Developmental and Morphological Indices of *Phaseolus vulgaris* L. and Soil Physico-chemical Properties during Serial Flooding in Bayelsa State, Nigeria

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ABSTRACT

***Background**:* Flooded soil is a significant agronomic problem because most plants do not tolerate excess water in the soil. Yenagoa, Bayelsa State is characterized by seasonal flooding that often engulf cultivated soils This study was conducted to assess the response of *Phaseolus vulgaris* to flooded soil condition in the study area.

***Methods**:* Viable seeds of the test crop were sterilized and sown in soils of Site A (control) and B (flooded soil) in rows. The research work was planned such that, the *P. vulgaris* seedlings were established up to one (1) month before the area (Site B) was flooded. Plant growth parameters such as plant height, leaf number, dry weight, nitrogen, phosphorus and potassium contents were examined. Standard methods were used to determine the mineral nutrient compositions in the test plant. Soil physico-chemical properties of the experimental soils were determined.

***Results**: P. vulgaris* exhibited moderate wilting and chlorosis during the first week of exposure to flood condition. The severity of wilting and chlorosis increased with increase in the duration of the stress condition. Other morphological characteristics observed were retarded growth, dropping of leaves, decrease leaf number, and reduced leaf size during the second and third week of exposure to flood condition, and death of the entire plant at the fourth week of study. The leaf number and dry weight of the crop decreased with increase in the duration of exposure to flood condition with values comparatively lower than that of the control. There were significant ($P< 0.05$) reductions in nitrogen, phosphorus and potassium contents of *P. vulgaris* under flooded condition relative to the control

***Conclusion**:* This study showed that *P. vulgaris* was susceptible to flooded soil. The test crop growth parameters were negatively affected by the flooded soil condition.

***Key words*— Developmental, Morphological, *Phaseolus vulgaris*, Soil properties, flooding**

1. INTRODUCTION

Flooding is one of the major abiotic stresses that play a crucial role in the determination of species distribution worldwide and is usually used to assess the success or failure of crops in much arable farmland by the frequency and extent of flooding [1]. Soil flooding has been identified as a major environmental hazard and the constraints it imposes on roots have marked effects on plant growth and development [2]. Flooding restricts aeration of the soil creating an oxygen-free environment in the root zone, thus damaging cultivated crops and resulting in poor growth and low yield [3]. This implies that soil flooding is a significant agronomic problem for crop production [4].The variety of habitats in which occasional or regular flooding takes place is large, and some are currently increasing in area. In consequence, certain habitats demand exceptional adaptations, especially when one or more essential resources is scarce or absent. The overriding conditions in wetlands are an example of such an extreme environment since the highly water-saturated soils exclude oxygen, one of the fundamental requirements for plant life [1]. *Phaseolus vulgaris* L. (Fabaceae) commonly called common beans has edible leaves often used in soups preparation with high protein content of the seeds, which makes it a valuable food for domestic consumption and as export crop [5,6]. The common bean is a major grain legume consumed worldwide for its edible seeds and pods, and it represents a rich source of protein, vitamins, minerals, and fiber, especially for the poorer populations

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of Africa and Latin America [7]. It is a highly polymorphic warm-season, herbaceous annual [8], which does better under subtropical and temperate conditions. It can be found in tropical areas but does not do well under very wet conditions, which cause fungal attacks and flower drop [6, 8]. Yenagoa, the Capital of Bayelsa State is characterized by seasonal flooding with its associated environmental problems. The test crop *P. vulgaris* has been reported to be highly prone to flooding damage, therefore, soil flooding is considered as one of the major factors that could restrict the productivity of the crop. This study becomes increasingly important in order to assess the response of *P. vulgaris* to stress condition resulting from flooding in Bayelsa State, Nigeria.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Equipment

Equipment and apparatus used include; soxhlet apparatus, heating mantle, blender, autoclave, incubator, automatic weighing balance, refrigerator, and spectrophotometer. glasswares used include; test tubes, beaker, conical flask, reagents used include; distilled water, petroleum ether, sulphuric acid , sodium hydroxide, anhydrous sodium sulphate, ethyl acetate, ferrous sulphate, ferrous chloride, aluminum chloride, ammonia solution,. Other materials include; aluminum foil, spatula and spectrophotometer.

2.1.2 Biological Materials

The biological materials used for this research were: the plant samples of *Phaseolus vulgaris* obtained from Opolo, Yenagoa, Bayelsa State.

2.2 Methods

2.2.1 Study Area:

The research was carried out in Opolo, Yenagoa, Bayelsa State, Nigeria. Yenagoa is located at coordinates of 4° 55' 33.51"N and 6° 15' 33.58"E. Bayelsa State lies in the heaviest rainfall area of Nigeria with a mean minimum monthly temperature ranging from 25^{o}C to 31^{o}C [9].

2.2.2 Collection of Samples:

Plant materials of the test species were collected from the two (2) sampling locations (Site A and B) in Opolo, Yenagoa, Bayelsa State, Nigeria. Similarly, soil samples of Site A and B were collected for determination of soil-chemical properties. Three replicates were maintained per treatment.

2.2.3 Analysis of Soil samples:

Top soils of about 0-20cm depth collected from the study areas were analysed for soil-chemical properties using standard procedures [10].

2.2.4 Germination and Growth Studies

A suitable site (Site B) was selected, mapped and prepared for cultivation of seeds of Phaseolus vulgaris. Soil samples were collected for analysis of physico-chemical characteristics. Site B was an area prone to seasonal flooding. The research work was planned such that, the P. vulgaris seedlings were established up to one (1) month before the area (Site B) was flooded. A corresponding site A (Flood free area) was use as control treatment. Viable seeds of the test crop were sterilized and sown in soils of Site A and B in rows (3 seeds per stand with 20 sampling units). The experimental set up of Site B was maintained for 4 weeks before being flooded and thereafter allowed for another 4 weeks in order to assess the effects of flooded soil on the test crop.

2.2.5 Mineral nutrient Analysis in Plant Samples

The method of [11] was used for mineral elements analysis in plant samples. Plant samples of *P. vulgaris* were washed several times with water and rinsed with distilled water. They were placed in polybags, and thereafter dried in an oven maintained at 60^o C to a constant weight. The dried plant samples were macerated to powder, and stored in sample bottles for analysis. The powdered plant samples were oven dried at 105^{o}C for 2 hours, 1.0g weighed into a platinum crucible and placed in a muffle furnace maintained at 400^{o}C. The powdered plant materials were ashed for 5 hours and then dissolved with 10cm^3 of 1M HCL. The solution obtained was filtered through Whatman No. 1 filter paper into 50cm^3 volumetric flask and made up to the required mark with distilled deionized water. Standard reagents for analytical experiment were used, and contents of mineral elements in the solution were determined using Atomic Absorption Spectrophotometer (AAS) of Unicam Model.

2.3 Statistical Analysis

The data generated from this study was assessed using Analysis of variance (ANOVA) and differences in the means were tested using Least Significant Differences (LSD) at probability level of 5% [12].

3. RESULTS

The soil characteristics of the study area (Control-Site A and Flooded area-Site B) are presented (Table 1).There were marked morphological changes of the growth attributes of *P. vulgaris* subjected to flood condition. *P. vulgaris* exhibited moderate wilting and chlorosis during the first week of exposure to flood condition. The severity of wilting and chlorosis increased with increase in the duration of the stress condition (Table 2). Other morphological characteristics observed were retarded growth, dropping of leaves, decrease leaf number, and reduced leaf size during the second and third week of exposure to flood condition. *P. vulgaris* could not survive beyond the fourth week of exposure to flood stress as was evident by the death of the entire plant (Table 2). The plant height of the crop exhibited retarded growth (52.20cm) during the first, second, and third week, and subsequent death of the entire plants at the fourth week. The leaf number and dry weight of the crop decreased with increase in the duration of exposure to flood condition. The values recorded under flooded soils were comparatively lower than that of the control (Table 3).There were significant ($P < 0.05$) reductions in nitrogen, phosphorus and potassium contents of *P. vulgaris* under flooded condition relative to the control (Table 4)

Table 1: Chemical Properties of Experimental Soils before Cultivation of *Phaseolus vulgaris*

Soil parameters	**Sampling locations**	
	Control (Site A)	**Site B**
pH	5.09 ±0.21	5.08±0.42
Organic carbon (%)	2.52± 0.11	3.14± 0.07
Total nitrogen (%)	1.89± 0.04	2.10± 0.52
Avail. Phosphorus (%)	4.09± 0.22	4.23± 0.38
Calcium (mg/100g)	2.30± 0.10	2.19±0.07
Magnesium (mg/100g)	2.02± 0.71	2.55± 0.90
Potassium (mg/100g)	2.90±0.06	2.72±0.46
Zinc (mg/100g)	0.09± 0.01	0.12±0.02
Copper (mg/100g)	0.33± 0.03	0.44±0.03
Cadmium (mg/100g)	0.23± 0.04	0.18±0.02
Iron (mg/100g)	0.14±0.06	0.10±0.05
Lead (mg/100g)	0.04± 0.01	0.08±0.01
Manganese (mg/100g)	0.09±0.02	0.04±0.05

Mean ± standard error from three replicates

Table 2: Morphological Characteristics of *Phaseolus vulgaris* under Varying Duration of Flooding

Sampling locations	Control (Site A)	Flooded Area (Site B)			
Flood duration-Weeks (Wk)	Week-1-4	Week- 1	Week-2	Week-3	Week-4
	Plant exhibited normal growth; no chlorosis, plant height, leaf number and leaf size increased with time.	Moderate wilting and chlorosis.	Wilting, chlorosis, retarded growth, decrease leaf number and reduced leaf size	Wilting, dropping of leaves, chlorosis, retarded growth, decrease leaf number and reduced leaf size	Dropping of leaves, and death of entire plants

Table 3: Growth Parameters of *Phaseolus vulgaris* under Varying Duration of Flooding

Flood duration- Weeks (Wk)	Week- 1	Week-2	Week-3	Week-4
Flooded Area				
Plant height	52.20±0.42	52.20±0.79	52.20±0.30	0.00±0.00
Leaf number	16.23±0.33	14.21±0.25	4.33±0.21	0.00±0.00
Dry weight	1.09±0.10	1.02±0.14	0.26±0.03	0.00±0.00
Control				
Plant height	52.20±0.38	56.72±0.46	58.24±0.55	62.35±0.23
Leaf number	16.33±0.16	20.18±0.22	20.33±0.25	23.03±0.46
Dry weight	1.26±0.11	1.29±0.27	1.30±0.23	1.32±0.21

Mean ± standard error from three replicates

Table 4: Nutrient Contents of *Phaseolus vulgaris* under Varying Duration of Flooding

Flood duration- Weeks (Wk)	Week- 1	Week-2	Week-3	Week-4
Flooded Area				
Nitrogen (%)	3.06±0.12	1.22±0.12	1.06±0.38	0.00±0.00
Phosphorus (mg/00g)	9.03±0.32	2.24±0.09	2.03±0.22	0.00±0.00
Potassium (mg/100g)	1.82±0.26	0.72±0.03	0.46±0.04	0.00±0.00
Control				
Nitrogen (%)	3.12±0.16	3.17±0.25	3.20±0.12	3.21±0.21
Phosphorus (mg/00g)	9.07±0.10	9.08±0.24	9.30±0.35	9.34±0.47
Potassium (mg/100g)	1.26±0.24	1.28±0.32	1.31±0.27	1.36±0.23

Mean ± standard error from three replicates

4. DISCUSSION

Growth reductions and deterioration in various attributes of *Phaseolus vulgaris* such as plant height, leaf number, leaf size, and dry weight were recorded in soils affected by flood as indicated in this study. Various studies have been conducted on the effects of soil flooding on plant growth and development [13, 14]. Plant species show variability in response to soil flooding. For most crops, excess water is a major constraint to productivity in many regions and situations [14]. Stress on plants imposed by flooding of soils has been reported to constitute one of the major abiotic constraints on growth, species distribution and agricultural productivity [13]. A major constraint resulting from excess water, particularly, for poorly adapted species, is an inadequate supply of oxygen to submerged tissues, and diffusion of oxygen through water has been shown to be 10^4-fold slower than in air [15]. Oxygen starvation in these soils has been reported to arise from a disparity between the slow diffusion of gases in water compared with air and the rate that oxygen is consumed by micro-organisms and plant roots. This results in flooded soil often becoming devoid of oxygen at depths below a few millimeters [1, 16]. Similarly, the flood water itself constitutes a negative factor, such that, broad unstirred boundary layers quickly develop around respiring tissues, thus leading to tissue oxygen deficiency within a few hours. The impact of this abnormal soil condition becomes enormous since roots and rhizomes are essentially aerobic organs, and can lead to death of plant tissues, as aerobic respiration ceases, levels of energy-rich adenylates drop rapidly, causing a drastic reduction in ion uptake and transport [17, 18]. Again, when floodwater deepens sufficiently to inundate the shoots as well as the roots, stress on the plants is much magnified possibly due to prevention of influx of aerial carbon dioxide for photosynthesis [1, 16]. In this study, there were significant reductions in nitrogen, phosphorus and potassium contents of *P. vulgaris* under flooded conditions relative to the control. During flooding, soil lost due to erosion can take with it valuable plant-available nutrients and organic matter. Although, deposition of sediments from floods may increase the level of nitrogen, phosphorus, silicon, and potassium in the soil, water soluble nutrients such as nitrate-nitrogen and potassium can be leached past the crop's rooting depth and potentially into the groundwater. Nitrogen in water-saturated soils can be converted to gaseous forms through the process of denitrification and lost to the atmosphere. Similarly, available phosphorus can be reduced due to flooding by decreasing the populations of microorganisms responsible for promoting phosphorus availability [19]. On waterlogged sites, both Mn toxicity and N deficiency may be induced by the low redox potential that produces plant-available Mn^{2+} and promotes denitrification of NO_3^-. It has been reported that water logging resulted in a decrease of N, P, K and Ca uptake by *Brassica napus* L [20]. Conversely, water logging changes the available ion concentration of the soil solution due to electron excess, such that Fe^{III} and Mn^{IV} are reduced to Fe^{II} and Mn^{II}, respectively [21]

5. CONCLUSION

The growth parameters of *Phaseolus vulgaris* were negatively affected by soil flooding. Growth parameters such as plant height, leaf number, leaf size, and dry weight, as well as nitrogen, phosphorus and potassium contents of plant exhibited negative responses to flooded soils.

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Conflict of Interest

There was no conflict of interest between the two authors.

Contribution of the Authors

Dr. Mbosowo Etukudo was fully in charge of the plant parameters while Dr. Benefit Onu was in charge of Soil Chemical characteristics. The Compilation of this paper was organized collectively by the two authors.

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