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Growth Performance of *Corchorus olitorius* (L.) under Varying Water Stress Conditions

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ABSTRACT

Although water deficit is a major constraint for vegetable crop production in tropical sub-Saharan Africa, systematic growth-analytical characterization of Jute Mallow, (*Corchorus olitorius* L.*; Tiliaceae)* under the various soil moisture stresses, is limited. In this study, the agronomic performance (classical growth analysis indices) of two varieties of *C. olitorius (Oniyaya* and Gbadu) were evaluated in relation to four water stress regimes under screen-house experiment conditions. The seeds were from the National Horticultural Research Institute (NIHORT), Ibadan, Nigeria and were planted in 4.5 litre plastic pots containing sandy-loam soil in a completely randomized design (CRD) with three replicates. The four water stress treatments applied were 100% field capacity (FC; control), 75%, 50% and 25% FC, each applied after 3 days (August – October, University of Agriculture, Abeokuta, Nigeria 7° 15′ N, 3° 25′ E). Agronomic parameters measured were plant height, number of leaves, leaf area, shoot dry weight, pod number, pod length, pod dry weight, relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR) measured weekly. An increase in water deficit resulted in significant ($P<0.05$) reduction in all agronomic parameters. The plant height of Oniyaya decreased from 65.00cm to 51.47cm as well as NAR and LAR which were also gradually reduced at 25% FC, while RGR found to be reduced from 0.61g g-1 month-1 to 0.25g g-1 month-1. Oniyaya also performed better than Gbadu in all parameters and under all stresses. Growth of *C. olitorius* and its yield is significantly affected by water stress. Oniyaya showed greater tolerance to drought and is recommended to be planted in water deficient conditions.

Keywords: *Corchorus olitorius*; Growth Analysis; Relative Growth Rate; Net Assimilation Rate; Leaf Area Ratio; Field Capacity; and Drought Stress

INTRODUCTION

Leafy vegetables are essential staple components of food and nutritional security in the tropical sub-Saharan African region, where they supply essential vitamins, minerals, dietary fibre, and secondary metabolites that complement staple cereal and tuber diets (Guzzetti *et al.*, 2021). Of these, jute mallow (*Corchorus olitorius L.; Tiliaceae*) is of special interest; it is a subsistence food crop and an income generation vegetable that is widely cultivated throughout Nigeria, Ghana, Egypt and other parts of West and North Africa (Guzzetti *et al.,* 2021). The leaves are mucilaginous and high in β-carotene, vitamin C, iron and calcium and are particularly significant for combating micronutrient deficiencies in rural populations (Sarker and Oba, 2020). Although *C. olitorius* is an important food plant, its cultivation is mainly rain fed in West Africa and thus highly susceptible to drought stress. Ayanlade *et al.* (2022) highlighted that with the changes in precipitation over Guinea Savanna zone of Nigeria, there is increasing frequency and severity of within-season dry spells, which pose threats to the consistent productivity of leafy vegetable systems. Water stress is known to affect the growth of vegetables by causing a decrease in turgor pressure, stomatal closure, reduction in carbon assimilation and decrease in nutrient uptake, all of which can be quantified using classical growth analysis (Mkhabela *et al.,* 2021) and all these physiological cascades have been demonstrated in jute species under drought, salinity and waterlogging stress (Rahman *et al.,* 2021a; Rahman *et al.,* 2021b). Growth analysis, such as the relative growth rate (RGR), net assimilation rate (NAR) and leaf area ratio (LAR), offers a mechanistic basis to understand the physiology underlying the growth response to environmental stress (Poorter *et al.*, 2019; Ajayi *et al*., 2026). RGR combines the efficiency of dry matter production (NAR) and the amount of leaf surface per unit of dry matter (LAR). Stomatal closure under water deficit results in suppression of NAR, but declining LAR (due to reduced leaf growth and premature senescence) increases the rate of reduction of RGR (Hatfield and Dold, 2019). While these relationships have been reported in various vegetable crops (Mkhabela *et al.,* 2021), they are poorly understood for *C. olitorius* varieties grown in southwest Nigeria, which is a target area for breeding the crop (Chourasia *et al.*, 2025). The Nigerian grown *C. olitorius* varieties, Oniyaya and Gbadu, have contrasting morphology and production characteristics under optimal soil-water conditions but their relative performance to increasing soil water deficits has not been carefully measured. This study was thus conceived to determine the entire set of agronomic performance components of Oniyaya and Gbadu in a controlled screen-house under four levels of water stress with special consideration of growth analysis indices.

MATERIALS AND METHODS

Study Area Geographical

The experiment was carried out in the College of Plant Science, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. During the rainy seasons of August – October, 2025. The geographical Coordinates of Abeokuta and FUNAAB are (latitude 7° 15′ N, longitude 3° 34′ E) and (latitude 7° 22′ N, longitude 3° 44′ E) respectively.

In the screen-house, rainfall was eliminated and soil moisture contents were carefully controlled during the experiment. The mean rainfall and temperature during the cropping season varied between 1200mm to 1500mm and 26 – 30^{O}C, respectively. Relative Humidity ranging from 63% to 96% and soil temperature ranges between 24.5 ^{O}C and 31.0 ^{O}C. Two cultivars of *Corchorus olitorius* L. (C1 - Oniyaya and C2 - Gbadu) were selected as sources of seeds. The seeds used were from the National Horticultural Research Institute, Ibadan, Nigeria. The two varieties are common in south western Nigeria for their mucilaginous leaves and are different morphological types of the species (Guzzetti *et al.,* 2021).

Soil Preparation and Potting

The soil sample was taken at 30cm depth from the FADAMA farm, Federal University of Agriculture Abeokuta, which is sandy-loam, and stones and pebbles were removed from the sample by sieving. Eight kg of homogenized soil was added to 4.5 litre perforated plastic pots (19 cm diameter and 20 cm deep). Pots were wet to 100% (field capacity) and subsequently allowed to be in equilibration for 72 hours prior to sowing. Gravimetric field capacity was calculated by the method developed by Liyanage *et al.* (2022).

Experimental Design and Water Stress Treatments

The experiment followed a completely randomised design (CRD) with four water stress treatments and three replications. These treatments consisted of 100% field capacity (FC) as the control, alongside 75%, 50%, and 25% FC. Treatments were initiated two weeks after germination. Water was added in three-day intervals by weighing gravimetrically the correct volume of water to obtain the intended water level for each pot. This protocol is based on the pot experiments, in which deficit irrigation is applied, under the following methodology (Liyanage *et al.,* 2022).

Planting and Plant Establishment

The seeds were sown at 5 mm depth at a rate of five seeds per pot, and thinned to twenty uniform seedlings per pot 7 days after emergence to ensure uniform stands and resource allocation to experimental units.

Agronomic Measurements

Parameters were measured at 7day intervals from 2 weeks after planting to harvest. Measurements taken were: plant height (cm) with a calibrated metre rule, number of leaves per plant (direct count), leaf area (cm2) measured as length of leaf × breadth of leaf, shoot dry weight (g), after 72 hours of oven drying to constant weight at 60°C in an electric oven, pod number (direct count), pod length (cm) measured with a ruler and pod dry weight (g) measured after 72 hours of oven drying to constant weight at 60°C in an electric oven.

Growth Analysis

Classical growth analysis formulae of Poorter *et al.,* (2022) and subsequently applied by Ajayi & Ojewumi (2023), were used to calculate relative growth rate (RGR, g g^{-1} $month^{-1}$), net assimilation rate (NAR, g g^{-1} $month^{-1}$), and leaf area ratio (LAR, cm^2 g^{-1}).

$RGR = (\ln W_2 - \ln W_1) / (t_2 - t_1)$

$NAR = [(W_2 - W_1) / (\ln A_2 - \ln A_1)] \times [(\ln A_2 - \ln A_1) / (t_2 - t_1)]$

LAR is the ratio of the total leaf area (A) to the total plant dry weight (W).

It is valid when the leaf area is measured at two different time points (A_1 and A_2) and the plant dry weight is measured at the same time (W_1 and W_2).

Data Analysis

One-way analysis of variance (ANOVA) was used to analyze the data in SPSS Statistics Version 27 (IBM Corp., 2020). The least significant difference (LSD) test was used to separate treatment means at P<0.05. All values given as Mean ± SE. Matplotlib (Matplotlib Development Team, 2023) was used to create figures with the aid of Python 3.11.

RESULTS AND DISCUSSION

Water Stress Negatively Affects Plant Height

The mean height of both varieties of *C. olitorius* was significantly (P<0.05) affected by water stress at all water deficits (Figure 1). Oniyaya height declined from 65.00 ± 3.00 cm at control to 51.47 ± 7.61 cm at 25% FC which is a reduction of 21%. Gbadu declined from 57.67 ± 4.93 cm at control to 50.00 ± 2.65 cm at 25% FC (13% reduction). Oniyaya was significantly taller than Gbadu at all treatment levels (P<0.05) due to the bigger vegetative architecture.

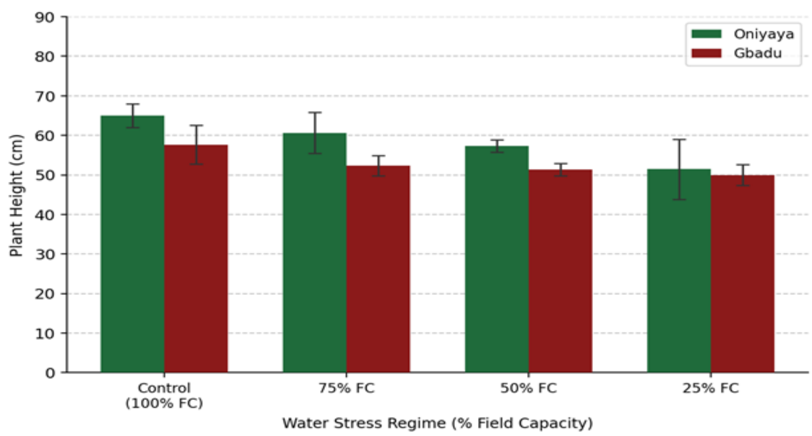

Figure 1: Effect of water stress on mean plant height (cm) of two varieties of *Corchorus olitorius*. Error bars = ± SE (n=3)

The number of leaves decreased with increasing water stress (Figure 2).
Both varieties showed significant (P<0.05) decreases in leaf number per plant, as the water deficit increased (Figure 2). Oniyaya produced 36.00 ± 3.65 leaves at control, declining to 23.25 ± 4.99 at 25% FC (a 35% reduction). Gbadu declined from 20.50 ± 3.11 to 16.00 ± 2.00 leaves over the same range. The leaf count of oniyaya was consistently higher than Gbadu at all stress levels, indicating a greater overall vegetative vigour of oniyaya than Gbadu.

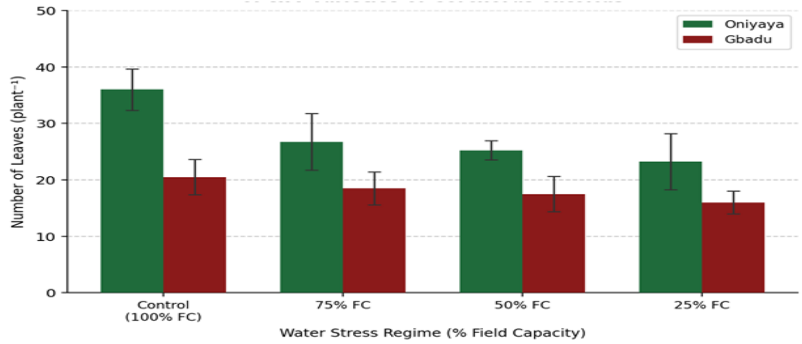

Figure 2: The mean number of leaves/plant of two varieties *Corchorus olitorius* under water stress. Error bars = ± SE (n=3)

Water deficit was found to significantly affect the leaf area. As water deficit increased, for both varieties, leaf area was significantly reduced (P<0.05) (Figure 3). Oniyaya mean leaf area declined markedly from 203.92 ± 6.22 cm² at control to 67.51 ± 4.86 cm² at 25% FC (65% reduction) whilst Gbadu declined from 64.77 ± 3.38 cm² to 47.64 ± 5.61 cm².

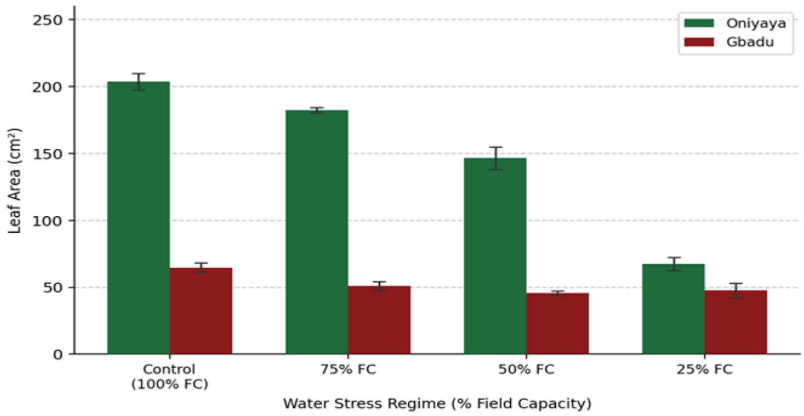

Figure 3: *Corchorus olitorius*, two varieties: effect of water stress on mean leaf area (cm²). Error bars = ± SE (n=3)

Dry weight of shoots was reduced by water stress. There was a significant (P<0.05) decrease in shoot dry weight with increasing water deficit for both varieties (Figure 4). Oniyaya dry weight fell from 9.20 ± 0.20 g at control to 2.93 ± 1.76 g at 25% FC (68% reduction), while Gbadu declined from 8.10 ± 0.70 g to 2.03 ± 0.32 g (75% reduction). Oniyaya has consistently higher DW in all treatments indicating its superior capacity for biomass accumulation.

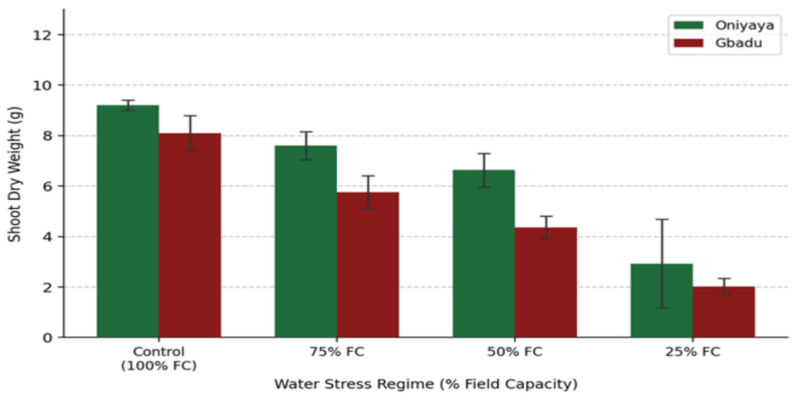

Figure 4: Responses of mean shoot dry weight (g) of two varieties of *Corchorus olitorius* under water stress. Error bars = ± SE (n=3)

The number of pods produced was affected by water stress. Water stress reduced the number of pods per plant for both varieties (Figure 5) but, again not always monotonically across the levels of water stress. Oniyaya produced 11.67 ± 0.58 pods at control and 3.50 ± 3.54 at 25% FC (70% reduction). Gbadu declined from 7.67 ± 2.52 at control to 3.67 ± 1.53 at 25% FC. Pod number varied with stress level but did not differ significantly (P>0.05) between the two varieties, indicating that the reproductive pod initiation process in *C. olitorius* is also equally sensitive to water deficit at each stress level. This result is in line with the fact that reproductive organs are most sensitive to abiotic stress compared to any other plant organ (Haq *et al.*, 2023).

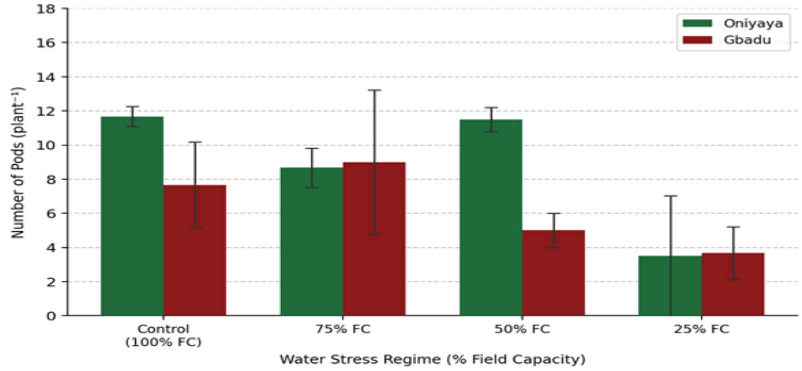

Figure 5: Mean pod number (plant-1) of two varieties of *Corchorus olitorius* under water stress. Error bars = ± SE (n=3)

The effect of water stress on the length of the pod length decreased with water stress in both varieties (Figure 6). The length of pod was shorter in Oniyaya at 25% FC compared to the control with a mean value of 5.93 cm and 7.37 cm, respectively. Gbadu, on the other hand, had higher values of pod length at both control (9.70 cm) and 25% FC (8.30 cm), and experienced a relatively smaller decrease. Varietal differences in pod length was probably due to genotypic differences in pod morphology rather than to differences in their sensitivity to stress as no significant difference was found between pod length treatments in either variety (P>0.05). Pod length was highly correlated with pod weight, and both were found to follow similar trends under increasing stress, similar to the pod-trait association reported for water-stressed okra, a related Malvalean vegetable (Haq *et al.*, 2023).

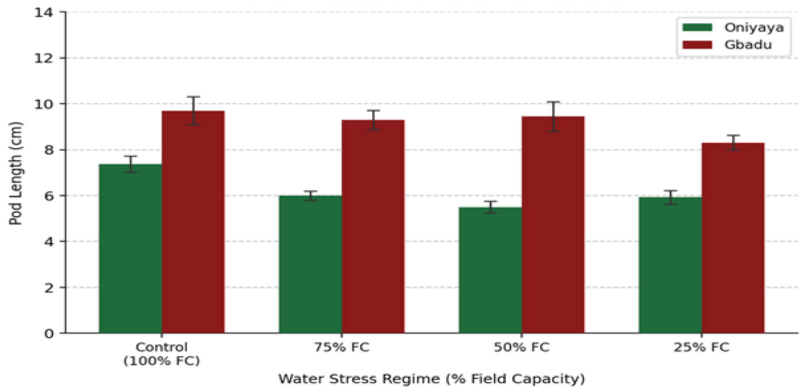

Figure 6: Water stress response of mean pod length (cm) of two varieties of *Corchorus olitorius*. Error bars = ± SE (n=3)

The effect of water stress on pod dry weight is presented is Figure 7 below. The increase in water stress caused significant reduction (P<0.05) in dry weight of the pods in both varieties. Oniyaya pod DW decreased from 2.93 g at control to 0.87 g at 25% FC and Gbadu decreased from 8.10 g to 2.03 g for the same range. Gbadu had significantly more pod dry weight at control and moderate stress levels compared to Oniyaya, indicating higher potential for pod filling in moderate and adequate stress. The considerable pod dry weight reduction at 25% FC in both varieties further supports the finding that the lowest water deficit level of this study is most detrimental to the marketable yield component of *C. olitorius.*

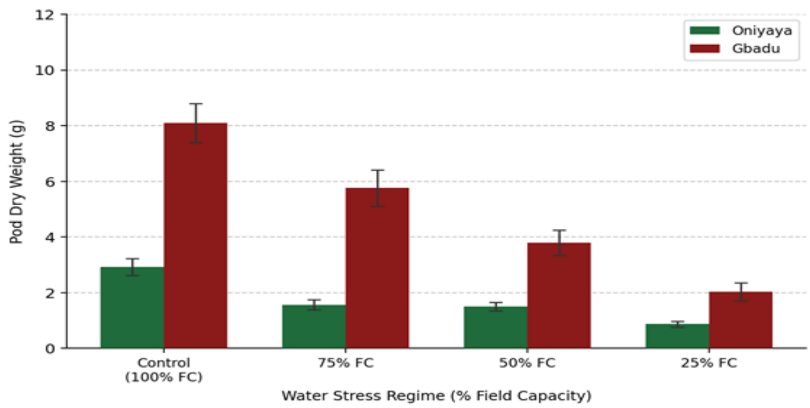

Figure 7: Mean pod dry weight (g) of two varieties of *Corchorus olitorius* under water stress. Error bars = ± SE (n=3).

The effect of water stress on relative growth rate (RGR) is as displayed in Table 2 below. As the water deficit increased, both varieties of *C. olitorius* had significantly reduced RGR (P<0.05). Oniyaya RGR declined from 0.61 ± 0.04 g g^{-1} $month^{-1}$ at control to 0.25 ± 0.01 g g^{-1} $month^{-1}$ at 25% FC while the value for Gbadu was less consistent. In all the treatment levels, Oniyaya consistently showed a higher RGR than Gbadu, which further validated its high growth rate even in the presence of stress.

Table 2: Relative growth rate (RGR g g-1 month-1) of two Varieties of Corchorus Olitorius under Effect of Water Stress (Mean ± SE)

Variety	Control (100% FC)	75% FC	50% FC	25% FC
Oniyaya	0.61 ± 0.04^a	0.40 ± 0.02^b	0.30 ± 0.01^c	0.25 ± 0.01^d
Gbadu	0.46 ± 0.42^a	0.26 ± 0.04^a	0.16 ± 0.03^b	0.95 ± 0.05^a

FC = field capacity. Values are mean ± SE (n=3). Means in the same row sharing the same superscript are not significantly different (P<0.05, LSD test).

Net Assimilation Rate (NAR) is affected by water stress.
Water stress had significant (P<0.05) effect on NAR of both varieties (Table 3). Values of NAR were not monotonic for treatments due to the opposite trends in leaf area dynamics and the rate of dry weight accumulation at the individual time steps. Overall, higher NAR were observed in the case of the Oniyaya than for Gbadu, as expected due to its higher leaf area and the efficiency of dry matter production.

Table 3: Effect of water stress on Net Assimilation Rate (NAR, g g^{-1} $month^{-1}$) of two Varieties of *Corchorus Olitorius* (mean ± SE)

Variety	Control (100% FC)	75% FC	50% FC	25% FC
Oniyaya	0.03 ± 0.02^a	0.05 ± 0.24^a	0.21 ± 0.19^b	0.01 ± 0.10^c
Gbadu	0.01 ± 0.01^a	0.13 ± 0.18^a	0.35 ± 0.01^b	0.00 ± 0.01^c

FC = field capacity. Values are mean ± SE (n=3). Means in the same row sharing the same superscript are not significantly different (P<0.05, LSD test).

Leaf Area Ratio (LAR)
The reduction of leaf area in relation to water stress (Table 4) was evident in LAR. The LAR for Oniyaya was higher than Gbadu throughout all water stress levels, which is consistent with more leaf area to biomass production.

Table 4: A comparison of the effect of water stress on Leaf Area Ratio (LAR, cm2 g-1) of two varieties of *Corchorus Olitorius* (mean ± SE)

Variety	Control (100% FC)	75% FC	50% FC	25% FC
Oniyaya	22.17 ± 1.84^a	23.99 ± 1.54^a	22.12 ± 1.68^a	23.04 ± 2.11^a
Gbadu	7.99 ± 0.72^a	8.87 ± 0.62^a	10.51 ± 0.44^a	23.47 ± 8.81^a

FC = field capacity. Values are mean ± SE (n=3). Means in the same row sharing the same superscript are not significantly different (P<0.05, LSD test).

Discussion
This study showed that the water stress level influences all the agronomic components of *Corchorus olitorius L.* in a significant and dose dependent manner. Progressive reduction was observed in plant heights, leaf numbers, leaf areas, shoot dry matter, pod numbers, pod dry matter, RGR, NAR and LAR. This reduction was also consistent with the previously reported physiological drought response in annual vegetable crops. It could be as a result of stomatal closure which led to the reduction of CO_2 assimilation, a decreased carbon supply to sink organs, impaired cell expansion and division, reduced above- ground vegetative growth and reproductive output (Mkhabela *et al.,* 2021; Saddiq *et al.,* 2021). This aligns with previous findings where imposed drought reduced above-ground vegetative growth and reproductive yield in jute mallow, a decline driven by

impaired relative water content (RWC), SPAD values, and above-ground biomass (Rahman et al., 2021a).

Mechanistically, the decrease in plant height and leaf number with increasing deficit is due to the termination of turgor-based cell elongation in the apical and intercalary meristems. The findings also support the results of Guzzetti *et al.,* (2021) who observed that vegetative growth of *C. olitorius* under the conservation-agriculture management was affected under reduced water availability. Similarly, Mkhabela *et al.,* (2021) and Sarker & Oba, (2020) reported that vegetative growth of other leafy vegetable species and *C. olitorius* is generally reduced by moderate water stress cycles applied during early vegetative growth.

The significant decrease in leaf area under severe stress (67% reduction in leaf area from control to 25% FC for Oniyaya) is important for the functioning of the canopy. Reduced leaf area leads to reduced light interception, which in turn leads to reduced RGR through two channels: First, by reducing LAR; Second, by reducing the photosynthetically active surface (PSA) available for carbon fixation, which results in reduced NAR (Poorter *et al.,* 2019). This coupled effect of water stress (reduction in leaf expansion) on both aspects of RGR is referred to as mechanistic interdependence and is responsible for the fact that the proportional decrease in RGR under severe water stress is normally greater than the decrease in either of the individual morphological parameters (Lambers & Oliveira, 2019)

At all stress levels, Oniyaya was consistently superior for the vast majority of parameters when compared to Gbadu. Its inherently higher leaf area, leaf number, shoot dry weight and RGR of both control and stressed plant suggest that the species Oniyaya is endowed with higher constitutive growth vigour which can possibly contribute to higher capacity of osmotic adjustment, accumulation of compatible solutes to maintain cell turgidity and continued meristematic activity under water deficit (as shown in other stress tolerant species for superior antioxidant enzymatic activity and drought tolerance by Hatfield and Dold, 2019). This is in line with the findings that the varieties with higher vegetative biomass at control condition tend to maintain a higher residual biomass under moderate stress as they have more reserves of stored carbohydrates and structural materials (Guzzetti *et al.,* 2021) and biochemical evidence that exogenous antioxidant compounds can mitigate drought-induced losses in jute morpho-physiological performance (Sharma *et al.,* 2024).

The best marketable yield (pod dry weight) obtained was with 75% FC for both varieties, while the lowest was obtained at 25% FC. This result is similar to the findings of Haqet et al., (2023) in okra, Ayub *et al.* (2021) in okra, and Saddiq *et al.* (2021) in wheat, indicating that moderate water deficit (25% reduction from full irrigation) can be applied to *C. olitorius* without the corresponding reduction in yield, provided SWR is not less than 0.5. This is in line with the two-year field trial that reduced up to 20% of irrigation water for jute mallow without significantly reducing biomass production (Mgolozeli *et al.,* 2022) as well as with the global meta-analysis indicating that moderate deficit irrigation regimes (50–75% of full irrigation) generally maintained vegetable yield while enhancing water productivity (Singh *et al.,* 2021). The application of complementary soil-management strategies, such as biochar amendment, has also been proven to alleviate the effects of deficit irrigation on vegetable crops in similar sandy loam soils in West Africa (Diedhiou *et al.,* 2024).

Although Gbadu had lower vegetative biomass, the pods had a marginally higher dry weight than Oniyaya in the same conditions of no stress and mild stress. This implies that Gbadu might allocate a greater percentage of assimilates into the reproductive organs, a reproductive strategy different from the other species. More detailed research into assimilate partitioning coefficients and harvest index under graded water deficit will be needed to better understand the agronomic implications of these varietal differences.

CONCLUSION

Water stress had a significant effect on all the agronomic parameter. Plant height, leaf number, leaf area, shoot dry weight, pod number, pod length, pod dry weight, RGR, NAR and LAR of *Corchorus olitorius* L. decreased steadily as the soil water deficit increased from 100% to 25% field capacity. At 25% FC, the degree of suppression was highest for all parameters. Oniyaya is the most suitable variety because it has consistently superior growth, biomass accumulation, leaf area preservation and growth rate indices under all water stress levels under the study.

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