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Full Length Research Paper

Effect of fruiting on some micronutrients, antinutrients and toxic substances in *Corchorus olitorius* grown in Minna, Niger State, Nigeria

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Experiment was conducted in a pot to determine the effect of fruiting on antinutrients (soluble and total oxalates), toxic substances (cyanide and nitrate) and some micronutrients (vitamin C, and β-carotene, a provitamin A) and mineral elements (Fe, Mg, Zn, Cu, Ca, Na and K) in *Corchorus olitorius* grown on nitrogen and non-nitrogen treated soil. The vegetable leaves were harvested at market maturity (vegetative phase) and fruiting (reproductive phase) and was subjected to chemical analysis. The results showed that fruiting significantly increased the β-carotene, cyanide, soluble and total oxalate concentrations in the control and nitrogen treated vegetable, except that the significant increase in β-carotene was observed only in control. Nitrate and vitamin C concentrations in the vegetable were however, reduced with fruiting irrespective of soil nitrogen levels. Similarly, fruiting significantly decreases the Fe, Mg and Cu concentrations in the control while significant decrease in K concentration was observed in nitrogen fertilized vegetable. The concentrations of Zn and Na in the vegetable were not affected by fruiting; however, the Ca concentration was significantly elevated in nitrogen treated vegetable. The results conclude that the concentrations of most plant toxins and nutrients were significantly elevated and reduced respectively, with fruiting of *C. olitorius*.

Key words: *Corchorus olitorius*, micronutrients, antinutrients, toxic substances, market maturity, fruiting, soil nitrogen levels.

INTRODUCTION

Corchorus olitorius called jews mallow or jute mallow in English is popular as vegetable in both dry or semi-arid regions and in the humid areas of Africa. The plant is also known for its fibre product, the jute (Schippers, 2000). Several species of *Corchorus* are used as vegetable, of which *C. olitorius* is most frequently cultivated. The plant prefers light (sandy), medium (loamy) and heavy (clay) soils. This vegetable does well in acid, neutral and basic (alkaline) soils (Facciola, 1990). *C. olitorius* is extremely consumed as a health vegetable, because it contains abundant β-carotene and other carotenoids, vitamins B_1, B_2, C and E, and minerals. The vegetable also has varying proportion of dietary fibre and protein required for health (Schipper, 2000). Despite these nutritional benefits of this leafy vegetable, accidental death of cattle was reported after being fed with vegetation containing the seeds, which contain cardiac glycoside 5(Shinobu et al., 2000). *C. olitorius* like other leafy vegetables also accumulates various toxic substances which can cause nutritional problem when present at high concentration.

For instance high levels of cyanide cause respiratory

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poison (Ames et al., 1981; Ellenhorn and Bercelonx, 1988). Oxalate leads to the formation of kidney stone and oxalemia (Antia et al., 2006; Proph et al., 2006; Ogbadoyi et al., 2006), while nitrate can be responsible for cancer and methaemoglobinemia in man (Onyesom and Okoh, 2006; Anjana et al., 2007; Musa et al., 2010). However, the amounts of these chemical substances (nutrients and toxic substances) in *C. olitorius* like other leafy vegetables are influenced by developmental stages of plant. It is in this direction that this study was conducted to examine the effect of fruiting on the levels of some micronutrients, antinutrients and toxic substances in *C. olitorius* grown in control and nitrogen treated soil. This is aiming at determine the stage of plant development that the derivable nutritional potential of *C. olitorius* can be best ultilized.

MATERIALS AND METHODS

The study area

The pot experiment was carried out in the nursery of the School of Agriculture and Agricultural Technology, Federal University of Technology, Minna, Niger State of Nigeria. Niger state has a Savannah climate characterised by maritime air and rainfull is between April and October. During harmattan, dry desert wind blow between between November and mid February while night temperature is very low. The geographical location of Minna is longitude 9° 40'N and latitude 6° 30'E. Minna lies in the Southern Guinea Savannah zone of Nigeria and has a sub-humid semi arid tropical climate with mean annual precipitation of 1200 and 1300 mm. About 90% of the total annual rainfull occurs between the months of June and September. Temperature rarely falls below 22°C with peaks of 40 and 30°C in February/March and November/December respectively. Wet season temperature average is about 29°C (Osunde and Alkassoun, 1998).

Soil sampling and analysis

The soil used in this study was collected from Minna. The soil has been classified as inseptisol (FDALR, 1985). The bulked sample was collected during the drying season from the field which has been under fallow for about four years. The bulked soil sample was passed through 2 mm sieve. Sub-sample of the soil was subjected to routine soil analysis using procedure described by Juo (1979). The soil particle sizes were analyzed using hydrometer method; pH was determined potentiometrically in the water and 0.01 M $CaCl_2$ solution in a 1: 2 soil/ liquid using a glass electrode pH meter and organic carbon by Walkey-Black method (Juo, 1979). Exchange acidity (E.A H^+ and Al^{3+}) was determined by titration method (Juo, 1979). Exchangeable Ca, Mg, K and Na were leached from the soil sample with neutral 1 N NH_4OA solution. Sodium and potassium were determined by flame emission spectrophotometry, while Mg and Ca were determined by E.D.T.A versenate titration method (Juo, 1979). Total nitrogen was estimated by Macrokjedal procedure and available phosphorus by Bray No 1 method (Juo, 1979).

Seeds

The seeds of jute mallow (*C. olitorius*) were obtained from Schools of Agriculture and Agricultural Technology's Farm/Nursery of Federal University of Technology, Minna.

Planting, experimental design and nursery management

About ten seeds of *C. olitorius* were planted in a polythene bag filled with 10.00 kg of top soil and after emergence the seedlings were thinned to two plants per pot. The factorial design was adopted to determine the effect market maturity and fruiting in control and nitrogen treated vegetable. Each treatment had 10 pots replicated three times. This gave a total of 60 pots for the vegetable. The seedlings were watered twice daily (mornings and evenings) using watering can and weeded regularly. The experimental area and the surroundings were kept clean to prevent harbouring of pest. The pots were lifted from time to time to prevent the roots of the plants from growing out of the container. Insects were controlled using Sherpa plus (Saro Agro Sciences) four weeks after planting at the rate of 5 ml per 5 L of water.

Fertilizer treatment

The fertilizer treatments for *C. olitorius* are stated as follows:

F_1: (control): 0 N, 30 mg P_2O_5/kg soil and 30 mg K_2O/kg soil.
F_2: 30 mg N/kg soil, 30 mg P_2O_5/kg soil and 30 mg K_2O/kg soil.

Harvesting

The leaves of *C. olitorius* grown in pot experiment in control and nitrogen treated soil were harvested at market maturity and at fruiting of plant development. The level of nutrients, antinutrients and toxic substances in the leaves were then determined.

Sample analysis

Both soluble and total oxalates in the samples were determined by titrimetric method of Oke (1966). The nitrate content in the test samples was determined by the colourimetric method as decribed by Sjoberg and Alanka (1994). Alkaline picrate method was used to analyse the cyanide content in the vegetable (Ikediobi et al., 1980). The mineral elements (Fe, Mg, Zn, Cu, Ca, Na and K) in samples were determined by using atomic absorption spectrophotometer (Alpha 4A AAS) flame photometer (Jenway PFP7) method (Ezeonu et al., 2002). The ascorbic acid concentration was determined by 2, 6-dichlorophenol indophenols method (Eleri and Hughes, 1983) while β-carotene was determined by ethanol and petroleum ether extraction method (Musa et al., 2010).

Statistical analysis

T-test was used to determine the effect of vegetative phase and reproductive phase in *C. olitorius* on of the parameters under investigation.

RESULTS

Physical and chemical properties of soil

Result of analyses of the soil used for pot experiment is shown in Table 1. The texture class of the soil is sandy loam indicating that the water holding capacity is moderate. The organic matter content, total nitrogen and

Table 1. Some physical and chemical properties of the soil (0 to 20 cm) used for pot experiment.

Parameters	Values
Sand (%)	74.40
Silt (%)	18.00
Clay (%)	7.60
pH (in H_2O)	6.51
pH (in 0.1 M C_aCl_2)	5.25
Organic carbon (%)	0.83
Organic matter (%)	1.43
Total nitrogen (%)	0.05
Available phosphorus (mg/kg)	6.69
K (cmol/kg)	0.92
Na (cmol/kg)	0.68
Mg (cmol/kg)	4.80
Ca (cmol/kg)	8.00
E. A (H^+ +AL^{3+})(cmol/kg)	1.50
CEC (cmol/kg)	15.90
Base saturation (%)	90.57
Texture class	Sandy loam

*Values represent means of triplicate determinations.

available phosphorus are low. Sodium and calcium contents are moderate while magnesium and potassium contents are high. The CEC (cation exchange capacity) is moderate while base saturation percentage is high. Soil pH indicates that the soil is slightly acidic (FAO, 1984; Black, 1985; FDALR, 1985).

Effect of fruiting on antinutrients and vitamins content

The investigation of the effects of fruiting on cyanide content in *C. olitorius* showed that the cyanide content increased significantly during fruiting irrespective of nitrogen levels. The mean values of cyanide at fruiting in control (1220.00 ± 142.00 mg/kg) and nitrogen applied (1325.00 ± 48.00 mg/kg) were significantly elevated compared to the level at market maturity (618.00 ± 106.00 mg/kg and 663.00 ± 48.00 mg/kg respectively) as shown in Table 2. The nitrate content in the vegetable significantly decreased with fruiting irrespective of the nitrogen levels. The mean values of nitrate at market maturity for controls (2028.00 ± 412.00 mg/kg) and nitrogen applied (2117.00 ± 370.00 mg/kg) were significantly higher than values (350.00 ± 54.00 and 235.00 ± 35.00 mg/kg respectively) at fruiting (Table 2). The soluble and total oxalates concentration in the vegetable leaves increased significantly during fruiting in control and nitrogen applied. The mean values of soluble oxalate obtained at market maturity and fruiting in control were 2.18 ± 0.21 g/100 g and 6.82 ± 0.48 g/100 g while the corresponding values obtained with the application of nitrogen fertilizer were 1.68.00 ± 0.14 g/100 g and 5.96 ± 0.29 g/100 g (Table 2). Similarly, the mean values of total oxalate at fruiting in control (8.79 ± 0.54 g/100 g) and nitrogen applied (7.45 ± 0.20 g/100 g) were significantly higher compared to levels at market maturity (3.20 ± 0.19 g/100 g and 3.15 ± 0.10 g/100 g, respectively) as shown in Table 2.

The mean β-carotene concentrations at market maturity and fruiting in control were 2626.00 ± 198.00 µg/100 g and 10278.00 ± 1034.00 µg/100 g; while the values obtained with the application of nitrogen fertilizer 10260.00 ± 581.00 µg/100 g and 11678.00 ± 639.00 µg/100 g. This data shows that the provitamin A concentration in *C. olitorius* increased significantly during fruiting in control, however with the application of nitrogen fertilizer, fruiting had no significant effect on β-carotene concentration in the vegetable (Table 2). The results obtained from the analysis of vitamin C content in *C. olitorius* showed that fruiting significantly decreased the vitamin content in the vegetable irrespective of the nitrogen levels. The mean values of vitamin C at market maturity for controls (101.70 ± 7.30 mg/100 g) and nitrogen treated (86.00 ± 8.60 mg/100 g) were significantly higher than the values (46.77 ± 2.70 mg/100 g and 37.37 ± 2.30 mg/100 g, respectively) at fruiting (Table 2).

Effect of fruiting on mineral elements content

Results obtained from the analysis of effect of fruiting on Fe content in *C. olitorius* showed that fruiting significantly decreased ($p < 0.05$) the mineral content in the vegetable in control, however no significant variation in the Fe content was observed when nitrogen fertilizer was applied. The mean values of Fe at market maturity and fruiting of the vegetable in control were 17.79 ± 1.90 and 7.31 ± 1.10 mg/kg while the corresponding values obtained with the application of nitrogen fertilizer were 10.29 ± 0.90 and 8.31 ± 0.86 mg/kg respectively (Table 3). Similarly, the determination of Mg content in the vegetable indicated that fruiting has a decreasing effect on the mineral concentration in control and had no significant effect in nitrogen fertilized vegetable. The Mg concentration in *C. olitorius* at market maturity in control (18.73 ± 0.46 mg/kg) and nitrogen fertilized (18.74 ± 0.69 mg/kg) while the corresponding values at fruiting were (15.19 ± 0.99 and 17.10 ± 0.35 mg/kg respectively). The determination of Zn and Na contents in the vegetable showed that fruiting had no significant effect on the mineral concentration in control and nitrogen fertilized *C. olitorius* (Table 3).

Results obtained from the investigation of the effect of fruiting on Cu level in *C. olitorius* also revealed that fruiting significantly decreased ($p < 0.05$) the mineral content of vegetable in control, however no significant

Table 2. Effect of fruiting on antinutrients and vitamins content in *Corchorus olitorius.*

Antinutrients and vitamins	Stage of analysis	
	Market maturity	Fruiting
Cyanide (mg/kg DW), control	618.00 ± 106.00[a]	1220.00 ± 142.00[b]
Cyanide (mg/kg DW) , nitrogen applied	663.00 ± 47.00[a]	1325.00 ± 48.00[b]
Nitrate (mg/kg DW), control	2028.00 ± 412.00[b]	350.00 ±56.00[a]
Nitrate (mg/kg DW), nitrogen applied	2117.00 ± 370.00[b]	235.00 ± 35.00[a]
Soluble oxalate (g/100 g DW), control	2.18 ± 0.21[a]	6.82 ± 0.48[b]
Soluble oxalate (g/100 g DW), nitrogen applied	1.68 ± 0.41[a]	5.96 ± 0.29[b]
Total oxalate (g/100 g DW), control	3.20 ± 0.10[a]	8.78 ± 0.54[b]
Total oxalate (g/100 g DW), nitrogen applied	3.15 ± 0.19[a]	5.04 ± 0.20[b]
β-carotene (µg/100 g FW), control	2626.00 ± 198.00[a]	10278.00 ± 1034.00[b]
β-carotene (µg/100 g FW), nitrogen applied	10260.00 ± 581.00[a]	11678.00 ± 639.00[a]
Vitamin C (mg/100 g FW), control	101.70 ± 7.30[b]	46.77 ± 2.70[a]
Vitamin C (mg/100 g FW), nitrogen applied	86.00 ± 8.60[b]	37.37 ± 2.30[a]

DW = Dry weight, FW = Fresh weight, Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other (P > 0.05).

difference in the mineral content was recorded when nitrogen fertilizer was applied. The amount of Cu at market maturity and fruiting of the vegetable in control were 13.50 ± 3.80 and 2.00 ± 0.31 mg/kg, while the corresponding values obtained when the nitrogen fertilizer was applied were 6.59 ± 0.84 and 6.000 ± 1.90 mg/kg respectively (Table 3). Determination of Ca in the vegetable indicated that fruiting had no significant effect on the mineral content of the vegetable in control, however, with the application of nitrogen fertilizer, fruiting significantly elevated the Ca content of the vegetable (Table 3). Similarly, the K concentration in the vegetable was not significantly affected during fruiting in control, however with the application of nitrogen fertilizer; the mineral content declined significantly (Table 3).

DISCUSSION

Significant increase in cyanide and oxalates (soluble and total) concentrations in *C. olitorius* during fruiting compared with values at market maturity is in agreement with the report of the following authors (Cleveland and Soleri, 1991; Waldemar et al., 2005; Carmen et al., 2007). Cleveland and Soleri (1991) and Carmen et al. (2007) independently observed that the cyanide content in the leaves of crucifers and cassava increase with the age of the plants respectively. The reason for the increase may likely be that during fruiting, the gene responsible for the synthesis of cyanogenic glycoside may be triggered by some hormonal action associated with fruit initiation and development to produce more of the compound for onward translocation into the fruiting body. This observation is likely to be correct, since one of the functions of cyanogenic glycoside in some plants is to protect the plants and their products from predators in order to ensure the continuity of their generation (Peter and Birger, 2002). Noggle and Fritz (2006) stated that the reason for higher level of oxalates during fruiting could be that oxalates like other secondary metabolites accumulate in plant tissues and organs with aging. Waldemar et al. (2005) observed the same trend in *Anethum graveolens.* This result gives enough warning sign why we must keep away from consumption of *C. olitorius* at reproductive phase because of the public health implications of these phytotoxins; oxalates are responsible for kidney stone, electrolytes inbalance and reduction of bioavailability of minerals in the body while cyanide causes respiratory poison, inhibition of ATP synthesis, cellular hypoxia and death.

The significantly lower nitrate content in *C. olitorius* at fruiting compared to values at market maturity is in line with report of Richard (1991) and Brown (1993) that young plant in the vegetative stage generally contains more nitrate than mature plants of the same species. Shigeru et al. (2003), Waldemar et al. (2005) and Carmen et al. (2007) also found the same trend in setaria grasses, *A. graveolens* and cassava leaves respectively. This decrease in the nitrate content during fruiting in *C. olitorius* may imply two things; firstly, that during fruiting

Table 3. Effect of fruiting on minerals content in *Corchorus olitorius.*

Minerals	Stage of analysis	
	Market maturity	Fruiting
Fe (mg/kg), control	17.79 ± 1.90[b]	7.31 ± 1.10[a]
Fe (mg/kg) , nitrogen applied	10.29 ± 0.90[a]	8.31 ± 0.86[a]
Mg (mg/kg), control	18.73 ± 0.46[b]	15.19 ± 0.99[a]
Mg (mg/kg), nitrogen applied	18.74 ± 0.69[a]	17.10 ± 0.35[a]
Zn (mg/kg), control	0.03 ± 0.01[a]	0.02 ± 0.01[a]
Zn (mg/kg), nitrogen applied	0.02 ± 0.01[a]	0.04 ± 0.01[a]
Cu (mg/kg), Control	13.50 ± 3.8[b]	2.00 ± 0.31[a]
Cu (mg/kg), Nitrogen applied	6.59 ± 0.84[a]	6.00 ± 1.90[a]
Ca (mg/kg), control	15.41 ± 1.80[a]	16.67 ± 1.70[a]
Ca (mg/kg), nitrogen applied	11.51 ± 1.50[a]	16.65 ± 1.80[b]
Na (mg/kg), control	6.67 ± 0.24[a]	4.43 ± 0.31[a]
Na (mg/kg), nitrogen applied	5.64 ± 0.33[a]	4.66 ± 0.18[a]
K (mg/kg), control	214.90 ± 26.00[a]	194.00 ± 7.80[a]
K (mg/kg), nitrogen applied	166.80 ± 12[b]	123.20 ± 9.90[a]

Control = No nitrogen applied. Values represent means of nine determinations. Row mean values carrying the same superscripts do not differ significantly from each other (P > 0.05).

there could be an increase in the activity nitrate reductase enzyme leading to an increase in amino acids and proteins required for fruiting and seeds development. This observation is likely to be correct since there is a report of significant negative correlation between nitrate concentration in the plant and nitrogen reductase activity (Anjana et al., 2007). Secondly, there is possibility of translocation of some of nitrate contents in the leaves during fruiting to the developing fruits (Noggle and Fritz, 2006). Even though the nitrate concentration in *C. olitorius* decreased significantly with fruiting, the nitrate concentration in the leaves at market maturity (vegetative phase) is within the acceptable daily intake (ADI) of 3.65 mg/kg for 60 kg body weight (219 mg/kg) if 100 g samples are consumed per day (Anjana et al., 2007). Thus, this does not give good reason for the inclusion of *C. olitorius* in our meal at the reproductive phase.

Our results that fruiting increase the β-carotene concentration in *C. olitorius* is contrary to the findings of Barros et al. (2007a, b) that the provitamin A concentration decreased in mature fruiting body of mushroom and *Lactarius piperatus*. The likely reason for the decrease of the compound in the vegetables may be due to the possible translocation of some of its content to the developing fruits and a decline in the concentration and activity of chlorophyll and associated light absorbing pigments (including caroteniods) following senescence induced by fruit formation and maturation (Noggle and Fritz, 2006). The variations observed in this study from the reports of these authors suggest that the influence of developmental phase on β-carotene concentration in the vegetables may depend on cultivars and other environmental factors. The elevated level in the provitamin A concentration during fruiting does not justify the consumption of the leaves of *C. olitorius* at fruiting because the β-carotene concentration at vegetative phase (market maturirty) can provide enough of vitamin A to meet adult recommended daily allowance (RDA). Observed significant decrease in vitamin C concentration and some of the mineral elements (Fe, Mg, Cu and K) in *C. olitorius* during fruiting compare to higher concentrations at market maturity is in line with findings of the following authors (Noggle and Fritz, 2006; Zofia et al., 2006; Bergquist et al., 2007). Zofia et al. (2006) and Bergquist et al. (2007) reported that vitamin C content is higher in the younger *A. graveolus* and baby spinach respectively, than in older ones. While Noggle and Fritz (2006) stressed that during fruit initiation and development, some metabolites for cellular synthesis and growth substances are translocated from the leaves, stems, and roots to the developing fruits.

They concluded that a growing fruit is an active sink that diverts and draws water and solutes from other regions of the plant. Lanyasunya et al. (2007) also observed that the rapid uptake of mineral by plants during early growth and the gradual dilution that occurs as plant matures would have been responsible for the decrease in some of the mineral content during fruiting. It is pertinent to note that in this vegetable also, increase in the level of Ca was observed when nitrogen was applied which is contrary to the aforementioned observations. It is therefore necessary to stress that the bioaccumulation of mineral elements in the two phases of plant development may depend on the mineral element in question, soil nutrients and other environmental factors (Guillermo et al., 2005; Signh, 2005; Aliyu and Morufu, 2006; Weerakkody, 2006). These factors must be carefully considered when interpreting results of this kind.

Conclusion

The results of this study revealed that the concentrations of vitamin C and some mineral elements (Fe, Mg, Cu and K) were reduced while the cyanide, soluble and total oxalates were elevated with fruiting. Thus evading consumption of *C. olitorius* at reproduction phase, which improves the levels of these micronutrients and reduces the incidence of diseases associated with high ingestion of cyanide (respiratory paralysis) and oxalate (kidney stone).

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