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THE ELM-LEAF BEETLE

THESIS FOR THE DEGREE OF M. S.

Walter F. Morofsky
1930

THESIS

Elm leaf-beetle

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THE ELM-LEAF BEETLE
Galerucella xanthomelaena (Shrank.)

Thesis for Degree of M.S.
Michigan State College.

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THESE

INTRODUCTION

THE ELM LEAF BEETLE

The elm leaf beetle, Galerucella xanthomelaena (Shrank.), is an introduced European insect which attacks elms of the northeastern United States and is gradually spreading westward. It is one of the most destructive pests of elm wherever it occurs. Its presence is most felt in cities where shade trees which have a high aesthetic value, are infested.

This insect is active throughout the entire growing season. The adults come from hibernation in April and May and thereafter adults and larvae feed throughout the entire season, the latter feeding on the under sides of the leaves.

The elm leaf beetle has thus far been found in two cities in Michigan, having been first reported at Monroe in 1924. The only other infestation now known is one at Rochester, Michigan, reported in 1927. But little damage has thus far been done in the last named city.

Observations in connection with this problem have been made by the writer at Monroe, Michigan, during the seasons of 1927, 1928, 1929, and 1930.

Studies of this pest, together with methods of control, have been made.

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The writer wishes to acknowledge the guidance of Professors R.H.Pettit and E.I.McDaniel in the collection and interpretation of the material herein presented, and to express his gratitude for their kindly assistance and advice.

It is also his desire to thank Mr. C. B. Dibble for his assistance in making **life** history observations, and to express his appreciations to Mr. Ralph Kidder, County Agricultural Agent, and Mr. V. Neuman, City Engineer of Monroe, for their cooperation in the field and in furnishing data concerning the applications and costs of control measures.

TAXONOMY

The elm leaf beetle was first described as Galerucella luteola by O. F. Müller in 1766. (In 1781 Shrank redescribed it as Galerucella xanthomelaena). (Fabricus, in 1801, next named it Galerucella gelatinariae) and (Harris, in 1852, as Galerucella cullmariensis). The **synonymy** of G. xanthomelaena (Shrank.) is therefore as follows,-

Galerucella luteola Müller 1766

Galerucella xanthomelaena Shrank 1781

Galerucella gelatinariae Fabricus 1801

Galerucella cullmariensis Harris 1852

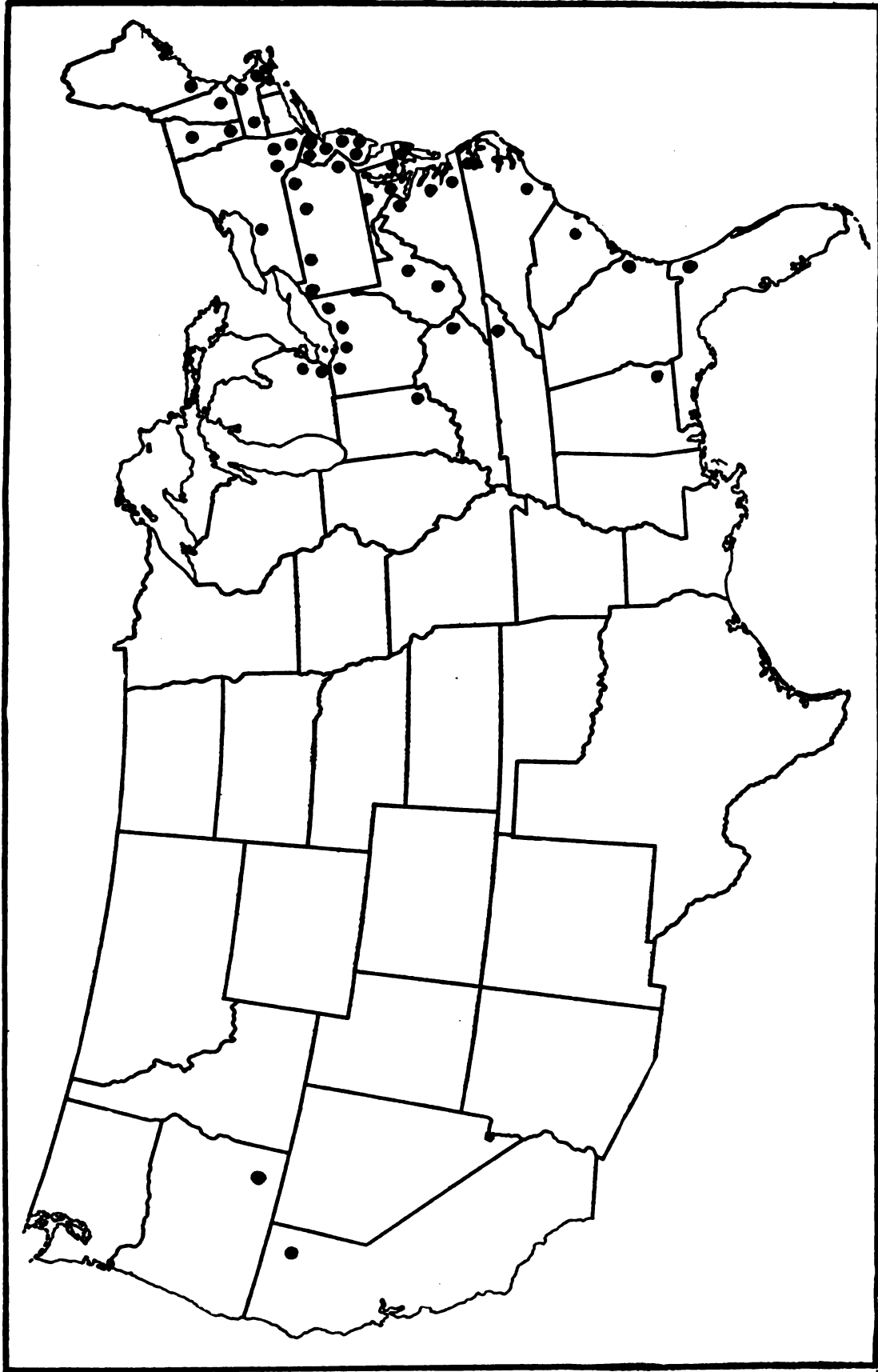
Galerucella xanthomelaena is commonly known as the elm leaf beetle, owing to the fact that both larvae and adults feed altogether on the foliage of elms. The name has been officially adopted and sanctioned by the American Association of Economic Entomologists.

EARLY HISTORY

The elm leaf beetle is said to be abundant in France, Southern Germany, Austria, and to a lesser extent in Italy, Corsica, and Sardinia. It is not known, however, in these countries as a very serious pest or as a killer of trees. It is believed to have been imported into the United States in 1837 and was first reported as working on elm in 1838 and 1839 at Baltimore, Maryland.

DISTRIBUTION

Since this time, the insect spread northward slowly, going through New Jersey and finally distributing itself over New England. At the present time it is found in Maine, New Hampshire, Vermont, Connecticut, Rhode Island, Washington D.C., Massachusetts, Pennsylvania, New York, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, Kentucky, Ohio, Indiana, Michigan, Oregon, and according to F. C. Roullard it was found to be abundant in 1924 at Fresno, California. It is a curious fact that up to the present time it has never been taken in Illinois.



MAP SHOWING STATES WHERE ELM LEAF BEETLE HAS BEEN FOUND.

FOOD PLANTS

The insect confines itself strictly to the various varieties of elm (*Ulmus*). According to Dr. W. E. Britton, State Entomologist of Connecticut, the elm leaf beetle prefers European species of elm to American species. He states that the first choice lies with the English elm, *Ulmus campestris*. Next comes the American elm, *Ulmus americana*, followed by the Scotch elm, *Ulmus montana*, the winged elm, *Ulmus alata*, the slippery elm, *Ulmus fulva*, the cork elm, *Ulmus suberosa*, and the rock elm, *Ulmus racemosa*, the choice seeming to be in the order named.

Observations made by the writer at Monroe, Michigan, showed that the attack there was most heavy on the American elm, *Ulmus americana*. The beetle was found working also on *Ulmus campestris* and on *Ulmus racemosa*. In this particular locality no other species of trees were found to be attacked. Fig.1 shows the defoliating effects of the beetle on the common American elm.

INJURY AND LOSSES

The insect was first observed doing serious injury to elms in Michigan in 1924 where its work on the elms at Monroe attracted attention. Following the period beginning 1924 and including 1926, it became apparent



FIG 1- YOUNG ELM IN FOREGROUND
ATTACKED BY ELM LEAF BEETLE.
• MONROE • MICHIGAN •

that unless checked, the pest was capable of bringing about the death of many trees. During this period, few if any trees were killed, but the effects of the beetle attacks were clearly to be seen. In certain parts of the city, the elms appeared to have been scorched and curled. Fig.2. The foliage was severely injured by the larvae which had been feeding on the under sides of the leaves and skeletonizing them, as shown in Fig.3. It is the habit of the adult beetles to feed on the upper surfaces of the leaves and to eat holes completely through them, whereas the larvae skeletonize the leaves from the under surface.

In order to visualize the **potentialities** for harm, possessed by the elm leaf beetle, one has merely to recall the stately giant elms which formerly graced the streets of New Haven, Connecticut, and then to be reminded of the fact that practically all of these aged giants were killed outright by the beetle soon after its establishment in this country. In 1898, one thousand elm trees were killed in Albany, New York, and fifteen hundred in Troy, by this pest, and many cases of the wholesale destruction of elm trees, could be cited in this connection. In 1904, the elm leaf beetle was discovered at Dayton, Ohio, and by 1907, some of the elm trees in Dayton had already been killed, according to Dr. J. S. Houser*. Fortunately, in Michigan the identity

*Ohio Experiment Station Bulletin #194 - J.S.Houser.



FIG 2. LARVAL INJURY TO ELM LEAVES.



FIG 3. BURNED APPEARANCE
AFTER LARVAL ATTACK.

of the pest was established long before any trees were killed outright, although by the time invasion was brought to the attention of the authorities, much defoliation had taken place.

DESCRIPTION OF THE VARIOUS STAGES.

THE EGG

The eggs of the elm leaf beetle are flask-shape and vary in color from bright yellow to orange. They are placed on end in groups or clusters, usually in irregular rows, although sometimes these rows are quite regular. The eggs are laid for the most part on the under sides of the leaves, but are also sometimes placed on twigs. They are quite conspicuous due to their brilliant color. Fig.4 shows a typical egg mass.

LARVA

The mature larvae are about one-half inch long. The head is shiny black in color. The body varies somewhat in color but in general may be said to be dull yellow with a pair of black stripes running lengthwise down the back and meeting near the end of the abdomen. The whole thorax is yellow with a large black spot on each side. Underneath, the body is yellowish with blackish sclerites. Legs are reddish brown to black, being lighter on the inner sides. When newly hatched, the larvae are nearly black, but with each succeeding molt the body becomes more and more yellow. The setae on the mature larvae are moderately long, strong,



FIG 3a - PUPA - ADULT - LARVA



FIG 4. CLUSTER OF EGGS

pointed, and yellow. They are present in numbers on the back and sides of the larvae. See Fig.3A.

PUPA

The soft, unprotected pupa which measures about one-fourth of an inch in length, varies in color from orange to yellow, with darker markings. It is covered with fine black spines and usually attaches itself in bark crevices and at the base of the tree.

ADULTS

Adult beetles vary in size and color. When the beetle first emerges, it is of a yellowish color, later becoming grayish or greenish. There are two distinct black lines extending from the base to the rear end of the elytron or wing-cover. On the pronotum are also several black spots varying in size and location. The antennae are eleven jointed and yellowish brown in color. The head is dark colored. Figure 3 shows adults enlarged.

LIFE HISTORY AND HABITS

EGG

The egg stage of this beetle usually lasts from five to ten days, depending greatly on weather conditions. On May 20, 1927, several egg masses were collected. On the 26th of May no new egg masses could be found, due to the late cold spring, although on May 21st, 1929, several egg masses had appeared. The eggs are at first orange-yellow but later change in color to a pale yellow as the hatching time approaches.

LARVAE

The young larvae appear in May. In 1927 and 1929 the writer found young larvae feeding on the foliage of elm, the newly hatched grubs being very active at that time. They begin feeding as soon as they emerge from the egg, scraping away the under surfaces of the leaves, and killing the parenthyma between veinlets. As the larva grows in size it includes more tissue, and its work becomes more conspicuous during the latter part of its development. Two or three weeks are required to complete its growth. The larva at the end of that period becoming very sluggish and showing a tendency to descend from the leaf, makes its way down on the trunk of the tree. The large elms at Monroe are old and the large crevices in the loose bark make an ideal place for pupation. Many of the larvae descend clear to the base of the tree and pupate under rubbish, grasses and dirt.



FIG 5. MASS OF PUPAE AND ADULTS AT BASE
OF ELM TREE.

PUPAE

When the larva has reached maturity it descends to the lower trunk and base of the tree and changes to a soft unprotected pupa. Figure 5 shows a collection of pupae at the base of a tree. In from five to seven days the bright adults emerge from the pupae and we find them ascending the tree on their way up to the foliage. When the adults appear they immediately migrate to the leaves and begin feeding. Here they collect on the upper surfaces of the leaves and eat round holes through the tissue as shown in Fig.6 and Fig.6A. At first they make their way about on foot rather than by the aid of their wings. Freshly emerged adults are very easily collected since they do not attempt to fly. After two or three days they begin to use their wings and move freely from tree to tree when disturbed. The adult stage extends over quite a long period. Adults emerging in July and August, remain over until the following May, at which time the females deposit eggs, after which the beetles die.

NUMBER OF GENERATIONS

One complete generation is usually developed and a partial second generation is often produced late in the season in this latitude. The first generation of the elm leaf beetle is produced from eggs laid during May and June by adults of the overwintering brood,



FIG 6. INJURY CAUSED BY
ADULTS.



FIG 6a- WORK OF ADULTS.

the bulk of the first generation reaching maturity in June or July. If there is to be a second generation as was the case in 1927, it is completed by the latter part of August or the first part of September. Just as soon as the temperature begins to drop, the beetles seek hibernation quarters. In 1928 a few egg masses were found on August 11th. Undoubtedly these egg masses belonged to the second generation. They did not hatch.

HIBERNATION

With the coming of frost in the autumn, this insect disappears from among the **trees** and seeks shelter in out of the way places where it passes the winter and remains until the following season. From the first until the latter part of May the adult beetles continue to come forth from their winter quarters, congregating on trees.

NATURAL ENEMIES

One of the important restrictive agencies of the elm leaf beetle is a fungus known as Sporotrichum globuli-ferum. This is occasionally found on pupae and adults in late summer, in moist wet seasons. Several species of Podisus are known to feed on this pest, besides several predatory beetles.

CONTROL MEASURES

Undoubtedly the most effective single control measure to be available for use against the elm leaf beetle, consists in a spray of arsenate of lead, using 6 pounds of the dry powder to 100 gallons of water, and applying so that the upper surfaces of the leaves shall be evenly coated at a time when they are one-half to two-thirds grown. A spray of arsenate of lead applied at this time is designed to kill the adult beetles before the eggs are laid. The adult beetles have the habit of feeding on the upper surfaces of the leaves during the period just before egg-laying time.

On the 21st of May, 1927, a demonstration of the **correct** method of spraying was given by Mr. Kelly of the United States Department of Agriculture, at the city of Monroe, Michigan. Both city and state officials were present and witnessed the **demonstration**. The heavy duty pump and tank used in corn borer work, were loaned to the city for this demonstration, **by the** Michigan Department of Agriculture, and in order to throw the spray **above** the tops of the highest trees, Worthley nozzles were made use of.

The Worthley nozzle is especially designed for spraying trees in cities and in forests when great heights are demanded. The Worthley nozzle **throws** a solid stream over 100 feet high. At the end of its

course the stream mushrooms out and breaks into a fine mist that settles on the surfaces of the leaves and makes it possible to reach very large trees without extensions or ladders.

Fibures 7 and 8 show such spraying outfits in operation, some of the trees sprayed reaching a height of 100 feet. At the time stated, practically all of the elm trees in Monroe were sprayed with the exception of a few small and scattering trees in alleys, back of old buildings, etc. Figure 9 shows one of these places that was left unsprayed. Apparently the date selected was about right and the weather conditions were entirely satisfactory. On July 30th, 1927, a survey was made and only a very few adult beetles found on sprayed trees, seemingly of the second generation. These beetles might nicely have bred on patches of elms nearby.

In 1928 the trees were again sprayed but at a later date, and as weather conditions were not as favorable as in 1927, the control was not quite so effective. Due to a late spring only one generation occurred and little damage was done.

In 1929 the work appeared somewhat spotted, some districts having a fair supply of beetles and others having apparently none at all. On April 6, 1929, an examination of several church towers and belfries was made, in order to find if the beetles were hibernating in such places. None were found however. On the 22nd.



FIG 7. SPRAYING OPERATIONS
AT MONROE • MICHIGAN • 1927.

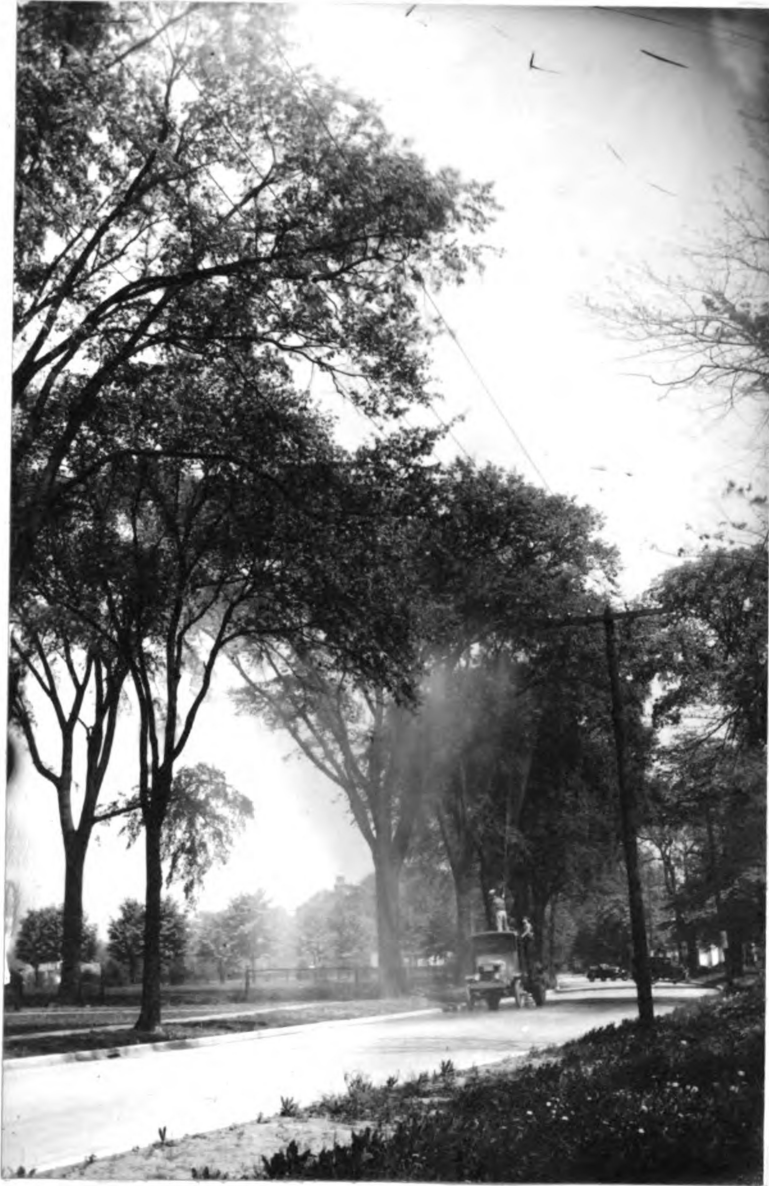


FIG 8- SPRAYING LEAVES ON
UNDERSIDES WITH ARSENICAL
• MONROE • MICHIGAN • 1927 •

to the 27th. of July, 1909, an examination was made throughout the entire city, and larvae, pupae, and adults were found here and there in spots. In making this survey it was observed that the heaviest infestation occurred near an old deserted home surrounded by elms, where the beetles may possibly have overwintered. No damage was caused. From the experience gained in these three years of observation, it is believed that the elm leaf beetle may be controlled by the use of an arsenical spray used at the strength of six pounds of arsenate of lead to 100 gallons of water, applied in early spring as soon as the leaves on the elms are one-half to two-thirds grown.

SUMMARY

The elm leaf beetle, Galerucella xanthomeloena (Schrank) is an important pest which feeds on the foliage of elms and on no other plant.

This species is distributed over parts of Europe and is rapidly spreading over the United States. In Michigan it has established itself in two cities, - namely, Monroe and Rochester.

The larvae have been found feeding on American elm, (Ulmus americana) and on English elm (Ulmus campestris).

The adult beetle is about one-fourth inch in length and varies in color from yellow to greenish, with two pronounced black lines on the elytra or wing covers.



FIG 9. UNSPRAYED STUMP
GROWTH OF ELM. IDEAL
BREEDING PLACE.
• MONROE • MICHIGAN • 1927 •

Adults of the overwintering brood emerge during the first part of May and June and lay their eggs soon thereafter. The eggs are laid in groups of two to sixty in a mass on the under sides of the leaves. The eggs hatch in a week to ten days, depending on weather conditions and the larvae feed on the under sides of the leaves. Pupation takes place in crevices in the bark, more commonly near the base of the tree and under rubbish.

In Michigan there is one complete brood and sometimes a partial second **brood**. Winter is passed in the adult stage.

In the East the elm leaf beetle is held in check somewhat by a fungus disease, but the most satisfactory control is a spray of arsenate of lead used at the rate of six pounds of the dry powder to 100 gallons of **water**. **This** spray applied at a time when the leaves are two-thirds to three-quarters grown, and evenly spread on the upper surfaces of the leaves to get the adult beetles before the eggs are laid, is very effective in controlling the European pest of elms.

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Figure 1 consists of two rows of scatter plots. The top row shows the relationship between the number of children (x-axis, 0 to 10) and the number of adults (y-axis, 0 to 10). The bottom row shows the relationship between the number of children (x-axis, 0 to 10) and the number of adults (y-axis, 0 to 10). The plots show a positive correlation between the number of children and the number of adults.

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2. The second part of the document focuses on the implementation of the proposed changes. It details the steps involved in the rollout process, from initial planning to final execution. This section also addresses potential challenges and provides strategies to overcome them, ensuring a smooth transition to the new system.

3. The third part of the document discusses the ongoing monitoring and evaluation of the project. It highlights the need for continuous communication and collaboration between all stakeholders involved. This section also provides a timeline for the project, with key milestones and deadlines clearly defined.

4. The fourth part of the document provides a summary of the findings and conclusions. It reiterates the importance of the project and the benefits it will bring to the organization. This section also includes a list of recommendations for future work, ensuring that the project remains a priority for the organization.

5. The final part of the document is a conclusion. It summarizes the key points of the document and expresses the confidence in the success of the project. It also includes a statement of appreciation for the support and cooperation of all stakeholders involved in the project.

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2. The second part of the paper focuses on the methodology used in the study. The authors describe the data collection process, the statistical models employed, and the validation techniques used to ensure the reliability of the results. They emphasize the importance of transparency and reproducibility in scientific research.

3. The third part of the paper presents the results of the study. The authors show that the proposed model accurately predicts the observed outcomes across different scenarios. They also discuss the limitations of the study and the need for further research to refine the model and explore new aspects of the system.

4. The fourth part of the paper discusses the implications of the findings for practice and policy. The authors suggest that the insights gained from this study can be used to inform decision-making and to develop more effective strategies for addressing the challenges at hand. They also highlight the need for ongoing monitoring and evaluation to ensure the continued relevance and effectiveness of the interventions.

5. The fifth part of the paper concludes the study and provides a summary of the key findings. The authors reiterate the importance of understanding the underlying mechanisms of the system and the need for a comprehensive approach to addressing the challenges it presents. They also express their hope that the findings of this study will contribute to the broader understanding of the system and inform future research.

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2. The second part is a detailed description of the methodology.

3. The third part is a discussion of the results.

4. The fourth part is a conclusion and a list of references.

5. The fifth part is a list of appendices.

6. The sixth part is a list of figures and tables.

7. The seventh part is a list of abbreviations.

8. The eighth part is a list of symbols.

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• $\mathbb{R}^n$ is a vector space over $\mathbb{R}$.

• $\mathbb{C}^n$ is a vector space over $\mathbb{C}$.

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• 1. The first step in the process of creating a new product is to identify a market need. This involves conducting market research to determine what consumers want and what problems they are trying to solve. Once a need is identified, the next step is to develop a concept that addresses that need.

• 2. The second step is to create a prototype. This is a physical model of the product that allows the designer to test and refine the design. Prototyping can be done in a variety of ways, from simple sketches and models to more complex 3D printed parts.

• 3. The third step is to conduct a feasibility study. This involves evaluating the technical, financial, and market viability of the product. A feasibility study can help identify potential risks and challenges, and provide a more realistic estimate of the costs and benefits of the project.

• 4. The fourth step is to develop a business plan. This is a document that outlines the business model, marketing strategy, and financial projections for the product. A business plan is essential for securing funding and guiding the development of the product.

• 5. The fifth step is to manufacture the product. This involves sourcing materials, finding a manufacturer, and producing the final product. Manufacturing can be a complex process, and it is important to choose a manufacturer that has experience with the product and can meet the required quality standards.

• 6. The sixth step is to launch the product. This involves marketing the product, distributing it, and providing customer support. Launching a new product can be a challenging task, and it is important to have a solid marketing and distribution strategy in place.

• 7. The seventh step is to monitor the product's performance. This involves tracking sales, customer feedback, and other key metrics to determine how well the product is performing in the market. Monitoring performance can help identify areas for improvement and inform future product development.

• 8. The eighth step is to iterate and improve the product. This involves making changes to the product based on customer feedback and market trends. Iteration is a key part of the product development process, and it allows designers to create products that better meet the needs of their target market.

• 9. The ninth step is to scale the product. This involves increasing production and distribution to reach a larger market. Scaling a product can be a challenging task, and it is important to have a solid plan in place for managing growth.

• 10. The tenth step is to exit the market. This involves selling the product or business to another company or liquidating the assets. Exiting the market can be a complex process, and it is important to have a solid plan in place for managing the exit.

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1. The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation

$$f(x) = \int_0^x \frac{1}{1+t^2} dt, \quad (1)$$

where x is a real number. It is well known that the function $f(x)$ is an odd function, i.e.,

$$f(-x) = -f(x). \quad (2)$$

Moreover, the function $f(x)$ is bounded on the entire real axis, i.e.,

$$|f(x)| \leq \frac{\pi}{2} \quad (3)$$

for all $x \in \mathbb{R}$. The function $f(x)$ is also continuous on the entire real axis.

2. The second part of the paper is devoted to the study of the function

$$g(x) = \int_0^x \frac{t}{1+t^2} dt, \quad (4)$$

where x is a real number. It is well known that the function $g(x)$ is an even function, i.e.,

$$g(-x) = g(x). \quad (5)$$

Moreover, the function $g(x)$ is bounded on the entire real axis, i.e.,

$$|g(x)| \leq \frac{\pi^2}{8} \quad (6)$$

for all $x \in \mathbb{R}$. The function $g(x)$ is also continuous on the entire real axis.

3. The third part of the paper is devoted to the study of the function

$$h(x) = \int_0^x \frac{t^2}{1+t^2} dt, \quad (7)$$

where x is a real number. It is well known that the function $h(x)$ is an even function, i.e.,

$$h(-x) = h(x). \quad (8)$$

Moreover, the function $h(x)$ is bounded on the entire real axis, i.e.,

$$|h(x)| \leq \frac{\pi^2}{8} \quad (9)$$

for all $x \in \mathbb{R}$. The function $h(x)$ is also continuous on the entire real axis.

4. The fourth part of the paper is devoted to the study of the function

$$k(x) = \int_0^x \frac{t^3}{1+t^2} dt, \quad (10)$$

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Figure 1. The effect of the number of trials on the number of correct responses. The number of correct responses was significantly higher than the number of incorrect responses for all conditions. The number of correct responses was significantly higher than the number of incorrect responses for all conditions. The number of correct responses was significantly higher than the number of incorrect responses for all conditions.

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• **Prevalence** – the proportion of a population that has a disease at a particular point in time

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• *Journal of the American Medical Association*, 2000; 284: 1039-1044

Figure 1. The effect of the number of trials on the number of correct responses. The number of correct responses was significantly higher than the number of incorrect responses in all cases. The number of correct responses was significantly higher than the number of incorrect responses in all cases. The number of correct responses was significantly higher than the number of incorrect responses in all cases.

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• *Journal of the American Medical Association*, 2000; 283: 2639-2644

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Figure 1. The effect of the concentration of the *Agrobacterium* suspension on the transformation efficiency of *Agrobacterium* strains. The number of transformed cells was determined by the number of colonies obtained on the selective medium. The results are the mean of three independent experiments. Error bars represent standard deviation.

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