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Sustainable Greenhouse Concept Design

Zeynep ESMER[1a*] Hüdayim BAŞAK[1b]

[1]Gazi Üniversitesi, Teknoloji Fakültesi, Endüstriyel Tasarım Mühendisliği Bölümü, 06500 Ankara/TÜRKİYE
zeynepesmerr@outlook.com

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Abstract: In this study, a new form is proposed to reduce the damage of greenhouses due to natural disasters and the loss of time in the repair process. It is predicted that the proposed structure will preserve the existing advantages and reduce the possible damage that may be encountered. Within the scope of the study, the design lens application was carried out with the biology-to-design thinking method, and a new type of greenhouse design proposal was presented by scaling the tetradecahedron form that forms the impact-resistant cell structure of watercress. The design lens defines the steps used in the transition from biology to design. These steps are explained in detail in the article and supported with visuals. The designed greenhouse is a form proposal that can survive natural disasters with minimal damage. Additionally, a design proposal has been developed that converts the functions of the proposed system, which are characterized as harmful (rain and hail) into useful functions (usable water) with a cycle within the proposed system, thus ensuring sustainability. In the studies conducted, improvement works were carried out using the TRIZ method to make the structure more resistant to hail.

Keywords: design lens, bio-TRIZ, watercress, tetradecahedron, biomimetic

1. Introduction

Greenhouse cultivation in Türkiye emerged in the 1940s. Greenhouses were established in the Mediterranean Region, which is the most suitable climatic location, to conduct research in some agricultural institutions in the region. "Except for places with geothermal resource infrastructures, greenhouse cultivation is concentrated in places where the average annual temperature is high." [1]. Between 1940 and 1960, greenhouse cultivation could not show an efficient development in our country. "Greenhouses are building elements covered with light-permeable materials such as Glass, plastic, and fiberglass, which can control or regulate environmental conditions to provide suitable conditions for the growth of plants." [2]. In the cultivation of vegetables and fruits in temperate climate conditions, glass covers are commonly used for vegetables and plastic covers for fruits. Plastic covers have started to be used with the development of production technologies and raw materials used in greenhouses [3]. Additionally, plastic material has become a more widespread greenhouse cover material due to its favourable initial cost and the light transmittance required for plant growth [4]. For this reason, fruit and vegetable cultivation is observed in the Mediterranean and Aegean regions, which have milder climates compared to other regions [5]. Although greenhouse activities are predominantly in the southern region of our country, they are also widely carried out throughout the country. Greenhouses damaged because of supernatural events such as storms in the regions where they are widespread cause material damage to the state and the producer.

Greenhouse cultivation is an important production type for the agricultural sector. To obtain high yields per unit area, various agricultural production methods are being developed to respond to the economic and environmental problems of greenhouses. [6]. Disruptions in this sector negatively affect production. After the damage assessment after a storm in Antalya, it was reported that the glass

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material used in the ceiling of the greenhouses was very difficult to repair after the damage, and the products in the greenhouse were also damaged when the glass on the roof fell. It was stated that the damage assessment studies take time, and the exact impact and cost of the damage will be determined within 10–15 days since the products cannot be preserved and they fall or blacken due to impacts such as hail [7]. Simultaneously, the damages related to the greenhouse are mostly realized in the form of tearing the greenhouse cover [8,9]. After the greenhouse cover is torn, the products remain unprotected and are exposed to unsuitable growing conditions. For these reasons, it is impossible to deliver most of the products to the consumer. Because of this situation that occurs every year, it is thought that strengthening the greenhouses and designing them in a form that will be minimally affected by the impacts will be a way to solve these problems. For the detection and solution of these problems, contradictions were identified with TRIZ and solutions were presented with biomimicry.

“Biomimicry is a new discipline that studies nature's best ideas and then imitates these designs and processes to solve problems.” [10]. It is not only aimed to reach a solution to a problem or a product by analysing observations in nature. In addition to this purpose, the development of biology-based concepts, products, and/or processes inspired by nature can be considered areas of use of biomimicry [11]. Its aim is to include the designer in the process with the design and to develop creative solutions inspired by nature [12]. Nature is the basis of design as it is the basis of everything, and designers have to learn and use the methods and functions in nature to see and interpret the opportunities offered by biomimicry [13].

In this study, the morphological method and the design-to-biology method were used. It is critical to identify the real problems to use the suggestions offered by nature in real and correct needs. The TRIZ method, supports the biomimicry approach was utilized in the study. TRIZ is a systematic idea generation community that includes many techniques. It was introduced by Genrich Altshuller, born in Tashkent, Soviet Union, in 1926. It emerged from the initials of the words Teoriya Resheniya Izobretatelskikh Zadatch (Теория Решения Изобретательских Задач). TRIZ is a methodology that is effectively used in the emergence of innovative ideas and facilitates the birth of these ideas [14]. It is an effective tool for product design in terms of increasing product complexity, sectoral transitions in product design, and new materials, as it expands the designer's alternative solution space. The method and method-based approach to the results instead of trial and error can also reduce R&D, design and therefore production costs and times in terms of the competitive advantage [15]. This study has been completed through the concept of Bio-TRIZ as the common point of the two approaches. General Systems Theory and TRIZ methods are two system approaches that can be used in the application of biological systems to engineering disciplines [16,17].

Within the scope of the study, a new type of greenhouse design proposal was carried out. First, contradictions were identified with the TRIZ method for the identification and solution of problems, and then a new type of biomimetic-based greenhouse concept was created by scaling the tetradecatron form that forms the impact-resistant cell structure of watercress by applying a design lens with the biology-to-design thinking method. The final concepts were reached using the Bio-TRIZ concept as the common point of the two approaches (TRIZ and biomimicry).

2. Design Lens and Bio-TRIZ Usage

Within the scope of this study, the idea of biomimicry, 39 engineering parameters from TRIZ tools, and 40 creative principles were used. In the contradiction matrix, there are 39 engineering parameters in the first row cells from top to bottom and in the first column cells from left to right. While the parameters from top to bottom indicate the parameters that are desired to be improved (included) in the design, the parameters from left to right indicate the parameters that weaken the design and are undesirable [18,19]. Thirty nine (39) TRIZ engineering parameters are given in Table 1, and almost all of the design problems that create contradiction/contradiction with these parameters can be expressed [20]. In TRIZ, there are 40 creative solution principles used in design problem solutions to be expressed as a contradiction (Table 2).

Table 1. 39 engineering parameters that create technical conflicts [13]

No	Engineering parameter				
1	Weight of moving object	14	Strength	27	Reliability
2	Weight of nonmoving object	15	Durability of moving object	28	Accuracy of measurement
3	Length of moving object	16	Durability of nonmoving object	29	Accuracy of manufacturing
4	Length of nonmoving object	17	Temperature	30	Harmful factors acting on object
5	Area of moving object	18	Brightness	31	Harmful side effects
6	Area of nonmoving object	19	Energy spent by moving object	32	Manufacturability
7	Volume of moving object	20	Energy spent by nonmoving object	33	Convenience of use
8	Volume of nonmoving object	21	Power	34	Reparability
9	Speed	22	Waste of energy	35	Adaptability
10	Force	23	Waste of substance	36	Complexity of device
11	Tension, pressure	24	Loss of information	37	Complexity of control
12	Shape	25	Waste of time	38	Level of automation
13	Stability of object	26	Amount of substance	39	Productivity

The act of designing contains certain design processes within itself. At the stage of integrating biology into the existing process, the process of determining the scope, creation, and evaluation stages are applied respectively.

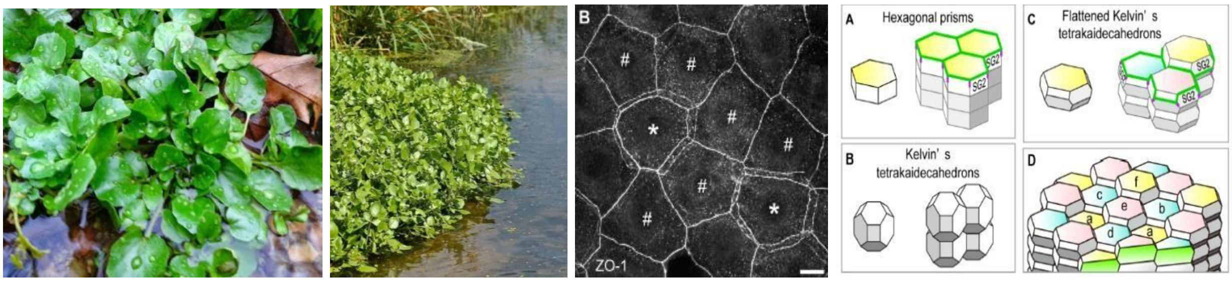
Table 2. Forty **(**40) Creative Principles For Resolving Technical Conflicts [13]

No	Creative Principle						
1	Segmentation	11	Beforehand cushioning	21	Skipping	31	Porous materials
2	Taking out	12	Equipotcntiality	22	Blessing in disguise	32	Colours changes
3	Local quality	13	The other way around	23	Feedback	33	Homogeneity
4	Asymmetry	14	Spheroidality	24	Intermediary	34	Discarding and recovering
5	Merging	15	Dynamics	25	Self-service	35	Parameter changes
6	Universabrationlity	16	Partial or excessive actions	26	Copying	36	Phase transitions
7	Nested doll	17	Another dimension	27	Cheap short-living	37	Thermal expansion
8	Anti-weight	18	Mechanical vibration	28	Mechanics substitution	38	Strong oxidants
9	Preliminary anti-action	19	Periodic action	29	Pneumatics and hydraulics	39	Inert atmosphere
10	Preliminary action	20	Continuity of useful action	30	Flexible shells and thin films	40	Composite material film

First, the preliminary identity of the problem and the contextual issues surrounding it, i.e., its scope, are determined, then creative design solutions are created despite a specific problem, i.e. the creation process is started, and finally the evaluation process is completed, i.e. the processes of measuring, evaluating and predicting the quality, capabilities, importance, scope, and nature of the specific solution.

2.1. Design Lens Application on Watercress

Watercress is a species of aquatic plants native to Asia and Europe. It grows in rivers affected by water flow to constant pressure, high flow velocities after rain, and any debris caught in the current (Figure 1). The cells that make up the stems of watercress plants are tetradecahedron-shaped, which allows the stem to absorb impact more effectively, making it resistant to breakage. This shape is resistant to impact and is also useful as a storage area [21].



(a) (b) (c) (d)

Figure 1. Watercress and its habitat (a) (b) and cell structure (c) (d) [21,22]

2.1.1. Application of the Design Lens

It is aimed to use the design structure of the Watercress organism, which is resistant to external factors, to improve the advantages in the greenhouse mentioned in the table and to eliminate the existing problems (Table 6, Table 7). Human and other living species living in the same natural rules face similar difficulties. For this reason, the problems faced by human beings are similar to the problems faced by other living things in nature.

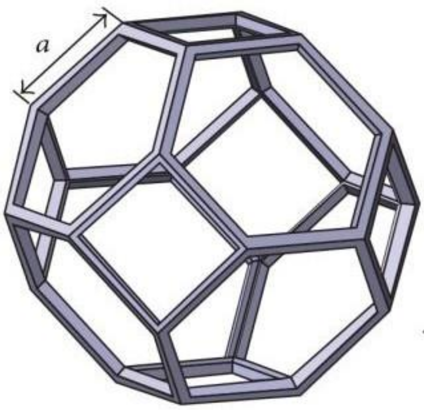


Figure 2. Tetradecahedrons [21]

Watercress is a plant species that survives under difficult conditions. In its habitat, it is exposed to constant pressure from the water flow, high flow rates after rain, and the effects of any debris caught in the current. For this reason, it has produced a solution to the existing problems to increase its productivity and continue its life. This is summarized in the table below (Table 3).

Table 3. Classification of biomimicry

Organism	Watercress lives in the river.
Difficulty	It is resistant to strong currents and impacts caused by the transport of parts by water.
Strategy	It grows in rivers subject to constant pressure from the flow of water, high flow rates after rain, and any debris caught in the current. The cells inserted into the stems of watercress plants are tetradecahedron-shaped, which allows the stem to more effectively absorb damage from impact, making the stem less prone to breakage in fast-flowing water [21, 23, 24].
Function	Its survival and survival depend on the cell shape in this structure.

2.1.2. Thought Scheme

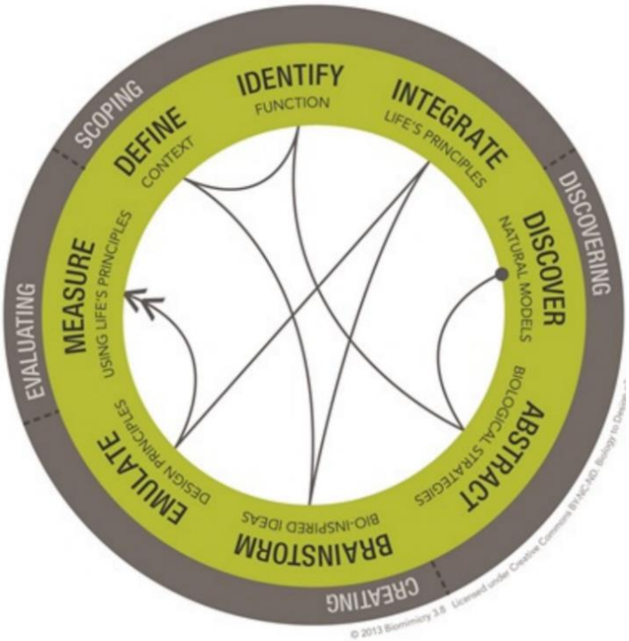


Figure 3. Biology to design thinking diagram [25]

Table 4. Stages of the thought schema of the watercress organism

1. Explore	Through Ask Nature, it was discovered how the watercress plant behaves despite adversity.
2. Thought (Biological strategy)	The biological strategy of the organism discovered by searching for the answer to the how question has been defined. The organism resists impact thanks to the tetradecahedron, the geometric form in the cell structure.
3. Function Definition	The function was reached by searching for an answer to the questionof why. Survival and survival depend on the cell shape in this structure.
4. Establishing context	This information was gathered together, and the information card, which is the first step of the design phase, was created.
5. Brainstorming	Based on the information defined, it has been considered on whichareas of need the tetradecahedron form and the form that resists impacts can be used. Several ideas are proposed in this direction.

2.1.3. Brainstorming Phase

Trees placed as windbreaks are insufficient against high winds such as storms and cause damage to the greenhouse. It has been evaluated that the disadvantages of the existing form of the greenhouse can be improved by arranging the tetradecahedron form for the greenhouse, the need for windbreaks insufficient despite storms can be eliminated, and many financial benefits can be achieved by increasing the service life of the greenhouse and protecting the crop.

2.1.4. Life Principle Phase

Figure 4. Life principles [25]

Life principles can be defined as a guideline that specifies the requirements for the realization of biomimetic design. At this stage, idea elimination was carried out by focusing on whether the ideas are sustainable or not. Biomimetic design reflects the concept of sustainability, which has not been considered so far, to designs. It is important to emphasize designs compatible with the system that nature maintains with efficient energy and minimum waste.

Table 5. Adaptation of life principles to greenhouse design

1. Adapt to Changing condition	The need for time to protect existing resources and to reuse the greenhouse damaged in disasters such as storms has increased the tendency toward more durable products.
2. Be Locally Attuned and Responsive	A durable greenhouse can be designed by adapting to thecurrent situation without harming the balance of nature.
3. Be Resource Efficiently (Materials and Energy)	The need for windbreak is eliminated. Energy, material, time, and cost savings should be provided with the design to be made.
4. Integrate Development with Growth	It can be produced in modular parts and brings a diversity of use.Additionally, energy savings can be achieved in many areas withthe solved problem.

Life principles have been used to address the problem of damage to greenhouses in inclement weather. An environmentally friendly design saves resources, time, materials and costs (Table 3). Storms, hailstorms, and floods damage greenhouses. These problems can be solved with the right design and form.

2.1.5. Design Phase

Before starting the design, Identified and listed which problems will be addressed by the existing biological strategy.

Table 6. Current problems

Current Problems	Being Solvable by Biological Strategy
Inability to resist the wind	+
Damage to the structure because of storm	+
The need for financial means for recovery after the damage	+
Long time requirement for repair after the damage occurred	+
Inadequate applications such as windbreaks	+
Surface damage after hail	+
Damage to crops after flooding	+

(a) (b)

Figure 5. Greenhouse damage images [6, 7]

Table 7. Existing advantages

Available Benefits	Maintaining Advantages with Biological Strategy
The crop area is wide	+
Suitable for comfortable circulation	+
Irrigation with the distillation system	+
Easy installation	+
Cheap material	-

2.1.6. Sketch Studies

The form was modeled in Fusion360 program. Based on the cell form, which is strengthened by coming together, various arrays have been created. In the greenhouse designed based on the form of the watercress cell, the cell-sized tetradecahedron form consists of an equilateral hexagon and a square. By drawing an equilateral hexagon and square, the form was proportionally enlarged and used in the design.

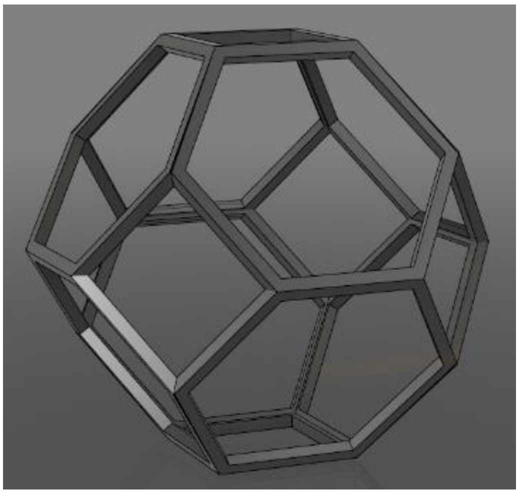


Figure 6. Tetradecahedron model

To be wind-resistant, different forms from the existing greenhouses were sought, and it was concluded that the dome form was suitable. It is aimed to prevent hard impacts by softening the wind. In the design, which is aimed to be affected by hail, wind, and floods with minimum impact, the surface is reinforced with the help of plastic pipes. Steel construction offers a solid structure. Plastic tarpaulin is covered on the construction, and a solution to reduce the severity of hail is offered with pipes on the tarpaulin.

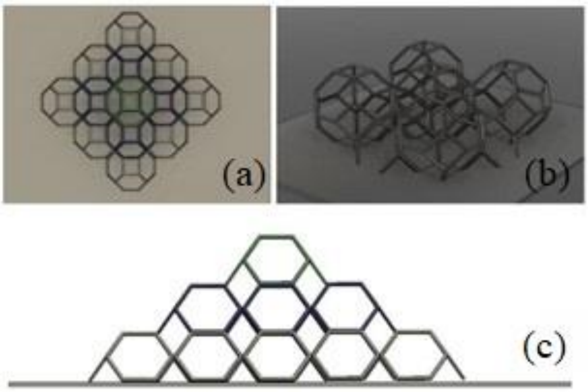


Figure 7. Trials

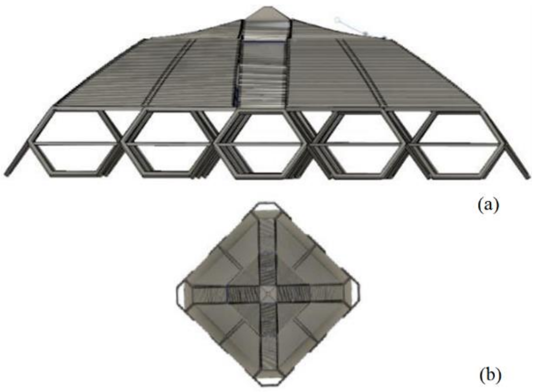
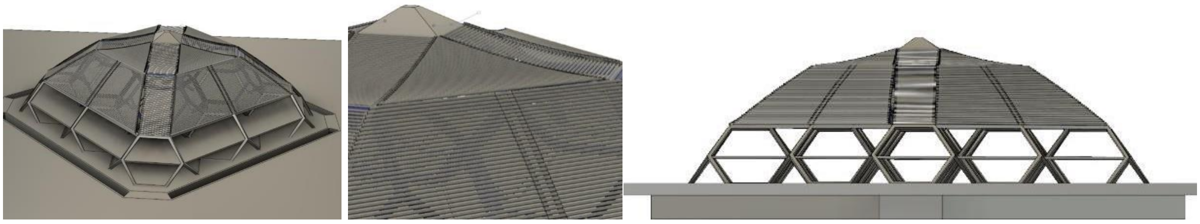


Figure 8. Final trial top (b) and side view (a)

In addition to wind damage to the greenhouse, solution alternatives were presented for flooding and hailstorm problems. The force and pressure applied by hail on the greenhouse surface cause damage to the greenhouse and crops become unsaleable. For this reason, a solution that does not block sunlight but reduces the intensity of hail is proposed. Pipes made of transparent plastic were used to cover the tarpaulin covering the greenhouse surface (Figure 16). The hail coming to the stretched tarpaulin now exerts force on the plastic pipes, and their intensity is reduced and directed to the storage under the greenhouse with the effect of gravity. In this way, sustainability and maximum energy and resource savings are achieved.

For flooding, the greenhouse surface was considered separately from the soil and placed at a high level (Figure 9). This level can be determined according to the precipitation rate of the region where the greenhouse is used. The tank under the greenhouse stores this excess water and stores it for later use. The gutters on the sides of the greenhouse are placed for hail and rainwater inlet and can be supported with grids and filters to prevent blockage.



(a) (b) (c)

Figure 9. Water tank entrance (a) hail damage solution proposal (b) flooding solution proposal (c)

2.1.7. Greenhouse Design

Based on watercress, the durability of the greenhouse was increased. Other problems found a place in the design phase and were solved to make the greenhouse sustainable.

(a) (b)

Figure 10. Render (a) and sequence examples (b)

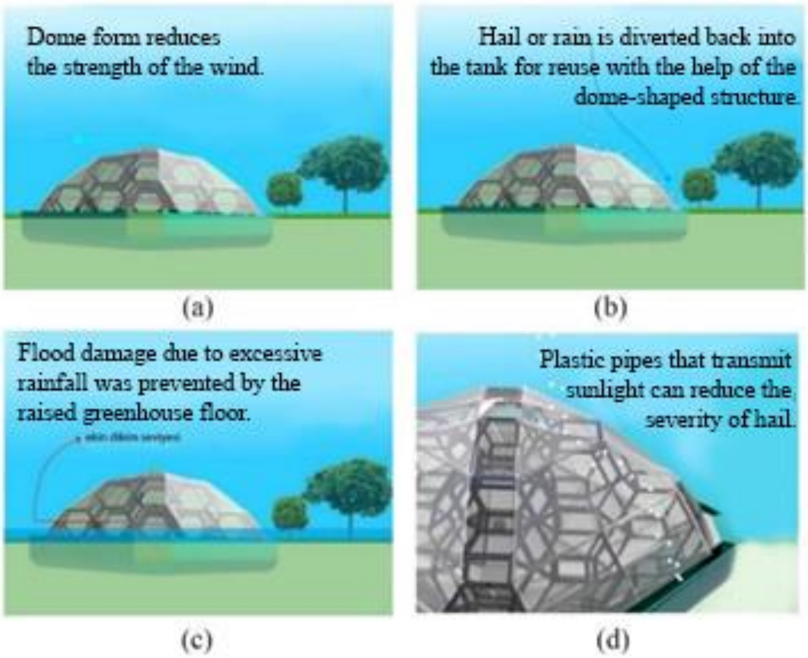


Figure 11. Visual representation of the proposed solutions

2.2. Improving Design Using Bio-TRIZ

2.2.1. Function Analysis

Functional analysis is used to examine the functioning of the system healthily and to detect errors. In the construction of the analysis, there are four types of connections between harmful and useful functions. These connections are expressed using arrows. When "→" is used, the function benefits the other function and produces good results, when "⇒" is used, the function negatively affects the other function and produces bad results, when "⇸" is used, the function negatively affects the good result in the other and function a produces bad results, when " " is used, the function positively affects the bad result in the other function and improves or stops the harmful situation.

Figure 12. Function relationships

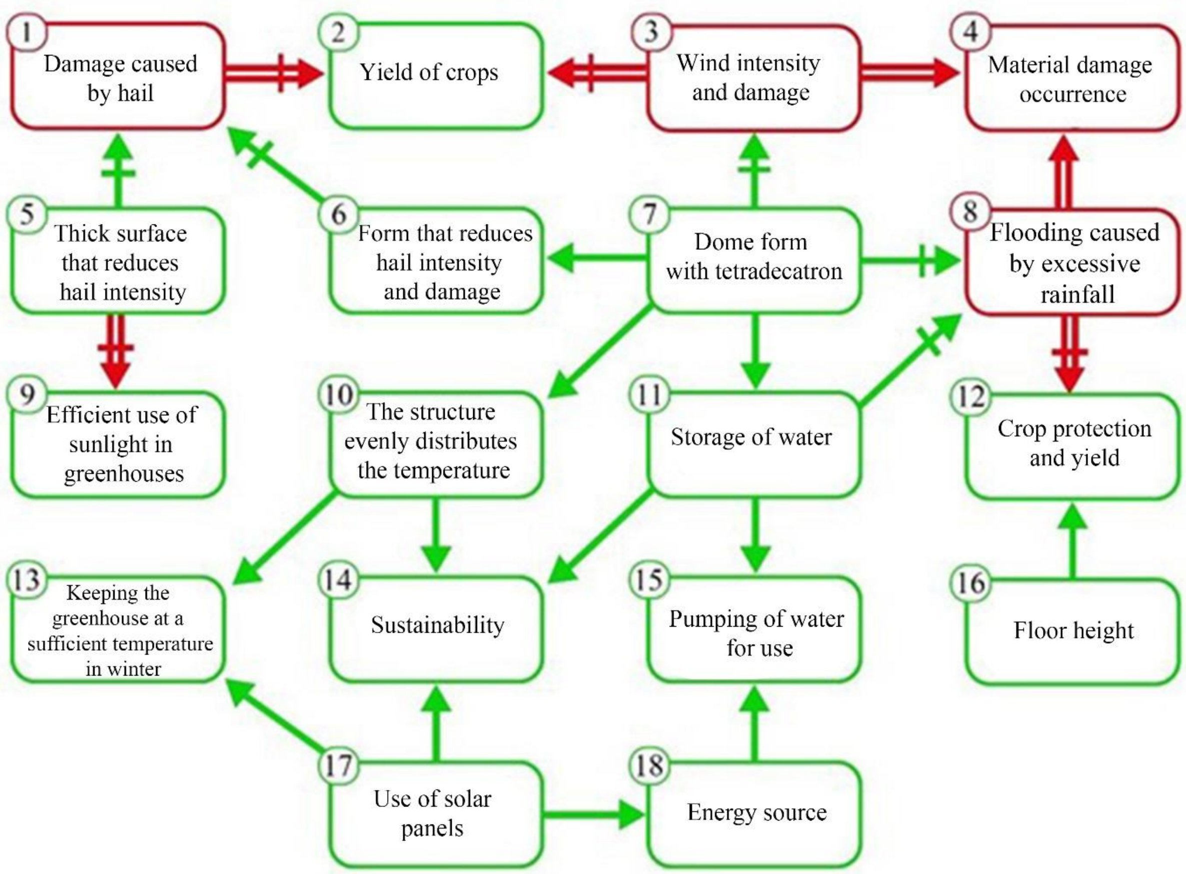


Figure 13. Function Analysis

These connections are given in the figure (Figure 12). Cause and effect sentences can be reached with relations between functions. These sentences are constructed using the words support, prevents, prevents, and causes. When the figure is analyzed, the connections between useful function/function and harmful function/function can be expressed in the following sentences. Useful functions are expressed with parentheses, and harmful functions are expressed with square brackets.

(Tetradecahedron) supports (storage of water),

Prevents (storage of water) [flooding after excessive rainfall],
Prevents [flooding after excessive rainfall] (protection and yield of crops), [Flooding caused by excessive rainfall] causes [Property damage],

Many sub-problem statements can be formed based on these sentences through the function analysis table.

1a. Find a different solution for [damage from hail] that does not prevent (yield of crops) and is prevented by (form that reduces hail intensity and damage) and (thick surface that reduces hail intensity).

1b. Find an improved solution for [damage caused by hail].

2a. Find a different solution to (yield of crops) where [wind intensity and damage] and [damage from hail] do not interfere.

2b. Find an improved solution for (crop yield).

3a. Find a different solution for [wind intensity and damage] that avoids the (Tetradecatron dome form) structure and does not cause (property damage) and does not interfere with (crop yield).

3b. Find an improved solution for [wind intensity and damage].

4a. Find a different solution where [wind intensity and damage] and [flooding caused by excessive rainfall] do not cause [material damage].

4b. Find an improved solution for [occurrence of material damage].

5a. Find a different solution for (thick surface that reduces hail intensity) that avoids [damage from hail] and at the same time does not prevent (efficient use of sunlight in the greenhouse).

5b. Find an improved way for (thick surface reducing hail intensity).

5c. Find a way to resolve the contradiction: (Thick surface that reduces hail intensity) favors the prevention of [damage from hail] but also favors (efficient use of sunlight in the greenhouse).

6a. Find a different solution for (form that reduces hail intensity and damage) supported by (dome form with tetradecahedron) that prevents the occurrence of [damage from hail].

6b. Find an improved solution for (form that reduces hail intensity and damage).

7a. Find a different solution for (dome form with tetradecahedron) that favors (water storage), (form that reduces the severity and damage of hail) and (structure that evenly distributes the temperature) and prevents [wind severity and damage] and [flooding due to excessive rainfall].

7b. Find an improved solution for (dome form with tetradecahedron).

8a. Find a different solution for [flooding caused by excessive rainfall] that does not favor [material damage], does not hinder (crop protection and yield), and does not require (dome form with tetradecahedron) and (storage of water).

8b. Find an improved solution for [flooding caused by excessive rainfall].

9a. Find a way to increase the impact or make efficient use of (efficient use of sunlight in the greenhouse).

9b. Find a way to utilize (efficient use of sunlight in the greenhouse).

10a. Find a different solution where (dome form with tetradecahedron) is not required in addition to (sustainability) for (evenly distributing the temperature of the structure) and supporting (keeping the greenhouse at a sufficient temperature in winter).

10b. Find an improved solution for (uniform distribution of temperature by the structure).

11a. Find a different solution that favors (sustainability) for (water storage) and (pumping of water for utilisation) and does not require (dome form with tetradecahedron) and avoids (excess rainfall and flooding).

11d. Find an improved solution for (water storage).

12a. Find a different solution for (crop protection and yield) that does not require (high ground) and that does not prevent (crop protection and yield) by [flooding due to excessive rainfall].

12b. Find an improved solution for (crop protection and yield).

13a. Find a different solution for (keeping the greenhouse at a sufficient temperature in winter) that does not require (even distribution of temperature by the structure) and does not require (use of solar panels).

13b. Find an improved solution for (keeping the greenhouse at an adequate temperature in winter).

14a. Find a different solution for (being sustainable) that does not require (the structure to distribute the temperature evenly), (the use of solar panels) and (the storage of water).

14b. Find an improved solution (to make it sustainable).

15a. Find a different solution where (energy source) and (storage of water) are not required for (pumping water for use).

15b. Find an improved solution for (pumping water for utilisation).

16a. Find a different solution for (crop protection and yield) that does not require (high ground).

16b. Find an improved solution for (high ground).

17a. Find a different solution for (using solar panels) that supports (keeping the greenhouse at the required temperature in winter), (being sustainable) and (energy source).

17b. Find an improved solution (using solar panels).

18a. Find a different solution for (energy source) that does not require (use of solar panels) and supports (pumping water for use).

18b. Find an improved solution for (energy source).

The greenhouse designed with a tetradecahedron form structure reduces the damage caused by wind and hail violence thanks to its dome form structure. Additionally, with this structure, rain is directed to the storage when there is rainfall at or above seasonal norms. The stored rain can be purified and used for the greenhouse in case of need, thus achieving a sustainable design. This can also reduce financial expenditure. The high ground is a precaution against flooding and has a positive effect on the formation of space for storage. Without the need to use windbreaks, it can soften and disperse the incoming strong wind and prevent the greenhouse from disintegrating. Functional analysis of the greenhouse design, which has been improved in many aspects, shows the areas that need to be improved. These areas were attempted to be solved with 40 creative TRIZ suggestions.

2.2.2. Use of the Contradictions Matrix

The contradictory situation that emerged because of the function analysis was concluded as follows: "(Thick surface that reduces hail intensity) supports the prevention of [damage caused by hail], but also supports (efficient use of sunlight in the greenhouse)." The simultaneous presence of improving and worsening factors in the product reveals a contradiction. The improving factor is that the damage caused by hail is eliminated using a thick surface in the structure and accordingly, it prevents the cost of hail damage work, loss of time and material damage caused by the time the products are unprotected. The deteriorating factor is that the thick surface used to protect from damage prevents sunlight from reaching the crops and therefore decreases productivity. The proposed creative principles for protecting the improving factor and the improvement of the deteriorating factor are shown (Table 8). If the deteriorating factor is improved, both the surface will be protected against hail intensity and damage and productivity will be ensured with sufficient sunlight reaching the crops.

Table 8. Contradiction matrix

Worsening Factor / Healing factor	39 Productivity
30 Factors damaging the object	22, 35, 13, 24

IFR (Ideal Final Result) / Intended result: The greenhouse is protected from damage caused by heavy hai; however, it retains the benefit of sunlight. Physical Contradiction: To protect against hail, the greenhouse must be covered with a thick surface. Sunlight must pass through the thin and transparent surface and reach the crops.

Among the proposals, the ones that resolve the contradiction in the design and provide a solution (35) parameter change, (24) Intermediary (13) "The other way round".

Table 9. Creative principles

22- Blessing in disguise	a) Use harmful factors (particularly, harmful effects of the environment or surroundings) to achieve a positive effect b) Eliminate the primary harmful action by adding it to another harmful action to resolve the problem c) Amplify a harmful factor to such a degree that it is no longer harmful
35- Parameter changes	a) Change the physical state of the object (solid, liquid, gas) b) Change the density or consistency of the object c) Change the elasticity level of the object d) Change the temperature of the object
13- "The other way round"	a) Invert the action(s) used to solve the problem (e.g. instead of cooling an object, heat it) b) Make movable parts (or the external environment) fixed, and fixed parts movable) c) Turn the object (or process) 'upside down
24- Intermediary	a) Use an intermediary carrier article or intermediary process b) Merge one object temporarily with another (which can be easily removed)

2.2.3. Sketch Phase

The contradiction was tried to be eliminated using creative principles, and the steps were explained with sketch drawings. After the steps were numbered on the visual, explanations were made. The solution proposal arrived at because of the sketch was modeled and a sample model applied on the greenhouse surface was added.

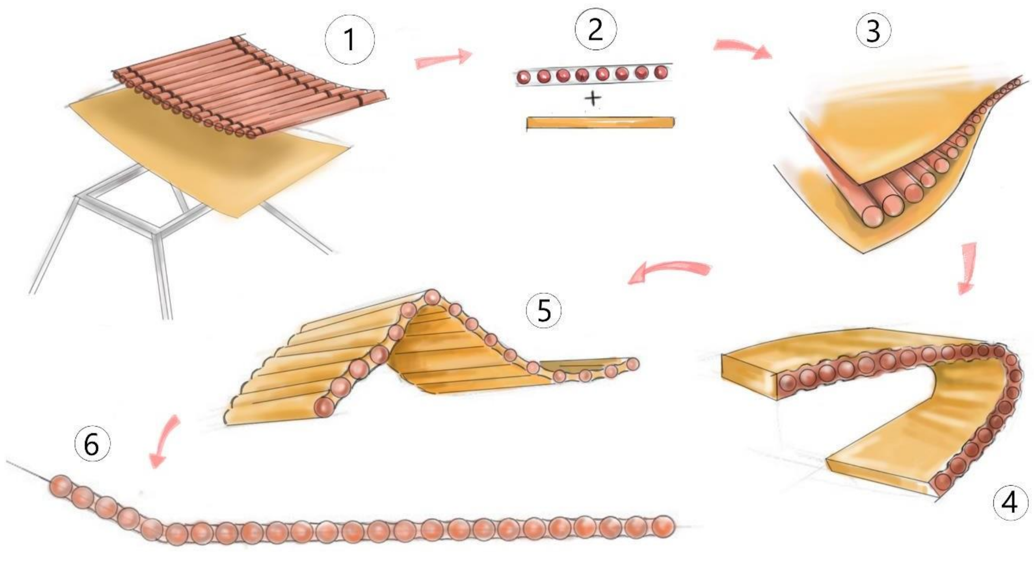
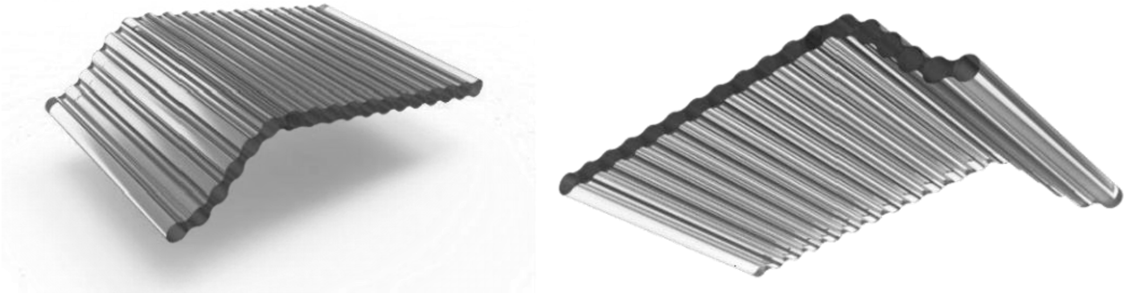


Figure 14. Solution proposal sketch

1-In the current proposal, plastic pipes are used to reduce the severity of hail and gaps are left at a certain distance between these pipes to allow them to stretch. To prevent the rain from flowing into the greenhouse through these gaps, a tarpaulin was considered for the subfloor.

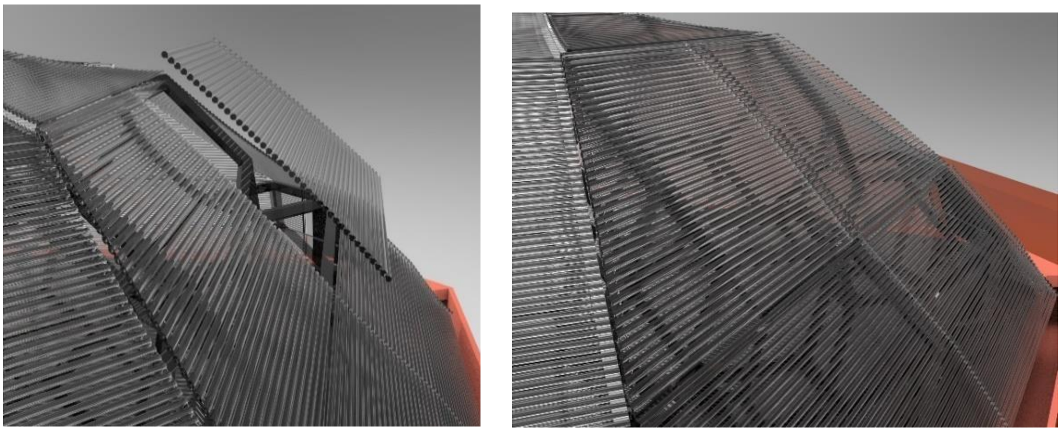
2-The first step toward the solution was taken by combining these proposed solutions in line with the creative solution with TRIZ.

3-To increase durability, the plastic transparent pipes are supported with tarpaulin at the top and bottom. 4, 5, 6-Thanks to the space determined between the pipes, the pipes can move at a certain angle toward alignment.



(a) (b)

Figure 15. Top (a) and bottom (b) views of the design



(a) (b)

Figure 16. Representation of the model on the greenhouse

2.2.4. Adaptation of Creative Principle to the Problem

By using the principles of (24) Intermediary and (13) "The other way round", two different proposals are merged into one. This provides financial advantage. The new proposal is easier to install and can be manufactured. The merged proposals are made more flexible and robust by using the (35) parameter change.

2.2.5. Ideality

Table 10. Nature's ideality model strategies and design principles

	Overall Strategy	Design Principle	Greenhouse Design
Increase benefit	More function	(1) Multifunctional design: by combining system parts make one -piece multifunctional.	Parts used for two different functions in one piece, and more than one function is assigned to a single piece.
Increase benefit	Stronger effect	(2) Intensify the interaction with the environment to achieve a stronger effect with a function -Repeating elements -Increased surface area	Owing to the repeated sequence, integrity is achieved and the piece is strengthened.
Reduce harm	Opportunistic strategy	(5) Utilization of physical, chemical or geometrical Effects and tendencies as energy sources.	Using solar panels for the energy needs of the greenhouse utilizing sunlight.

3. Discussions and Conclusion

In this study, the problems experienced in greenhouse cultivation were identified and ideas were developed within the framework of conceptual design to prevent damage because of natural disasters by using the biological function of the watercress plant with a design lens. Greenhouse material should be durable, easy to install, and manufacture. In this new design, the stacked installation of the Tetradecahedron unit is thought to fulfill these requirements. Bio-TRIZ was used to make further improvements in the proposed structure. Functional analysis was performed with TRIZ, and a solution was proposed with the help of a matrix of contradictions. The layers that prevent the damage to the greenhouse and prevent the passage of water into the greenhouse are combined and a new proposal is presented. The product, which is produced by heating, gluing and vacuuming the plastic pipes together with the tarpaulins covering the upper and lower surfaces of the plastic pipes, connects the pipes to each other and gives flexibility. The presented proposal provides many advantages in terms of cost and production. It is also very easy to install. In the greenhouse, which creates its own cycle for sustainability, it is aimed to direct rainwater and hail to the storage. With the dome form, it is predicted that the increase in the roof slope will allow orientation.

Authors' Contributions

ZE and HB wrote the manuscript. The authors have read and approved the final version of the manuscript.

Competing Interests

The authors declare that they have no competing interests.

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