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Growth, Yield and Nutrient Use Efficiency of *Corchorus olitorius* under Irrigated and Rain-fed Conditions in Northeastern Benin (West Africa)

Sabaï Katé[1*], Pierre G. Tovihoudji[2], Michel Batamoussi-Hermann[3], Elvire L. Sossa[4], Rodrigue Idohou[5,6], Emile Codjo Agbangba[6] and Brice Sinsin[7]

[1]Institut National des Recherches Agricoles du Benin, Cotonou, Benin.
[2]Laboratory of Hydraulics and Environmental Modeling (HydroModE-Lab), Faculté d'Agronomie, Université de Parakou, 03 BP 351 Université, Parakou, Benin.
[3]Département de Production Végétale, Faculté d'Agronomie, Université de Parakou, BP 123, Parakou, Bénin.
[4]Département de Production Végétale, Laboratoire des Sciences du Sol, Université d'Abomey-Calavi, Cotonou, Benin.
[5]Ecole de Gestion et de Production Végétale et Semencière, Université Nationale d'Agriculture, Benin.
[6]Laboratoire de Biomathématiques et d'Estimations Forestières, Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 04 BP 1525, Cotonou, Benin.
[7]Laboratoire d'Ecologie Appliquée, Université d'Abomey-Calavi, Bénin.

Authors' contributions

This work was carried out in collaboration among all authors. Authors SK and PGT designed the study, collected and analyzed the data and drafted the manuscript. Authors ELS and RI supervised the data analysis and revised the manuscript. Authors MBH and ECA contributed to the interpretation of findings and improved the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Investigated the influence of organic manures (municipal solid waste compost [MSWC] and cow dung) and N-fertilizer on growth, yield and nutrient use efficiency of jute mallow (*Corchorus olitorius* L.) under two water regimes (rain-fed and irrigated).

**Corresponding author: Email: katesabai38@gmail.com;*

Study Design: Randomized complete block.
Place and Duration of Study: Farm of Faculty of Agricultural Sciences, University of Parakou, Northern Benin (latitude 09°20'16.8''N and longitude 002°38'54'' E, 353 m asl), during 2013 rainy (June to August) and dry seasons (October to December 2013).
Methodology: Ten treatments derived from a factorial combination of five levels of organic manures (control, MSWC at 10 t/ha, MSWC at 20 t/ha, cow dung at 10 t/ha and cow dung at 20 t/ha) and two levels of N-fertilizer (0 kg and 50 kg urea/ha), arranged in a randomized complete block with three replicates were considered.
Results: Results showed that water regime significantly (p<.001) affected growth and yield of jute mallow. In addition, the growth and yield parameters showed significant differences (p<.001) in relation to different rates of organic manures. The integrated use of organic manure and urea increased plant height, number of leaves, stem diameter, number of branches, leaf growth parameters and leaf yield. The maximum amount of leaf yield (7554.88 kg/ha) was obtained with 20 tons/ha of MSWC and 50 kg urea/ha.
Conclusion: Fertilizer types also had highly significant effects on nutrient use efficiency. Application of these treatments could help to enhance yield and growth of the jute mallow.

Keywords: Corchorus olitorius; fertilizer; growth; leaf yield; Benin.

1. INTRODUCTION

Jute mallow or Krin-krin (*Corchorus olitorious* L.) is an important leafy vegetable found in the wild and cultivated in many tropical countries of Africa and Asia [1-3]. It plays an important role in nutrition of the household and the food security reach. The leaves are mucilaginous like okra fruit, which is prepared as a sauce. They are rich in calcium, galactose, galacturonic acid, glucose, glucuronic acid, rhamnose, magnesium, iron and contains a high content of vegetable protein [3]. Leaves are also rich in fesolate and iron which are used for the prevention of anaemia [4,5]. Despite its nutritional and economic importance, jute mallow has received little scientific attention in Benin. In the nature, the crop grows more easily in rural subsistence farming systems when compared to exotic species like cabbage and spinach [1,6] This makes the vegetable a very important local resource for poor communities of sub-Saharan Africa in fighting food insecurity and malnutrition [7].

Nowadays, a significant reduction occurs in the area devoted to the production of jute mallow. A solution is the practice of intensive agriculture; thus, producing high yields and good quality leaves. This could be accompanied through development of quality fertilizers and their efficient use in farming systems. In Benin, jute mallow growers are mostly peasant men/women who cannot afford the use of recommended dose of chemical fertilizer due to their high cost and availability when needed. Farmers grow the crop on poor soils and apply small amounts of fertilizer. As such, these soil fertility management practices are not adequate and could not therefore satisfy the nutritional requirements of the plant and produce high yield. One way to increase the nutrient status is by boosting the soil nutrient content either with the use of organic materials or with the use of inorganic fertilizers [8].

Several studies showed that jute mallow responds well to fertilization, particularly nitrogen [9,10] Moreover, this crop is mostly grown by marginalized producers of whom access to mineral fertilizers is difficult because of their low income [11]. Besides, excessive and indiscriminate use of chemical fertilizers leads to soil degradation and imposes a serious threat to human health [12]. A possible option to reduce chemical fertilizer use is the adoption of environmentally-free amendments and recycling of the organic wastes. The application of organic manure (e.g. municipal waste compost and cow dung) help to improve the chemical, physical and biological characteristics of soil and provide the required plant nutrients [13-15] and increase soil nutrient levels [16-20]. On the other hand, use of organic manure alone to sustain cropping has been reported to be inadequate due to relatively low nutrient contents [21,22]. Nutrients contained in organic fertilizer are released more slowly and stored for a longer time in the soil, ensuring long residual effect [23]. Nutrient supply from organic source may not be adequate for an annual crop with short cycle which requires that nutrients be supplied early during the growing period. However, an important dose applied may compensate the initial low and slow release of nutrients. All the above-mentioned reasons underscore the need of integrated nutrient management (INM) approaches through the judicious mixing of organic manure as well as chemical sources of nutrients for sustainable crop production.

Irrigation helps to improve agricultural crops production, maintain landscapes, and revegetate disturbed soils in dry areas and during periods of less than average rainfall. Irrigation also has other uses in crop production, including frost protection, suppressing weed growth in grain fields and preventing soil consolidation [17,18]. Rainfed agriculture is a type of farming that relies on rainfall for water. It provides much of the food consumed by poor communities in developing countries. Both systems are important in sustainable crop production [17].

Integrated management of organic and chemical fertilizers constitutes an important opportunity to seize. It contributes to the maintenance of a sustainable system while increasing farm income above a subsistence level. This approach is an imperative, and will not only add to economizing the use of inorganic fertilizers but also improve the physico-chemical status of the soil while contributing to sustainable, and long-term production [24,25].

This study explored the effects of fertilizer combination on growth, dry matter production and partitioning and nutrient use efficiency of *Corchorus olitorius* under two water regimes in Northeastern Benin.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiments were conducted during 2013 rainy (June to August) and dry seasons (October to December) at the Teaching and Research Farm of Faculty of Agricultural Sciences, University of Parakou, Northern Benin (latitude 09°20'16.8''N and longitude 002°38'54'' E, 353 m asl). The climate is Sudanian with a rainfall between 800-1100 mm and mean monthly temperature between 24 – 31°C range. The rainy season extends from May to October. The relative humidity ranges from 18 – 99%. The monthly irrigation/ precipitation and temperature of the area during the experiments are presented in Table 1.

2.2 Experimental Design and Crop Management

Before setting up the experiment, bulk soil sample was collected between 0-20 cm depth. Samples of the organic materials were also collected and analyzed for physical and chemical properties. Soil samples were air-dried, grounded and passed through a 2mm sieve. The organic materials were also taken, dried and grounded. Soil pH was measured using a glass electrode (pH meter) in a soil to water ratio of 2:1 according to the method described by [26]. Organic carbon was determined by wet combustion [27] and total nitrogen by the Macro-Kjeldahl method [28]. Available phosphorus was also determined by the method of [29]. Exchangeable cations (Ca, Mg, K) were extracted with 1.0 M ammonium acetate solution and their levels determined by atomic absorption spectrometry [30] The bulk soil sample had a pH 6.7, organic C 0.6%, total N 0.1%, available P 0.2 $mg.kg^{-1}$ and exchangeable K 23 $mg.kg^{-1}$ (Table 2). For proper seed bed preparation, the site was plowed and left for 2 weeks. The individual plots were prepared according to the treatments. Each plot had a 4m x 1.2 m length with 1 m spacing between plots. Each block was separated from the other by a 2.0 m allay. Seedlings of *C. olitorius* were transplanted when they reached three weeks after sowing (WAS).

Table 1. Irrigation water/ precipitation and temperature during the experiments

Months	Season 1 (rain-fed)					
	Tmax (ºC)	Tmin (ºC)	Effective rainfall (mm)	Irrigation water applied (mm)	Total Water applied (mm)	Rainy days (No.)
June	30.8	22.5	205.5	19.5	225	14
July	29.5	21.9	44.7	0	44.7	10
August	28.2	21.2	96.8	0	96.8	7
	Season 2 (irrigated)					
October	31.4	22.1	7.9	144	151.9	16
November	35	22.1	7.1	279	286.1	31
December	35.2	20.8	0	135	135	15

Tmax=Maximum temperature; Tmin=Minimum temperature

Transplanting was carried out in the evening with seedlings transplanted at a spacing of 0.4 m x 0.1 m for a total of 250,000 plants. ha^{-1}. Plants were watered immediately after transplanting.

The experiment consisted of a factorial arrangement of five levels of organic manures including a control (i.e. Municipal solid waste compost MSWC 10 t/ha, MSWC 20 t/ha, Cow dung 10 t/ha, Cow dung 20 t/ha and a control); and two levels of urea fertilizer (0 and 50 kg urea/ha), arranged in a randomized complete block with three replicates.

The MSW compost was obtained from the solid waste recycling and composting station at Parakou, where it was produced under aerobic conditions. Composting took about four months; however, the compost was collected and stored before field application. Composts and cow dung were analyzed for nutrient contents. Samples were air-dried at room temperature for three days, digested with nitric-perchloric-sulphuric acid mixture and resulting aliquots were used to chemically characterize the amendments. Results for compost and cow dung macro- and micronutrient analyses are shown in Table 2. The organic fertilizers were sun-dried and incorporated into the soil three week before transplantation of seedlings while urea was applied two weeks after transplanting (WAT). Fertilizers were applied by band placement at 5 cm depth and 7 cm away from the plants, with proper covering up to the holes to prevent washing away of nutrients (fertilizers) by run-off. The same organic materials were used for the two experiments. Weeding was done manually at two weeks.

2.3 Growth and Yield Data

The growth and yield parameters collected were: plant height, number of leaves per plant, number of branches per plant, stem diameter (measured with a digital caliper), stem length, stem width, petiole length, leaves, shoot and root fresh weight per plant, leaves dry matter weight per plant (after drying at 80°C for 48h) and leaves yield per hectare. For the plant growth measurement, five plants were selected randomly in each plot (leaving the border plants) and tagged. Morphological parameters were measured at 2, 4, 6 weeks after transplanting (WAT).

Nutrient use efficiency which refers to the ratio of leaf yield to the total nutrient applied was computed for the three major nutrients (N, P, K).

2.4 Statistical Analyses

Data were submitted to analysis of variance in R 2.14.1 software [32] using a randomized complete block structure with three replications in which the two years were considered as the main-treatments. Differences between treatments were considered at error probabilities ≤0.05. Quadratic and linear regression analyses were performed to model crop response to total nutrient supply over the cropping season.

Table 2. Physical and chemical properties of the organic fertilizers and initial soil sample [31]

Soil parameter	Units	MSWC	Cow dung	Soil
pH (water: material)		8,12	6.0	6.7
MO	%	34.0	nd	1.0
Organic C	%	17	3.8	0.6
Total nitrogen	%	4.0	6.1	0.1
Available phosphorus	mg kg^{-1}	1.5	1.4	0.2
Exchangeable cations				
Ca	Cmol (+)/kg	4.6	6.9	4.0
Mg	Cmol (+)/kg	3.7	0.9	6.4
K	Cmol (+)/kg	14.1	2.6	23.0
Na	Cmol (+)/kg	2.5	nd	89.0
Physical characteristics				
Sand	%	nd	nd	22
Silt	%)	nd	nd	43
Clay	%	nd	nd	35

nd: Not determined

3. RESULTS

3.1 Plant Growth Attributes

The organic fertilizer levels significantly affected plant height, number of leaves, stem diameter and number of branches during all sampling periods (p<.001; Table 3). However, at the early growth period (2 and 4 WAT) there was no significant difference between MSWC 10 t/ha, Cow dung 10 t/ha, Cow dung 20 t/ha. The highest amount of MSWC (20 t/ha) was significantly higher than the one of other groups. At 6 WAT, the tallest plants were obtained with MSWC at 20t/ha (68 cm). Conversely, control treatment showed shorter plants (42.5 cm) (Table 3). The plants fertilized with MSWC 20 t/ha produced the highest number of leaves per plant (114 leaves). A lower number of leaves per plant was obtained from control and plants fertilized with cow dung 10 t/ha and cow dung 20 t/ha. Wider stem diameter was observed in MSWC 20 t/ha (6.8 mm) and was similar to MSWC 10 t/ha (6.4 mm). The smallest stem diameter was recorded in control (4.5 mm). Among the treatments, MSWC 20 t/ha gave significantly higher number of branches (15 branches) than all other treatments, followed by MSWC 10 t/ha (13 branches) (Table 3). Interestingly, plants fertilized with MSWC 20 t/ha were significantly taller, had more leaves, a wider stem diameter and more branches than the other treatments (Table 3).

Urea application had a very significant effect on plant height, number of leaves, stem diameter and number of branches during all sampling periods. The use of 50 kg/ha of urea produced taller plants (54.3 cm), more leaves per plant (81 leaves), wider stem diameter (6.1 mm) and more branches per plant (13 branches) at 6 WAT than the control. Water regime significantly influenced all growth parameters. The best growth performance was observed under irrigated conditions (Table 3). A significant interaction was observed between organic and nitrogen fertilizer treatments for all growth parameters except plant height and number of leaves per plant at 4 WAT (Table 3). In contrary, interaction between water regime and organic fertilizer was not significant for plant height and number of leaves per plant but significant for stem diameter and number of

Table 3. Vegetative growth of *C. olitorius* as influenced by water regime, organic and nitrogen fertilizer levels and their interactions

Treatments	Plant height (cm)			No. of leaves			Stem diameter (mm)	No. of branches
	2 WAT	4 WAT	6 WAT	2 WAT	4 WAT	6 WAT		
Water regimes								
Irrigated	14.5a	35.4a	54.5a	10.1a	52.7a	77.3a	6.8a	12.4a
Rain-fed	16.6b	31.9b	47.2b	8.8b	44.8b	66.7b	4.2b	11.6b
Organic materials (t/ha)								
Control 0	14.1a	27.3a	42.5a	7.4a	38.6a	53.4a	4.5a	10.4a
MSWC 10	18.5c	36.2b	55.1b	10.3b	52.5b	95.6b	6.4b	13.4b
MSWC 20	16.8b	44.9c	68.0c	11.8c	61.1c	114.1c	6.8b	15.4c
Cow dung 10	14.4a	32.9b	45.5d	9.9b	50.6b	58.6a	5.2c	11.5d
Cow dung 20	14.8ab	33.3b	48.3d	9.8b	51.1b	57.1a	5.4c	11.3d
Urea (kg/ha)								
0	16.2a	35.4a	54.3a	9.7a	52.191a	80.7a	6.1a	12.9a
50	14.9b	31.9b	47.1b	9.1b	45.3b	63.3b	4.9b	11.0b
F-test: Main effect								
Water regime (W)	24.90***	17.82***	46.20***	55.04***	19.05***	10.21**	607.84***	14.22***
Organic Manures (OM)	10.53***	40.57***	54.29***	76.05***	15.42***	42.43***	56.48***	66.55***
Urea (U)	9.52**	17.09***	42.92***	16.93***	14.36***	28.36***	123.15***	90.74***
Interactions								
W * OM	0.13 ns	0.11 ns	0.47 ns	1.46 ns	0.10 ns	0.15 ns	3.31**	4.29**
W * U	0.11 ns	0.05 ns	0.37 ns	0.03 ns	0.09 ns	0.02 ns	7.22**	1.70 ns
OM * U	5.31***	1.25 ns	6.04***	3.54**	2.21 ns	2.28 *	10.82***	11.03***
W * OM * U	0.11 ns	0.003 ns	0.05 ns	0.03 ns	0.01 ns	0.44 ns	0.64 ns	0.69 ns

For each factor, means with different letters within columns are significantly different at 5% (*), 1% (**) and 0.1% (***) levels of probability respectively; ns: non-significant; WAT: Weeks After Transplanting; MSWC: Municipal Solid Waste Compost branches per plant. This also applies for water regime and nitrogen fertilizer treatments except stem diameter where the interaction was significant. No significant interaction was observed between water regime and fertilization treatments for all growth parameters.

3.2 Biomass Partitioning

A significantly high (p<.001) effect of organic fertilizer levels was observed on fresh weight of the leaf, stem, root and consequently on fresh total biomass (Table 4). Likewise, the effect of organic fertilizer levels was highly significant on leaf dry matter (p<.001). Application of 20 t/ha of MWSC produced maximum fresh total biomass (78.4 g/plant), while no application of organic fertilizer produced minimum fresh total biomass (32.5 g/plant) which was similar to other organic fertilizer application.

Nitrogen fertilizer significantly affected fresh leaves', root weight per plant and fresh total biomass but did not influence fresh stem biomass and leaves dry matter (Table 4). Use of 50 kg/ha urea produced maximum fresh total biomass (52.1 g/plant). Under irrigated conditions, *C. olitorius* had the highest fresh leaves, root, total biomass and leaves dry matter (Table 4). Water regime significantly affected these parameters, but no significant affect was observed on fresh stem biomass. Irrigation increased fresh total biomass by 9.9 g/plant and decreased leaf dry matter by 7.8%. Interaction of water regime x organic fertilizer, water regime x urea and organic fertilizer x urea as well as water regime x organic fertilizer x urea were not significant (Table 4).

3.3 Leaf Yield and Leaf Attributes

Plants that received MSWC 20 t/ha had a marketable yield that was higher (7298.8 kg/ha) and with a larger leaf length (8.4 cm), a larger leaf width (7.3 cm) and a higher petiole length (8.9 cm) than those that received MSWC 10 t/ha, cow dung 10 t/ha, cow dung 20 t/ha and control treatments (Table 5). Nitrogen fertilizer significantly affected marketable yield, largest leaf length, and largest leaf width and petiole length (Table 5). Use of 50 kg/ha urea produced maximum marketable yield (4816.9 kg/ha).

Table 4. Biomass partitioning in response to water regime, organic and nitrogen fertilizer levels and their interaction

Treatments	Fresh leaves wt. (g.plant^{-1})	Fresh stem wt. (g.plant^{-1})	Fresh root wt. (g.plant^{-1})	Fresh total biomass (g.plant^{-1})	Dry matter (%)
Water regimes					
Irrigated	20.9a	23.0a	6.8a	50.7a	31.2a
Rain-fed	16.6b	18.7a	5.5b	40.8b	39.0b
Organic manures (t/ha)					
Control 0	15.1a	13.5a	3.9a	32.5a	30.3ab
MSWC 10	17.4a	24.3a	6.9b	48.6a	45.7bc
MSWC 20	29.9b	39.2b	9.3c	78.4b	27.8a
Cow dung 10	15.1a	13.7a	4.6ab	33.4a	38.3c
Cow dung 20	17.0a	13.5a	6.3ab	36.8a	33.4ab
Urea (kg/ha)					
0	20.9a	23.9a	7.3a	52.1a	32.3a
50	16.7b	17.7b	5.1b	39.5b	35.9a
F-test: Main effect					
Water regimes (W)	11.72**	1.47 ns	4.22*	4.24*	11.04**
Organic Manures (OM)	23.42***	7.79***	8.74***	11.69***	7.30***
Urea (U)	11.83**	2.89 ns	13.11**	5.54*	0.47 ns
Interactions					
W * OM	0.26 ns	0.08 ns	0.09 ns	0.13 ns	0.09 ns
W * U	0.13 ns	0.03 ns	0.14 ns	0.06 ns	0.01 ns
OM * U	1.65 ns	0.92 ns	0.62 ns	1.48 ns	1.08 ns
W * OM * U	0.02 ns	0.01 ns	0.01 ns	0.02 ns	0.01 ns

MSWC: Municipal Solid Waste Compost; for each factor, means with different letters within columns are significantly different at 5% (*), 1% (**) and 0.1% (***) levels of probability respectively. ns: non-significant

At harvest, marketable yield, largest leaf length and leaf width were significantly higher under irrigated conditions than rain-fed conditions (Table 5). Irrigation increased by 1393.1 kg/ha, 3 cm and 1.9 cm for marketable yield, the largest leaf length and leaf width respectively. There was no significant difference in the petiole length among the plants either under irrigated conditions or rain-fed conditions. Plants under rain-fed conditions had shorter petioles (Table 5).

Results indicated that interaction effects of water regime × organic fertilizer had no significant (p<.01) effect on marketable yield, largest leaf length and largest leaf width, but had a slightly significant effect on petiole length of *C. olitorius* (Table 5). No significant interaction between water condition and nitrogen fertilizer treatments was found for marketable yield (Table 5), while a significant interaction was observed between organic fertilizer and nitrogen fertilizer for marketable yield and their components. Interaction effects of water regime x organic fertilizer, water regime x urea and organic fertilizer × urea as well as water regime x organic fertilizer x urea were not significant for marketable yield and their components (Table 5).

3.4 Response to Nutrient Application

We found that jute mallow yield significantly responded to combined application of nutrient (N, P_2O_5 and K_2O) from organic and mineral fertilizer in quadratic models (Fig. 1). Linear regression was considered for jute mallow yield response to phosphorus and potassium application.

A highly significant (p<.01) effect of fertilizer type on all nutrient use efficiency was observed in this study (Table 4). Similarly, the effect of water regime was highly significant on NUE but not significant on PUE and KUE. The interaction effect of water regime x fertilizer type was not significant for all calculated parameters (Table 6). The maximum NUE (7 kg/kg), PUE (17.7 kg/kg) and KUE (13.8 kg/kg) were observed with compost application under irrigated conditions (Fig. 2).

Table 5. Effect of water regimes and fertilizations on leaf yield and its components

Treatments	Yield (kg ha^{-1})	Largest leaf length (cm)	Largest leaf width (cm)	Petiole length (cm)
Water regimes				
Irrigated	5050.2a	8.6a	7.0a	6.2a
Rain-fed	3657.1b	5.6b	5.1b	6.9a
Organic manures (t/ha)				
Control 0	1921.7a	6.3a	5.4a	5.5a
MSWC 10	4332.8b	7.4b	6.3b	7.3b
MSWC 20	7298.8c	8.4c	7.3c	8.9c
Cow dung 10	3640.5d	6.9b	5.7a	6.3b
Cow dung 20	4573.9b	7.3b	6.5b	6.8ab
Urea (kg/ha)				
0	4816.9a	7.9a	6.9a	7.7a
50	3890.3b	6.3b	5.3b	5.6b
F-test: Main effect				
Water regimes (W)	72.20***	498.83***	278.08***	0.02 ns
Organic Manures (OM)	112.69***	22.48***	25.91***	30.46***
Urea (U)	31.94***	148.42***	188.87***	105.31***
Interactions				
W * OM	1.67 ns	1.01 ns	0.68 ns	2.96*
W * U	3.49 ns	6.69 *	5.01*	0.06 ns
OM * U	6.05*	13.49***	10.01***	5.48***
W * OM * U	0.36 ns	0.61 ns	0.26 ns	0.05 ns

MSWC: Municipal Solid Waste Compost; For each factor, means with different letters within columns are significantly different at 5% (*), 1% (**) and 0.1% (***) levels of probability respectively. ns: non-significant

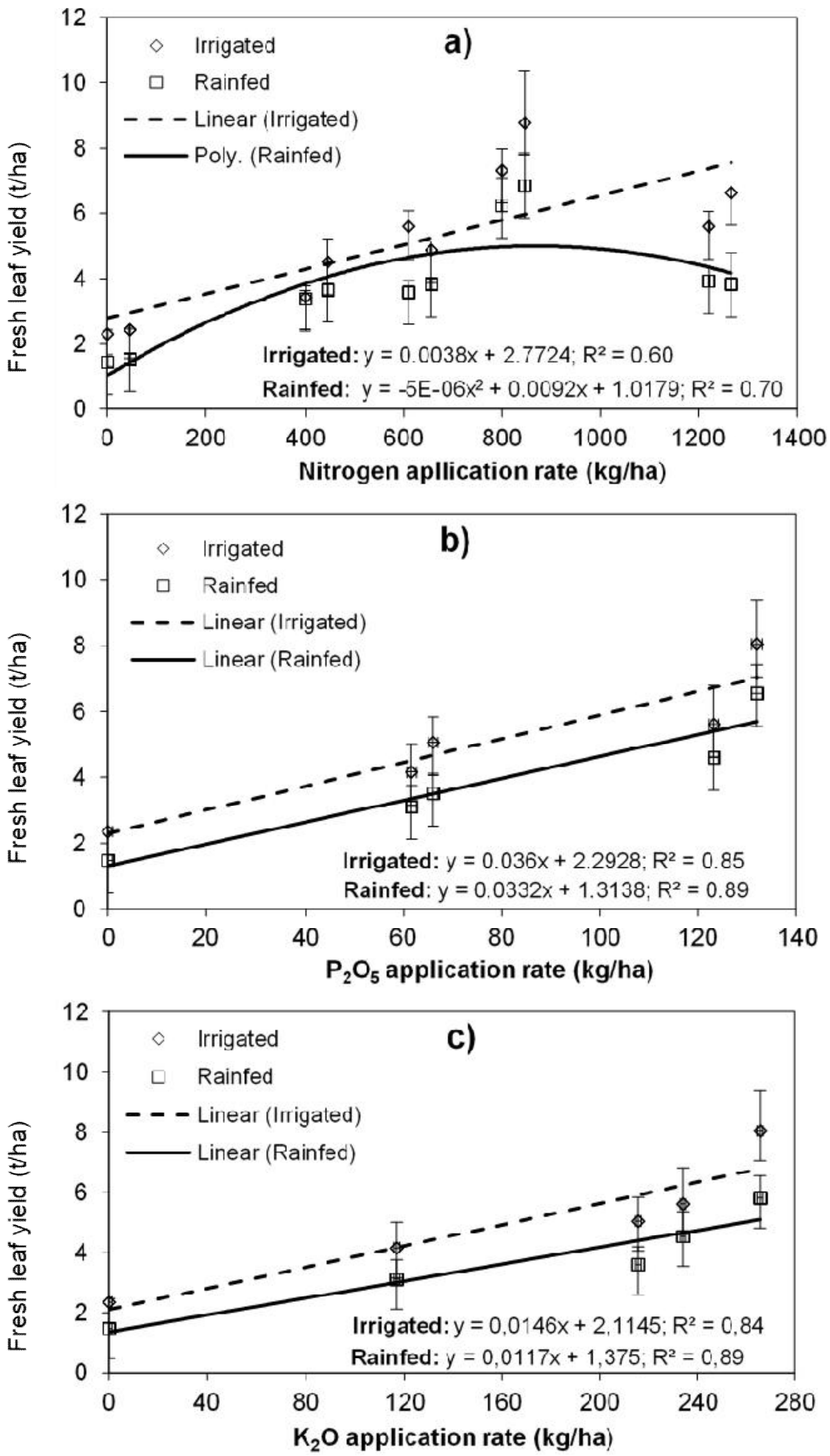

Fig. 1. Yield response to Nitrogen (a), Phosphorus (b) and Potassium (c) input from combined application of organic fertilizer (MSWC or Cow dung) and urea fertilizer in 2013 under irrigated and rain-fed conditions. Measured yields are average of three replicates (with standard deviations as error bars) modeled by parabolic curves or linear trend lines (equation and R^2)

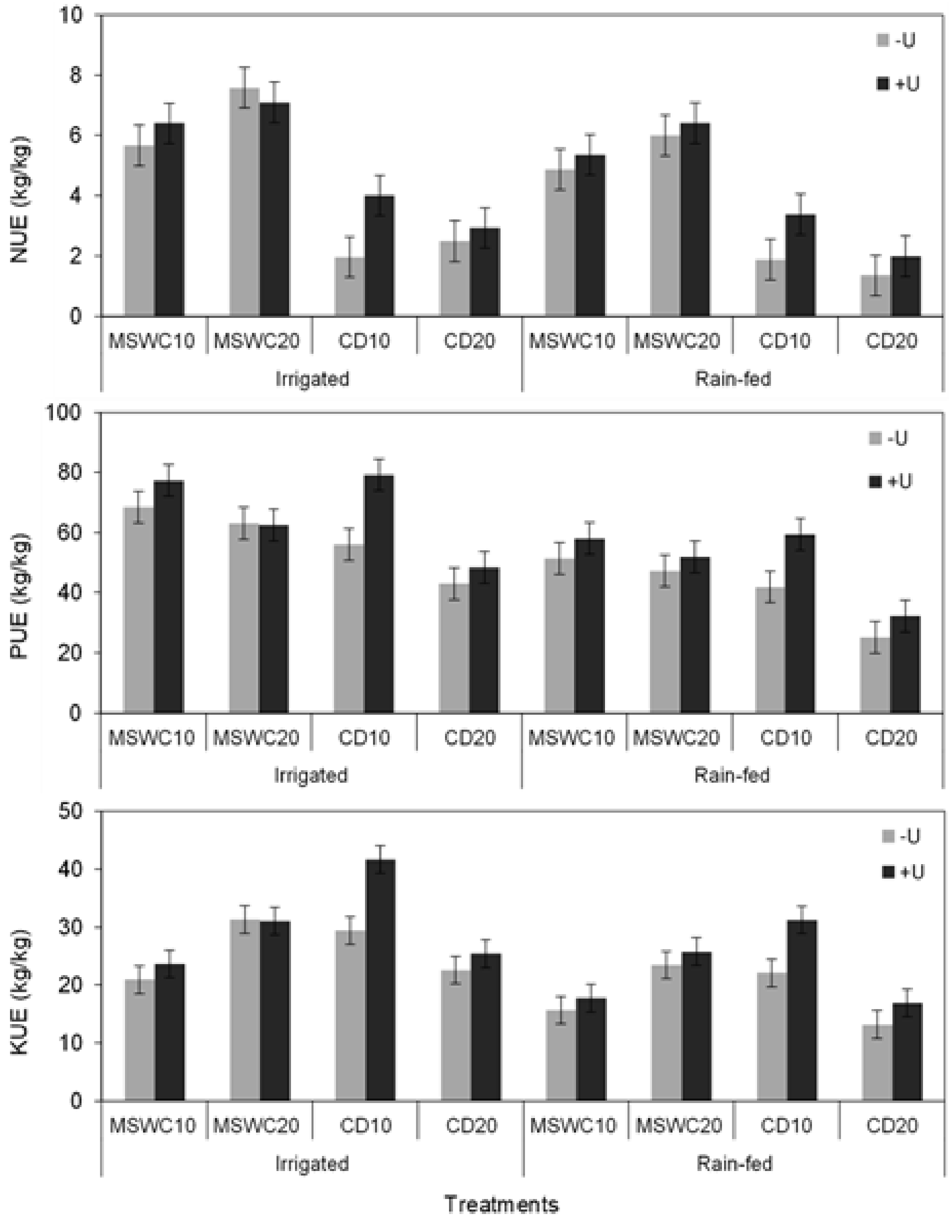

Fig. 2. Effect of water regime and various fertilizations on nitrogen, phosphorus and potassium use efficiency (NUE, PUE and KUE respectively)

MSWC: Municipal solid waste compost; CD: Cow dung; U: Urea

Table 6. Analysis of variance for nitrogen, phosphorus and potassium application efficiency

Sources of variation	df	NUE (kg/kg)		PUE (kg/kg)		KUE (kg/kg)	
		Mean square	Sig.	Mean square	Sig.	Mean square	Sig.
Water regimes (W)	1	9.66	**	2.63	ns	1.22	ns
Fertilizer type (FT)	2	53.57	***	55.36	***	18.67	***
W * FT	2	0.73	ns	0.55	ns	0.24	ns

*Sig: level of significance; *, **, ***: Significant at 5%, 1% and 0.1% levels of probability respectively. ns: non-significant*

4. DISCUSSION

This study explored the influence of organic manures and N-fertilizer on growth, yield and nutrient use efficiency of jute mallow. Main findings were that the application of organic fertilizer significantly enhanced the growth (plant height, number of leaves, stem diameter total leaf area and number of branches) of *C. olitorius*. The application of MSWC at 20 t/ha significantly influenced the different growth parameters at 6 WAT. This had been largely due to higher nutrient and nitrogen availability from organic fertilizer (MSWC and cow dung). This situation had profound influence in the mobilization of the nutrients from the unavailable form mainly due to improved physical, chemical and biological properties of the soil. Increase in the height and number of leaves, confirm the important role of nitrogen in promoting vigorous vegetative growth in leafy vegetables [33]. This also showed that nitrogen stimulates the formation of new leaves and increases the size and height of plant. As well established previously in the literature, organic fertilizer increases the organic matter and plant nutrient availability, and improves some soil physical properties [34]. The use of some combinations of inorganic and organic fertilizer seemed to make available enough nutrients to support leaf area development and plant stem diameter. Plants had more time to grow, with good harvest and plant height, stem diameter and number of leaves/plants increased with time. Several scholars mentioned similar results on different crops such as [35] on amaranth, [36] on cabbage, [37] on Red Amaranth, [38] and [39] on *Corchorus olitorius*.

In the current study, the treatment with organic matter, especially MSWC 20 $t.ha^{-1}$ combined with urea recorded significantly higher yield. This could be attributed to the increased solubilization effect and availability of nutrients and the increased physiological activity leading to the buildup of sufficient food reserves for the phenology of the species. Our results also corroborated those of [36], who demonstrated that the maximum amount of plant height, shoot dry matter and leaf yield of amaranth were obtained by the combined use of vermin compost and chemical fertilizer. According to [40] and [41], the organic sources of nitrogen, as well as their combinations with inorganic sources, have been reported to significantly improve plant height, fresh and dry weight of both above-ground parts and roots in basil compared to plots receiving only inorganic N. Similar findings were obtained by [10] who observed a great increase in yield of tomato when N fertilizer was combined with compost manure. The higher crop productivity from the application of urea in this study can be explained by enhanced organic carbon content and microbial activity in soils [42], reduced emissions from nitrogen fertilizer use, and higher nitrogen use efficiency [43]. Thus, the separate application of nitrogen fertilizer and cattle manure has a positive effect on growth but their combined use has more beneficial effect on the above-mentioned parameters. Moreover, the integrated use of cattle manure and nitrogen fertilizer could be an advisable option for achieving optimum growth characteristics and subsequently increased leaf yield.

It was observed that plants seem to perform better in treatments receiving compost due to the presence of growth promoting substances, micro-nutrients, and a variety of inorganic and organic compounds. At the same time, addition of organic amendments improves soil structure, aggregate stability and moisture retention capacity [44,45]. Lower growth and yield of plants fertilized with urea may be associated with larger gaseous nitrogen losses [46].

As regards the jute mallow grown under two water regime treatments, results indicated that all the studied characteristics were significantly affected by water regime, except for petiole length. Results also showed that the highest leaf yield and its components were obtained under irrigation conditions. This could be attributed to the fact that increasing available soil moisture during vegetative and reproductive growth of plants increases yield and its components. Application of these results in horticulture could be highly beneficial to peasant farmer and contribute to food security and nutrition reach strategy in Benin.

5. CONCLUSION

The present investigations have demonstrated the improvement of *C. olitorius* growth and yield with the use of cow dung and compost when they were compared with chemical fertilizer. Main findings were that the application of organic fertilizer improved the growth (plant height, number of leaves, stem diameter total leaf area and number of branches) of *C. olitorius*. It is quite possible to get higher yield by the integrated use of organic and inorganic fertilizers. In addition, the highest leaf yield and its components were obtained under irrigation conditions. This will result in soil quality improvement, which should be investigated under field conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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