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Article

An exploration of western mosquitofish as the animal component in an aquaponic farming system

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SUMMARY

Current agricultural techniques can't sustain the growing human population. Aquaponics offers a solution, but its high cost and large size make it inaccessible to most people. This study addresses the pressing need for sustainable alternatives to traditional aquaponic practices by exploring the potential of western mosquitofish (*Gambusia affinis*) as a possible option. With the environmental impact and resource demands associated with tilapia farming, identifying alternative species with comparable benefits becomes crucial. The primary aim of the research is to assess whether mosquitofish can survive in aquaponic conditions and, if so, to what extent they can enhance plant growth, focusing on basil (*Ocimum basilicum)* as a representative crop. Mosquitofish waste, which contains nutrients like nitrate/nitrite, can be used to fertilize plants. We hypothesize that an aquaponic mosquitofish setup will result in higher germination rates and superior plant quality due to increased nitrate/nitrite levels acting as a natural fertilizer. We compared an aquaponic mosquitofish setup, a soil-based aquaponic setup using water from a tank with fish, and a control group with basil grown in soil and tap water. Our findings reveal that the aquaponic setup outperformed others, exhibiting the highest germination rates and superior plant quality. Nitrate/nitrite concentrations were lower than in the control setup, indicating efficient nutrient absorption. These results suggest that mosquitofish serve as a sustainable option other than the commonly used Tilapia (*Oreochromis niloticus*) in aquaponic systems, particularly in aquaponic setups. This study contributes valuable insights into optimizing nutrient cycling, enhancing plant productivity, and advancing environmentally friendly agricultural practices.

INTRODUCTION

As the human population continues to grow, the need for space-saving, highly efficient agricultural techniques become more evident (1). The most common agricultural practice worldwide is monocropping. Monocropping refers to the continual replanting of a particular crop year after year in the same areas (2). This repeated replanting depletes the soil of its nutrients and moisture, leaving it vulnerable to wind erosion. Decades of monocropping have been known to eventually cause desertification of land (3). Furthermore, the depletion of soil nutrients eventually leads to a dependance on fertilizers (3). Pesticide and fertilizer overuse have been associated with a plethora of negative effects on local ecosystems. Fertilizer leaking into ground waterways is a common problem in agricultural communities, jeopardizing the often-minimal water supply (2). One of the proposed alternatives to monocropping is an agricultural technique called "Aquaponics."

Aquaponics is the combination of aquatic plant farming (hydroponics) and fish production (aquaculture). Fish waste from the enclosures is introduced to the plants through the shared water, acting as a fertilizer. This type of agricultural technique can provide a solution to the need for efficient, space-saving food production and has largely been applied to mid-sized crops, such as lettuce (4). The farms require a large investment to set up, and aquaponic systems are not commonly attempted with smaller herbs or microgreens since they have less return on investment. In an aquaponic setup, larger fish species such as tilapia are typically preferred. However, there are many other fish that can be used in this process with differing potential (4). The general public has not considered mosquitofish as a possible option. They are not commonly kept as pets due to their hyper competitive behavior that makes them incompatible with many other fish species (5). In dense urban areas with little farmland, a small aquaponic setup can be arranged in different ways to accommodate the lack of space (7). Not only could mosquitofish be a space saving alternative, but they could also monitor mosquito populations, which would make them extremely practical in areas struggling with mosquitos-borne diseases (6). Mosquitofish are very resilient to a wide variety of temperatures (8). They can survive in different water parameters and control their population by resorting to cannibalism of their offspring if they become overly abundant, thereby mitigating the risk of overpopulation within their enclosure (9). Another advantage to these fish is their availability, as they are live-bearing fish that can give birth to 60 or more young per brood (10). Moreover, mosquitofish are affordable and often sold by pet stores (11). The ease of maintaining mosquitofish could enable the general public to develop their own aquaponic systems, enhancing the accessibility of fresh food in areas that currently have limited access to it (12).

The goal of this study is to test if mosquitofish are a viable option in the aquaponic cultivation of herbs and microgreens. To do this, we exposed the mosquitofish to the conditions in the aquaponic system. Germination rates were recorded in three different herb production methods: soil watered with tap water, soil watered with aquaponic water, or no soil maintained in an aquaponic environment with mosquitofish. Nitrate, nitrite, bromine, pH, ammonia chloride, and alkalinity levels were compared between the aquaponics setup and a fish

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tank with no plants. This experiment also aims to determine if mosquitofish produce enough nutrients for the plants to absorb. We predicted that the aquaponic mosquitofish set up would have a higher germination rate as well as produce better quality plants. This is likely due to the increased nitrate/nitrite levels from the fish tanks acting as a natural fertilizer for the plants. Our results show that germination rate and plant quality where better in the aquaponic system that had mosquitofish as opposed to the control setup and the soil setup. This is because the mosquitofish waste provided adequate amounts of nutrients that the plants could use. The consistent availability of nutrients like nitrate and nitrite, due to the roots being submerged in water, was sufficient to enhance both the germination rate and plant quality. The incorporation of mosquitofish in aquaponic systems can potentially allow them to be smaller and more versatile then the current standard aquaponic techniques. All while being able to produce food with at a faster rate than other agricultural techniques. This would be a great asset in densely populated urban communities that lack space or lack nutrients in their soils.

RESULTS

Water quality measures

The goal of this study was to determine if mosquitofish can survive in aquaponic conditions and if they could, to what extent can they enhance plant growth? In order to answer the first part, water parameters were regularly tested. The water parameters had to remain safe enough to allow for the mosquitofish to survive and be able to provide a substantial amount of nutrients for the basil. The pH levels remained consistent throughout the whole experiment (**Figure 1**). The bromine levels remained consistent throughout the majority of the experiment, except for two peaks in the control tank on days 11 and 29 (**Figure 2**). The control tank also had a rapid increase in nitrate and nitrite levels between days 27 and 33 (**Figure 3**). This may have been due to the fish waste building up since there were no plants directly in contact with the water in this tank. The water aquaponic setup did not have such rapid increases in nitrate or nitrite levels possibly because the plants were taking the nutrients directly from the water. The alkalinity was usually slightly higher in the control tank compared to the aquaponic tank (**Figure 4**). The ammonia

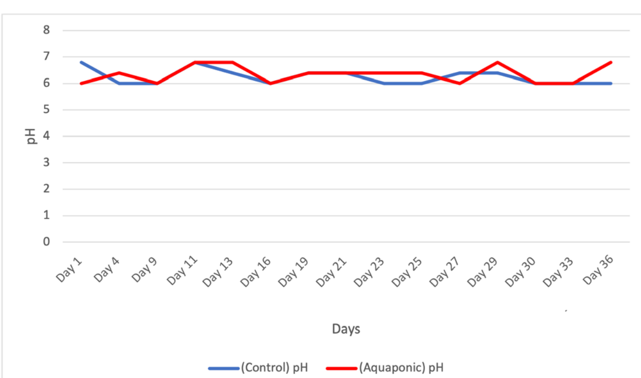

Figure 1: Line graph demonstrating pH levels for the aquaponic tank and the Control tank. Data recorded from the 1st day to the 36th day. The data was collected using water test strips, with results documented immediately after each strip was submerged in water.

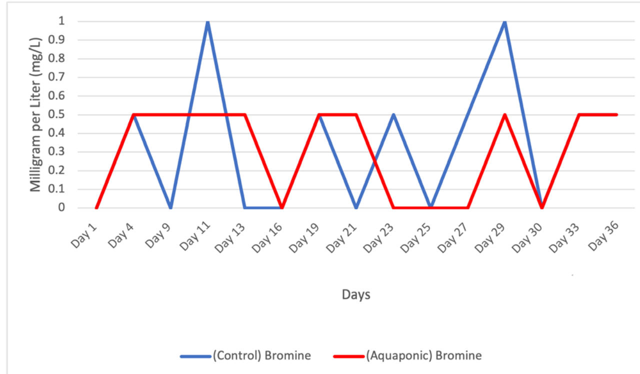

Figure 2: Line graph demonstrating Bromine levels for the aquaponic tank and the Control tank. Data recorded from the 1st day to the 36th day. The data was collected using water test strips, with results documented immediately after each strip was submerged in water.

chloride levels were higher in the aquaponic set up (**Figure 5**). On some degree the plants taking nutrients directly out of the water ensured that all the chemical levels remained consistent. The control tank on the other hand, had the levels vary a lot more, possibly due to the lack of direct contact with plants.

Plant growth and quality

To assess the extent to which mosquitofish can enhance plant growth, the germination rate and plant health were recorded. The plants in the aquaponic setup consistently outperformed all the other set ups in germination rate and development rate (**Figures 6 and 7**). The aquaponic setup had a germination rate of approximately 93.85%. Conversely, the soil and control set up had lower germination rates of about 50.77% and 61.54%, respectively. The control was the only setup to lose one sprout. The soil setup had the most consistently healthy sprouts, followed by the aquaponic set up and the control. The aquaponic setup had the fastest sprout growing rate, with 31.15% of the plant sprouting a second set of leaves on day 33. The soil and control setup did not reach this level of development until day 34 (**Table 1**).

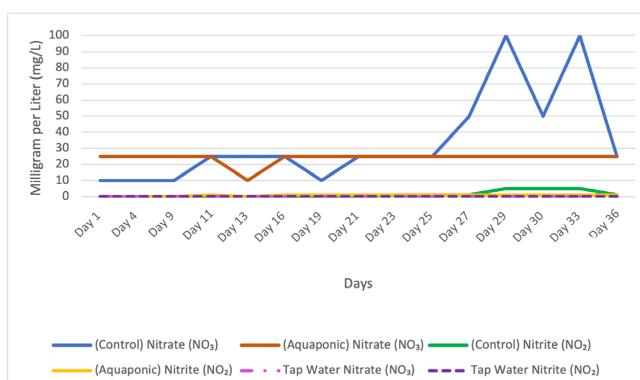

Figure 3: Line graph demonstrating Nitrate and Nitrite levels for the aquaponic tank and the Control tank. Data recorded from the 1st day to the 36th day. The data was collected using water test strips, with results documented immediately after each strip was submerged in water.

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Date	Soil	Aquaponic setup	Control setup
	Total number of sprouts	Total number of sprouts	Total number of sprouts
Day 9 (Sep/28/23)	20	54	19
Day 11 (Oct/1/23)	27	54	36
Day 13 (Oct/3/23)	30	54	39
Day 16 (Oct/6/23)	32	60	40
Day 19 (Oct/9/23)	33	61	41
Day 21 (Oct/11/23)	33	61	40
Day 23 (Oct/13/23)	33	61	40
Day 25 (Oct/15/23)	33	61	40
Day 27 (Oct/17/23)	33	61	40
Day 29 (Oct/19/23)	33	61	40
Day 30 (Oct/20/23)	33	61	40
Day 33 (Oct/23/23)	33	61	40
Day 34 (Oct/24/23)	33	61	40
Day 36 (Oct/26/23)	33	61	40

Table 1: Table documenting the plant numbers after sprouting. As well as plant health observations. Data recorded from the 9th day to the 36th day.

In the soil setup, 9.09% of sprouts developed a second set of leaves, whereas the control's rate was less at 5%. By the end of the experiment, 49.18% of sprouts in the aquaponic setup had a second set of leaves. The soil and control setups had 24.24% and 15%, respectively. In terms of the average plant health scale, the aquaponic setup's plants received a score of 4 or above 96.9% of the time. The soil setup received this score 91.3% of the time and the control had it 92.5%. The control setup outperformed the soil setup, which indicates that the soil may have impeded the nutrients in the water from reaching the plants. This is supported by the fact that the plants in the aquaponic system had the highest germination rates.

DISCUSSION

We attempted to determine whether mosquitofish can survive in aquaponic conditions and, if so, to what extent they can enhance plant growth. We hypothesized that the plants in the mosquitofish setup would produce higher germination rates and superior plant quality due to increased nitrate/nitrite levels acting as a natural fertilizer. The experiment involved three identical containers each set up to assess different conditions for plant growth and water quality. The first container served as a control group, utilizing normal potting soil and regular tap water. In contrast, the second container used the same soil but was watered with dechlorinated water from a fish tank, which contained additional nutrients and components from aquatic animals. The third container operated under an aquaponic system, where plants grew directly in the dechlorinated fish tank water without any soil medium. The increased chemical levels and germination rate data supports our hypothesis. The aquaponic mosquitofish set up had a higher germination rate, as well as better quality plants. The increased nitrate and nitrite levels from the fish tanks possibly acted as a natural fertilizer for the plants. The plants with more direct exposure to the water may have been able to absorb the most nutrients from the water. Hence, this is a likely explanation to why the soil set up did not perform as well. Even if the plants were given the same type of fish tank water, the soil itself could have prevented the plant roots from absorbing the nutrients. In our tested conditions, the soil might be a hinderance to the plants rather than an asset.

The plants in the aquaponic system had constant contact with water. The soil setup was only watered once a day, which only allowed for a set window of time for the water to reach the plants before it evaporated. Furthermore, despite the best effort of the researchers to water the plants evenly, the soil would absorb the water at different rates. From this observation it can be deduced that the soil itself may act as a sponge and absorb water unevenly. Thus, it is possible that the soil could have blocked the plants from accessing nutrients as readily as the plants in the non-soil setup.

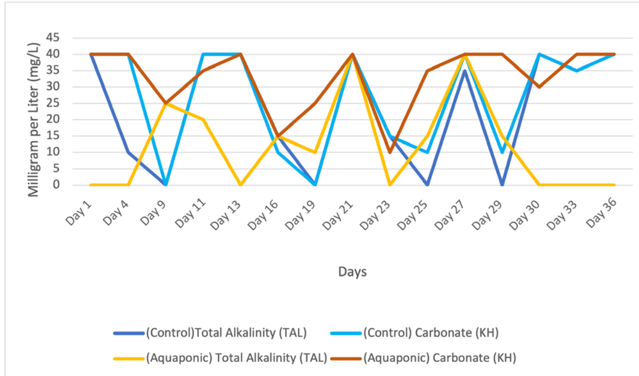

Figure 4: Line graph demonstrating Total Alkalinity and Carbonate levels in (mg/l) for the aquaponic tank and the Control tank. Data recorded from the 1st day to the 36th day. The data was collected using water test strips, with results documented immediately after each strip was submerged in water.

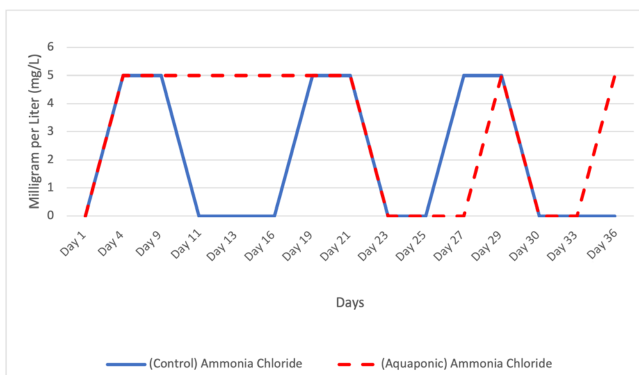

Figure 5: Line graph demonstrating Ammonia chloride readings (in mg/L) for the aquaponic tank and the Control tank. Data recorded from the 1st day to the 36th day. The data was collected using water test strips, with results documented immediately after each strip was submerged in water.

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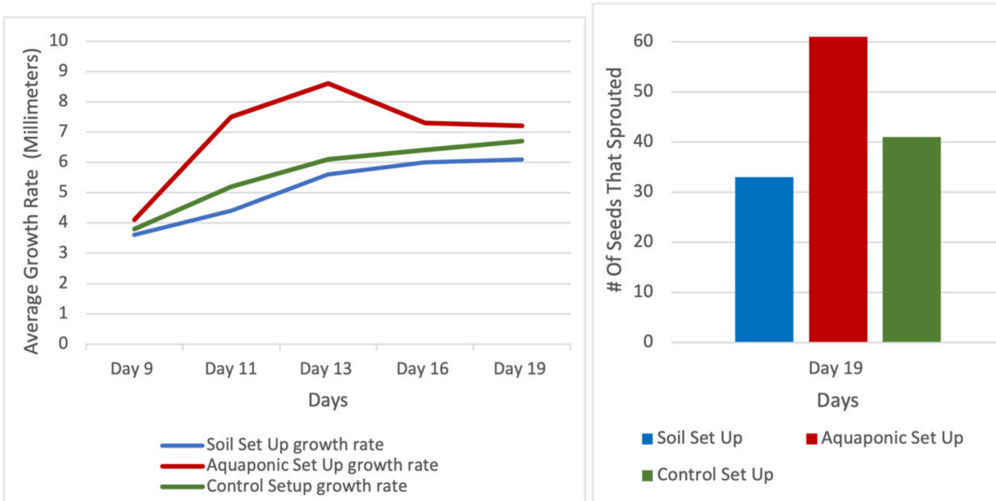

Figure 6: Bar graph demonstrating germination rate and Line graph demonstrating average growth rate in (mm) during germination period, for the following setups: The aquaponic set up that had no soil involved. Containing dechlorinated tap water with the animal components. The Soil set up watered with only water from a separate fish tank set up, also containing dechlorinated tap water with the animal components. The Control setup containing normal tap water. Data recorded from the 9th day to the 19th day. Sprouts were measured with a ruler to document growth rate.

Overall, the chemical concentration levels in the aquaponic set up were lower than in the control set up. This suggests that the basil plants may have absorbed a significant amount of nutrients from the water. Additionally, the water parameters remained safe enough for the fish to live. Thus, mosquitofish are a viable option for aquaponic setups. They can survive the conditions and simultaneously provide enough nutrients to the plants.

As previously stated, the sample size for this experiment was smaller compared to most other farm-scale research sites. This is a limitation that could effectively be addressed by planting more seeds in a larger setup. Having more variety in the plant species being tested can also help to determine if similar results can be found in plants other than basil. This future research is especially important since different plants may vary in their reaction to the aquaponic conditions. Another potential subject that requires further investigation is how well the mosquitofish perform when directly compared to tilapia. This experiment has determined that the mosquitofish can function as an option. However, it did not compare the tilapia and mosquitofish to each other. Further examination is required to decide which can provide more or better nutrients.

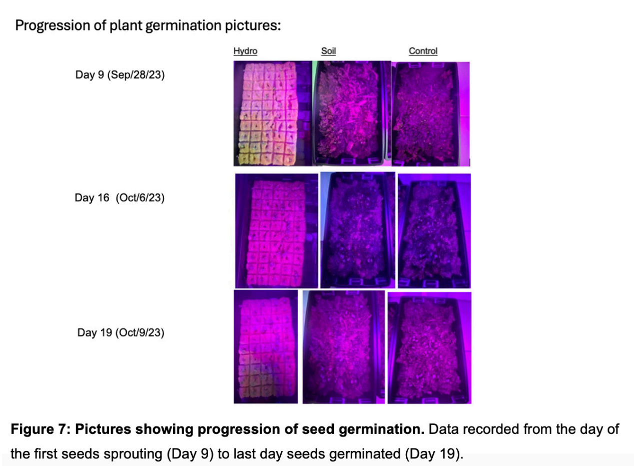

Figure 7: Progression of seed germination. Data recorded from the day of the first seeds sprouting (Day 9) to last day seeds germinated (Day 19).

This experiment was conducted on small-scale models of various agricultural setups. A hydroponic control group would have been an excellent addition to this experiment, comparing two water-based agricultural setups. Thus, future experiments could contain a hydroponic system as an additional comparison group. The experiment should be repeated multiple times to show the statistical significance of the data. However, the experiment cannot be repeated at the moment due to a lack of resources and time. So, these results should be taken more as proof of concept demonstrating the potential of mosquitofish. It should form a starting line for future investigation into the subject.

In areas struggling with nutrient-poor soils, mosquitofish aquaponic setups can be a good farming alternative. Indoor aquaponic systems eliminate the farmer's reliance on weather and seasons, and plants can be cultivated year around. Additionally, the plants have direct access to nutrients 24 hours a day and will grow faster on average than plants grown in soil. Mosquitofish are easy to breed in large quantities at a fast rate (5). They can survive a wide range of environmental conditions so they are guaranteed to live in almost any outside environment (5). Mosquitofish can be an option for individuals who want an aquaponic setup but cannot afford to care for tilapia. Outside aquaponic setups that use these fish could also monitor mosquito populations. This would make them extremely practical in areas struggling with mosquitos being disease vectors. Aquaponic systems using mosquitofish can grow the same number of plants in smaller spaces than typical monocropping techniques. Using a smaller species like mosquitofish increases the accessibility

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for people who do not have enough space for larger fish like tilapia, lowering the barrier to entry. Moreover, for the places that lack horizontal space, mosquitofish can be incorporated in vertical aquaponic setups. This technology can increase access to healthy food all around the world. Not only can aquaponic techniques be used for industrial scale farms, but it could potentially work well in personal microgreen gardens. More people growing their own plants increases access to healthy food in places that would otherwise be food deserts. This would be an especially effective solution in densely populated urban areas.

MATERIALS AND METHODS

Fish origin and husbandry

For our experiment, 26 mosquitofish were bought from PetSmart. Fourteen were kept in a 6.5-gallon fish tank, and 12 were kept in a 6-gallon fish tank. Air pumps were installed in both tanks. The water was changed periodically every few days. Water siphon was used to clean any debris that accumulated in the bottom of the tank. Water quality was monitored via testing with water test strips. The fish were fed Tetra USA Fish Flakes once a day. Sometimes additional water was added to top off the tanks after water evaporated. Observations in health and activity were recorded every two to three days. Both fish tanks were kept at about room temperature, approximately 17°C to 20°C.

Procedures

There were three identical containers with dimensions (36.83cm x 18cm x 5.84cm). The first container acted as the soil-based control group and had normal potting soil that was watered with normal tap water. The second container had normal potting soil and was watered with water from a separate fish tank set up. This fishtank water contained dechlorinated tap water with the animal components. The third container had the aquaponic set up with the plants growing directly in the water, with no soil involved. This setup also contained dechlorinated tap water with the animal components. Grow lamps were provided for each set up and were positioned the exact same distance from each container (27 cm). There were 65 basil heirloom seeds planted in each container. Periodic water changes were carried out every set number of days. More water would be added to the tanks to mitigate evaporation, the presence of various chemicals in the tank water was measured every few days using the appropriate test strip. The strips were dipped into the water for two seconds, then retrieved and the color marker on the test strip was compared with the reference key on the test strip bottle. The measurement of tap water is only taken once since it remained constant. Tank water was tested every two to three days to assess the following parameters: nitrate (NO_3), nitrite (NO_2), general hardness (GH), ammonia chloride, bromine, total alkalinity (TAL), carbonate (KH), and pH. Tap water was tested once to establish another potential metric for comparison between the two different types of water used (tank water and tap water). Another purpose for testing the water is to maintain stable levels that both provide nutrients to the plant and allow the fish to live. The test was carried out with water testing strips. When the water was tested, observation of plant health was recorded on a scale between 1 and 5, with 1 indicating poor health and 5 indicating excellent health. General observations of fish health were recorded, relating to observations on how active and responsive the fish were.

Data Collection and Calculations

The raw numerical data from all of the measurements having to do with chemical concentrations and sprout rate was imputed into an Excel spreadsheet. The Excel spreadsheet software was used to generate all the figures. The software was also used to generate all of the percentages and rates that are seen in this paper.

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Vertebrate Animal Form (5A)

Required for all research involving vertebrate animals that is conducted in a school/home/field research site. (SRC approval required before experimentation.)

Student's Name(s) Isabella Medina

Title of Project Assessing the vitality of Mosquito fish and hydroponic farming.

To be completed by Student Researcher:

1. Common name (or Genus, species) and number of animals used.
   26 Mosquitofish (Gambusia affinis)
2. Describe completely the housing and husbandry to be provided. Include the cage/pen size, number of animals per cage, environment, bedding, type of food, frequency of food and water, how often animal is observed, etc. Add an additional page as necessary.
   Husbandry described in additional page attached to this document.
3. What will happen to the animals after experimentation?
   They will be transfered to a 15 gallon fish tank and kept as pets.
4. Attach a copy of wildlife licenses or approval forms, as applicable
5. The ISEF Vertebrate Animal Rules require that any death, illness or unexpected weight loss be investigated and documented by a letter from the qualified scientist, designated supervisor or a veterinarian. If applicable, attach this letter with this form when submitting your paperwork to the SRC prior to competition.

To be completed by Local or Affiliate Fair Scientific Review Committee (SRC) BEFORE experimentation.

Level of Supervision Required for agricultural, behavioral or nutritional studies (select one):

- [x] Designated Supervisor REQUIRED. Please have applicable person sign below.
- [ ] Veterinarian and Designated Supervisor REQUIRED. Please have applicable persons sign below.
- [ ] Veterinarian, Designated Supervisor and Qualified Scientist REQUIRED. Please have applicable persons sign below and have the Qualified Scientist complete Form (2).

The SRC has carefully reviewed this study and finds it is an appropriate study that may be conducted in a non-regulated research site.

Local or Affiliate Fair SRC Pre-Approval Signature:

Livan Escudero
SRC Chair Printed Name

Signature

09/20/23
Date of Approval (must be prior to experimentation) (mm/dd/yy)

To be completed by Veterinarian:

- [ ] I have reviewed this research and animal husbandry with the student before the start of experimentation.
- [ ] I have approved the use and dosages of prescription drugs and/or nutritional supplements.
- [ ] I will provide veterinary medical and nursing care in case of illness or emergency. (Fees may apply.)

Printed Name

Email/Phone

Signature

Date of Approval (mm/dd/yy)

To be completed by Designated Supervisor or Qualified Scientist when applicable:

- [x] I have reviewed this research and animal husbandry with the student before the start of experimentation and I accept primary responsibility for the care and handling of the animals in this project.
- [ ] I will directly supervise the experiment.

Claudia Alvarez
Printed Name

ms.alvarez42@dadeschools.net
Email/Phone

Signature

9/20/23
Date of Approval (mm/dd/yy)

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