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Flooding Effects on Yield of an Indigenous Vegetable (*Amaranthus cruentus L.*) in the Niger Delta Region of Nigeria

PAUL O. ANEGBEH and PETER A. AKOMEAH

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ABSTRACT

Experiments were conducted in 1987 and 1988 to study the response of *Amaranthus cruentus* L. to flooded soils at Ekpoma, situated in the Niger Delta Region of Nigeria. The objective of this study was to examine the effect of flooding on yield of *A. cruentus*. The study revealed that the negative response of the vegetable crop to flooding was significant ($P<0.05$). The general effects were low dry weight yields, wilting and yellowing of leaves leading to senescence and eventual death of the plants. At week eight, control plants had significant ($P<0.05$) higher dry matter yields of 4 g/plant than 0.3 g/plant dry matter recorded for plants in flooded conditions. The flooding effects resulted in 93.4% yield decrease. Similarly, leaf area of flooded plants was 4.4 cm^2/plant while that of control plants was 12.8 cm^2/plant. Thus, a 65.6% reduction was obtained due to flooding effects. The response of the plants to flooding confirmed that yield decrease significantly ($P<0.05$) as the flooding persisted. This thorough understanding of how flooding affect *Amaranthus cruentus* would aid in the development of strategies for the cultivation and availability of the leafy vegetable crop in the Niger Delta Region for enhanced livelihoods. Further studies examining flooding effects on other leafy vegetable crops are likely to increase our understanding of the response of valuable vegetables to water stress.

KEYWORDS: *Amaranthus cruentus*, flooding, leaf area, vegetables, yield

INTRODUCTION

Amaranthus cruentus L. is commonly called African Spinach and green vegetable. It is a source of cheap, but protein and vitamin-rich vegetable crop. Vegetables and fruits are the regular and reliable sources of nutrients and vitamins, especially vitamins A and C, which are readily available to most rural househood (Ojeniyi and Adejobi, 2002). Flooding is a common phenomenon in the Niger Delta Region of Nigeria. Consequently, many farmers and researchers are investigating response of vegetable crops to flooding, and developing strategies for ensuring that adequate quantities are available through out the year including off-season (Ojo and Obigbesan 2001).

Amaranthus cruentus is extensively cultivated in the Southwest of Nigeria to alleviate the suffering of malnourished and starving people especially children (Omidiji *et al.*, 1986). It is also cultivated in Northern Nigeria (Ayuba *et al.*, 2001). *Amaranthus cruentus* is useful both as a leafy vegetable and as a grain (Bressani, 1988; Kauffman, 1992; Akingbala *et al.*, 1994). It has a protein content of 16 percent (Olufolaji and Tayo, 1980). Protein levels in some wild *Amaranth* species have been reported at about 30 percent (Wesche-Ebeling *et al.*, 1995). *Amaranthus cruentus* is also a useful crop for livestock, particularly ruminants (Stordahl *et al.*, 1999; Sleugh et al., 2001). However, flooding is among the factors constraining its production. Therefore, the production of *A. cruentus* in the Niger Delta Region requires investigation on flooding effects.

But research on its response to flooding, in the Niger Delta Region remains poorly documented. As Kauffman (1992) pointed out, realizing the potential of *Amaranth* and availability and accessibility of the vegetable to people would reduce hunger, poverty and human suffering.

The objective of this paper, therefore, was to study the response of *A. cruentus* to flooding with a view to suggesting strategies for the production and availability of the crops throughout the year especially in some flooded areas of the Niger Delta Region. This would go a long way towards enhancing livelihoods of Nigerians.

MATERIALS AND METHODS

Seeds of a local variety of *Amaranthus cruentus* were obtained from farmers' gardens at Ibadan in February 1987. They were sown in germination trays at the Experimental Farm of Ambrose Alli University, Ekpoma, Edo State Nigeria (06^0 42' N Latitude 06^0 08' E Longitude) using garden soil (Table 1) Mean elevation is 509 m above sea level. Ekpoma falls within the tropical rainfall zone, which lies in the Niger Delta Region of Nigeria. Seedlings were transplanted into individual polyethylene bags measuring 25 cm x 15 cm and allowed to harden prior to planting out in the field.

Table 1: Selected chemical properties of soil used for the experiment (0-15cm depth)

pH (H_2O)	5.15
Org. C (%)	1.92
N (%)	0.08
P ($mg.kg^{-1}$)	4.41
Ca (cmol (+).kg^{-1})	1.00
Mg (cmol (+).kg^{-1})	0.12
K (cmol (+).kg^{-1})	0.05
Na (cmol (+).kg^{-1})	0.29
ECEC (cmol (+).kg^{-1})	2.56
Total acidity (cmol (+).kg^{-1})	1.10

PAUL O. ANEGBEH, World Agroforesrty Centre (International Centre for Research in Agroforestry ICRAF), International Institute of Tropiccal Agriculture (IITA), IITA high rainfall station, River State, Nigeria. Email: P. Anegbeh @ cgiar. Org. or anegbehpaulo @yahoo.com.
PETER A. AKOMEAH, Department of Biological Science, Faculty of Natural Science, Ambrose Alli University, Ekpoma, Edo State, Nigeria

The vegetable crop was tested during the dry seasons, in 1987 and 1988, in controlled conditions, to avoid rainfall interference with the treatments. The treatments were (1) flooded treatment, where soil was completely flooded with water throughout the experimental period, (2) Control treatment, where regular watering was done daily. Seedlings for the treatments involving flooded condition were laid inside metal containers, each measuring 204 cm x 160 cm x 30 cm, where they were flooded with water. The level of water above the soil surface was 2 cm. This level was topped up daily when it was necessary to re-fill the containers to the flooding level.

The experiments were arranged in the field in a Completely Randomized Design with four replicates using 30 cm x 30 cm spacing between and within rows respectively. Temperature and relative humidity were determined during the testing period, and mean value for the cropping periods are summarized in Table 2.

Table 2: Mean Temperature and Relative Humidity during the Sampling period*

Period (week)	Mean Temperature (^{0} C)	Mean Relative Humidity (%)
1	29.6 ± 1.4	72.2 ± 3.5
2	31.2 ± 0.8	71.0 ± 1.9
3	32.6 ± 0.5	66.5 ± 2.5
4	30.2 ± 1.3	72.1 ± 1.8
5	28.0 ± 1.6	69.0 ± 2.4
6	31.6 ± 0.9	71.1 ± 3.1
7	28.2 ± 1.8	68.0 ± 0.7
8	27.4 ± 1.1	69.5 ± 0.9
Mean	30.5 ± 1.2	69.9 ± 2.1

* Values are means of two years data.

Sampling commenced 6 weeks after treatment application to enable them acclimatize to the weather. For every year, the sampling was done weekly over a period of 8 weeks. For every sampling week, five plants of the species per replicate were selected randomly and harvested from each treatment for growth analysis. The sampled plants in the potting bags were soaked in a bucket of water for 15 minutes prior to harvesting and were carefully pulled out from the polyethylene bags without losing any of the roots. The sampled plants were separated into roots, stems and leaves and the fresh weights of the different parts were taken. The plant parts were dried in an oven at 65^0 C until constant weights were achieved and they were re-weighed to obtain dry weights.

The response of the species was studied using leaf area, and fresh and dry weights of the plants. Leaf area was determined using the predictive equation described by Hunt (1978).

Y = 1.26 + 0.85X, where Y and X are predictive and calculated (leaf length x leaf width) leaf areas respectively.

All data were analyzed by analysis of variance (ANOVA) procedures with SAS statistical software package (SAS, 1987). Means separation for the effects were obtained by Fischer's Least Significant Different (LSD) test as described by Clark (1980). Effects were considered significant in all statistical calculations if P-values were less than 0.05 ($P<0.05$).

RESULTS AND DISCUSSION

The dry matter yields of *A. cruentus* plants are shown in Fig.1. Seedlings of the species grown in control treatment had significantly ($P<0.05$) higher dry matter (4 g/plant) than the seedlings grown in flooded condition (less than 1 g/plant). This was expected on the basis of availability of optimum water for physiological processes in the control plants. As Boot *et al.*, (1986) pointed out, the fact that the dry matter of waterlogged plants was reduced suggest strongly that flooding reduces growth rate of plants because cell division and enlargement on which growth depends are affected.

Fig. 2 shows result of leaf area. The significantly smaller leaf area in treatment involving flooding (less than 5 cm^2/plant) is normal. Control treatment developed larger leaf area (13 cm^2/plant) than flooding treatment, indicating that plants in control treatment produced larger leaves to account for the regular water applied to them, which was probably optimum for plant growth.

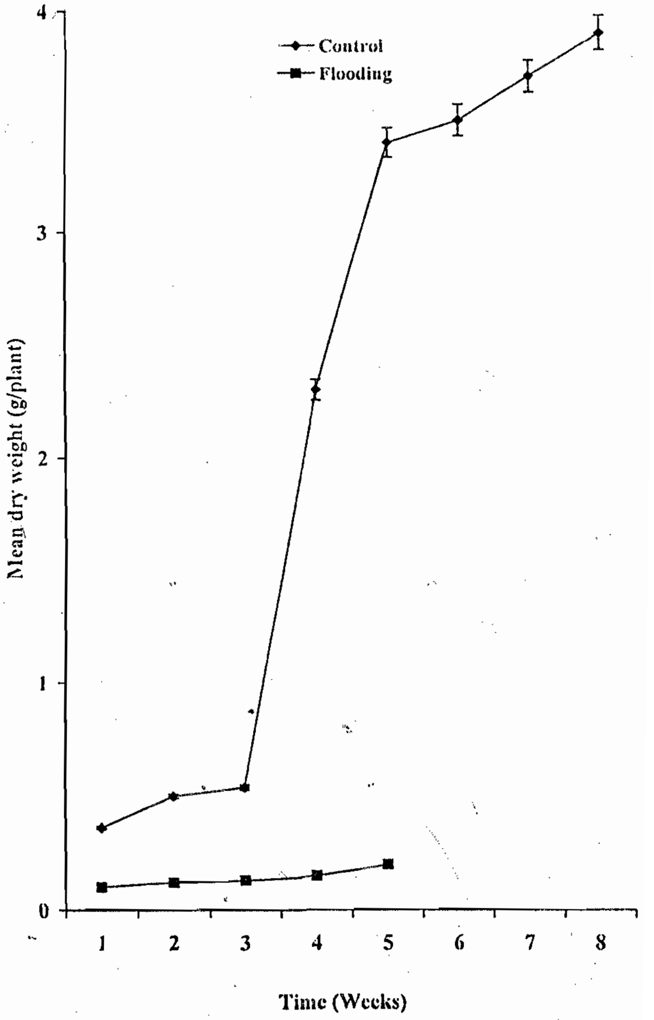

Fig. 1. Mean dry weights of *Amaranthus cruentus* L. as affected by flooding in Ekpoma, Nigeria

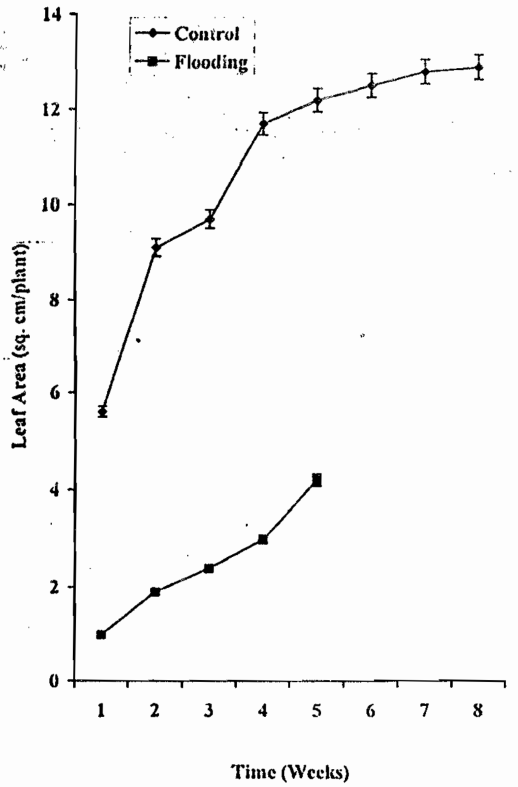

Fig. 2. Leaf Area of *Amaranthus cruentus* L. as affected by flooding in Ekpoma, Nigeria

In general, flooded plants performed poorly, as expressed by dry weights and a reduced total leaf area compared to the control plants. Nevertheless, they maintained their healthy appearance and green qualities up to week 5, implying that prolonged flooding leads to plant death and thus, *Amaranthus cruentus* tolerates flooding to 5 weeks.

As expected, plants grown in the control treatment developed extensive shoot and root and they flowered at week eight, as compared with the plants grown in the flooded condition. They also produced large and green leaves, thus produced higher yields throughout the two years experimental period than the plants in flooded condition. This was probably due to adequate water application. Also, the application of too much water to plants, in the flooding treatment, resulted in a yield decrease of 93.4 %. It is most probably that the growth rate of the species depended on the water treatments imposed on the plants. But other factors, such as temperature (Eze, 1973; Fawusi and Ormrod, 1981), and soil fertility (Awodun and Ojeniyi 2002; Ojeniyi and Adejobi, 2002) have been known to contribute to plant growth. Further experiments that will include growing *A. cruentus* in different locations could help to confirm this assumption.

Significant results from the two years data were consistent with lower yields and smaller leaf areas btained from flooded soils than regularly watered soils of the control treatment. Flooding effects also appeared in form of yellow colour on leaves. Based on these findings, it could be said that the yellowish leaves, together with senescence observed in *A. cruentus* under flooded condition, was probably due to a response to adverse effects, as earlier observed in other crops (Schmidt, 1971; Davies 1984; Trought and Drew, 1980).

Generally, flooding effects were first observed during the third week. It is notable that yellow colour appeared on leaves during the third week of flooding, indicating reduced metabolic processes.

CONCLUSION

Results of the experiment showed poor performance of *A. cruentus* in flooded soils. These results are of particular interest since virtually all Nigerians depend on vegetable for improved health, nutrition and wellbeing. Clearly, the lower growth rate of *A. cruentus* plants in flooded condition is unsurprising, in view of the stressed conditions imposed on them. The vulnerability of *A. cruentus* to flooding seems to be a discouraging feature of the species. That the effects of flooding seem to be pronounced in the plants tested indicate that the capacity of *A. cruentus* to tolerate flooded conditions may be relatively low.

It is obvious from dry matter production and leaf area development that production of *A. cruentus*, in the Niger Delta Region, can not be encouraged during the peak of rainy season since farmers would loose roughly 90% of vegetable yield if grown on flooded and poorly drained soils. We recommend that, with moderate rainfall, *A. cruentus* should be cultivated in the dry-land areas of the Niger Delta Region. Furthermore, it could be cultivated near the riverbank especially during the off-season dry period when other vegetable crops are not available in the markets.

Investigation on water stress of other vegetable crops needs to be carried out to better understand water stress and predictable impacts on vegetable crop production.

For practical purpose, off-season vegetable production has an advantage in that livelihood of the people will be enhanced, since poverty can be reduced via food security.

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