Research Title:	Assessing and Improving Soil Fertility at Chonradsadornumrung School Using the Selected Organic and Inorganic Substances
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Level:	High School (Grade 11)
School:	Chonradsadornumrung School
Advisors:	Ms. Rawadee Meesuk and Mr. Marvin Servallos

ABSTRACT

This scientific investigation aims to assess and improve the soil fertility at Chonradsadronumrung School using various organic and inorganic substances. The quality of the soil from the chosen site was tested using the standard protocol from Globe and equipment from Extech. The study site was divided into 6 sections and treated with organic and inorganic substances such as egg shells, oyster shells, shredded papers, fruits, and combined substances while the other section has no treatment (control). The results of the different experiments were observed, gathered, and compared using one-way ANOVA and Tukey HSD Test. Based on the experimentations, results and gathered data, the researchers concluded that there was a significant difference ($p<0.05$) in soil pH, relative humidity, air temperature, and soil temperature measured at 5 cm and 10 cm depth. The organic and inorganic substances can improve the soil fertility at Chonradsadronumrung School and among the treatments, the combined substances are the most effective in increasing the amount of nitrogen (N), phosphorus (P), and potassium (K). In addition, more research should be done to test the other soil properties in the study site and the amount of NPK will be measured after 1 month.

Keywords: Soil Fertility, soil parameter, ANOVA and Tukey HSD Test

INTRODUCTION

The primary goals of the current environmental research are to improve the soil fertility by using the organic and inorganic substances at Chonradsadornumrung School, as well as to reduce the food waste from school canteen. The said school is one of the famous public secondary schools located in the Eastern part of Thailand that promotes academic excellence. The Educational Service Area Office evaluated and certified the school as an ASEAN model school at the educational area level. This is due to the fact that the results of the national achievement test for Mathayom 3 (Grade 9) and Mathayom 6 (Grade 12) students were higher than the average scores at the provincial and national levels. Numerous infrastructures have recently been constructed on campus to address the issue of a lack of classrooms as well as sports facilities to improve the students' athletic endeavors. Lastly, the area where the school is located has been experiencing drought because it hasn't rained in almost three months. As a result, the ground surrounding the school is completely dry. The current soil quality inside the school must be assessed, hence soil testing is unquestionably required.

The campus's huge amount of inorganic and organic wastes in the canteen is being thrown and wasted. Food wastes can be utilized to nutrient-poor soils because it is typically rich with nitrogen. According to O'Connor et al. (2022), dehydrated vegetable FW has a high concentration of plant-available N (1.71 g kg^{-1}) and total N (3.25%), making it suitable for use as a fertilizer to enhance crop growth. Anaerobic digestate from food wastes in particular has a high N concentration. Before drying, the digestate typically contains 1.5 to 6.2 g kg^{-1} of total nitrogen (Du et al., 2018). These situations prompted the researchers to conduct this environmental research entitled "Assessing and Improving Soil Fertility at Chonradsadornumrung School using the Selected Organic and Inorganic Substances". This current investigation aimed to improve the soil quality in the school by using organic and inorganic substances.

Research Questions:

1. Is there a significant difference in various soil parameters measured for four times at Chonradsadornumrung School?
2. Can various organic and inorganic compounds improve the soil fertility at Chonradsadronumrung School?

3. Which substance is the most effective in improving the soil fertility at Chonradsadronumrung School?

Objectives:

1. To find out whether there is significant difference in soil parameters measured for four times at Chonradsadornumrung School.
2. To evaluate the capacity of organic and inorganic substances in improving the soil fertility at Chonradsadornumrung School.
3. To determine the most effective substance in improving soil fertility at Chonradsadronumrung School.

Hypotheses:

Alternative: There is a significant difference in various soil parameters measured and the selected organic and inorganic substances can improve the soil fertility at Chonradsadronumrung School.

Null: There is no significant difference in various soil parameters measured and the selected organic and inorganic substances cannot improve the soil fertility at Chonradsadronumrung School.

RESEARCH METHODOLOGY

Research Design

This environmental science research employed a true experimental research design, which relies on statistical analysis to prove or disprove a hypothesis. It is the most accurate type of experimental design for this type of environmental research because it includes a control group as well as variables that can be manipulated by the researcher. This is extremely relevant and useful for soil testing to determine if there is significant difference among the gathered data. The results of soil quality measurement were compared using the appropriate statistical tool. Following that, the researchers can choose to accept or reject the given hypothesis. Descriptive research was also used, that involves observing and describing a subject's behavior without influencing it in any way. It is extremely important during the qualitative testing, as well as in describing the quality of soil inside Chonradsadronumrung School campus.

Materials and equipment used in this environmental research.

Thermo Hygrometer	4 in 1 Soil Survey Instrument	NPK measuring kit
pH Meter	2 in 1 Soil Analyzer	Beakers
Stirring rod	Digital Balance	Shovel
Meterstick	3 Way Soil Meter	Water container

Study Site

The study site is located at Bansuan, Chonburi Coastal Area with Latitude 13°21'00"N, and Longitude 100°58'42"E.

Figure 1. The study site at Bansuan, Chonburi, Thailand.

Survey and Preparation of Materials

The researchers conducted a survey around Chonradsadornumrung School, a government school located in Bansuan, Chonburi, Thailand. The soil near the Emerald pool was chosen as the study site because it is an ideal location for soil testing and soil sample collection. After the survey and selection of the study site, needed laboratory materials and equipment for soil quality testing were procured from the science laboratory of Chonradsadornumrung School. Some of the materials used to dig the soil such as shovel and hand forks were borrowed from the home economics department of the school.

Figure 2. Researchers at the study site.

Soil Quality Testing

Various soil parameters were considered in assessing the quality of soil at Chonradsadornumrung School such as soil pH, temperature, moisture, soil texture, soil consistency, soil fertility, also the air temperature and relative humidity of the study site was included. To determine the soil pH, the following steps were carried out: 40 g of dried and sieved soil with 40 mL of distilled water (or other amount in a 1:1 soil to water ratio) was mixed in a beaker using the stirring rod, the mixture was allowed to settle until a supernatant (clearer liquid above the settled soil) formed, the pH of the supernatant was measured using the pH meter. The same steps were followed for the 2 soil samples in separate beakers taken from the same site and soil horizon. Extech standard thermo-hygrometer was used to determine the air temperature and relative humidity of the study site. Digital NPK measuring kit was used to determine the amount of nitrogen, phosphorus, and potassium present in the soil. The soil characterization protocols from www.globe.gov were used in all the tests needed to evaluate the current status of the soil found in the said school.

Figure 3. *In situ* measurement of soil quality

Application of Organic and Inorganic Substances

After the measurement of soil parameters, the researchers then prepared the organic and inorganic substances from the school canteen such as egg shells and fruit peels. The shredded paper was gathered from the office of English Program while oyster shells were collected from Angsila market. All of the substances were weighed

Figure 4. Applying Organic and Inorganic Substances to soil.

using the digital balance. Each substance mass was 200g. After the substances were prepared, the researchers brought them to the study site.

The soil in the study site were divided into 6 sections with 30cm x 30cm dimension and each section represented one substance (Control, egg shells, oysters, shredded papers, fruit peels, and combined substances). Before the addition of various substances, soil parameters were measured first. Then, the prepared organic and inorganic substances were then mixed with the soil. After mixing, enough amount of water was added and the soil with the substance was mixed well using the shovel. The set-up was covered with the unused tarpaulin. After 7 and 14 days, the researchers measured the soil fertility and other parameters using the NPK measuring devices.

Figure 5. Measuring soil NPK after 14 days.

RESULTS AND DISCUSSIONS

The figures below until the next page show the data encoded on Globe web page from 22 December 2023 to 24 January 2024. Figures 7 to 13 shows the Globe data entry for air temperature, relative humidity, soil temperature, and soil pH measured at Chonradsadronumrug School, Chonburi, Thailand.

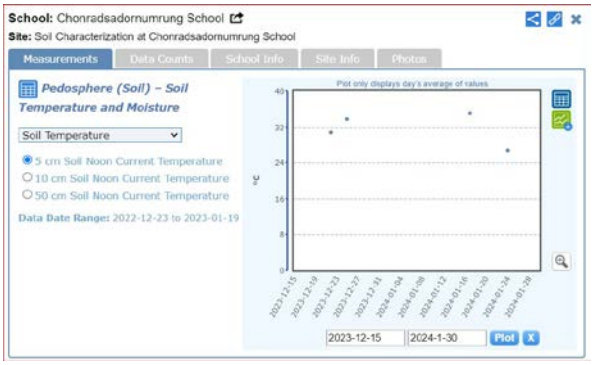


Figure 6. Globe Data Entry for soil temperature (5 cm).

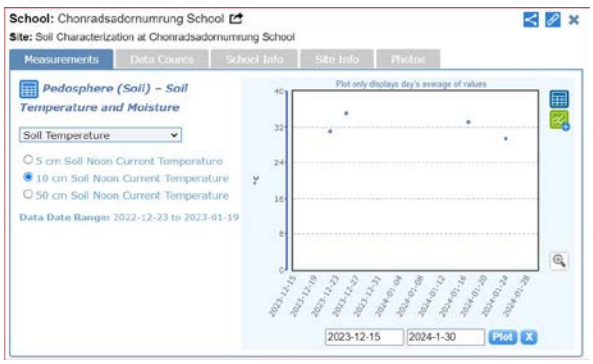


Figure 7. Globe Data Entry for soil temperature (5 cm).

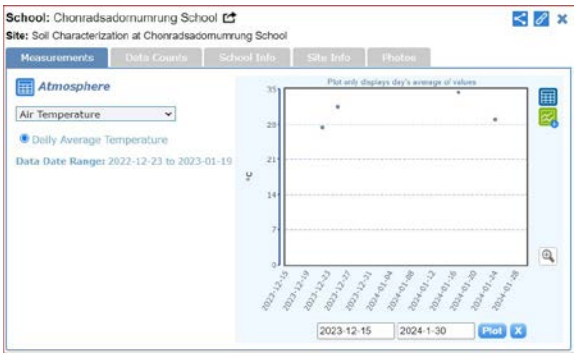


Figure 8. Globe Data Entry for air temperature

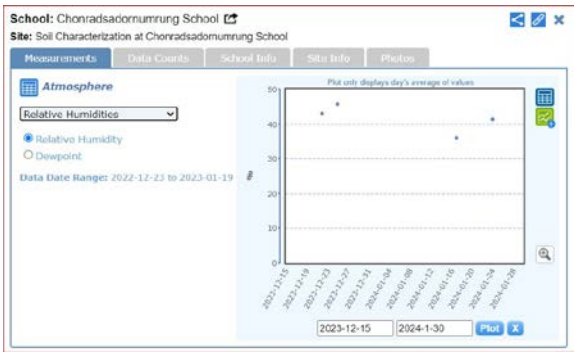


Figure 9. Globe Data Entry for relative humidity.

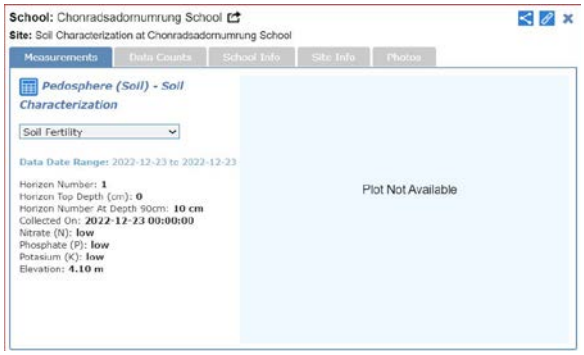


Figure 10. Globe Data Entry for soil fertility.

Table 1. Average results of soil parameters (without organic and inorganic substances) measured at Chonradsadornumrung School.

Parameters	22 Dec. 2023 (4:00 PM)	25 Dec. 2023 (4:30 PM)	17 Jan. 2024 (4:30 PM)	24 Jan. 2024 (4:30 PM)
Soil pH	7	7	7	7
Soil Temperature (5 cm)	30.67	33.67	35	26.67
Soil Temperature (10 cm)	31	35	33	29.33
Relative Humidity (%)	43	45.67	36	41.33
Air Temperature (°C)	27.3	31.4	34.3	28.9
Soil Color	Grayish brown	Grayish brown	Grayish brown	Grayish brown
Soil Structure	Granular	Granular	Granular	Granular
Soil Texture	Medium Loam	Medium Loam	Medium Loam	Medium Loam
Soil Consistency	Loose	Loose	Loose	Loose
Soil Moisture	Dry	Dry	Dry	Dry

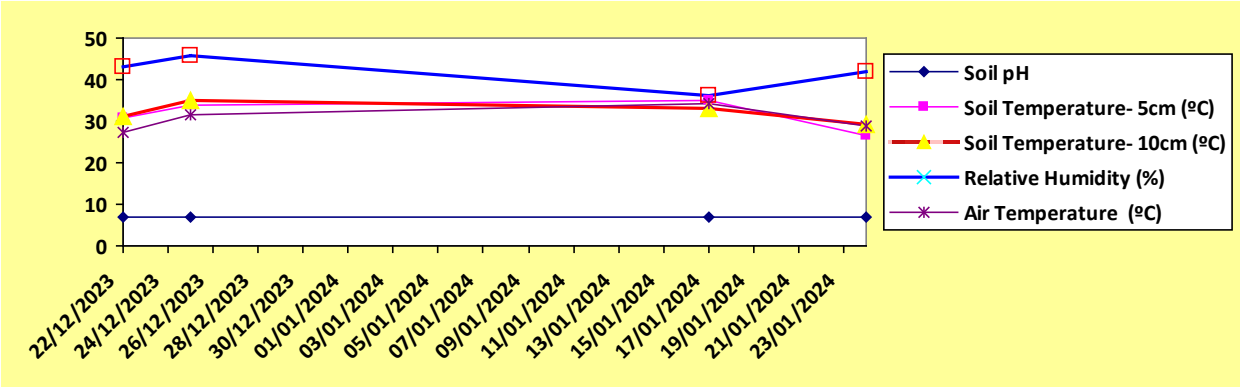
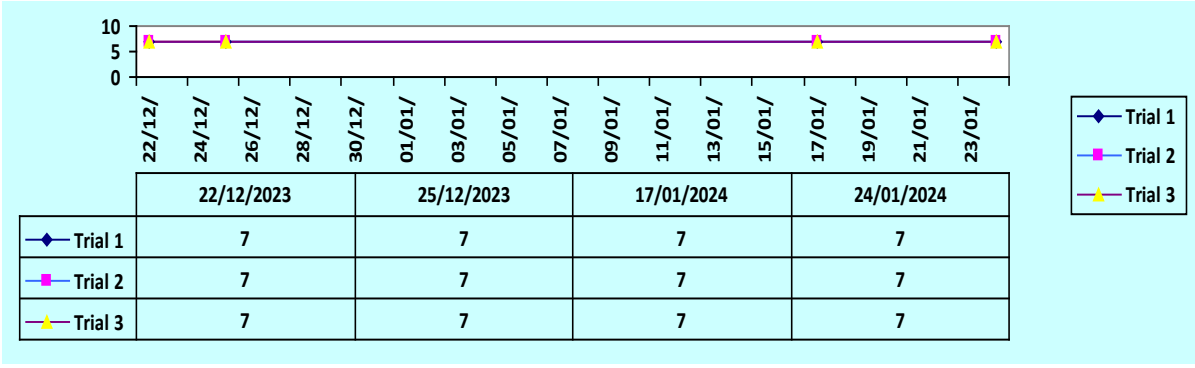


Figure 11. Average results of all soil parameters measured at Chonradsadornumrung School.

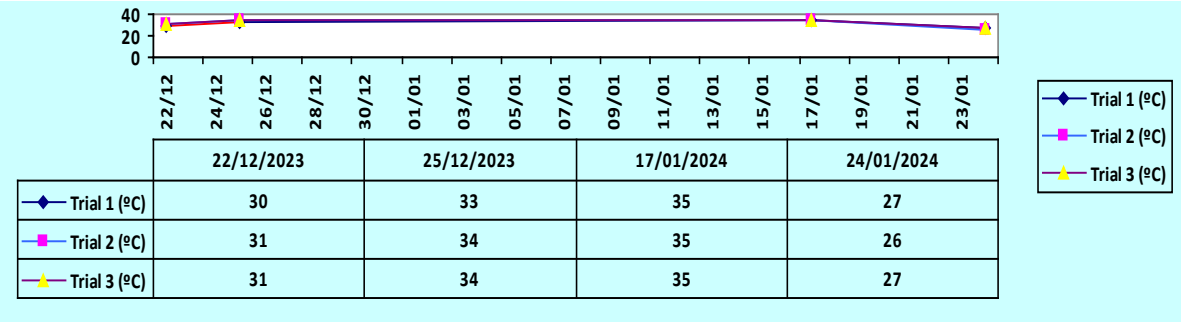
Table 1 and Figure 11 shows the average results of all soil parameters (without the organic and inorganic substances) measured at Chonradsadronumrung School, Chonburi, Thailand. These results were summarized after 4 series of experiments that started from 22 December 2023 to 24 January 2024. The average soil pH is 7, soil temperature at 5cm depth ranges from 26.67 - 35ºC, soil temperature at 10cm depth ranges from 29.33 - 35ºC, relative humidity ranges from 36 – 45.67%, and air temperature ranges from 27.3 – 34.3ºC. The soil tested from the experimental site also possess the following characteristics: grayish brown color, granular soil structure, medium loam texture, loose consistency, and dry.

One-way ANOVA and Tukey HSD test were used to determine if there is significant difference in all soil parameters measured quantitatively at Chonradsadornumrung School. It was found out that the p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05 for soil temperature measured at 5 cm and 10 cm depth, soil pH, relative humidity, and air temperature suggesting that one or more treatments is/are significantly different.



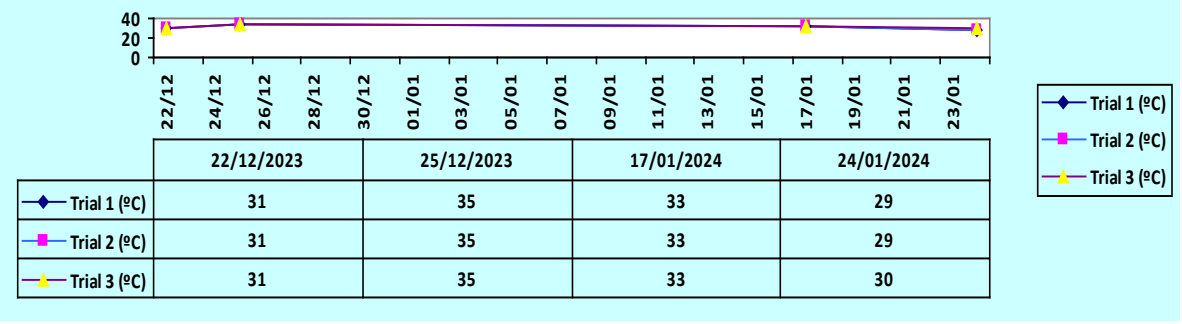
	22/12/2023	25/12/2023	17/01/2024	24/01/2024
Trial 1	7	7	7	7
Trial 2	7	7	7	7
Trial 3	7	7	7	7

FIGURE 12. Soil pH



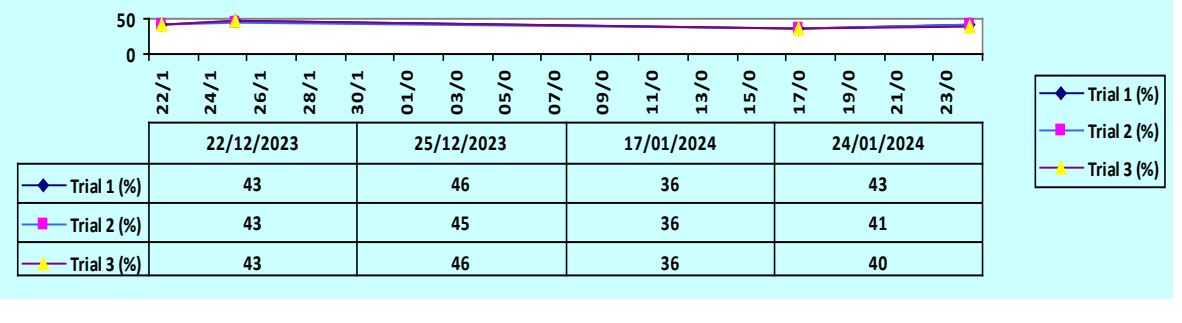
	22/12/2023	25/12/2023	17/01/2024	24/01/2024
Trial 1 (ºC)	30	33	35	27
Trial 2 (ºC)	31	34	35	26
Trial 3 (ºC)	31	34	35	27

FIGURE 13. Soil temperature at 5 cm depth (ºC).



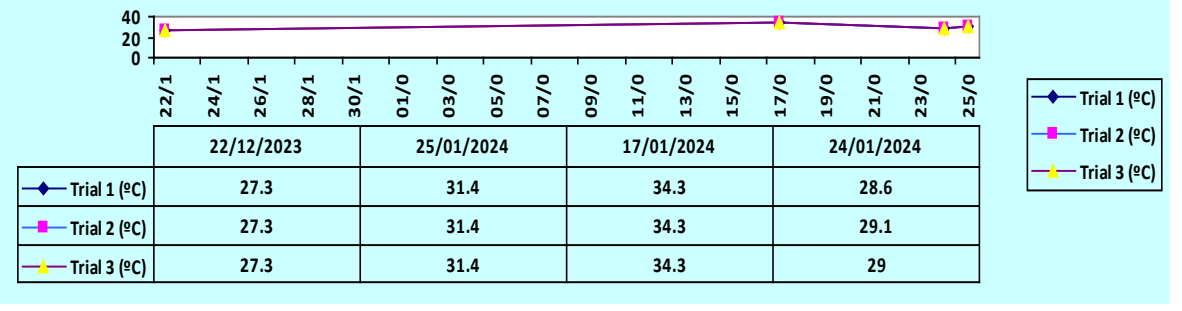
	22/12/2023	25/12/2023	17/01/2024	24/01/2024
Trial 1 (ºC)	31	35	33	29
Trial 2 (ºC)	31	35	33	29
Trial 3 (ºC)	31	35	33	30

FIGURE 14. Soil temperature at 10 cm depth (ºC).



	22/12/2023	25/12/2023	17/01/2024	24/01/2024
Trial 1 (%)	43	46	36	43
Trial 2 (%)	43	45	36	41
Trial 3 (%)	43	46	36	40

FIGURE 15. Relative humidity (%).



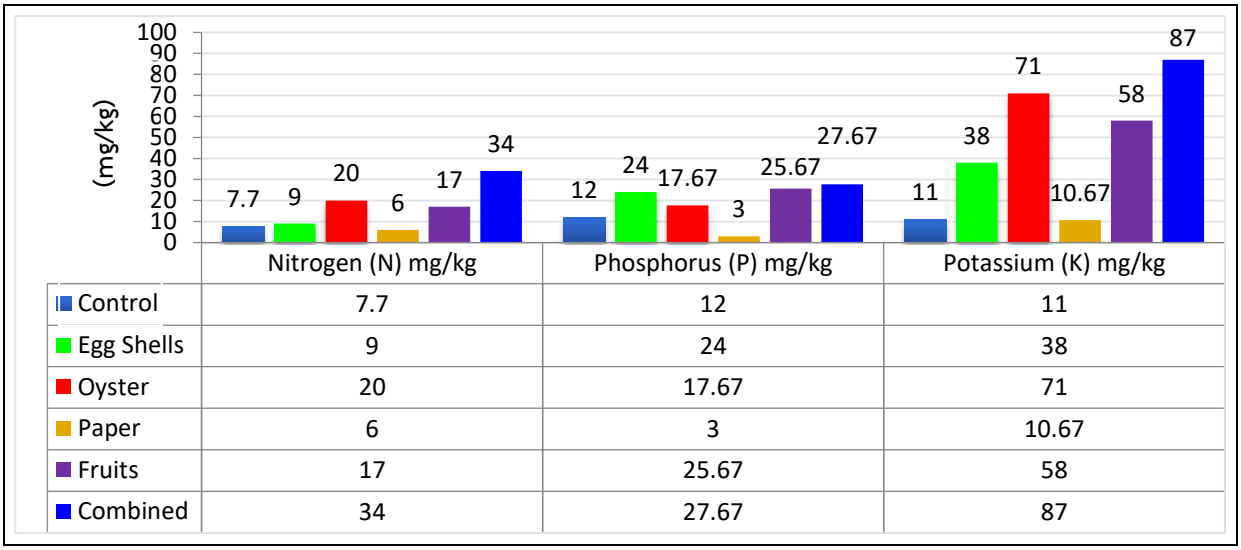
	22/12/2023	25/01/2024	17/01/2024	24/01/2024
Trial 1 (ºC)	27.3	31.4	34.3	28.6
Trial 2 (ºC)	27.3	31.4	34.3	29.1
Trial 3 (ºC)	27.3	31.4	34.3	29

FIGURE 16. Air Temperature (ºC).

FIGURE 12 to 16 shows all the soil parameters (soil pH, soil temperature, relative humidity, and air temperature) measured at Chonradsadornurung School, Chonburi, Thailand from December 22, 2023 to January 24, 2024. Each parameter was measured 3 times to get

the valid result. All of the graphs above revealed that there are changes in all factors measured for 4 times. Analysis of variance and Tukey HSD test were the statistical method used to compare these results and to find out if there are significant differences among the collected data.

Results of Soil Treatment



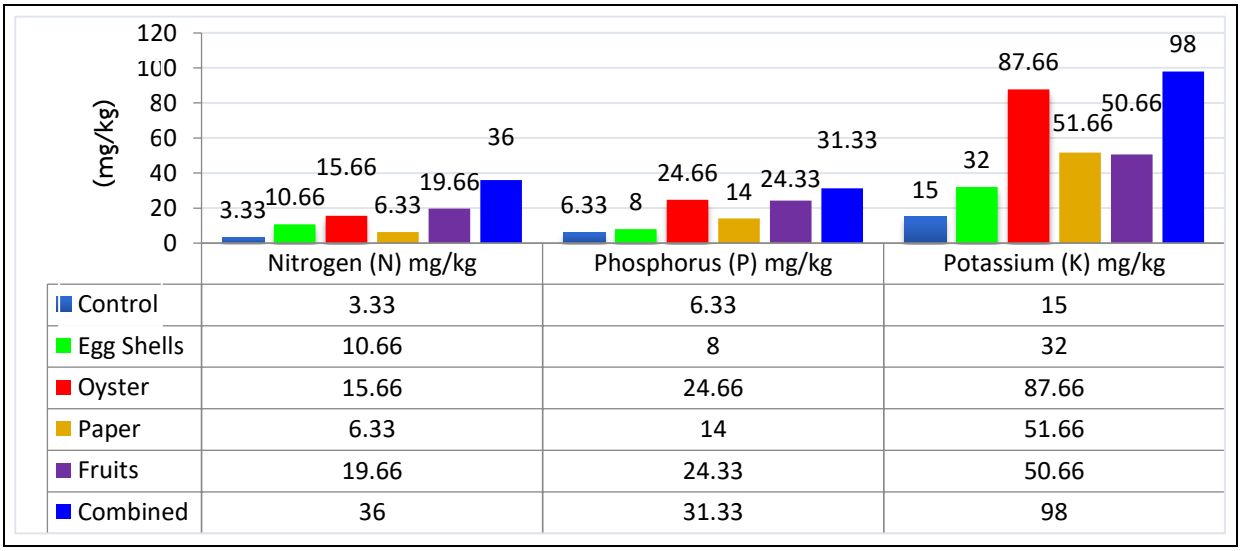
	Nitrogen (N) mg/kg	Phosphorus (P) mg/kg	Potassium (K) mg/kg
Control	7.7	12	11
Egg Shells	9	24	38
Oyster	20	17.67	71
Paper	6	3	10.67
Fruits	17	25.67	58
Combined	34	27.67	87

Figure 17. Average nitrogen (N), phosphorus (P), and potassium (K) level of soil (mg/kg) after 7 days of applying the organic and inorganic substances.

Figure 17 shows the average results of nitrogen (N), phosphorus (P), and potassium (K) level of soil (mg/kg) after 7 days of applying the organic and inorganic substances. It can be seen that there are differences in the amount of NPK among the treatments. The control (water) and paper showed the lowest level of NPK while the combined substances exhibited the highest increase of the essential soil nutrients. The ranges of available nitrogen among the treatments were 6 – 34 mg/kg. Amounts of available phosphorus varied considerably from 3 – 27.67 mg/kg while for potassium, the ranges were from 11 – 87 mg/kg. The study published by Ramadas, S. et. al, 2018, indicated that the amount of nitrogen (N) is low if it is lower than 140 mg/kg (<140mg/kg). From the graph, it can be seen that nitrogen concentration of all treatments are still low but the difference between control and experimental groups are evident. In the same study, if the amount of phosphorus (P) is <5 mg/kg it is low, 5 - 12.5 mg/kg (medium), >12.5 mg/kg (high). The results above showed that soil section with egg shells, oyster, fruits, and combined substances has high level of phosphorus while paper has low P level and the control has medium P level. The research

of Ramadas, S. et. al, 2018 also emphasized that potassium (K) level is low if it is <60 mg/kg, medium if 60-140 mg/kg, and high if >140 mg/kg. The results revealed that most of the treatments have low level of potassium (K) and only oyster and combined substances exhibited medium concentration of K (71 and 87 mg/kg repectively).

One-way ANOVA and Tukey HSD test were used to determine if there is significant difference in all treatments used to improve the soil fertility at Chonradsadornumrung School. It was found out that the p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05 ($p<0.05$), it means that one or more treatments is/are significantly different.



	Nitrogen (N) mg/kg	Phosphorus (P) mg/kg	Potassium (K) mg/kg
Control	3.33	6.33	15
Egg Shells	10.66	8	32
Oyster	15.66	24.66	87.66
Paper	6.33	14	51.66
Fruits	19.66	24.33	50.66
Combined	36	31.33	98

Figure 18. Average nitrogen (N), phosphorus (P), and potassium (K) level of soil (mg/kg) after 14 days of applying the organic and inorganic substances.

Figure 18 shows the average results of nitrogen (N), phosphorus (P), and potassium (K) level of soil (mg/kg) after 7 days of applying the organic and inorganic substances. It can be seen that there are differences in the amount of NPK among the treatments. The control (water) and paper showed the lowest level of NPK while the combined substances exhibited the highest increase of the essential soil nutrients. The ranges of available nitrogen (N) among the treatments were 3.3 – 36.15 mg/kg. Amounts of available phosphorus varied considerably from 8 – 31.33 mg/kg while for potassium, the ranges were from 15 – 98 mg/kg. The study published by Ramadas, S. et. al, 2018, indicated that the amount of nitrogen (N) is low if it is lower than 140 mg/kg (<140mg/kg). From the graph, it can be seen that nitrogen

concentration of all treatments are still low but the difference between control and experimental groups are evident. In the same study, if the amount of phosphorus (P) is <5 mg/kg it is low, 5 - 12.5 mg/kg (medium), >12.5 mg/kg (high). The results above showed that soil section with oyster, paper, fruits, and combined substances has high level (>12.5mg/kg) of phosphorus while egg shells and control have low P level. The research of Ramadas, S. et. al, 2018 also emphasized that potassium (K) level is low if it is <60 mg/kg, medium if 60-140 mg/kg, and high if >140 mg/kg. The results revealed that most of the treatments have low level of potassium (K) and only oyster and combined substances exhibited medium concentration of K (87.66 mg/kg and 98 mg/kg respectively).

One-way ANOVA and Tukey HSD test were used to determine if there is significant difference in all treatments used to improve the soil fertility at Chonradsadornumrung School. It was found out that the p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05 ($p<0.05$), it means that one or more treatments is/are significantly different.

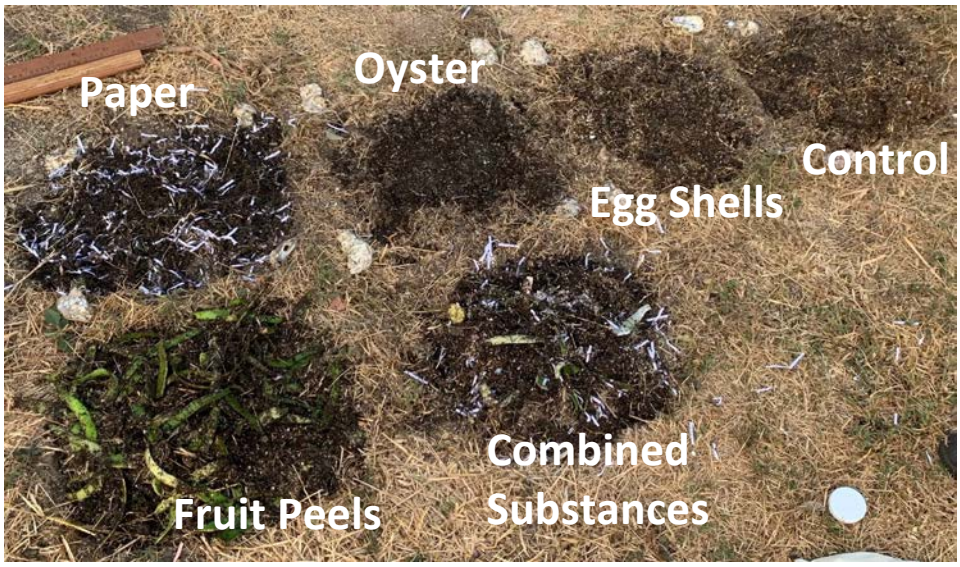


Figure 19. Soil Sections in the study site with specific substance.

Discussion

The results of field measurement, ANOVA, and post-hoc Tukey HSD test showed that there was a significant difference in soil parameters measured at Chonradsadornumrung School such as soil temperature measured at 5 cm and 10 cm depth, relative humidity, soil pH and air temperature. It shows that there were significant changes in the soil quality inside

the campus of Chonradsadronumrung school due to the changes taking place and drought season. The other factors that can contribute to changes in soil health are soil organisms, including the abundance and diversity of bacteria, fungi, and nematodes, as they respond sensitively to anthropogenic disturbance (Lynch, 2015).

The amount of nitrogen, phosphorus, and potassium in the study site prior to the application of various substances is quite low. It shows that anthropogenic activities and drought season have significant effects in the quality of soil inside the campus. When the selected organic and inorganic substances were added, there were significant improvement in soil fertility. These findings are in line with the research published by Barnossi et al., 2021; Lu and Xu, 2021, which cited that food wastes can increase soil fertility and crop yield by acting as direct nutrient sources (macronutrients such as C, N, P, K and micronutrients such as Ca, Fe, and Zn) and/or improving nutrient availability via modifying soil porosity, water retention, surface interactions, soil pH, and cation exchange capacity. The result of the study has an important impact to the environment especially in utilizing the wastes and turning them as essential fertilizers to the soil. According to UNEP, 2021, improper food wastes management poses environmental, social, and economic impacts with global concerns such as land and water pollution, biodiversity loss, and climate change. It was estimated that 8–10 % of global greenhouse gas (GHG) emissions were associated with food wastes.

CONCLUSION

Based on the experimentations, results and gathered data, the researchers concluded that there are significant differences ($p<0.05$) in soil pH, relative humidity, air temperature, and soil temperature measured at 5 cm and 10 cm depth. Additionally, the organic and inorganic substances can improve the soil fertility at Chonradsadronumrung School and among the treatments the combined substances are the most effective in increasing the amount of nitrogen (N), phosphorus (P), and potassium (K).

RECOMMENDATIONS

For the improvement of the study, more research should be done to test the other soil properties in the study site and the amount of NPK will be measured after 1 month to determine the level of nutrients. Furthermore, more organic and inorganic substances will be used to improve the soil fertility at Chonradsadronumrung School

GLOBE Badges

I am a Collaborator

This environmental research was finished completely because of the collaborative efforts of various individuals. During the conduct of the study, the researchers were thoroughly guided and given knowledge by their teachers namely Ms. Rawadee Meesuk and Mr. Marvin Servallos. Furthermore, the soil quality testing was carried out properly because of some of the materials provided by the home economics department of the school such as shovel and hand forks. Food wastes were provided by kind and generous vendors of the school canteen. Thorough guidance and invaluable ideas from the above names were very significant to completely understand all the scopes of this research. Finally, the researchers of this science project have cooperated to finish the work entirely from the planning stage, experiments, analyzing of data, and packaging of the final research paper.

I Make an Impact

The observations of the researchers around Chonradsadronumrung School such as construction of infrastructures also the prolonged drought in Chonburi Province, Thailand led them to develop this type of research. The methods and results gathered in this study have great impact to the community of Chonradsadornumrung School especially, to the students because it serves as an eye opener for them that young learners like the researchers can have a valuable contribution in discovering the effects of human activities and natural phenomenon like drought to their environment. This research will significantly impact not just the community at school but everywhere because the food wastes that are thrown away, can be used to improve the soil quality which will later on produce good agricultural products.

I am a Data Scientist

The researchers have studied systematically the current condition of soil sample from Chonradsadronumrung School campus. The results were collected, recorded, and analyzed properly. All of the data gathered from the field measurement were analyzed using some statistical models like ANOVA (Analysis of Variance) with post-hoc Tukey HSD (Honestly Significant Difference) Test. The results of the analysis were discussed and

presented properly. Moreover, the results of the experiment were linked to the research done by other researchers.

I am a STEM Professional

This environmental research is not possible without the invaluable insights from various STEM Professionals. The researchers were able to formulate research topic and questions by asking their Biology teacher pertaining to possible studies that they can pursue that is relevant to Globe mission and vision. During data gathering and interpretation, the statistician of the school was consulted about the accurate statistical method that can be used in interpreting the data about soil quality in Samet, Chonburi, Thailand as well as the results of biological testing. From the consultation with the school's statistician, the researchers learned that ANOVA (Analysis of Variance) and post-hoc Tukey HSD (Honestly Significant Difference) Test are the most appropriate tool to analyze the collected data. Moreover, the researchers also asked help from the statistician of the school to calculate and interpret the results of the study.

Acknowledgment

The researchers of the study would like to acknowledge the following for making this science project possible. First, they would like to convey their genuine thanks to the Head of CRU English Program Ms. Rawadee Meesuk for her utmost support, suggestions, and encouragement as well as for providing all the Laboratory equipment and chemicals that they need in their study. Second, the researchers would like to thank their Science teacher- Mr. Marvin Servallos, for his guidance towards the completion of the study. Finally, the researchers would like to give their special thanks to the committee of IPST, Globe Student Research Competition, and Globe International Virtual Science Symposium for conducting this prestigious event that enabled young scientists to share their scientific discoveries.

REFERENCES

Kebede, T. et. al, 2023. *The Effect of Organic Solid Waste Compost on Soil Properties, Growth, and Yield of Swiss Chard Crop (Beta vulgaris L.)*. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10615583/

Milosevic et al. 2020. *Soil fertility: Plant nutrition vis-à-vis fruit yield and quality of stone fruits.* Retrieved from https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/soil-quality

Palansooriya, K. et. al, 2023. *Converting food waste into soil amendments for improving soil sustainability and crop productivity: A review*. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0048969723019307#:~:text=Food%20waste%20is%20generally%20rich,fertilizer%20for%20improving%20crop%20growth.

Ramadas, S. et. al, 2018. Strengthening Value Chain in Wheat and Barley for Doubling Farmers Income. Retrieved from https://www.researchgate.net/figure/Rating-chart-for-soil-test-values-of-available-nutrients_tbl5_332111366

https://www.globe.gov/do-globe/globe-teachers-guide/soil-pedosphere; December 8, 2023

https://www.globe.gov/documents/352961/166877a8-ad47-480c-9714-2a3f64bbe870; December 8, 2023

https://www.globe.gov/documents/352961/8de1fc2a-dc4e-41c5-a5d9-985865b0d67f; December 8, 2023

https://www.globe.gov/documents/352961/166877a8-ad47-480c-9714-2a3f64bbe870; December 8, 2023

Appendix 1

ANOVA (Analysis of Variance) for soil temperature at 5 cm depth measured at Chonradsadornumrung School for 4 consecutive times.

Treatment ⟶	A	B	C	D
Input Data ⟶	30.0	33.0	35.0	27.0
	31.0	34.0	35.0	26.0
	31.0	34.0	35.0	27.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	123.0000	3	41.0000	164.0000	1.6024e-07
error	2.0000	8	0.2500		
total	125.0000	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Tukey HSD results for soil temperature at 5 cm depth.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	10.3923	0.0010053	** p<0.01
A vs C	15.0111	0.0010053	** p<0.01
A vs D	13.8564	0.0010053	** p<0.01
B vs C	4.6188	0.0457399	* p<0.05
B vs D	24.2487	0.0010053	** p<0.01
C vs D	28.8675	0.0010053	** p<0.01

Appendix 2

ANOVA (Analysis of Variance) for soil temperature at 10 cm depth measured at Chonradsadornumrung School for 4 consecutive times.

Treatment ⟶	A	B	C	D
Input Data ⟶	31.0	35.0	33.0	29.0
	31.0	35.0	33.0	29.0
	31.0	35.0	33.0	30.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	54.2500	3	18.0833	217.0000	5.3186e-08
error	0.6667	8	0.0833		
total	54.9167	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Tukey HSD results for soil temperature at 10 cm depth.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	24.0000	0.0010053	** p<0.01
A vs C	12.0000	0.0010053	** p<0.01
A vs D	10.0000	0.0010053	** p<0.01
B vs C	12.0000	0.0010053	** p<0.01
B vs D	34.0000	0.0010053	** p<0.01
C vs D	22.0000	0.0010053	** p<0.01

Appendix 3

ANOVA (Analysis of Variance) for relative humidity measured at Chonradsadornumrung School for 4 consecutive times.

Treatment ⟶	A	B	C	D
Input Data ⟶	43.0	46.0	36.0	43.0
	43.0	45.0	36.0	41.0
	43.0	46.0	36.0	40.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	149.6667	3	49.8889	74.8333	3.4018e-06
error	5.3333	8	0.6667		
total	155.0000	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Tukey HSD results for relative humidity.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	5.6569	0.0166565	* p<0.05
A vs C	14.8492	0.0010053	** p<0.01
A vs D	3.5355	0.1344001	insignificant
B vs C	20.5061	0.0010053	** p<0.01
B vs D	9.1924	0.0010053	** p<0.01
C vs D	11.3137	0.0010053	** p<0.01

Appendix 4

ANOVA (Analysis of Variance) for air temperature measured at Chonradsadornumrung School for 4 consecutive times.

Treatment ⟶	A	B	C	D
Input Data ⟶	27.3	31.4	34.3	28.6
	27.3	31.4	34.3	29.1
	27.3	31.4	34.3	29.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	84.1425	3	28.0475	1,602.7143	1.8723e-11
error	0.1400	8	0.0175		
total	84.2825	11			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Tukey HSD results for relative humidity.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	53.6816	0.0010053	** p<0.01
A vs C	91.6515	0.0010053	** p<0.01
A vs D	20.9489	0.0010053	** p<0.01
B vs C	37.9699	0.0010053	** p<0.01
B vs D	32.7327	0.0010053	** p<0.01
C vs D	70.7026	0.0010053	** p<0.01

Appendix 5

ANOVA (Analysis of Variance) for Nitrogen level of the Soil with Organic and Inorganic Substances after 7 days.

Treatment →	A	B	C	D	E	F
Input Data →	9.0	3.0	20.0	5.0	21.0	36.0
	3.0	11.0	19.0	4.0	14.0	36.0
	11.0	13.0	20.0	9.0	16.0	30.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	1,667.11	5	333.42	25.76	5.0175e-06
error	155.3333	12	12.94		
total	1,822.4444	17			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	0.6419	0.8999947	insignificant
A vs C	5.7770	0.0147099	* p<0.05
A vs D	0.8024	0.8999947	insignificant
A vs E	4.4932	0.0678106	insignificant
A vs F	12.6772	0.0010053	** p<0.01

Appendix 5

ANOVA (Analysis of Variance) for Phosphorus level of the Soil with Organic and Inorganic Substances after 7 days.

Treatment →	A	B	C	D	E	F
Input Data →	6.0	16.0	14.0	5.0	29.0	23.0
	12.0	35.0	20.0	3.0	22.0	27.0
	18.0	22.0	19.0	1.0	26.0	33.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	1,357.6111	5	271.5222	8.9349	0.0010
error	364.6667	12	30.3889		
total	1,722.2778	17			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of

significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

treatments pair	**Tukey HSD Q statistic**	**Tukey HSD p-value**	**Tukey HSD inference**
A vs B	3.8751	0.1372709	insignificant
A vs C	1.7805	0.7791892	insignificant
A vs D	2.8278	0.3971986	insignificant
A vs E	4.2940	0.0855007	insignificant
A vs F	4.9224	0.0407946	* p<0.05

Appendix 6

ANOVA (Analysis of Variance) for Potassium level of the Soil with Organic and Inorganic Substances after 7 days.

Treatment →	A	B	C	D	E	F
Input Data →	4.0	45.0	82.0	13.0	67.0	56.0
	14.0	46.0	60.0	8.0	56.0	85.0
	15.0	23.0	72.0	11.0	52.0	121.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	15,119.11	5	3,023.82	12.48	0.0002
error	2,908.67	12	242.39		
total	18,027.78	17			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	3.0038	0.3376550	insignificant
A vs C	6.7121	0.0048920	** p<0.01
A vs D	0.0371	0.8999947	insignificant
A vs E	5.2659	0.0270724	* p<0.05
A vs F	8.4922	0.0010053	** p<0.01

Appendix 7

ANOVA (Analysis of Variance) for Nitrogen level of the Soil with Organic and Inorganic Substances after 14 days.

Treatment →	A	B	C	D	E	F
Input Data →	4.0	14.0	13.0	7.0	23.0	37.0
	4.0	10.0	13.0	6.0	18.0	35.0
	2.0	8.0	21.0	6.0	18.0	36.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	2,078.28	5	415.66	59.85	4.577e-08
error	83.333	12	6.9444		
total	2,161.61	17			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	4.8200	0.0460818	* p<0.05
A vs C	8.1063	0.0010227	** p<0.01
A vs D	1.9718	0.7093222	insignificant
A vs E	10.7354	0.0010053	** p<0.01
A vs F	21.4707	0.0010053	** p<0.01

Appendix 8

ANOVA (Analysis of Variance) for Phosphorus level of the Soil with Organic and Inorganic Substances after 14 days.

Treatment →	A	B	C	D	E	F
Input Data →	8.0	6.0	17.0	15.0	22.0	38.0
	7.0	9.0	34.0	12.0	27.0	30.0
	4.0	9.0	23.0	15.0	14.0	26.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	1,446.44	5	289.289	10.519	0.0005
error	330.00	12	27.5000		
total	1,776.44	17			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of

significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	0.5505	0.8999947	insignificant
A vs C	6.0553	0.0105684	* p<0.05
A vs D	2.5322	0.5046994	insignificant
A vs E	4.8442	0.0447724	* p<0.05
A vs F	8.2572	0.0010053	** p<0.01

Appendix 9

ANOVA (Analysis of Variance) for Potassium level of the Soil with Organic and Inorganic Substances after 14 days.

Treatment →	A	B	C	D	E	F
Input Data →	18.0	33.0	112.0	66.0	55.0	100.0
	14.0	30.0	81.0	55.0	52.0	95.0
	13.0	33.0	70.0	34.0	45.0	99.0

source	sum of squares SS	degrees of freedom	mean square MS	F statistic	p-value
treatment	15,212.50	5	3,042.50	23.34	8.4959e-06
error	1,564.00	12	130.333		
total	16,776.50	17			

Conclusion from ANOVA:

The p-value corresponding to the F-statistic of one-way ANOVA is lower than 0.05, suggesting that one or more treatments are significantly different for that level of significance. The Tukey HSD test multiple comparison tests follow. This post-hoc tests would likely identify which of the pairs of treatments are significantly different from each other.

Treatments pair	Tukey HSD Q statistic	Tukey HSD p-value	Tukey HSD inference
A vs B	2.5792	0.4875591	insignificant
A vs C	11.0247	0.0010053	** p<0.01
A vs D	5.5629	0.0189829	* p<0.05
A vs E	5.4112	0.0227557	* p<0.05
A vs F	12.5925	0.0010053	** p<0.01