^2 (39.0 ± 2.9 cm^2) and 30/100 cm^2 (43.7 ± 2.9 cm^2), respectively.

Effect of different planting densities on size proportions of *Corchorous olitorus* planted in a hydroponics system in dry and rainy seasons at harvest

Results obtained from the analysis of variance revealed significant differences ($p < 0.05$) among the treatments (population densities) on the different size proportions in the 1st and 2nd planting cycles (Figure 1).

The percent proportion of plants with a height above 30 cm in the density of 10/100 cm^2 in the 1st cycle (60.24±2.1) and 2nd cycle (63.2±1.8), respectively were significantly ($p < 0.05$) higher than the proportions obtained in the other population densities in the 2 cycles of planting.

Table 1. Effect of different planting densities on the germination and growth parameters of *Corchorous olitorus* planted in hydroponics system in dry and rainy seasons

	Germination (%)		Plant height (cm)		Number of leaves		Leaf area (cm^2)	
Densities	Cycle1	Cycle2	Cycle1	Cycle2	Cycle1	Cycle2	Cycle1	Cycle2
Ten	96.0^{a}	97.0^{a}	39.0^{a}	49.7^{a}	26.0^{a}	42.0^{a}	54.9^{a}	59.6^{a}
Fifteen	89.4^{a}	91.6^{ab}	37.4^{ab}	43.4^{b}	23.0^{ab}	35.0^{b}	54.1^{a}	47.7^{ab}
Twenty	86.0^{a}	89.0^{b}	32.8^{bc}	37.8^{bc}	23.0^{b}	28.0^{c}	52.7^{a}	51.7^{ab}
Twenty-five	84.8^{a}	81.0^{c}	30.2^{c}	32.2^{c}	19.0^{c}	23.0^{d}	43.6^{ab}	39.0^{c}
Thirty	84.6^{a}	86.6^{bc}	28.2^{c}	31.8^{c}	18.0^{c}	23.0^{d}	38.5^{b}	43.7^{bc}
LSD (0.05)	12.4	7.7	4.9	6.3	2.7	3.9	11.6	8.7
SE	4.2	2.6	1.0	2.1	0.9	1.3	3.9	2.9

Means followed by the same letter down the group are not significantly different from each other at 5% level of significance. LSD: Least significance differences, SE: Standard error.

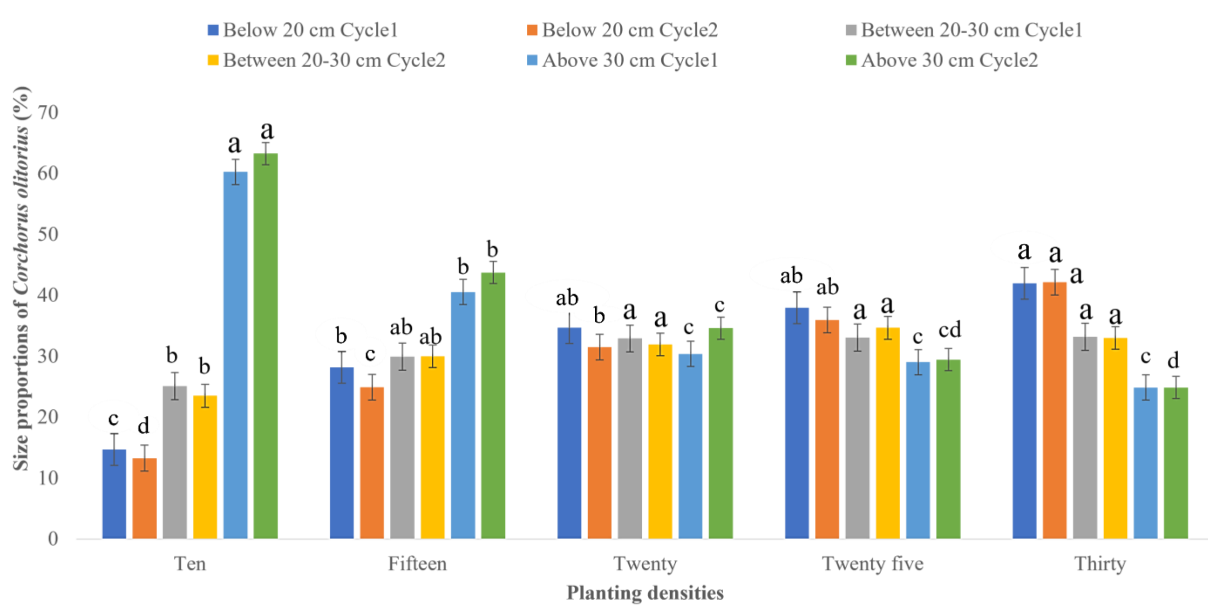

Figure 1. Effect of different planting densities on size proportions of *Corchorus olitorus* planted in a hydroponics system in dry (Cyclie 1), and rainy (Cycle 2) seasons at harvest. Means followed by the same letter across the groups are not significantly different from each other at a 5% level of significance using Least significance differences (LSD) Values are means ± Standard error.

However, the percent proportions between the range of 20 to 30 cm height had its highest number observed in the population density of 30/100 cm^2 (31.2 ± 2.2%) in the 1st cycle, which was only significantly higher than the proportion obtained in the density of 10/100 cm^2 (25.1 ± 2.2%), while in the 2nd cycle, the highest proportion was observed in the population density of 25/100 cm^2 (34.7 ± 1.9%), and it was also significantly higher than the population density of 10/100 cm^2 (23.5±1.9%). In the 1st cycle of planting, the percent proportion of the plants below 20 cm was significantly highest in the population density of 30/100 cm^2 (41.9 ± 2.60%) than the plants in the population density of 10/100 cm^2 (14.7 ± 2.6%) and 15/100 cm^2 (28.1 ± 2.60%), respectively. Whereas in the 2nd cycle of planting, the proportion of plants below 20 cm height in the population density of 30/100 cm^2 (42.1±2.1) was not significantly different from that of 25/100 cm^2 (35.9 ± 2.1) but was significantly higher than the other treatments.

Effect of different planting densities on the weight proportions of *Corchorous olitorus* plants planted in a hydroponics system in dry and rainy seasons at harvest

Results obtained on the effect of different planting densities on the weight proportions of *Corchorus olitorus* planted in a hydroponics system in the 1st and 2nd planting cycles at harvest showed varied significant differences among the different plant population densities (treatments) in terms of the weight of different plant size categories (Table 2). In the 1st cycle of cultivation, the treatment with a plant population density of 15/100 cm^2 had the heaviest shoot weight (18.4 ±1.2 g) of plants with height above 30 cm, and this was significantly heavier than the other treatments (population densities). However, in the 2nd cycle, the weight of the plants above 30 cm high in the population density of 10/100 cm^2 (28.0 ±1.1) was significantly heavier than the other treatments. In the plants between 20 and 30 cm high, the population density of 20/100 cm^2 produced the heaviest shoots of 14.1 ± 0.7 g and 13.0 ± 0.6 g in the 1st and 2nd cycles of planting, respectively which were significantly heavier than the weights obtained in the other population densities. Finally, in the weight of the shoots below 20 cm high in both 1st and 2nd planting cycles, plants grown in a population density of 25/100 cm^2 had the heaviest weight of 10.0 ± 0.4 and 6.6 ± 0.5, respectively, which was significantly heavier than the rest treatments (population densities).

Table 2. Effect of different planting densities on the weight proportions of *Corchorous olitorus* plants planted in hydroponics system in dry and rainy seasons at harvest

	Weight of plants above 30 cm (g)		Weight of plants between 20-30 cm (g)		Weight of plants below 20 cm (g)	
Densities	Cycle1	Cycle2	Cycle1	Cycle2	Cycle1	Cycle2
Ten	12.0^{bc}	28.0^{a}	3.8^{c}	4.9^{c}	1.6^{c}	1.6^{d}
Fifteen	18.4^{a}	23.1^{b}	7.7^{b}	10.0^{b}	1.5^{c}	3.3^{c}
Twenty	14.4^{b}	16.7^{c}	14.1^{a}	13.0^{a}	3.9^{b}	4.9^{b}
Twenty-five	08.6^{c}	16.4^{c}	8.1^{b}	10.7^{b}	10.0^{a}	6.5^{a}
Thirty	14.0^{b}	15.2^{c}	8.4^{b}	9.9^{b}	3.9^{b}	4.3^{bc}
LSD (0.05)	3.5	3.3	2.2	1.9	1.2	1.3
SE	1.2	1.1	0.8	0.6	0.4	0.5

Means with the same letter, down the groups are not significantly different from each other at 5% level of significance. LSD: Least significance differences, SE: Standard error.

DISCUSSION

In this study, both the 1st and 2nd cycle of plantings had a seed germination rate of 81% and above in the different planting densities. However, the less-density treatments had the highest germination rate. This shows that despite the viable state of the seeds, the population density still had little effect on the germination rate of seed which can be in form of mechanical constraint, as some seeds can fall on top of other seeds that dropped earlier, or some seeds may have fallen off the platform. Also, the period of planting contributed to the germination rate as the later plantings (cycle 2) had an improved germination rate relative to the 1st cycle.

The height, number of leaves, and leaf area of the plants grown in a population density of 10/100 cm^2 plants/trough were the highest among the different population densities. However, these parameters were not significantly different from the plants grown in a population density of 15/100 cm^2 which is closest to 10/100 cm^2. This shows that at a lower population density, the majority of the plants grew steadily at a similar pace, hence, some are not being shaded from phototropism. This agrees with the findings of Law-Ogbomo and Osaigbowo (2016). Also, the lesser the number of plants receiving the available food (nutrient) from the surroundings, the more even the nutrients are being spread across the available plants. Thus, the reason for the lower leaf production rate in the more densely populated treatments with reduced food production rate is a direct result of competition. Makinde et al. (2009) also reported a highly significant effect of overpopulation on the population of *Corchorus olitorius*.

The proportion of plants above 30 cm high in the population density of 10/100 cm^2 was higher than the other population densities, and there was a decreasing proportion as the population density increased. However, the reverse was the case in the proportions below 30 cm high where the 25/100 cm^2 and 30/100 cm^2 population densities had the lowest values in the 1st and 2nd cycles respectively. This shows that there was a more repressive effect by few plants on the peers in the more populated densities than 10/100 cm^2, thereby retarding their growth and development. This is a direct consequence of overcrowding which was less telling in the more spaced population density. Kshkooll et al. (2020) also observed the enhanced physiological development of plants in an optimally spaced planting condition rise as the chances of photosynthetic activity increase.

Despite the higher proportion obtained in the population density of 10/100 cm^2, it was the population density of 15/100 cm^2 that gave the highest shoot weight in the categories above 30 cm high in the first cycle. This could be to the higher value in actual number which when worked out in a proportionate value might be less as the former is being divided by a factor of 10, while the latter is by a factor of 15. Contrary to the weight obtained in the 1st cycle, the second cycle had the highest weight of 30 cm above the category produced in the population density of 10/100 cm^2, which indicated a much proportionate gap in their actual number relative to the divisive factors. However, the weight obtained in the category between 20 and 30 cm high showed the population density of 20 having the highest weight relative to the rest population densities, while the category below 20 cm had its highest weight in the population density of 25. This shows that despite the repressive situation by some of the outliers in the population, much of the plant proportions grew steadily at an average rate. The significant effect of intraspecific competition on the growth and yield of *Celosia argentea* has also been reported by Makinde and Macarthy (2006). Different vegetable crops have been successfully cultivated using the hydroponics system in advanced countries, and this research has shown the practicability of using a hydroponics system in the cultivation of *Corchorous olitorius* as it offers an alternative to soil farming constraints due to their ease of manipulation without secondary effect on the surrounding environment (Ossai et al., 2021).

CONCLUSION

Corchorous olitorius is an important vegetable worldwide due to its wide array of nutritional benefits. This study has demonstrated the practicability of *Corchorous olitorius* production using the hydroponics system as an alternative to soil farming at the peasantry level. However, while cultivating it in a hydroponics system, adequate attention should be given to the population density per trough size as overcrowding will hinder its optimal growth and yield. We recommend a population density of 10/100 cm^2 density as the optimal production population density for the cultivation of *Corchorous olitorius* in a hydroponic system.

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AUTHORS CONTRIBUTION STATEMENT

All the authors contributed to this research work and manuscript preparation. Also, all authors meticulously proofread, reviewed, and approved the final version of the article.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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