TDSC2172/ SP2172 – Investigating Science
Theme: Energy
Project Report

INVESTIGATING THE EFFECTS OF SOUND ENERGY ON PLANT GROWTH.

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ABSTRACT

In this project, we studied the effects of sound energy on plant growth. We wanted to investigate the effects of music on plants and determine if it matches our hypothesis that sound energy *promotes* plant growth.

We carried out the experiments by subjecting various plants to two types of music, and compared the results to a set of control plants.

From our results we can conclude that, regardless of the type of music, with a greater volume of music, more growth is observed in plants. For example, the percentage increase in the leaf area of the *Zea mays* plants were the highest for those that were exposed to louder music, with those exposed to classical music showing an increase of 91.6% and those exposed to heavy metal, an increase of 86.2%. The same was observed in the % increase in fresh weight.

Furthermore, louder music appears to be have positive effects on germination. This is especially so in kidney beans, where those seeds exposed to louder music germinated faster and had a % germination of 60%, as compared to 23% germination in the control plants.

INTRODUCTION

Studies have been done on the use of music to improve crop yield and quality in plants such as tomato plants (Hou and Mooneyham, 1999), barley (Spillane, 1991), and vegetables (Xiao Hai, 1990). This field of science is known as acoustic biology, whereby plants are subjected to sound waves or music in order to improve the crop yield and quality, and is still

in its infancy. Not much study was done in this area, as there was a lack of precise instruments to measure the responses of the plants as well as a lack of proven scientific theories in this area of study. However a study was done by Hou *et al* (1994) to establish the fact that plants do respond to external sound stimulation. Preliminary results do show that sound waves indeed increased the quality of the crops, such as tomatoes, turnips, mushrooms and beets.

In our experiments, we decided to study the effects of two types of music, a classical piece and a heavy metal piece on various parameters of plant growth, such as fresh weight of plant, leaf area, length of plant, as well as the chlorophyll concentration. This was carried out on maize plants, *Zea mays.* (Refer to Section 1)

We studied germination as well, on maize, green bean, kidney bean and rice seeds. This was done with the classical piece (refer to Section 2). We also did a short experiment on the effects of music on the uptake of water by orchids (Section 3).

We hope that if we do find results that suggest that music does have a beneficial effect on crop yield and quality, acoustic biology can then have some viable applications in agriculture. This could bring about new discoveries into the development of novel farming methods.

SECTION 1.

Analysis of the two pieces of music used in this project.

The two pieces of music used in this project are regarded as music from two very types of genre. The first piece is a classical piece, known as "Air on the G String" by *Yehudi*

Menuhin. The second is a piece of music is heavy metal, a track by *Pantera* known as "Medicine Man". We may perceive them to be two very different types of music, like the classical piece would be regarded as soothing and gentle, and the heavy metal piece would be regarded as jarring and even noisy. However we have no way to determine how plants perceive these two genres of music, whether they find them conducive for growth or stressful and disruptive.

Instead, we try to analyze the music and determine the differences between them. We have attempted to analyze the music by determining the beats per minutes, as well as the frequencies of the two pieces of music at 100, 200, 2000 and 10,000Hz.

RESULTS

Type of music	Beats per minute	Occurrence of frequency of sound waves.			
		100Hz	200Hz	2000Hz	10,000Hz
Classical	70	None	High	High	None
Heavy metal	110	A regular wave at 100Hz detected.	High	High	High

SECTION 2.

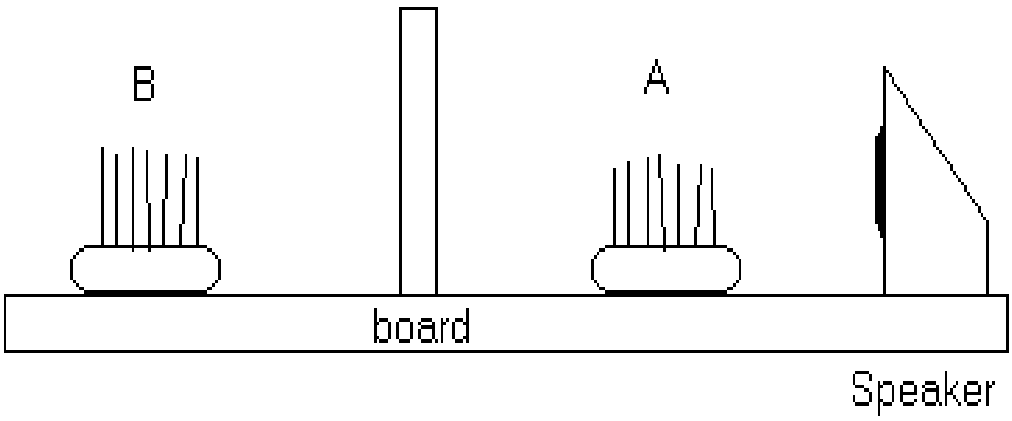
Effects of music on the growth of *Zea mays*.

In this experiments we aimed to study if exposure to music would improve or adversely affect plant growth. This was done to prove the validity of our hypothesis, which

was that music is made of sound waves and these waves would aid in the transportation of water and minerals up a plant, which in turn would promote plant growth.

We set up three sets of *Zea mays* plants. The first set was to be exposed to the piece of classical music. The second was to be exposed to the piece of heavy metal music, and the final set was the control group, to be grown in an environment that does not possess any significant sound waves. Music was played from a portable compact disc player.

The seeds used were genetically identical, so as to rule out any variations in growth due to the genetic factor. Hence any differences observed were due to the difference in the environmental conditions. For each set of plants, eight pots were used in the experiments, with 4 seeds in each pot. The control set was grown in an environment without exposure to music, whereas the other two sets were allowed to germinate without music for a week and then exposed to 24 hours of music, on alternate days. For these two sets, the plants were further separated into 2 subsets; one that was nearer to the source of music (A), and hence subjected to a louder volume of music, and the other which was further away from the source and hence subjected to a lower volume of music (B). (Please refer to the diagram below.) Temperature and light intensity was kept the same for all plants.



Setup of the experiment.

Four readings were obtained for each set of plants, taken at 3-4 day intervals on the following growth parameters, length of plant, leaf area, fresh weight, chlorophyll intensity, and photosynthetic efficiency (PEA) readings. 4 replicates were taken for each set of readings for each set of plants. This experiment spanned 17 days.

It is important to note that plants were randomly selected for the readings and we did not monitor the growth of a same plant over time. Instead different plants were used as the experiment proceeded. This was because the plants were destroyed to obtain the readings of certain parameters. Hence the readings may possess some discrepancies.

RESULTS

Table1. Volume of music played.

Type of music	Control environment	Classical (near)	Classical (far)	Heavy Metal (near)	Heavy Metal (far)
Volume of music (dB)	~5	~50	~35	~50	~35

Table2. Percentage increase in height of *Zea mays* plants above soil level.

Environment of plant	% Increase in height at the end of 17 days
Classical (near)	119.1
Classical (far)	123.1
Heavy metal (near)	130.7
Heavy metal (far)	127.1
Control	100

Table3. Percentage increase in leaf area.

Environment of plant	% Increase in leaf area at the end of 17 days
Classical (near)	131.0
Classical (far)	124.9
Heavy metal (near)	127.3
Heavy metal (far)	111.7
Control	100

Table4. Percentage change in the fresh weight of *Zea mays* at the end of the experiment.

Environment of plant	% change in fresh weight at the end of 17 days
Classical (near)	127.3
Classical (far)	112.1
Heavy metal (near)	153.4
Heavy metal (far)	123.6
Control	100

Table5. Percentage increase in Chlorophyll concerntration.

Environment of plant	% Increase in Total Amt of CHL at the end of 17 days	% Increase in carotenoids at the end of 17 days
Classical (near)	101.7	103.0
Classical (far)	89.6	90.2
Heavy metal (near)	91.6	91.5
Heavy metal (far)	86.8	86.5
Control	100	100

Table6. PEA readings.

Environment of plant	Fv/Fm (10^{th} day)	Fv/Fm (14^{th} day)	Fv/Fm (17^{th} day)
Classical (near)	0.803	0.798	0.800
Classical (far)	0.807	0.800	0.807
Heavy metal (near)	0.806	0.794	0.799
Heavy metal (far)	0.728	0.791	0.799
Control	0.797	0.781	0.794

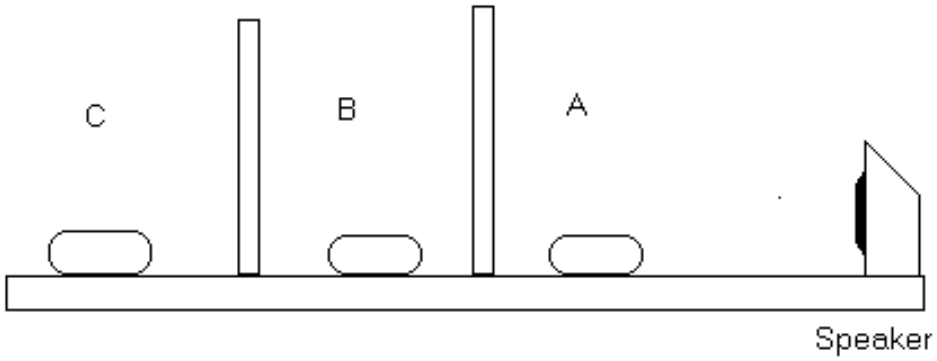
SECTION 3.

Effects of music on the germination of maize, kidney bean, green bean and rice seedlings.

In this experiment, we wanted to study the effects of music on the germination of various plants. From the previous experiment, we observed that the piece of classical music

had a more positive effect on plant growth, and hence for this experiment we decided to study the effects of only the classical piece on germination.

Two batches of the following plants were set up, maize, kidney beans, green beans and rice. 3 pots of 10 seeds per plant were sowed per batch. One batch was subjected to music non-stop for a period of 7 days. (Refer to the diagram below.) After that period of time, the plants were then allowed to germinate in an environment without significant sound waves. The other batch was the control batch, and all the seeds were allowed to germinate in an environment without significant sound waves. Temperature and light intensity were kept the same for all plants.



Setup of experiment.

Seeds were sowed in pots, watered and allowed to germinate. The seeds were subjected to the music treatment for a period of 7 days, non-stop. The pots at Position A were

the closest to the music source and hence the seeds were exposed to the greatest volume of music. The pots at B and C were increasingly further away from the music source and hence their seeds were exposed respectively to increasingly lower volumes of music.

The number of seedlings that emerged were obtained on the 7^{th}, 11^{th} and the 14^{th} day of the experiment. The results obtained are expressed as a percentage of the original number of seeds in the pot, i.e. 10 seeds.

RESULTS

Table7. Percentage germination of the batch of plants nearest to music source.

Age of plants (days)	Green bean (%)	Rice (%)	Maize (%)	Kidney bean (%)
7	90	0	40	60
11	100	60	40	60
14	100	80	40	60

Table8. Percentage germination of the batch of plants next nearest to music source.

Age of plants (days)	Green bean (%)	Rice (%)	Maize (%)	Kidney bean (%)
7	100	30	70	40
11	100	80	70	40
14	100	90	70	50

Table9. Percentage germination of the batch of plants furthest away from music source.

Age of plants (days)	Green bean (%)	Rice (%)	Maize (%)	Kidney bean (%)

7	100	20	50	50
11	100	80	70	60
14	100	90	70	60

Table10. Percentage germination of the control batch of plants.

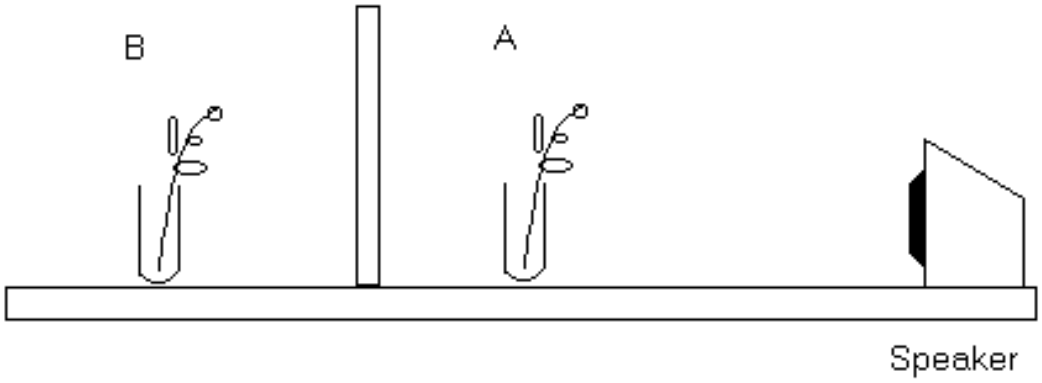
Age of plants (days)	Green bean (%)	Rice (%)	Maize (%)	Kidney bean (%)
7	73	20	27	13
11	87	90	83	23
14	87	90	83	23

SECTION 4.

Effects of music on the uptake of water by orchids.

We carried out this final experiment to test our hypothesis that sound waves aid in the movement of water and minerals up the plant. We placed individual stalks of orchids in tubes of coloured water. The water contained green dye so that we can detect the extent of the uptake of water. 10 stalks of orchids were placed in an environment without music, and they served as a control, while another 20 were exposed to music. The music treatment spanned a period of 14 days, non-stop. Of the 20 stalks that were subjected to the music, 10 stalks were placed in closer to the music source, hence exposed to a higher volume of music and the other 10 stalks further away, and hence were exposed to a lower volume. Again in this experiment,

the classical piece of music was used. Temperature and light intensity was kept the same for all plants.



Setup of experiment.

Stalks of orchids placed at Position A were closer to the music source, and hence were exposed to a greater volume of music. Orchids at Position B were further away and hence exposed to a lower volume of music.

We left the orchids in their experimental environment for 14 days and at the end of this period of time we count the number of flowers and buds remaining on each stalk as a percentage of the number of flowers and buds on the respective stalk at the start of the experiment.

RESULTS

Table11. Percentage of flowers and buds left on orchids at the end of the experiment.

	Orchids nearer to music source	Orchids further away from music source	Control batch of orchids
Flowers	60.34%	50%	51.51%
Buds	70.27%	56.41%	40.54%

CONCLUSIONS

We started this project by analyzing the two selected pieces of music, and then observing the effects these music have on the growth of *Zea mays*. From the results gathered, the heavy metal piece has more beats per minute and we can hence deduce that the heavy metal piece has more vibrations and hence carry more energy.

Furthermore the heavy metal piece has a pulsating 100Hz wave, due to the bass. From a study done by Hou *et al* (1994), they found that a particular plant, the phylodendron plant responds best to an external sound stimulation of a frequency at approximately 100Hz. This has interesting implications on our study.

We decided to use *Zea mays* seeds as they grow fast and are easy to grow.

Our hypothesis is that sound waves carry energy in the form of vibrations and these vibrations help in the transportation of water molecules and minerals up the plant.

The results we polled from our experiments does suggests that our hypothesis's validity. In Section 2, we observed that the % increase in leaf area is the highest for the plants

exposed to louder music, that is, those subjected to louder classical and heavy metal music. Plants exposed to louder classical music recorded an increase of 91.6%, whilst those exposed to louder heavy metal recorded an increase of 86.2%. The control plants only increased by a meager 46.4%.

The same was observed in the % increase in fresh weight of the *Zea mays* plants. Those exposed to louder music showed more growth. Plants exposed to loud classical music recorded an increase of 11.5%, whilst those exposed to louder heavy metal increased by 34.3%.

Plants exposed to loud heavy metal music also showed the highest % increase in total length of plant, 41.4%. However plants exposed to loud classical did not do as well, recording a decrease by 4.1% in length. However it is important to note that inaccuracies could result due to the small sample size, and the fact that we did not monitor the growth of the same plant, but randomly select plants at different stages of the experiment to take readings.

At this point we can observe that loud heavy metal music, despite the common belief that it would be disruptive to plants and plant growth, seems to bring about advantageous effects on the *Zea mays* plants. This is observed in the results collated in % increase in fresh weight, total length and leaf area. This could be related to the study mentioned above; by Hou *et al*. Heavy metal music has a pulsating beat, with the bass producing the regular 100Hz wave. If plants do respond best to sound waves at 100Hz, this would account for our results obtained.

The next parameter measured would be % increase in amount of chlorophyll. Louder music treatment does seem to increase the chlorophyll concentration of the leaves. As observed in Table5, plants exposed to a louder volume of music record a higher increase in

the amount of Chlorophyll A, Chlorophyll B, total amount of Chlorophyll and carotenoids. For example plants exposed to louder classical music showed the highest increase in total amount of Chlorophyll and carotenoids, 35.0% and 36.7% respectively. However, it is interesting to note that the control plants showed a consistent high % increase in all the above parameters.

Photosynthetic efficiency is measured by chlorophyll fluorescence, or PEA readings. It measures the fast kinetics in the light reaction of photosynthesis. Fv/Fm measures photosynthetic efficiency. With reference to the results obtained in Table6, we observed that all plants exposed to music, especially classical, showed a slightly higher increase in photosynthetic efficiency as compared to the control. However, the differences between the readings were too minute to be significant and hence, we can only conclude that all the plants were healthy, as the Fv/Fm values were in the range of 0.79 - 0.81. At this range, all biochemical reactions in Photosystem II were occurring at an efficient rate.

In Graph1-3 (Please refer to Appendix), we observed that the plants exposed to both types of music, especially heavy metal music, loud and soft alike, showed a slight increase in the PEA readings. The control readings were lower in all three graphs. Hence we can conclude that plants exposed to both types of music show an increase in photosynthetic efficiency.

Section 3 was on the effects of the volume of music on germination. We decided to use only the classical piece, as it does not contain fluctuations in the frequencies emitted, but consist of more even sound waves, mainly at the frequencies of 200 and 2000Hz.

The results show that music had a marked effect on the germination of kidney beans. With exposure to loud music, the germination of kidney beans was at 60%, as compared to the

control, which had 23% germination. This was so for green bean as well. With exposure to loud music, or with exposure to music at all, the % germination has increased 100%, whilst the control plants only recorded an increase of 87%.

However music seems to affect the germination of maize adversely. Maize plants exposed to louder music resulted in 40% germination, while control plants showed an increase of 83%. This discrepancy could be due to the fact that the effects of music on plants are species-related.

The final experiment, Section 4, was carried out to prove our hypothesis. The orchids were exposed to music non-stop for a period of 2 weeks and at the end, the number of flowers and buds remaining were compared. The results show that the orchids exposed to loud music had the greatest % of flowers and buds remaining on the stalks, with 60.34% of flowers and 70.27% of buds remaining. The control on the other hand had the lowest % of flowers and buds remaining, with 51.51% flowers and 40.54% buds remaining. Most of the buds on the control had fallen off before they could bloom into flowers.

With this experiment, we can safely conclude that the louder the music, the greater the vibrations, and with these stronger vibrations, water and minerals can be more extensively transported around the plant and hence lead to more growth and germination.

However, these are just preliminary observations. More experiments have to be done in order to push forth our claims.

ACKNOWLEGDEMENTS

We would like to express our sincere gratitude to our mentor, Dr Ong, who had guided us right from the day we selected our topic to the very end. We also would like to thank Wan Yee, who taught us all we needed to know and helped us in every way she could, Rehka and Yu Hua for their assistance and encouragement.

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APPENDIX

Table12. Absolute Total Length of *Zea mays*.

Environment of plant / length of time (days)	Average length of root (cm)			Average length of leaf + stem (cm)			Average Total length (cm)		
	10	14	17	10	14	17	10	14	17
Classical (near)	18.2	14.6	12.4	20.5	20.3	24.6	38.6	34.9	37.0
Classical (far)	13.2	14.5	13.3	19.6	22.1	24.5	32.7	36.6	37.8
Heavy metal (near)	12.3	12.4	13.3	15.5	23.7	26.0	27.8	36.2	39.3
Heavy metal (far)	12.1	13.0	9.4	13.9	19.7	25.3	26.0	32.7	34.7
Control	12.6	15.9	13.9	18.8	25.0	19.9	31.4	39.5	33.8

Table13. Absolute Leaf area of Zea mays over time.

Environment of plant / length of time (days)	Average Leaf area (cm^2)			
	7	10	14	17
Classical (near)	5.86	9.74	9.81	11.23
Classical (far)	5.86	8.93	8.98	10.70
Heavy metal (near)	5.86	5.80	10.46	10.91
Heavy metal (far)	5.86	5.24	9.81	9.57
Control	5.86	8.33	9.72	8.57

Table14. Absolute Fresh weight of plants over time.

Environment of plant / length of time (days)	Averaged Total Fresh Weight (g)			
	7	10	14	17

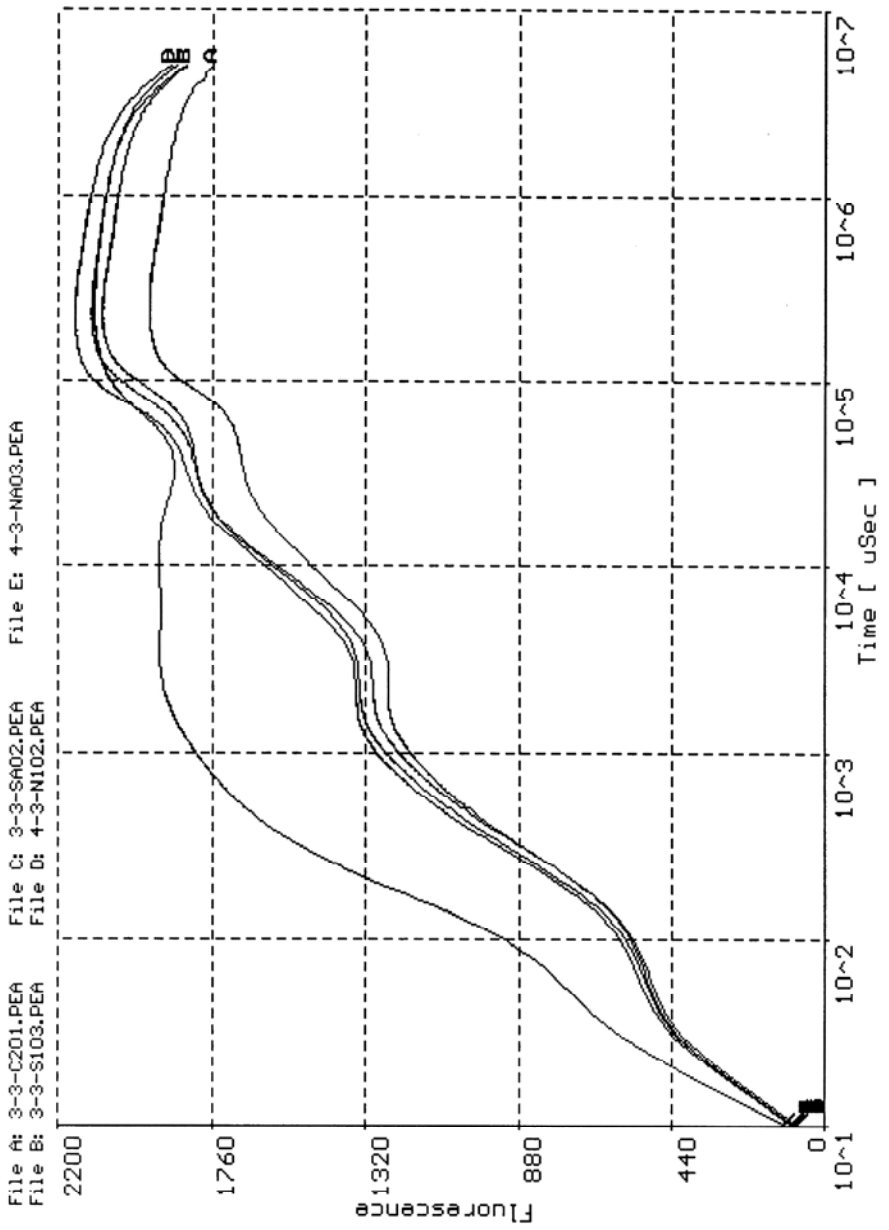
Classical (near)	0.706	0.746	0.784	0.787
Classical (far)	0.706	0.810	0.757	0.693
Heavy metal (near)	0.706	0.680	0.772	0.948
Heavy metal (far)	0.706	0.606	0.699	0.764
Control	0.706	0.677	1.033	0.618

Table15. Chlorophyll concentration of *Zea mays* leaves over time. (Absolute)

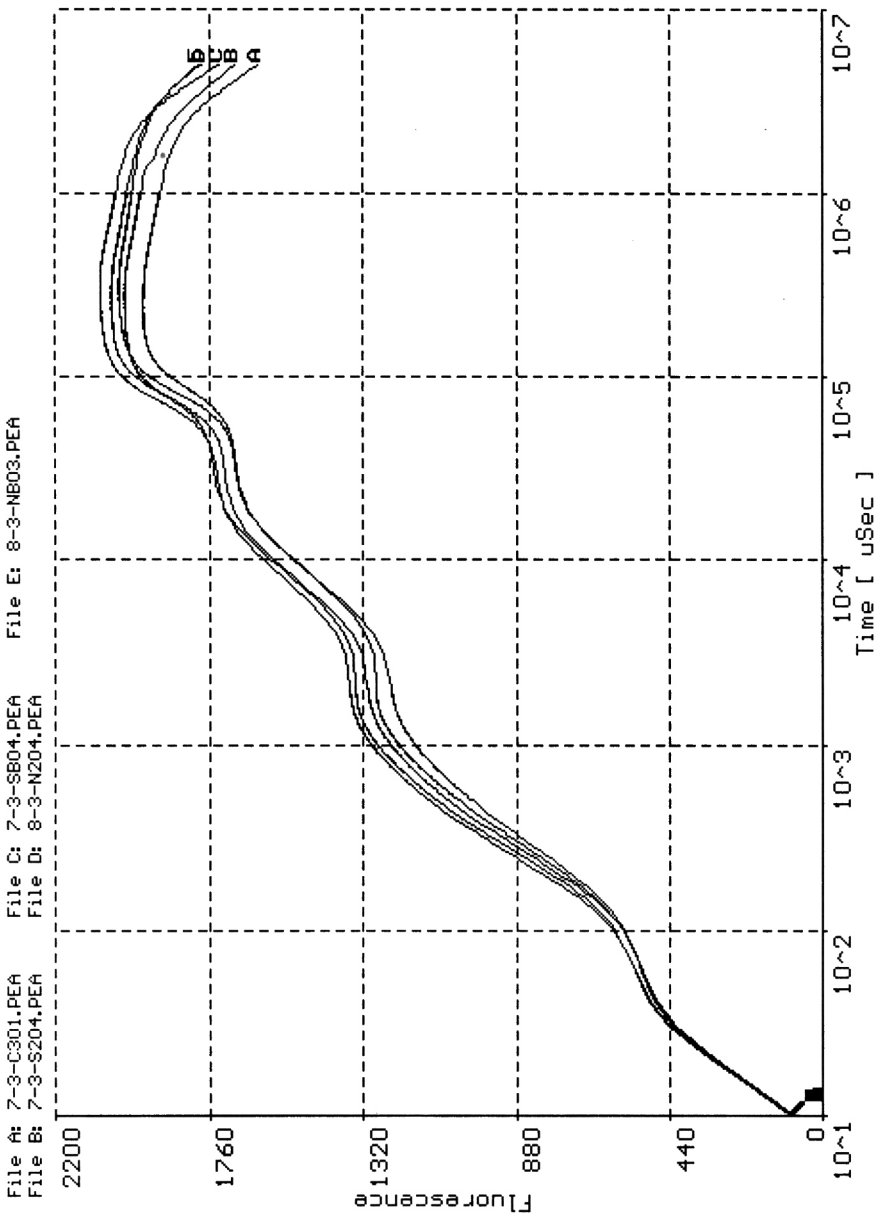
Environment of plant / length of time (days)	Amt of CHLa (mgm^{2-})				Amt of CHLb (mgm^{2-})				Total amt of CHL (mgm^{2-})			
	7	10	14	17	7	10	14	17	7	10	14	17
Classical (near)	25.4	27.4	27.9	35.4	58.6	63.9	61.5	75.0	233.9	253.7	252.9	315.7
Classical (far)	25.4	25.3	28.9	30.6	58.6	57.9	64.4	67.9	233.9	232.5	262.6	278.2
Heavy metal (near)	25.4	25.8	29.7	30.8	58.6	57.6	70.0	71.3	233.9	235.1	276.0	284.3
Heavy metal (far)	25.4	26.2	30.4	29.0	58.6	59.9	78.6	68.2	233.9	240.4	293.4	269.4
Control	25.4	26.9	30.7	33.8	58.6	61.9	76.4	77.2	233.9	247.8	291.8	310.5

Amt of carotenoids (mgm^{2-})			
7	10	14	17
42.3	45.8	46.1	57.9
42.3	42.1	47.8	50.7
42.3	42.8	49.7	51.4
42.3	43.6	51.9	48.6
42.3	44.9	52.0	56.2

Graph1. PEA readings on the 10th day.



Graph2. PEA readings on the 14th day



Graph3. PEA readings on the 17th day