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Effect of Different Growing Media on the Growth and Yield of Jute Mallow (*Corchorus olitorius* L.)

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Abstract: *The study was carried out at Botswana College of Agriculture (BCA) garden to evaluate the response of Corchorus olitorius grown in four different growing media as follows; clay, sandy, commercial compost and loam soil being the treatments 1-4, respectively. A completely randomized design (CRD) with each treatment replicated four times was used. Productivity parameters and yield components measured were as follows; plant height, canopy spread, leaf area, stem diameter, number of leaves, branches and pods, both fresh leaf and dry masses, both fresh plant (stem + branches) and dry masses, both fresh root and dry masses, and both fresh pod and dry masses. Biomasses were also calculated for leaf, plant, roots and pods. C. olitorious yielded significant ($p<0.01$) results under clay, sandy and to some extent loam soils with respect to plant height, canopy spread, leaf area, stem diameter, number of leaves, branches and pods, both fresh leaf and dry masses, both fresh plant and dry masses, both fresh root and dry masses, both fresh pod and dry masses, plant biomass and pod biomass. A non-significant treatment effect was observed for root and leaf biomasses. Based on the results it is concluded that the use of clay and sandy soils enhanced production in jute mallow.*

Keywords: *Growing Media, Growth and Yield Parameters, Corchorus olitorious, Indigenous Vegetable*

1. INTRODUCTION

Indigenous leafy vegetables are important in human diets [1, 2] and valuable sources of income and traditional medicine [3, 4] in many developing countries. Indigenous leaf vegetables are collected in their natural growing habitats as wild species [2, 5, 6]. Although traditional vegetables are consumed in relatively small quantities as a side-dish or a relish with the staple food, they play a critical role in the livelihoods of rural communities [7, 8, 9, 10, 11], especially during times of famine [12] because they are the only alternative sources of medicine, nutrition [13, 14, 15, 16] and cash income [17, 18, 19].

Most plant parts of traditional leaf vegetables such as leaves, roots, stems, flowers, calyces, immature seeds or fruits are edible. These parts are important dietary supplements and sources of trace elements, proteins, minerals and vitamins [20, 21, 22, 23]. Prior studies have suggested that some traditional leaf vegetables are more nutritious than most of their conventional cultivated counterparts [2, 6, 17, 18, 24, 25, 26, 27, 28, 29, 30, 31]. Traditional leafy vegetables are relatively cheaper than exotic vegetables and many are gathered from the wild [2].

Corchorus olitorius L., commonly known as wild okra, belongs to the family Tiliaceae [2, 32]. Although *C. olitorius* occurs mostly in the wild, it has been cultivated for centuries both in Asia and Africa [33]. In most parts of Africa, its leaves are cooked and widely consumed as a vegetable [2, 34, 35, 36] with addition of bicarbonate of soda, tomatoes and onions [37]. It is also eaten in some parts of Asia [38] and is used in traditional medicine to treat ailments such as gonorrhea, chronic cystitis, pain fever and tumors [39]. It is a popular vegetable in West Africa where is commonly cultivated [40]. *C. Olitorius* is a very good source of proteins, vitamins (A, C,

E) and is also rich in mineral nutrients like calcium and iron [27, 41, 42] potassium, copper, manganese and zinc [42]. In addition it is known to contain high levels of iron and folate which are useful in preventing anaemia [27, 40].

In most countries in southern Africa *C. olitorious* is found growing naturally in open acacia bushland, grassland, flooded pans and dams and as weed in cultivated lands. Studies conducted in South Africa revealed that wild traditional vegetables are an important source of food, mainly in the rural areas of the country [43, 44, 45, 46]. In Botswana it is mostly found in the north eastern part of the country where it is popular among people of all classes. Women and children normally pick it to make relish or for sale in the summer when it is dominant. It is also air dried and stored for sale and consumption during times of shortage. Economic cultivation of *C. olitorius* in Botswana is limited and hindered by the fact that people still consider it as a weed though it is used as food. Moreover, traditional leaf vegetables have not received considerable attention in terms of research and commercial cultivation in Botswana due to lack of agronomic information for their cultivation. *C. olitorius* can be grown either as a single crop or intercropped with other field crops such as sorghum or maize [2]. Indigenous leafy vegetables are resistant to drought, pests and diseases than their exotic counterparts. The integration of indigenous leaf vegetables such as *C. olitorius* in farming systems could contribute in alleviation of food shortages in addition to fighting diseases such as cancer [38, 39] and HIV and AIDS [2]. Therefore, the objective of this study was to evaluate effects of different growing media on growth and yield parameters of *C. olitorius*.

2. MATERIALS AND METHODS

2.1. Experimental Site

A pot experiment was conducted at the Botswana College of Agriculture (BCA) nursery during 2013−14. The College is situated in Sebele content farm (24°33’S, 25°54’E). The elevation is 994 m above sea level. Sebele is located 10 km from Gaborone City Centre along Gaborone-Francistown road.

2.2. Experimental Design and Establishment

A completely randomized design (CRD) with 4 treatments and 4 repetitions was used. The four treatments were as follows; clay soil, sandy soil, commercial compost and loam soil being treatments 1-4, respectively. The river sandy used in this study was obtained from Shashe river near Mathangwane village in the Central District and clay and loam soils from Sebele. The compost soil was bought from commercial shops. Seeds were obtained from Poverty Eradication Garden (PEG) in North East District, City of Francistown. Equal amount of decomposed chicken manure (10 kg) was added to the composite sample and thoroughly mixed and applied to each treatment. Plastic pots (inner diameter 35 cm), four for each treatment were filled with the medium and placed under a 60% green net shade to minimize the rate of evapotranspiration. The pots were randomly allocated in the nursery. Seeds used to start the new plants were soaked in simmering hot water (98.5°C) for 24 hours to break the seed dormancy prior to sowing as recommended by [47]. Thereafter, the seeds were sown in 200 plugs seedling trays and after developing two true leaves five vigorous seedlings were transplanted into each pot. Seedlings were watered twice a day, in the morning and in the afternoon when necessary throughout the duration of the experiment. Weeds were uprooted whenever they appeared in the experimental units. Cultivation was also carried out to avoid soil capping and to improve aeration.

2.3. Performance Indicators

The following parameters were measured on weekly basis: plant height, canopy spread, leaf area, stem diameter, number of leaves, branches and pods. However, means at termination are presented here. The plant height was measured using a meter ruler from the base to the terminal bud. Number of leaves was determined quantitatively by counting immediately after true leaves had fully grown or expanded as well as the number of branches and pods. Ten fully expanded leaves were randomly sampled from each replicate pot and the area was measured by tracing the leaf on a graph pad with grid squares, each measuring 1 cm × 1 cm. The average was calculated to represent each replicate. A meter ruler was used to measure the canopy spread for each plant.

Calibrated vernier caliper was used to measure the stem diameter. All plants were used and the mean was calculated to represent the replicate.

The leaves and pods were harvested when ready and their masses measured and recorded. Fresh mass was determined by weighing the fresh samples in the laboratory using an electronic balance (PGW 4502e), max: 4500 g and readability: 0.01 g. The same samples were then sun dried to constant weight. Plants and roots were harvested at termination and their mass measured and recorded. Plants (stem + branch) were harvested and placed in weighing paper bags and taken to the laboratory to measure fresh weight using an electronic balance. The same samples were then oven dried to constant weight at 80^{o}C using a hot air oven (Scientific Series 2000) to determine their dry weight. Prior to weighing the fresh roots were placed in a 2 mm mesh sieve and gently washed in a big tub filled with water. The roots were then separated from fine soil and debris by floating. Soil free roots were dried of any surface moisture using a paper towel.

2.4. Statistical Analysis

The data collected was subjected to analysis of variance (ANOVA) using the STATIATIX-8 program. Where a significant F-test was observed and means comparison test was carried out using Least Significant Difference (LSD) at $p \leq 0.05$ to separate treatment means.

3. RESULTS AND DISCUSSION

3.1. Growth Media Physical and Chemical Characteristics

The physical and chemical properties of growth media data presented in Table 1 shows that the growth media was slightly acidic with pH ranged from 5.3 to 6.3. According to Roberts [48] the availability of mineral nutrients in growing media is influenced by its pH. Acidic soil normally lack calcium and magnesium, while higher pH causes deficiency in iron and phosphorus [49]. The CEC differed ($p<0.01$) significantly between the loam soil and other growth media with values ranging from 1.17−1.61 cmol kg^{-1}. Total N varied significantly ($p<0.01$) between treatments and was higher in the loam soil. Total N values ranged from 0.36−0.87%. Available P differed ($p<0.01$) significantly between the commercial compost and other media, with values ranging from 1.60 to 98.00 parts per million. Exchangeable K^+ ranged from 1.52 to 2.98% and the highest was recorded in the commercial compost while the lowest in sandy soil. Overall, the growth media was slightly acidic with good aeration, high permeability, and low water holding capacity, low in nitrogen content, phosphorus and potassium.

Table1. *Physical and chemical properties of growth media*

Growth media	pH (H_2O)	CEC (cmol kg^{-1})	Total N (%)	Available P (ppm)	Exchangeable K^+ (%)	Textural class		
						Sand (%)	Clay (%)	Silt (%)
Clay soil	5.3	1.17^a	0.36^c	8.00^b	1.52^b	39	40	21
Sandy soil	6.2	0.37^b	0.07^d	1.60^b	0.20^c	91	2	7
Commercial compost	5.0	-	0.74^b	98.00^a	2.98^a	-	-	-
Loam soil	6.3	1.61^a	0.87^a	7.00^b	1.78^b	87	7	6
Significance	ns	**	**	**	**	-	-	-
LSD 0.05	ns	0.71	0.10	8.00	0.28	-	-	-
CV (%)	16.13	33.90	9.90	14.83	9.31	-	-	-

*** Highly significant at $p<0.01$. Means separated by Least Significance Difference (LSD) Test at $p \leq 0.05$, means within columns followed by the same letters are not significantly different, ppm denotes parts per million.*

3.2. Growth Attributes

3.2.1. Plant Height

Plant height was affected by growing media (data not shown) in the first weeks of study. No significant ($p>0.05$) difference was observed in plant height between plants grown in the clay soil, sandy soil and loam soil at termination of the study (Table 2). Plants grown in the commercial compost were significantly ($p<0.01$) shorter than their counterparts grown in other growing media. Application of manure enhances the organic carbon content of soil, induces water infiltration and increases their capacity to retain nutrients against leaching losses, thereby improve soil fertility [50] as observed in the present study (Table 1). The results are in agreement with other studies on other crops which reported that availability of farm yard manure enhances plant growth [51, 52, 53, 54, 55, 56, 57, 58, 59]. Amending sandy, clay and loam soils with decomposed chicken manure may have released nutrients in addition to improving infiltration and water holding capacity [59]. The short plants observed in the commercial compost could be attributed to poor aeration as a result of poor drainage.

3.2.2. Canopy Spread

Clay soil significantly ($p<0.01$) enhanced the spread of *C. olitorius* canopy (Table 2) probably because of improved aeration, water retention and increased nutrients due application of decomposed chicken manure. There was no significant difference in canopy spread between plants grown in the sandy and loam soil. Amending the growing media with decomposed chicken manure could have improved the biological, physical and chemical properties as reported in numerous studies [60, 61, 62, 63] and released nutrients for plant uptake by plants [64]. Improved plant growth in soil amended with organic manure has been attributed to availability of NPK [65]. Commercial compost reduced the canopy spread probably due to poor drainage.

3.2.3. Leaf Area

Leaf area is a crucial growth indices determining the capacity of plant to trap solar energy for photosynthesis and has marked effect on growth and yield of plant [64]. Table 2 shows that the effect of growing media on leaf area was highly significant ($p<0.01$). The highest leaf area (58.00) was obtained under clay soil which was statistically at par with sandy soil (52.19). However, the leaf area of plants in the clay and sandy soil was significantly higher than in the commercial compost and loam soil. Application of organic manure to soil improves the water holding capacity of sandy soil and drainage in clayey soil [66] which was observed in this study (Table 1). Chicken manure could have provided nutrients for soil micro-organisms and increase the activities, which in turn convert unavailable plant nutrients into available form to promote plant growth [66]. The higher leaf area in the sandy and clay could also be attributed to the solubility, absorption and translocation of the absorbable nutrients by the plant for leaf synthesis as a result of decomposed chicken manure [2, 32]. The leaf area of plants grown in the commercial compost was significantly ($p<0.01$) lower than in the loam soil probably due to poor drainage.

3.2.4. Stem Diameter

The data on stem diameter are presented in Table 2. Results show that the effect of media on stem diameter was highly significant ($p<0.01$). The clay soil (0.69 cm) and sandy soil (0.65 cm) produced statistically similar stems which were significantly ($p<0.01$) thicker than in the other two growing media. The thicker stems could be attributed to the application of chicken manure which improved the structure of the sandy and clay soil by improving the water holding capacity, aeration and drainage which encouraged root growth and nutrient uptake. Studies conducted elsewhere showed that organic manures such (i.e. sewage sludge) improved plant growth and soil characteristics due to availability of organic matter and adequate nitrogen and phosphorus [67, 68, 69]. Stems of plant grown in the loam media (0.53 cm) were significantly ($p<0.01$) higher than in the commercial compost. The commercial compost produced plants with the smallest stem diameter.

3.2.5. Number of Leaves

Results in Table 2 shows that the effect of growing media on the number of *C. olitorius* leaves was highly significant ($p<0.01$). The sandy soil had the highest number of leaves (76.23) which were statistically at par with plants (62.00) grown in the clay soil. This could be attributed to the solubility, absorption and translocation of the absorbable nutrients by the plant for leaf synthesis as a result of amending growing media with decomposed chicken manure. In addition, organic manure increases carbon, nitrogen, pH, cation exchange capacity and exchangeable Ca, Mg and K which invariably enhance crop yield and improves productivity [70] which occurred in *C. olitorious* plants grown in the sandy and loam soil (Table 1).

The number of leaves in the sandy soil was significantly ($p<0.01$) higher than in the loam soil and commercial compost probably because of excellent drainage. The application of chicken manure has been found to increase growth in vegetables [71] and the good performance observed in sandy soil could be attributed to increased nitrogen levels [71] derived from chicken mature amendment. The number of leaves in the sandy soil was significantly ($p<0.01$) higher than in the loam soil and commercial compost. The number of leaves observed in the clay soil were higher (62.00) but not statistically different from loam soil (51.06). The number of leaves in plants grown in the commercial compost were significant fewer ($p<0.01$) than those grown in other three growth media. The lower number could probably be attributed to poor water retention and nutrient leaching. Mathowa et al. (72) reported a significant ($p<0.01$) decrease in leaf chlorophyll content which is related to plant growth due to leaching of essential plants nutrients.

3.2.6. Number of Branches

The effect of growing media (Table 2) on the number of *C. olitorius* branches was highly significant ($p<0.01$). More branches per plant (9.00) were observed in the clay soil followed by sandy soil with statistically similar number of branches per plant (7.75). Organic manure improves cation exchange capacity (CEC) and its application can also result in higher water holding capacity especially in sandy soils [73]. Statistically similar number of branches were observed in the in the loam soil (6.50). The commercial compost produced statistically ($p<0.01$) fewer branches (4.00) than the other three growing media probably due to poor drainage.

3.2.7. Number of Pods

Table 2, show that the effect of growing media on the number of pods was highly significant ($p<0.01$). Plants grown in the sandy and clay soil produced statistically more ($p<0.01$) pods than in the loam soil and commercial compost (Table 2). Pods harvested from plants grown in the sandy soil (20.56) were slightly higher than in the clay soil (16.23). No significant difference was observed with respect to pod number between the commercial compost and loam soil.

Table2. *Effect of growing media on C. olitorius plant height, canopy diameter, leaf area, stem diameter, number of leaves, branches and pods.*

Treatments	Plant height (cm)	Canopy spread (cm)	Leaf area (cm^2)	Stem diameter (cm)	Number of leaves	Number of branches	Number of pods
Clay soil	47.13^{a}	38.45^{a}	58.00^{a}	0.69^{a}	62.00^{ab}	9.00^{a}	16.23^{a}
Sandy soil	63.69^{a}	32.60^{b}	52.19^{a}	0.65^{a}	76.23^{a}	7.75^{ab}	20.56^{a}
Commercial compost	20.75^{b}	22.29^{c}	21.75^{c}	0.36^{c}	23.08^{c}	4.00^{c}	3.17^{b}
Loam soil	53.44^{a}	29.63^{b}	40.08^{b}	0.53^{b}	51.06^{b}	6.50^{b}	9.11^{b}
Significance	**	**	**	**	**	**	**
LSD 0.05	17.97	4.00	11.11	0.09	24.61	2.43	6.98
CV (%)	25.22	8.44	16.77	10.66	30.03	23.11	36.94

*** Highly significant at $p<0.01$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.*

3.2.8. Leaf Fresh and Dry Weight

Leaf fresh weight was significantly affected ($p<0.01$) by growing media (Table 3). The clay soil produced plants with statistically higher ($p<0.01$) leaf fresh weight (100.26 g $plant^{-1}$) than the sandy soil (75.14 g $plant^{-1}$), commercial compost (11.75 g $plant^{-1}$) and loam soil (27.35 g $plant^{-1}$). This could be attributed to the stimulating effect of decomposed chicken manure that supplies plant with nutrients required for better yield [74]. The poor performance observed in the commercial compost could be probably be attributed poor aeration as a result of poor drainage or delayed decomposition of organic matter by microbial action due to small number of microbes in pots. This is supported by Hassink [75], who reported that the influence of soil texture on organic matter decomposition and net mineralization depend, on the accessibility of organic substrate to soil organism. The fresh leaf weight of plants grown in the sandy soil was significantly higher ($p<0.01$) than the commercial compost and loam soil. The application of decomposed chicken manure probably improved the water holding capacity of the sandy soil and increased nutrient availability. Studies conducted elsewhere on other plants have shown that organic manures effectively enhance the vegetative growth [76, 77]. No significant difference in leaf fresh weight was observed between the commercial compost and loam soil media.

The effect of growing media on leaf dry weight was highly significant ($p<0.01$). The leaf dry weight of plants grown in clay and sandy soil was significantly higher ($p<0.01$) than those grown in commercial compost and loam soil. There was no significant difference ($p>0.05$) in leaf dry weight between plants raised in the commercial compost and loam soil. Plant leaf biomass was not affected by different growing media.

3.2.9. Plant Weight

There were no significant ($p>0.05$) difference in fresh weight among plants grown in the clay, sandy and loam soil (Table 3). The commercial compost produced plants with significantly ($p<0.01$) lower fresh weight that those grown in clay and sandy soil. The fresh weight of plants raised in the loam soil and commercial compost were not statistically different. The effect of media on plant dry weight was highly significant ($p<0.01$). Sandy soil and clay soil produced plants with significantly ($p<0.05$) higher dry weight than plants in the commercial compost and loam soil. This could be attributed to the general improvement in the soil physical and chemical properties of the sand and clay due to application of decomposed chicken manure (Table 1) which also improved the fresh and dry weight. Plant growth in the commercial compost produced yield significantly ($p<0.01$) lower dry weight probably due to poor drainage. Plant biomass in the present study was significantly ($p<0.01$) affected by growth media. The biomass of plants grown in the sandy and loam soil was significantly ($p<0.01$) higher compared to other treatments. The dry weight of plants grown in the commercial compost was significantly lower than in the clay soil.

3.2.10. Root Weight

The effect of growth media on fresh and dry root weight (Table 3) was highly significant ($p<0.01$). The sandy and clay soil produced plants with significantly ($p<0.01$) higher fresh and dry root weight than the other media. The fresh root weight of plants grown in the loam soil was significantly ($p<0.01$) higher than in the commercial compost media. The maximum fresh root weight (97.99 g) was recorded in the sandy soil and the minimum (10.50 g) in the commercial compost. There were no significant differences in root biomass between the different media. However, the maximum root biomass per plant (17.79%) was recorded in the sandy soil and the commercial compost gave the lowest root biomass (11.14%).

3.2.11. Pod Weight

Table3. *Effect of growing media on C. olitorius leaf, plant (stem + branch), roots, pods masses and biomasses over the period of the study*

Treatments	Leaf (g)			Plant (g)			Roots (g)			Pods (g)		
	FW	DW	Biomass (%)	FW	DW	Biomass (%)	FW	DW	Biomass (%)	FW	DW	Biomass (%)
Clay soil	100.26^{a}	17.53^{a}	17.52	37.59^{a}	4.40^{a}	11.70^{b}	3.65^{a}	0.59^{a}	15.98	72.76^{ab}	20.59^{ab}	27.95^{a}
Sandy soil	75.14^{b}	16.29^{a}	22.75	17.79^{a}	4.80^{a}	14.04^{a}	3.76^{a}	0.69^{a}	17.79	97.99^{a}	28.50^{a}	29.04^{a}
Commercial compost	11.75^{c}	1.96^{c}	17.11	11.14^{b}	0.40^{c}	9.30^{c}	0.73^{c}	0.08^{b}	11.14	10.50^{c}	1.45^{c}	13.28^{c}
Loam soil	27.35^{c}	6.48^{b}	23.36	13.16^{ab}	2.21^{b}	14.58^{a}	2.03^{b}	0.27^{b}	13.16	40.79^{bc}	10.31^{bc}	24.74^{b}
Significance	**	**	ns	**	**	**	**	**	ns	**	**	**
LSD 0.05	21.82	4.30	ns	11.41	1.62	2.11	1.14	0.30	ns	37.36	11.05	3.20
CV (%)	26.40	26.45	21.79	32.33	35.67	11.03	29.12	48.33	48.33	43.69	47.12	8.75

*** Highly significant at $p<0.01$, ns non-significant at $p>0.05$. Means separated by Least Significance Difference (LSD) Test at $p\leq0.05$, means within columns followed by the same letters are not significantly different.*

No significant ($p>0.05$) differences in pod fresh and dry weight (g) were observed between the clay and sandy soil (Table 3). Similarly, no significant difference was observed in pod fresh weight between plants grown in the clay and loam soil as well as between the commercial compost and loam soil. However, the maximum pod fresh weight was recorded in the sandy soil (97.99 g) and the lowest in the commercial compost (10.50 g). The results did not reveal any significant difference in pod dry weight between plant raised in clay and sandy soil. However, the pod dry weight was slightly higher in the sandy soil (28.50 g) than the clay media (20.59 g). No significant difference occurred in pod dry weight between *C. olitorius* plants grown in the loam and commercial compost. However, plants grown in the sandy soil yielded the highest pod dry weight and the lowest was recorded in commercial compost. The effect of media on *C. olitorius* pod biomass was highly significant ($p<0.01$). The clay and sandy soil produced plants with the highest pod biomass than the other two treatments. In addition, the loam soil produced plants with significantly ($p<0.01$) higher pod biomass than the commercial compost. Overall, the maximum pod biomass was observed in plants raised in the sandy soil (29.04%) with the minimum in the commercial compost (13.28%).

4. Conclusion

Corchorus olitorious yielded significant results under clay and sandy and to some extent loam soils with respect to plant height, stem diameter, number of leaves, branches and pods, leaf area, canopy spread, fresh plant and dry masses, pod mass, fresh leaf and dry masses, pods and plant biomasses, whereas root and leaf biomasses revealed a non-significant treatment effect. Based on the results it is concluded that the use of clay and sandy soils enhanced production in jute mallow.

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