The Innovative Design of Seedling Transplanting Combination Mechanism with TRIZ

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Abstract. Aiming at the problem of poor gathering effect of seedling transplanting combination mechanism that is designed independently, the intensive study has been done by using the main tools of TRIZ: the functional analysis, the physical contradiction and technical contradiction, the Su-Field model. And four feasible solutions have been found during the intensive study. Comparing the advantages and disadvantages of solutions and Taking the actual engineering situation into consideration, the final solution is obtained by collecting the advantages of the former solutions. The final solution can solve the poor gathering problem very well.

1. Introduction
The modern industry of flowers and plants, which started to develop since 1980s in china, is developing rapidly during the 30 years [1]. In 2012, the total area of flowers and plants production in China was 1120.3 thousand hectares, the total sales amount was 12.0772 billion yuan and the total export value was 533million USD. The sales and export growth rates are both more than 10% at a stable growth trend [2]. Currently, the most domestic planting of potted flower in greenhouse are in factory form, which requires multiple transplanting operations in the planting process. However, the task of transplanting and combinating seedling is usually done by artificial, which leads to the low efficiency. It’s very important to invent a highly efficient and reliable transplanting combination device.

In order to study the scientific principles of human inventions and solve the technical problems, the research staff, led by S. Alt shuller G, summed up the basic principles of TRIZ (TRIZ stands for the theory of inventive problem solving) after analyzing and studying the world's nearly 250000 high level inventions patents since 1946 [3]. The TRIZ process of solving problems: at first, transform the problem of professional field to the standard problem of TRIZ, then get the general solution by the standard problem, finally find the special solution by the general solution (as shown in Figure 1). The theory of TRIZ can’t directly provide the solution to the special problem, but it can open up our minds to find the solutions [4].
2. The Background of Project

2.1. The transplanting

The transplanting seedling is planted in the tray with specification $15 \times 7$ in this project (as shown in Figure 2). The seedling is transplanted to the 110mm pots in a method of one group combined by three strains when it’s cultivated for a period of time (as shown in Figure 3).

2.2. The process of transplanting combination

There are four steps to transplant seedling from trays to pots (as shown in Figure 4).

- The grippers grab three strains of seedling.
- The combination of three strains of seedling by using the combination mechanism.
- The three strains of seedling are transplanted in the 110mm pots.
- The compacting mechanism compacts the soil media in the 110mm pots.

3. The Analysis Of TRIZ
The classic TRIZ, mainly combined by three parts: the functional analysis, the physical and technical contradictions, the Su-Field model, is applied to solve the failure problems of existing mechanism. The failure problems of seedling transplanting combination mechanism in this project belong to the field, where the tools of TRIZ are available to help.

3.1. The functional analysis

The functional analysis is combined by three parts: the analysis of component, the analysis of interaction and the function model. The component refers to a part of an engineering system or a super system. And the engineering system refers to the system that can perform a certain function, the super system refers to the system that is consisted by the engineering system and other systems [5]. The engineer system in this project is the system of seedling transplanting combination device. The engineer system is consisted by the components: the combination mechanism, the transplanting gripper, the compacting mechanism, the stem of seedling, the matrix of seedling. And the components of the super system include the pots, the soil cavity of pots (as shown in Table1). The system of seedling transplanting combination mechanism is as shown in figure 5.

| The system          | Components                          |
|---------------------|-------------------------------------|
| The engineering system | the combination mechanism            |
|                     | the transplanting gripper            |
|                     | the compacting mechanism             |
|                     | the stem of seedling                 |
|                     | the matrix of seedling               |
| The super system    | the pots                             |
|                     | the soil cavity of pots              |

The interaction analysis (as shown in TABLE II) refers to the relationship between components. If it is a "+", it means the components have a kind of relationship. If it is a "-", it means there is no relationship between presentation components.

In Table2, “a” stands for the combination device, “b” stands for the transplanting gripper, “c” stands for the stem of seedling, “d” stands for the matrix of seedling, “e” stands for the soil cavity of pots, “f” stands for the compacting device, “g” stands for the pots.
Table 2. The analysis of interaction

|   | a   | b   | c   | d   | e   | f   | g   |
|---|-----|-----|-----|-----|-----|-----|-----|
| a | +   | -   | -   | -   | -   | -   | -   |
| b | +   | +   | +   | -   | -   | -   | -   |
| c | -   | +   | -   | -   | -   | -   | -   |
| d | -   | +   | -   | +   | +   | -   | -   |
| e | -   | -   | -   | +   | +   | +   | -   |
| f | -   | -   | -   | +   | +   | -   | -   |
| g | -   | -   | -   | -   | +   | -   | -   |

The function model (as shown in figure 6) describes the function of the components, as well as performance and costs. In the function model, the function is divided into two categories: useful and harmful functions (" ∨ ∨ ∨ "). Useful function is divided into normal function (" → "), insufficient function (" → "), excessive function (" → ").

According to the functional model, the problem of TRIZ is proposed: the engineering system wants the space of three strains of seedling small to improve the effect of ornamental and the area of the matrix of three strains of seedling small to avoid scattering the soil cavity of pots.

The problem of TRIZ should be highlighted to form a sharp contradiction:

- If the space of three strains of seedling is smaller, then the effect of gather and ornamental will be better, but the area of the matrix of three strains of seedling will get bigger to scatter the soil cavity of pots.
- If the space of three strains of seedling is bigger, then the area of the matrix of three strains of seedling won’t get bigger and the soil cavity of pots won’t scattered, but the effect of gather and ornamental will get worse.

Figure 6. The function model
3.2. The physical and technical contradiction

The physical conflict means the two sides of a single physical parameter of an object are reasonable and required in the problem. The bigger and smaller space of three strains of seedling are wanted in the engineering system. The bigger space of three strains of seedling and the smaller area of the matrix of three strains of seedling are required to facilitate the seedling fall into pots. The smaller space of three strains of seedling are required to improve the ornamental after the seedling falling into the pots. The separation principles are available to give the general solutions for the physical contradiction. The separation principles include the spatial separation principle, the time separation principle, the separation principle based on the relationship, the separation principle based on system. The spatial separation principle means the contradiction exists in different places of an engineering system. The time separation principle means the contradiction exists in different time. The separation principle based on relationship means the components of contradiction come from the super system. The separation principle based on system means the contradiction exist in the engineering system and the super system [6].

According to the engineering system, the first solution (as shown in figure 7) is proposed by using the time separation principle: the combination mechanism only complete the task of combination and transplanting, the compacting mechanism is designed to complete the task of gathering the stems of three strains of seedling and compacting the matrix [7].

![Gathering and Compacting](image)

**Figure 7.** The first solution

The technical contradiction means that a parameter of the system is improved, which will lead to the deterioration of another parameter. The technical contradiction in this engineering system is that the improvement of ornamental (the smaller space of three strains of seedling) lead to the bigger area of the matrix of three strains of seedling, which will scatter the soil cavity of pots. The improving parameter is the area of the moving object (the space of three strains of seedling), the worsening parameter is the shape (the area of the matrix of three strains of seedling). Querying the matrix of technical contradiction (as shown in Table 3), the four principles are available for finding the solutions. The four principles are No.4 the asymmetry-adding principle, No.5 the combination principle, No.29 the principle of pneumatic and hydraulic, No.34 the abandon and regenerate principle. No.4 the asymmetry-adding principle means the symmetrical objects can be turned into asymmetrical objects or the degree of asymmetry can be increased. No.5 the combination principle means the same or similar objects can be combined. No.29 the principle of pneumatic and hydraulic means the fixed part of the object can be replaced by gas and fluid. No.34 the abandon and regenerate principle means the parts, who complete its function, can be abandoned by using the methods of dissolution and evaporation or can be changed into the useful one in the working process.
Table 3. The matrix of technical contradiction

| Worsening feature→ | Improving feature↓ |
|-------------------|-------------------|
| No.12 the shape   | No.5 the area of the moving object |
| No.5 No.34        | No.29 No.4        |

Figure 8. The second solution

The second solution (shown in figure 8) is obtained by using the No.4 principle. The shape of soil cavity, which is the symmetrical circular, is changed into asymmetric shape. It won’t expand the area of the soil matrix of the three strains of seedling in the process of transplanting, and it will facilitate the seedling fall into the pots.

The third solution (as shown in figure 9) is obtained by using the No.34 principle. The matrix of seedling is the growing environment of seedling before the transplanting operation. The soil matrix of pots can replace the mission of the matrix of seedling after the transplanting operation. So the matrix of seedling can be broke up to shrink the space of the three strains of seedling and improve the ornamental.

Figure 9. The third solution

3.3. The Su-Field model

The Su-Field model, which is short for (the Substance–Field model), means the system is consisted of substances and fields. The substance means the parts owning static quality in the engineering system, for example: transplanting gripper, combination mechanism, etc. The field refers the general concept of energy, for example: the mechanical field, the electric field, the magnetic field, the gravity field, the biological field, etc. An effective Su-Field model must have two substances beneficial function and a field at least. The field builds the interaction between substances [8]. The Su-Field model of engineering system is shown in figure 10. The seedling is transplanted into the pots by the grippers under the mechanical force F1. The soil matrix of pots (S1) is too loose to fix the transplanting seedling (S3). The fourth solution (as shown in Figure 11) is obtained by using the Su-Field model. In order to improve the strength of soil matrix, The substance water (S3) is added in the process of transplanting.
4. Conclusions
The four solutions are obtained by using the TRIZ tools to solve the failure problems of the seedling transplanting combination mechanism. Comparing the advantages and disadvantages of four solutions and according to the key problem “the poor gathering effect of seedling transplanting combination mechanism”, the final solution is decided. The matrix of seedling is removed in gripping process (according to the analysis of the technical contradiction), which will facilitate the combination of seedling (according to the analysis of the physical contradiction). The substance water is added to improve the strength of the matrix of the pots after the seedling transplanting operation.

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