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Abstract -- Water lilies have been an environmental problem in the Tixtla de Guerrero lagoon for many years, and there are no studies on how to control them. However, efforts have been made to collect them and convert them into organic fertilizers. The objectives were 1) to determine the viability of this plant as a raw material for producing vermicompost with other materials and 2) to determine its nutritional content for use by farmers. The research follows a quantitative approach, using a completely randomized design to establish the treatments in seedling production. For analysis, the samples were sent to the University of Chapingo's Central University Laboratory. Information was obtained on the effect of this fertilizer as a substrate in the production of seedlings of different horticultural species, as well as the nutrient concentrations of each sample, in order to develop practical recommendations for producers in the region, based on proposals from similar studies. This research represents progress in finding an environmental solution to this plant, which causes havoc in crop fields as a result of rising water levels in the lagoon, and will help to mitigate the consequences of its invasion.

Keywords-- Fertilizer, Eutrophication, Humus, Nutrient, Sustainable.

Abstract -- The water lily has been an environmental problem in the Tixtla lagoon in Guerrero for many years, and there are no studies on how to control it. However, efforts have been made to collect them and convert them into organic fertilizers. The objectives have been 1) to determine the viability of this plant as a raw material to produce vermicompost with other materials and 2) to determine its nutritional content for use by farmers. The research follows a quantitative approach. A completely randomized design was used to establish treatments in seedling production, and samples were sent to the Central University Laboratory at the University of Chapingo for analysis. It was possible to obtain information about the effect of this fertilizer as a substrate in the production of seedlings of different horticultural species, as well as the nutritional concentrations of each sample to develop a practical recommendation to producers in the region, based on proposals for similar work. With this research, progress is made in the environmental solution of this plant that wreaks havoc on crop fields as a result of the increase in the water level of the lagoon and will reduce the consequences of its invasion.

Key words-- Fertilizer, Eutrophication, Humus, Nutrient, Sustainable.

INTRODUCTION

Based on the problems encountered in Tixtla de Guerrero, in the state of Guerrero, located in the central region, where there are three bodies of water: 1) **the drinking water reservoir**, where runoff from streams is collected to supply the city with water; 2) **the Juan Catalán Verbera water storage dam**, which supplies water to farmland in the lower part of the Tixtla Valley; and

3) **the black lagoon**, a body of water that collects, first, rainwater runoff, second, soapy water (resulting from domestic activities) that is poured into the city streets, and finally, contaminated water from the drainage and sewer system, which, in short, is not functional and whose waters flow into this body of water.

We find the case of the black lagoon, so named because of its high nutrient content, which tends to exhibit the phenomenon of eutrophication, which is an accumulation of nutrients that allows aquatic plants to grow rapidly. In other words, this phenomenon occurs in places where nutrient concentrations in the water are generally high due to agricultural runoff, deforestation, and insufficient wastewater treatment [1], causing not only ecological, social, and economic problems. This is where the problem of water lilies arises, as they tend to cause a series of issues such as a decrease in water volume due to high transpiration rates and the uncontrolled growth of this invasive plant, which prevents farmers from carrying out their activities. Therefore, the best option for them is to collect and incinerate it. This is where the importance and justification of the research lies, since considering that the community can take advantage of all natural resources and that, in the case of Tixtla de Guerrero, the water lily can be used as a valuable raw material to generate economically profitable activities [2].
The strategy designed in the research aims to contribute to the treatment of water hyacinth through vermiculture, involving the following processes: collection, chopping the plant into small pieces for easier handling, composting, and vermicomposting, with the intention of producing organic fertilizer for use in crop production.
It is important to develop a strategy for treating this invasive plant that allows us to generate knowledge, management techniques, and proposals for its use in agriculture as a material available for seedling production and to improve soils by adding it to them as organic fertilizer.
Given this, and giving technical importance to the different proposals for solutions in the control of this plant or its definitive elimination, it was proposed to work on a strategy that would help develop efficient, ecological, and social management.

Meanwhile, regarding the study and management of aquatic plants in Mexico, [3] mentions:
In the last ten years, there has been a reported decline in pollinating insects (bees, bumblebees) as a result of the massive use of insecticides. In the case of plant control, herbicides account for more than 65% of pesticides used in agriculture for the control of both terrestrial and aquatic weeds. These pesticides have widely documented toxic, carcinogenic, and mutagenic effects that affect human health and contribute to environmental degradation, which is why their use is considered high risk.
In the search for the most important activities in which water lilies can be used, [4] mention that: This plant is used as the sole raw material in four different processes:

1. Composting: this consists of the aerobic decomposition of biomass, which converts organic matter into a stable, hygienic product rich in humic compounds and minerals, i.e., compost. The use of compost in soil increases its water and nutrient retention capacity, improves aeration, and reduces the use of chemical fertilizers.
2. Vermicomposting: this process is based on the interaction between earthworms and certain microorganisms. The worms break down and condition the substrate to improve degradation by microbial activity. Currently, these products comply with standard [5] NMX-AA-109-SCFI-2008 for obtaining type II compost and vermicompost.
3. Biogas: this fuel is produced by anaerobic fermentation and contains a mixture of methane and carbon dioxide. Biogas can be used to produce heat (in boilers), as fuel, to generate electricity (using engines or turbines), and even as a raw material.
4. Absorbent material: dried water lilies contain a high number of fibers that give them significant absorbency (up to 12 times their own weight in water). This can be used for the recovery of hydrocarbons or oils, in addition to other potential applications.

In relation to vermicomposting, [6] mentions that worm humus, also known as vermicompost, is obtained from a process in which worms digest organic material, breaking it down thanks to the action of their digestive enzymes and the microflora present in their bodies. It is the best organic fertilizer available; a single ton of worm humus is equivalent to 12 tons of cattle manure and 4 tons of compost (p. 25).
The objectives of the research were:
In the first stage: to determine the viability of water lilies as a material for producing organic fertilizers through vermiculture and, subsequently, to ascertain their degree of effectiveness as a substrate.
In the second stage: to use laboratory analysis to determine the nutritional content of mixtures of waste materials with water lilies.

DEVELOPMENT

The research was carried out at the Agricultural Technology High School No. 191, located in the municipality of Tecoanapa, Guerrero. It is located 850 meters above sea level, southeast of Chilpancingo, between parallels 16°48' and 17°11' north latitude and 99°00' and 99°11' west longitude relative to the Greenwich meridian. The predominant climate is warm subhumid with average annual temperatures of 31°C. In the coldest months, January and February, temperatures reach 24.9°C. Rainfall occurs from July to October, with an average annual precipitation of 1,600 millimeters; this climate is the most humid of the warm subhumid climates.

It was developed as an **experimental study**, as it seeks to specify the important properties provided by the water lily plant in its contributions to the generation of a technical proposal and in the production of vermicompost for the development of seedlings of various crops.
As part of the statistical design process, **a quantitative methodology** was developed **based on a completely randomized design with five treatments and four replicates, resulting in a total of 20 experimental units.**
The research was carried out in three stages, related to the objectives set: collecting organic materials and water lilies, mixing the materials according to the established treatments, and producing organic fertilizer from vermiculture with the materials obtained from the compost to proceed with the production of seedlings of the selected vegetables.
Polypropylene trays with the substrates obtained from the mixtures were placed in a space in the school greenhouse. Each of the trays with the previously disinfected substrate was filled, and a seed was placed in each cavity.

The treatments studied according to the mixtures prepared were as follows:

Treatment 1: 50% rootless water lily material mixed with 50% cattle manure **Treatment 2**: 50% rootless water lily material mixed with 50% plant waste obtained from the municipal market.
Treatment 3: 25% water lily with 25% recycled office material and 50% plant waste material such as dry leaves.
Treatment 4: 50% water lily with 50% horse manure.
Treatment 5: control group with water lily only.
The trays were sown with vegetable seeds. Once this step was completed, a process was implemented to ensure that the seeds germinated with high quality and without physiological problems.
The variables analyzed were: days to composting, composting pH and days of vermicomposting, as well as days to germination, total percentage of germinated seeds, plant height 15 and 20 days after sowing, identification of nutritional deficiencies, and seedling quality. The data obtained during the processes were analyzed using the free Minitab statistical software.
This statistical analysis package produced analyses of variance, which allowed us to interpret what had happened between the variables studied. If the conditions were met, the Tukey mean test was applied to the analysis of the means obtained at a 95% probability.
The results obtained will allow us to generate recommendations, indications, and, of course, formulate conclusions that will enable decisions to be made about the effect obtained in mixtures of water lilies with different organic materials in the production of organic fertilizer using vermiculture and its application as a substrate in the production of seedlings for crops such as tomatoes and chilies.

Once the results of the first stage were obtained, in which the objective was to determine the viability of water lilies as a material for producing organic fertilizers using vermiculture and subsequently to ascertain their degree of effectiveness as a substrate, each of the treatments was taken as a reference to determine the nutritional content of the samples.
These materials were sent to the Central University Laboratory of the Autonomous University of Chapingo in order to determine the values of the elements, perform the corresponding analyses, compare them with other research, and thus generate a recommendation for their use in the agricultural fields of Tixtla.
The laboratory issues the results with its assessments, with which the other treatments must be analyzed. This methodology indicates what may be appropriate to do, taking into account the composting processes (times and management), vermicomposting (times and cultural activities), and their use in germination trays to determine the effect of organic fertilizers obtained from water lilies with other materials.

DISCUSSION AND ANALYSIS OF RESULTS

Days to composting, pH, and days to vermicomposting

Table 1. *Data obtained from the decomposition process of organic materials mixed with water lilies.*

Treatments	Days of composting	pH value	Days of vermicomposting
1	45	7.8	49
2	35	7.2	45
3	45	7.4	51
4	50	7.8	61
5	45	6.5	42

Source: *own elaboration with data from the research project.*

The decomposition times are within the parameters of research related to this work. as is the case in [7], where sheep excrement waste and market vegetables, combined with water lilies, were pre-composted for a period of 30 days, which was sufficient to produce food for the worms, taking into account the decomposition processes (p. 2).

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[8] mentions that pH is a factor of vital importance in optimal plant development, since nutrients are dissolved in water, which is composed of hydrogen and hydroxyl ions that combine to form it; However, there is a constant concentration of free hydrogen and oxygen ions, called the free hydrogen and oxygen ion constant, known as the water ionization constant. Therefore, if there is no influence from other ions, the pH of the medium is neutral and its value is 7. When this amount varies due to the capture of hydrogen ions by some anions present in the medium, the pH is greater than 7, and if, on the contrary, the amount varies due to the capture of hydroxyl ions by some cations, the medium will be acidic. The optimal range for the growth of the vast majority of crops is between 5.5 and 6.8 (p. 81).

The pH ranges in the results are within the parameters of research carried out by other authors, such as [9], who mentions that the pH of composting depends on the source materials and varies in each phase of the process (from 4.5 to 8.5). In the early stages of the process, the pH becomes more acidic due to the formation of organic acids. In the thermophilic phase, due to the conversion of ammonium to ammonia, the pH rises and the medium becomes alkaline, finally stabilizing at values close to neutral (Román et al., 2013). During the iris composting process, the pH varied between 6.83 and 8.04 in the treatments evaluated (p. 240).

The production of vermicompost depends on many activities, which must be carried out properly so as not to cause any technical problems that could harm the worms.

This is the result of the interaction between the number of worms inoculated and the amount of substrate to be processed. High inoculation at the juvenile stage of the plant reduces the production time of vermicompost to 70 days for maturation, or 10 weeks or more [7].

Reviewing the characteristics of the substrates that define a function in the seed germination process, in this case for vegetables, it is necessary that they comply with certain properties. Thus, [10] defines the physical and chemical properties that a substrate must contain:

Physical properties

Support function. It must be firm and dense to keep the botanical or vegetative seed in place.

High porosity to allow adequate drainage and oxygenation, low bulk density, and fine texture for botanical seeds.

Stable structure: it must maintain its volume, not shrink too much when dry or swell too much when wet.

Retentive, high water retention capacity to maintain constant moisture throughout the propagation stage—good moisture Germination and rooting depend on this, and it should not have to be watered too often.

Clean, to avoid health problems—fungi, nematodes, bacteria, wireworms, etc.—or the presence of substances that are toxic to plants, especially in the case of substrates obtained from recycled waste.

Chemical properties

It must be possible to sterilize it without undergoing transformations or changes that could affect the propagation material, such as precipitation or the release of toxins.

It must not contain excess salts that could delay germination or cause seedling death.

High organic matter content, especially in botanical seeds.

Moderate to high cation exchange capacity and minimal decomposition rate (p. 26).

Days to germination and germination percentage

Table 2. *Results of the effects on the days to germination of vegetable seeds and percentages obtained*.

Crop	Days to germination	% germination
Tomato	**7**	**95**
Chili pepper	**11**	**95**
Cucumber	**5**	**97**
Zucchini	**5**	**97**
Watermelon	**5**	**95**

Source: *own elaboration with data from the research project*.

Most of the seeds used offer a high germination rate, as shown in the table above.

This indicates that regardless of the substrate used, the seed has a high germination rate if the process is carried out with care to control any adverse factors, thereby achieving the objective of a high germination rate.

Plant height

Table 3. *Plant height 10 days after germination of different vegetable seeds using water lily vermicompost and other materials as substrate*.

Plant height 10 days									
Chili		Tomato		Zucchini		Cucumber		Watermelon	
T2	**4.05a**	**T2**	**6.94a**	**T3**	**5.22a**	**T5**	**6.67a**	**T2**	**6.57a**
T1	3.91a	**T1**	6.36a	**T1**	5.10a	**T3**	6.07ab	**T2**	6.2ab
T3	3.84a	**T4**	6.31a	**T5**	4.20a	**T2**	6.00ab	**T4**	5.8ab
T5	3.82a	**T3**	6.29a	**T4**	4.20a	**T4**	5.88ab	**T3**	5.08b

T 4	3.7 6a	**T 5**	6.0 0a	**T 2**	4.0 0a	**T 1**	5.57 b	**T 5**	4.9 b

Source: *own elaboration with data from the research project*.

Table 4. *Plant height 20 days after germination of different vegetable seeds using water lily vermicompost and other materials as substrate*.

Plant height 20 days									
Chili		Tomato		Zucchini		Cucumbe r		Watermel on	
T 5	**12. 0a**	**T 2**	**13. 5a**	**T 3**	13.50 **a**	**T 4**	**9.1 5a**	**T 5**	**19.5 0 to**
T 3	9.5 0b	**T 3**	12 ab	**T 1**	13.05 ab	**T 2**	8.7 2 ab	**T 3**	19.2 5 to
T 1	9.5 0b	**T 4**	12 ab	**T 4**	12:55 abc	**T 1**	8.7 2 ab	**T 1**	19.8 2 a
T 4	9.2 5b	**T 1**	11 ab	**T 5**	12.1a bc	**T 3**	8.7 2 ab	**T 4**	18.6 0 to
T 2	9.2 5b	**T 5**	9.7 b	**T 2**	11.90 bc	**T 5**	8.0 7 b	**T 2**	18.3 0a

Source: own elaboration with data from the research project.

The results of plant heights in the different established vegetables show certain statistical characteristics, as shown in Table 3 below.

The cultivation of chili peppers and tomatoes at plant heights of Ten days after birth, there are no significant differences, given that the data are practically similar, with 4 cm and 6 cm for each crop, respectively. Twenty days after planting, due to the effects of the vermicompost substrates, differences are observed in the data in the case of the chili crop, which is 12 cm taller than the rest, representing the distance between the samples of the averages obtained, with a difference of 3 cm in height between them. The tomato crop 20 days after germination shows a significant difference of
13.5 cm above the compared averages, which, given Tukey's result, yields up to 9.75 cm with the lowest average. The treatments that show the best results are T2 and T5, which contain water lily combined with vegetable market waste, as well as those that come from 100% water lily, respectively.

The cultivation of zucchini in the measurement of the same variable plant height shows significance 20 days after birth, but not 10 days after birth; the comparison of means shows a very marked difference in the treatments corresponding to T3, which contains water lily combined with paper waste and decomposing leaf litter. According to the results of both the composting and vermicomposting processes, this treatment had the shortest periods of decomposition and production as fertilizer.

Cucumber cultivation, in line with the results of the mean comparisons, shows significant differences , with data that are not very far apart. However, the Tukey test considers that the data are different from each other. The best treatments are those containing water lily alone and water lily combined with horse manure, respectively.

In watermelon cultivation, significant differences were found in the onset of plant growth, such as 10 days after germination, but not in the 20 days in which comparisons of means showed no differences. The best treatments for this variable were water lily with market waste and water lily with horse manure.

In a study based on the incorporation of organic fertilizers into the soil one month in advance [11], no significant differences were found in plant heights in the cultivation of jalapeño and serrano peppers. It is therefore determined that organic fertilizers have an effect on important stages of plant growth, as well as on yield (87).

[12] cites several researchers who have shown that adding worm humus to soils and growing media significantly increases the growth and productivity of a large number of horticultural crops such as tomatoes, peppers, garlic, strawberries, medicinal plants, legumes such as green chickpeas, grasses such as sorghum and rice, aromatic herbs such as basil, fruit trees such as bananas and papayas, and ornamental plants such as geraniums, tagetes, petunias, chrysanthemums, and poinsettias.

Seedling and root ball quality

Corresponding to the quality of the root ball, which guarantees its viability in use [13], it states that in order to determine this, it is necessary to know the root system of the plants, the depths and surface area of the roots in order to choose an appropriate size so that profuse growth is obtained, guaranteeing the formation of a consistent root ball. Horticultural plants can be grouped according to the nature of their root system, its volume, depth, arrangement, and water absorption capacity, and the nature of their leaf system is also taken into account (p. 7). From what has been said so far, it can be inferred that the nature of their root systems, penetration, root volume, absorption capacity, and the nature of their leaf system have a lot to do with choosing the right dimensions for the cells in the root ball trays and the water requirements in the initial growth stage of the seedlings in order to obtain a well-formed root ball, i.e., roots that are capable of supporting the substrate surrounding them. However, a more in-depth understanding of the root system of the main species is necessary for decision-making (p. 23).

According to (Castillo, 2002), cited by [14], the quality of the plant is the result of the integration of numerous physiological and morphological characteristics that control the possibilities for further development and growth of the plants. It is one of the most important factors determining the success of the plantation. Historically, the quality of plants has been determined by their ability to survive under stressful conditions and predict vigorous growth after planting.

Thus, [14] mentions that the use of seedlings allows for greater uniformity in the field, since individuals of similar sizes are started in the tray and transferred to the field, which can be further improved by completing the selection process during transplanting. This advantage reduces the risk of a poor start to the production season, lowering the cost of sanitary applications, improving the use of nutritional amendments, and obtaining a more concentrated harvest, among other benefits. In this sense, the main objective of seedling production and transplanting is to obtain a quality seedling.
The following results were obtained from the Central University Soil Laboratory of the Autonomous University of Chapingo, as shown in Tables 5 and 6, respectively.

To analyze the values obtained, the results of various studies were compared. some of which are proposals for the management of water hyacinth in different uses, such as phytoremediation, biogas production, compost production, vermicompost production, and finally the production of seedlings of various vegetables, with the aim of supporting the control and management of this invasive plant in the different locations where the research has been carried out.
The comparisons between the values obtained and those presented by different authors determine the nutritional quality that vermicompost should have. Vermicompost with other materials has values that comply with criteria according to their countries of origin, others according to local laboratories, and in Mexico according to NOM/SCFI/2008, which provides ranges of characteristics that vermicompost must meet to be considered high-quality, stable, and mature.
Tables 5 and 6, respectively, show the results of the analysis of the samples obtained.

Table 5. *Results of two worm compost samples obtained from water lilies from the black lagoon of Tixtla de Guerrero with other materials*.

Parameter	T1	T2
pH	7.01	8.38
C.E.	1.64	4.64
M.O.	15.19	36.00
N	1.31	1.66
P	0.08	0.48
K	0.16	1.11
Ca	0.18	2.14
Mg	0.14	1.20
Na	0.49	0.45
C.I.C.	37.3	53.00
Faith	0.19	0.50
Cu	29.00	82.75
Zn	151.75	186.25
Mn	376.00	277.50
B	136.52	267.60
C/N	8.4	12.6
Da	1.02	0.74

Source: UACh Central University Laboratory.

Table 6. *Results of three worm compost samples obtained from water lilies from the black lagoon in Tixtla de Guerrero with other materials*.

Parameter	T3	T4	T5
pH	7.62	7.08	8.46
C.E.	0.60	4.75	4.84
M.O.	2:00 p.m.	8.07	43.00
N	1.23	2.19	1.55
P	0.37	0.48	0.50
K	0.38	0.33	1.17
Ca	0.33	2.87	2.13
Mg	0.15	1.67	1.52
Na	0.11	0.84	0.45
C.I.C.	24.5	45.6	69.5
Faith	1.05	0.41	0.47
Cu	23.50	120.25	58.00
Zn	86.75	249.00	171.50
Mn	294.00	324.00	374.75
B	243.87	100.65	253.00
C/N	6.6	36.0	16.1
Da	1.00	0.75	0.67

Source: *UACh Central University Laboratory*.

Table 7. Comparison of values for López's vermicompost (2012) with the results in Tables 6 and 7, respectively.

Values López (2012)	Comparison with laboratory samples.
Nitrogen (N) 1.0 to 2.6% Phosphorus (P205) 2.0 to 8.0 % Potassium (K20) 1.0 to 2.5% Calcium (CaO) 2.0 to 8.0% Magnesium (MgO) 1.0 to 1.3%	All elements are within the range of values obtained in the research.
Organic Matter 30 to 50 %	T2 and T5 are the only ones that show consistent values.
C:N ratio 10 to 11	None of the treatments fall within the values mentioned.

In a study to determine the effect of water lily as a substrate on fungal germination, mixtures of this plant with corn cobs and bran. Although there is not much information and results to contrast their evaluations, they recommend that for better growth of the Reishi mushroom mycelium, the water lily should be composted after being finely cut into small pieces (p. 302). This is one of the different uses that can be given to the water lily plant [2].

Analysis of the data shown in Table 5, for comparison of the research results, shows that the parameters do not differ or deviate significantly, and nitrogen input is within the permitted ranges. With regard to OM, the treatments that comply with the values are T2 and T5, respectively. Very low values in the C/N ratio, with only T1 complying with a value of 36 considered adequate. The standard has a range of values from 5.5 to 8.5 for pH. The research obtained results from 7.01 to 8.46, which means that within the comparison, the values represent an adequate pH. There is a disparity in electrical conductivity values, as only 3 of the 5 treatments show adequate salinity, namely T2, T4, and T5, respectively, according to the results shown in Tables 5 and 6.

The ranges of the parameters issued in relation to humus quality are shown below.

Table 8. *Physicochemical specifications of worm humus according to NMX-FF-109-SCFI-2008*.

Characteristic	Value
Total nitrogen	1 to 4% (dry basis)
Organic matter	20% to 50% (dry basis)
C/N ratio	≤ 20
Moisture	20 to 40% (on wet matter)
pH	5.5 to 8.53
Electrical conductivity	≤4 dSm^{-1}
Cation exchange capacity	> 40 cmol kg-l
Apparent density on dry matter dry weight weight	0.40 to 0.90 g mL^{-1}
Added materials	Absent

Table 9. *Chemical properties and moisture content of water lily-based vermicompost taken from Ríos (2021).*

Determination	Units	Value	Optimal value
pH Electrical	---	8.96	5.2 - 6.3
conductivity	dS m^{-1}	5.80	0.75 - 1.99
Organic carbon			
C/N ratio Organic	%	29.3	20
matter Moisture	---	19.8	20 – 40
Ash Nitrogen	%	50.6	> 80
Total	%	49.4	---
Phosphorus	%	49.4	< 20
(P)	%	2.29	18.90
Potassium			
(K)			
Calcium	%	1.77	6–10
(Ca)	%	3.00	150–249
Magnesium (Mg)	%	4.15	> 200
Sodium (Na)	%	1.35	> 70
Sulfur (S) Iron	%	0.29	---
(Fe) Copper (Cu)	%	0.68	---
Manganese (Mn)	%	68885	0.3 – 3.0
Zinc (Zn)	ppm	76.6	0.001 –
Boron (Br)	ppm	741	0.5
	ppm	543	0.02 – 3.0
	ppm	58.8	0.3 – 3.0
			0.05 – 0.5

From the table above, it can be deduced that there are some high values, which may have negative effects on nutrient availability, such as pH and EC. The C/N ratio is adequate, but the OM content is low. In terms of nutrients, the major elements are within acceptable ranges, and the microelements are at reasonable levels, allowing us to conclude that this material has acceptable physicochemical characteristics, except for the need to improve the first two elements.

Ramírez et al. (2023), using different doses of vermicompost produced with water lilies and other organic materials, produced vegetable seedlings and presented data on germination and plant height at 15 days, which means that fertilizers of this type, produced with water lilies, have a high influence due to the organic matter they contain and at the same time act as a natural fertilizer (p. 42).

CONCLUSIONS

The management strategy implemented for this invasive plant using vermiculture allows us to incorporate, based on various studies and collaborations on the subject, a procedure that contributes to the correct treatment of the waste obtained from the removal of this plant, which causes ecological, economic, health, and tourism problems in different parts of Mexico. Therefore, according to the results, the nutrient concentrations of the mixtures of water hyacinth with different materials are highly viable as natural fertilizers, as they directly influence each of the phenological stages of the seedlings. The pH values and the number of days elapsed in the composting and vermicomposting processes are within the limits permitted for the production of organic fertilizers through vermiculture. Therefore, water lilies are a viable material for the production of these fertilizers and thus contribute to the manual control of this invasive plant for its ecological use in agriculture.

Laboratory results indicate that these organic fertilizers can be used in the crop selected by the producer. However, taking important considerations into account, such as analyzing them with soil analysis, may result in an efficient technological package for the production of the selected crop.

Finally, water lilies are considered a viable material for vermicomposting. In this area, from being an invasive plant, it now has a use that benefits producers. It is well known that organic fertilizers improve soil quality by reducing soil compaction and enhancing the activity of microorganisms in the root zone, allowing nutrients to be released slowly and preventing soil leaching over time.

It is considered important to continue with research to find the right proportions to generate nutrient-rich fertilizers with physicochemical characteristics that allow for the availability of nutrients.

Research lines within sustainability should continue to explore these types of activities that generate knowledge and strategies for working with water lilies. Therefore, it is recommended to establish research on the effectiveness of biomass in the generation of fuels and energy in the area of influence in the town of Tixtla de Guerrero, with the aim of providing these inputs in commercial establishments and generating savings for producers.

Similarly, another line of research that can be explored is the development of innovative materials such as bioplastics from biodegradable materials that can replace conventional plastics.

In the contributions of [15], it is mentioned that substrates obtained from water lilies with different substrates have good nutrient availability and presented satisfactory results in terms of seedling and root ball quality.

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