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An Assessment of the Effect of Automobile Emmission on Selected Roadside Vegetation

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ABSTRACT: Comparative phytoassessment of some selected vegetation exposed to automobile emission along Sapele road, Benin City, Nigeria at different distances from the road was carried out. Three plots (100 cm^2 in area) were mapped out at intervals of 10 m away from the road to serve as treatment plots. The plots were designated as A (0 m – 10 m), B (10 m – 20 m) and C (20 m – 30 m) and a fourth plot was the control (100 m – 110 m) plot. Three plants, *Sida acuta, Sida garckeana and Mariscus alternifolius*; were selected for physiological studies as they were common to all the plots. The leaves of *Sida acuta* were analyzed for the presence of heavy metals. There was no direct relationship between the results of the growth parameters investigated and distance from the road except for leaf area which increased with increase in distance from the road. For example control, A (0 m – 10 m), B (10 m – 20 m) and C (20 m – 30 m) plots recorded 24.61 ± 1.98 10.60 ± 0.75 15.19 ± 1.68 and 18.05 ± 2.47 cm^2 for leaf area of *Sida garckeana.* Disposal of organic wastes in the immediate environment of the road may have masked the effect of these metals. The plant analysis revealed that there was progressive decrease in heavy metals content of the plant with increase in distance away from the road.

Keywords: Phytoassessment, Vegetation, *Sida acuta, Sida garckeana*, *Mariscus alternifolius*

Introduction

Pollution is the presence of substances in the environmental media (air, water or land) whose nature, location or quantity produces undesirable effects. Environmental pollution is a product of urbanization and technology, increase in population density, unorganized industrialization and increased use of automobiles. Natural events are also a contributing factor to environmental pollution. Environmental pollution is presently a great concern as pollutants have toxic effect on humans as well as the ecosystem at large (Jenan *et al.,* 2012; Santosh, 2012; Sharma and Prasad, 2010).

In modern times, pollution has become the biggest menace for the survival of the biological species (Kumar *et al.,* 2013). Anthropogenic activities such as fossil fuel combustion, industrial effluents and solid waste disposal, agricultural practices (use of fertilizers, insecticides, pesticides and herbicides), mining and metal processing, automobile emissions and other industrial processes have altered the environment significantly (Wang *et al.,* 2008).

Among the numerous environmental pollutants, an important role is ascribable to heavy metals whose concentration in soils, water and air are continuously increasing as a consequence of anthropogenic activity (Abechi *et al.*, 2010). The term heavy metal includes transition metal, metalloids, lanthanides and actinides which have been propounded based on their density, atomic number and their chemical properties and toxicity (John, 2002).

Pollution of the natural environment by heavy metal is a worldwide problem because these metals are indestructible and most of them have toxic effect on living organisms when they exceed a certain concentration (Ghrafet and Yusuf, 2006). Notwithstanding, the fact that some heavy metals at low concentration are essential micronutrients for plants, their high concentrations cause metabolic abnormalities and growth reduction in various plant species particularly those growing along roadsides (Nawazish *et al.,* 2012)

Road side soils have been shown to have considerable contamination due to both deposition from vehicle derived-heavy metals and relocation of metals deposited on the road surface (Harrison *et al.,* 1981). According to Adefolalu (1980) and Mabogunje (1980), in developing countries like Nigeria, improved road accessibility creates a variety of auxiliary employment which include vehicle repairers, vulcanizers, welders, auto electricians, battery chargers and dealers in other facilitators of motor transportation. These activities send trace metals into the soil as well as into the air which are subsequently deposited into nearby soils.

Roads serve as major link among communities through which foods and other important commodities are transported. It plays a role in enhancing social and economic activities. However road construction has also resulted in heavy metal pollution especially on soils (Bai *et al.*, 2009). The pollution of soils by heavy metals from automobile sources is a serious environmental issue. Results show that road side soil near motorways is heavily polluted by heavy metals from automobiles (Onianwa and Adoghe, 1997). These metals are released during different operations of road transport such as combustion, component wear, fluid leakage and corrosion of metals (Okunola *et al.,* 2008). There have been many studies on heavy metal contamination in soils along major roads due to adverse environmental, ecological and health effects of these heavy metals, which can be harmful to the road side vegetations, wildlife and the neighbouring human settlements (Turer and Maynard, 2003; Awofolu, 2005).

This study was carried out at Sapele road Benin City, a road with very high volume of traffic and also the centre for sale of used cars. The objective of the study was to investigate the impact of pollution from automobiles that ply this road on the vegetation of this area.

Materials and Methods

Study Area: The study was carried out at Sapele Road, Benin City, Edo state.

Methodology: In the present study, distance (10m intervals) from the road served as treatment. Four plots (100 m^2 each) of known physicochemical properties were mapped out on the site. Plots A (0 m – 10 m), B (10 m – 20 m) and C (20 m – 30 m) were the treatment plots while the fourth plot was the control (100 m – 110 m) plot. The 0 m point is the edge of the tarred road.

Study Plants: Three plants species (*Sida acuta, Mariscus alternifolius* and *Sida garckeana*) common to all the plots were selected for the physiological studies and the following parameters were determined.

Measurement of Plant Height: The height (cm) of each study plant present in each of the plot was measured from the soil level to the terminal bud using a measuring tape.

Number of leaves: This was done by counting the number of leaves on three plants of the three species selected in each plot.

Measurement of Leaf Area: Leaf area was determined by the proportional method of weighing a cut-out of traced area with standard paper of known weight to area ratio (Eze, 1965).

Plant Girth: The plant girth was measured from a constant height of 30cm above the ground for each species. The girth of the plant was obtained by measuring the diameter (d) of the plant with a vernier calliper and calculated for the girth using the formula πd

Root Length: The root length (cm) was measured using a measuring tape.

Shoot - Root Ratio: This was determined by separating the roots of the plants from their shoots and weighing them separately. The dry weights of the shoot of the plants were divided by their individual root dry weights (g).

Sample Preparation / Analysis of Metals

Plant samples were ground into fine powder. 2.0 g portion of each the sample was weighed accurately and 10.0 ml of concentrated $HN0_3$ was added to each. The samples were digested on a hot plate for 15 minutes. The digest was cooled and 5 ml of concentrated $HN0_3$ was added and heated for additional 30 minutes. The later step was repeated and the solution was reduced to about 5 ml without boiling. The sample was cooled again and 5ml of concentrated HCL and 10 ml of distilled water was added and the sample was heated for additional 15 minutes without boiling. The sample was cooled and filtered through a whatman.No.42 ashless filter paper and diluted to 60 ml with distilled water. Heavy metal content in the digested samples were analyzed using the Atomic Absorption Spectrophotometer.

Statistical Analyses: Statistical analysis was carried out by determining the mean of three replicates, their various standard deviation and standard error (Ogbeibu, 2005) using SPSS version 16.0 software.

Results

The data collected for the various treatment plots and control plot did not show any trend in relation to distance away from the road for the growth parametres investigated except for leaf area which increased with distance away from the road. There was however a pattern of decrease in heavy metals in the plant along the distance gradient.

The mean heights of the selected plant species on the site are presented in Table 1. The results did not follow a consistent pattern. *Sida acuta* had the highest mean height in treatment C (20 m - 30 m) and lowest in treatment B (10 m - 20 m). *Mariscus alternifolu*s had the highest mean height in Control and the least in treatment B (10 m - 20 m) while *Sida garckeana* had the highest mean value in treatment A (0 m - 10 m) and least in treatment B (10 m - 20 m). Treatment B (10 m - 20 m) had the least value in all the plants used.

Table 1: Effects of automobile emission on the height (cm) of some selected plant species

Plot	*Sida acuta*	*Mariscus alternifolius*	*Sida garckeana*
CONTROL	64.66 ± 1.20	58.00 ± 4.04	85.66 ± 7.12
A (0 m – 10 m)	70.00 ± 3. 60	49.00 ± 11.06	72.00 ± 0.50
B (10 m – 20 m)	55.16 ± 1.30	39.66 ± 5.04	57.33 ± 9.52
C (20 m – 30 m)	76.66 ± 6.83	43.66 ± 2.84	61.33 ± 9.40

Each value is the mean of three replicates

The results for number of leaves of sample plants (Table 2) did not follow a consistent pattern. For example *Mariscus alternifolius* recorded its highest number of leaves in control and the lowest in treatment B (10 m - 20 m). All the sample plants had the lowest number of leaves in Treatment B (10 m - 20 m).

Table 2: Effects of automobile emission on the number of leaves of some selected plant species

Plot	*Sida acuta*	*Mariscus alternifolius*	*Sida garckeana*
CONTROL	204.67 ± 15.62	12.00 ± 1.00	108.00 ± 22.03
A (0 m – 10 m)	391.00 ± 58.28	9.00 ± 1.15	259.33 ± 61.52
B (10 m – 20 m)	80.66 ± 1.45	6.66 ± 0.88	27.00 ± 2.30
C (20 m – 30 m)	338.33 ± 79.46	7.00 ± 0.57	111.67 ± 38.64

Each value is the mean of three replicates.

The results for the leaf area (cm^2) of the representative plants (Table 3) show a definite pattern consistent with distance away from the road. The leaf area increased with increase in distance away from the road. Control plants had the highest leaf area for all the plants. For example when *S. garckeana* leaf area was 10.60 ± 0.75 cm^2 in treatment A (0 m - 10 m), Control was 24.61 ± 1.98 cm^2.

Table 3: Effects of automobile emission on leaf area (cm^2) of some selected plant species

Plot	*Sida acuta*	*Mariscus alternifolius*	*Sida garckeana*
CONTROL	10.56 ± 0.89	9.34 ± 0.44	24.61 ± 1.98
A (0 m – 10 m)	4.75 ± 1.27	7.00 ± 0.72	10.60 ± 0.75
B (10 m – 20 m)	8.58 ± 1.24	7.15 ± 1.29	15.19 ± 1.68
C (20 m – 30 m)	9.01 ± 0.09	7.86 ± 1.02	18.05 ± 2.47

Each value is the mean of three replicates

Table 4 shows the girth of the plant species used for physiological studies. Control plants recorded the highest girths while treatment B (10 m - 20 m) had the lowest value except for *M. alternifolius* which had the lowest value in treatment C (20 m - 30 m).

Table 4: Effects of automobile emission on the girth (cm) of some selected plant species

Plot	***Sida acuta***	***Mariscus alternifolius***	*Sida garckeana*
CONTROL	1.15 ± 0.10	1.10 ± 0.09	1.58 ± 0.01
A (0 m – 10 m)	0.83 ± 0.52	0.73 ± 0.20	1.46 ± 0.05
B (10 m – 20 m)	0.61 ± 0.01	0.44 ± 0.09	0.89 ± 0.13
C (20 m – 30 m)	1.04 ± 0.27	0.36 ± 0.05	1.19 ± 0.30

Each value is the mean of three replicates

Table 5 shows the root length of the sample species. The result did not follow a consistent pattern. *S. acuta* recorded the highest root length in treatment C (20 m - 30 m), *M. alternifolius* in treatment A (0 m - 10 m) and *S. garckeana* in the control. As in previous results, treatment B (10 m - 20 m) had the least root length except in *M. alternifolius* which recorded its lowest value in treatment C (20 m - 30 m).

Table 5: Effects of automobile emission on the root length (cm) of some selected plant species

Plot	***Sida acuta***	***Mariscus alternifolius***	***Sida garckeana***
CONTROL	28.33 ± 3.33	12.00 ± 1.52	34.00 ± 3.00
A (0 m – 10 m)	29.50 ± 4.19	12.66 ± 0.66	31.66 ± 2.66
B (10 m – 20 m)	22.00 ± 0.57	11.00 ± 1.00	22.33 ± 2.40
C (20 m – 30 m)	32.33 ± 1.45	10.00 ± 0.00	30.33 ± 2.72

Each value is the mean of three replicates

Table 6 shows the shoot- root ratio of the plants. *M. alternifolius* and *S. garckeana* recorded their highest shoot – root ratio in the control. The shoot – root ratio of *S. acuta* was highest in treatment C (20 m - 30 m). Treatment B (10 m - 20 m) recorded the lowest value in the plants measured except in *S. garckeana* which recorded the lowest value in treatment A(0 m – 10 m).

Table 6: Effects of automobile emission on the shoot-root ratio (g) of some selected plant species

Plot	*Sida acuta*	*Mariscus alternifolius*	*Sida garckeana*
CONTROL	4.36± 0.45	1.90 ± 0.21	6.38 ± 1.38
A (0 m – 10 m)	4.35 ± 0.34	1.41 ± 0.40	2.37 ± 0.49
B (10 m – 20 m)	3.56 ± 0.68	0.63 ± 0.16	4.07 ± 1.27
C (20 m – 30 m)	5.19 ± 0.61	1.12 ± 0.23	6.31 ± 1.95

Each value is the mean of three replicates

Table 7 shows the result for heavy metal analysis of *M. alternifolius* from the various treatment plots. There was decrease in heavy metals content in the plants with increasing distance away from the road. The treatment A (0 m - 10 m) had the highest values compared to all the other treatments while control had the lowest values for the heavy metals analyzed. Iron was the most abundant heavy metal in all the samples. Cadmium level was negligible in control i.e the value is ‹ 0.001.

Table 7: Heavy metal levels (ppm) of plant samples from soils of the four locations

Parameters	CONTROL	A (0 m – 10 m)	B (10 m – 20 m)	C (20 m - 30 m)
Fe	4.19	164.9	102.5	96.67
Cd	<0.001	0.13	0.08	0.05
Cr	0.02	0.47	0.21	0.15
Pb	0.11	0.52	0.53	0.41
Ni	0.14	0.76	0.46	0.38
Zn	1.87	6.9	5.95	4.84
Cu	0.61	1.27	1.14	1.06

Discussion

In this study, data obtained for height (Table 1) and number of leaves (Table 2) of the sample plants did not follow a consistent pattern in relation to distance away from the road. In the study conducted by Voegborlo and Chirgari (2007), the concentrations of lead, cadmium, nickel, zinc, copper, chromium and manganese in soil and vegetations all decreased with distance from the road, indicating their relation to traffic. In this study, there was no defined effect of heavy metals on the plants along the distance gradient. This could be as a result of the various organic wastes deposited in the immediate environment of this road which may have largely cushioned the impact of these heavy metals on the plants. This is contrary to the report of Orcutt and Nilsen (2000), Cseh (2002) and Fodor (2002) who reported the toxic effect of heavy metals on plant growth. According to Abechi *et al.* (2010), the method of binding heavy metals and hence their bioavailability depends on several soil properties which include granulometric composition, organic matter content, pH value, content of micro and macronutrients, activity of micro-organisms and conductivity.

Leaf area (as indicated in Table 3) values obtained for the plant species indicated an increase in area with distance away from the road. Control plants recorded the highest values for leaf area when compared to the treatments. It is thus apparent that heavy metals negatively affected the leaf area of the plants. This is in agreement with the report of Tiwari *et al* (2006) who recorded reduction of leaf area and petiole under pollution stress conditions. Anoliefo and Osubor (1998), reported significant decrease in leaf area of *Cucumeropsis manni* in cadmium treated soil. The reduced leaf area results in reduced absorbed radiations and subsequently in reduced photosynthetic rate (Tiwari *et al*., 2006).

Stem girth measurements (Table 4) recorded indicate that the values obtained for plants in the control plot were higher than those in the treatment plots for the three species. This further corroborates the findings of Levitt (1980) who reported that heavy metals in the plant environment operate as stress factors causing physiological changes and in the process reduce plant vigour, or in the extremes totally inhibit plant growth.

The results obtained for the root length (Table 5) of the plants did not follow a consistent pattern also. *S. acuta* recorded its longest root in treatment C (20 m – 30 m plot), *M. alternifolius* in treatment A (0 m – 10 m plot) and *S. garckeana* in control. In a number of studies, the effect of lead on plants revealed that growth inhibition is more prominent in root systems than the shoots (Wozny and Jerczynska, 1991; Kahle, 1993). The presence of excessive amount of Cd in soils causes many toxic symptoms in plants, such as reduction of growth, especially root growth (Weigel and Jager, 1980). The apparent lack of adverse effect in this study may be attributed to the high organic content of the soil due to human activities on the road sides.

Shoot – Root ratio of *S. acuta* was highest in plot C (20 m – 30 m plot) with a value of 5.19 g followed by control with a value of 4.36 g. *M. alternifolius* had the highest value in the control (1.90) while *S. garckeana* had the highest value also in control (6.38). A high shoot – root is an indication that shoot growth is better favoured than root growth. The results in this study revealed that root growth was most adversely affected in treatment A, the plot with highest amount of heavy metals. The reduction in shoot-root ratio in some of the plots can be interpreted as an indication of stress response or as a strategy applied by some plants facing nutrient deficiency (Merkl *et al*., 2004).

Analysis of the leaves of *S. acuta* revealed the presence of heavy metal in the leaves. The quantities of heavy metals decreased with increasing distance away from the road. This is in agreement with Voegborlo and Chirgari (2007) who reported that the concentrations of lead, cadmium, nickel, zinc, copper, chromium and manganese in soil and vegetations decreased with distance from the road, indicating their relation to traffic. There is a positive relationship between heavy metals bioaccumulated and that present in the soil. The assessment of heavy metals in soil is an index to determine the degree of metal contamination in the plant tissues (Galiulin *et al*., 2002). Heavy metals are of significant ecological concern because they are not biodegradable and have long half life thus predicating far reaching effects on biological systems including soil microorganisms and other soil biota as well as ground cover (Adeniyi, 1996; Ram *et al.,* 2000; Vwioko *et al.,* 2006). According to Adeniyi (1996), these metals also get accumulated when plants and crop cultivated along major roads are consumed by man and animals especially livestock. They may lead to geo-accumulation, bio-accumulation and bio-magnification (Lokeshwarri and Chandrappa, 2006; Ray, 1990).

Conclusion

The findings of this study shows that road side soils have a measure of pollutants and that the presence of organic matter can decrease their effect on plants. Though the vegetation may appear luxuriant, their consumption could constitute a health hazard.

References

Abechi ES, Okunola OJ, Zubairu SMJ, Usman AA and Apene E: Evaluation of heavy metals in roadside soils of major streets in Jos metropolis, Nigeria. J Environ Chem Ecotoxicol 2(6): 98-102, 2010.

Adefolalu AA: 'Transport and rural integrated development In: Proceedings of the National conference on Integrated Rural Dev Women Dev 1: 294-299. 1980

Adeniyi AA: Determination of Cd, Cu, Fe, Pb, Mn and Zn in Waterleaf (*Talinum triangulare*) in Dumpsites. Environ Int 22(2): 259-262. 1996.

Anoliefo GO, Osubor CC: Effects of cadmium on growth and metabolism of *Cucumeropsis manni* Naudin. J Environ Sci Health 1: 22-26. 1998

Awofolu OR: A survey of trace metals in vegetation, soil and lower animal along some selected major roads in metropolitan Lagos. Environ Monitor Ass 105**:** 431- 447. 2005

Bai J, Cui B, Wang Q, Gao H, Ding Q: Assessment of heavy metal contamination of roadside soils in Southwest China. Stoch Environ Res Risk Assess 23(3): 341-347. 2009

Cseh E: Metal permeability, transport and efflux in plants. In: M.N.V. Prasad and K. Strzalka (Eds.). Physiology and Biochemistry of Metal Toxicity and Tolerance in Plants. Kluwer Academic*,* Dordrecht. pp 1-36. 2002

Eze JMO: Studies on growth regulation, salt uptake and translocation PhD Thesis*,* University of Durham, United Kingdom pp. 31-33. 1965

Fodor F: Physiological responses of vascular plants to heavy metals. In: Prasad MNV and Strzalka K (eds.). Physiology and Biochemistry of Metal Toxicity and Tolerance in Plants. Kluwer Academic Dordrecht 149-177. 2002

Galiulin, R, Vladimir V, Bashkin N, Galiulina AR, Kucharski R: Airborne soil contamination by heavy metals in Russia and Poland, and its remediation. Land Contam Reclaim 10: 3 2002

Ghrefat H, Yusuf N: Assessing Mn, Fe, Cu, Zn and Cd pollution in bottom sediments of Wadi Al-Arab Dam, Jordan. Chemosphere 65: 2114–2121. 2006

Harrison RM, Laxen DPH, Wilson SJ: Chemical associations of lead, cadmium, copper and zinc in street dusts and roadside soils. Environ Sci Tech 15: 1378-1383. 1981

Jenan A, Abbas HS, Thamer JM: Equilibrium and kinetic studies adsorption of heavy metals onto activated carbon. Can J Chem Eng Tech 3: 4. 2012

John HD: Heavy metal, a meaningless term. Pure Appl Chem 74: 793-807. 2002

Kahle H: Response of roots of trees to heavy metals. Environ Exp Bot 33: 99-119. 1993

Kumar P, Kumar A, Dhyani BP, Kumar P, Shahi UP, Singh SP, Kumar R, Kumar Y, Kumar RS: Soil fertility status in some soils of Muzaffarnagar District of Uttar Pradesh, India, along with Ganga canal command area. Afri J. Agric Res. 8(14): 1209-1217. 2013

Levitt J: *Responses of Plants to Environmental Stress*. (2nd Edn.) Academic Press, New York. 1980

Lokeshwari H, Chandrappa GT: Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation. Curr Sci 91(5): 622 – 627. 2006

Mabogunje AL: 'Development process a spatial perspective' Hutchinson and Co Publishers Ltd. pp. 234-244. 1980

Merkl N, Schultze-Kraft R, Infante C: Phytoremediation in the tropics- the effect of crude oil in the growth of tropical plants. Bioremed J 8: 177-184. 2004

Nawazish, S., Hussain M, Ashraf M, Ashraf MY, Jamil A: Effect of automobile related metal pollution (Pb^{2+}& Cd^{2+}) on some physiological attributes of wild plants. Int J Agric Biol 14: 953 - 958. 2012.

Ogbeibu AE: *Biostatistics*. Mindex Publishing Company Limited, Benin City, 264p. 2005

Okunola OJ, Uzairu A, Ndukwe GI, Adewusi SG: Assessment of Cd and Zn in roadside surface soils and vegetations along some roads of Kaduna metropolis, Nigeria. Res J Environ Sci 2(4): 266-274. 2008

Onianwa PC, Adoghe JO: Heavy metal content of roadside gutter sediments in Ibadan, Nigeria. Environ Int 23(6) 873-877. 1997

Orcutt DM, Nilsen ET: Phytotoxicity and soil pollution: Heavy metals and xenobiotics. In: John Wiley & Sons, In: The Physiology of Plants Under Stress: Soil and Biotic factors. New York, USA pp 481-517. 2000.

Ram MS, Singh L, Suryanarayana MVS, Alam SI: Effect of Iron, Nickel, Cobalt on bacterial activity and dynamics during anaerobic oxidation of organic matter. Water Air Soil Pollut 117: 305-312. 2000

Ray M: Accumulation of heavy metals in plants grown in industrial areas. Indian Biologists 22(2): 33 – 38. 1990

Santosh KP: Biomonitoring and speciation of road dust for heavy metals using *Calotropis procera* and *Delbergia sissoo.* Environ Skep Cri 1(4): 61-64. 2012

Sharma S, Prasad FM: Accumulation of Lead and Cadmium in soil and vegetable crops along major highways in Agra (India). Elect J Chem 7(4): 1174 -1183

Tiwari S, Agrawal M, Marshall FM Evaluation of ambient air pollution impact on carrot plants at a sub urban site using open top Chambers. Environ. Monit Assess 119:15-30. 2006

Turer DG, Maynard JB: Heavy metal contamination in highway soils. Comparison of Corpus Christi, Texas and Cincinnnati, Ohio shows organic matter is key to mobility. Clean Tech Environ Pol 4: 235-245, 2003

Voegborlo RB, Chirgawi MB: Heavy metals accumulation in roadside soil and vegetation along a major highway in Libya. J Sci Tech 27: 86-96. 2007.

Vwioko DE, Anoliefo GO, Fashemi SD: Metal contamination in plant tissues of *Ricinus communis* L. (Castor Oil) grown in soil contaminated with spent lubricating oil. J Appl Sci Environ Manage 10(3): 127 – 134, 2006

Wang PF, Zhang SH, Wang C, Hou J, Guo PC, Lin ZL: Study of heavy metal in sewage sludge and in Chinese cabbage grown in soil amended with sewage sludge. Afri J Biotech **7**(9): 1329-1334, 2008

Weigel HJ, Jäger HJ: Subcellular distribution and chemical forms of cadmium in bean plants. Plant Physiol 65:480-482, 1980

Wozny A, Jerczynska E. The effect of lead on early stages of *Phaseolus vulgaris* L. growth *in vitro* conditions. Biologia Plantarum 33: 32-39, 1991