University of Thi-Qar Journal of agricultural research

Thi-Qar Journal of agricultural research

ISSN Onlin:2708-9347, ISSN Print: 2708-9339 Volume 14, Issue 2 (2025) PP 407-419

https://jam.utq.edu.iq/index.php/main *https://doi.org/10.54174/utjagr.v13i1.323*

Design and implementation of a self-propelled single-line vegetable planter and evaluation of its field performance

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Abstract

The primary objective of this study was to design, manufacture, and evaluate a semi-automatic vegetable planting machine. This machine consists of a main frame, seedling transport trays, a speed-controlled motor, a planting mechanism, a seedling burying mechanism, and a seedling burying mechanism. The planting mechanism plants the seedlings onto the soil created in front of the planting mechanism, while the burying mechanism applies pressure to the sides of the plant to stabilize the soil .It is buried well, and when the arms attached to it rotate, the planting mechanism receives the seedlings and plants them in the soil at specific distances between each seedling.

A field test was conducted. The percentage of successful seedling planting and the productivity of the machine were verified. The tests were conducted using a factorial experiment based on a randomized complete block design with three replications .The processors consisted of three forward speed levels (0.85, 1.3, 1.75) km/h and three planting depths (40, 80, 120) mm. The results showed that soil type, forward speed, and planting depth affected the successful planting rate and machine productivity. The highest planting success rate was achieved at a speed of 0.85 km/h and a planting depth of 100 mm, reaching 95%. The highest machine efficiency was achieved at a forward speed of 1.75 km/h and a planting depth of 40 mm, reaching 0.92 hectares/hour.

Keywords: vegetable planter design, machine testing, successful planting rate, actual productivity

I. Introduction

The availability of agricultural machinery in the agricultural production process is considered an important factor in the development of agriculture in any country. The method of planting seedlings is an important part of the mechanized agricultural production process in modern vegetable cultivation (7). In many studies, planting machines were classified, with bucket planters being the most widely used and widespread in planting seedlings, and bucket planters being the most common Either they can be articulated and rotate vertically, or buckets that rotate horizontally (12). Studies have shown that the community has a year-round demand for vegetables, so it has become necessary to use machines Agriculture is very widely used in agricultural production processes, as the type of agricultural machinery used in agriculture greatly affects the overall productivity (5).

Research has shown that combining automated vision technology with automated seedling cultivation can produce seedlings with the same level of health and reduce the time spent and labor requirements. Therefore, it is possible to consider the use of sensors to monitor the health and vitality of seedlings (17) Studies have concluded that in the case of planting using mechanical machines, the distance between rows and the number of plants in the rows are greater than in the case of manual planting. Also, in the case of traditional planting, we

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cannot control the depth of planting, as it is determined by the skill of the workers. It was found that to cultivate one hectare with a machine, we need 48 workers, while with the traditional method, we need 800-960 workers to cultivate the same area (11).

The method of planting seedlings is considered an important part of the mechanized agricultural production process in modern vegetable cultivation (7). Previous studies have shown that the time and labor requirements for advanced agriculture are equal to half the requirements of the manual method, and the costs of planting seedlings using advanced machinery have decreased by 33.01% compared to the manual method. This machine can be used to plant various vegetable crops. This machine has facilitated the planting process and completed the process more quickly and with less human power. It is considered a suitable machine for small farmers and seedlings that need to be covered with a polyethylene film (2). It was found that increasing the speed leads to an increase in the percentage of planting failure and planting depth with a decrease in the actual productivity of the planting machine (3). Studies have shown that in the case of mechanical farming, we can control the depth of farming, as it is determined by the skill of the workers. It has also been found that to farm one hectare with a machine, we need 48 workers, while with the traditional method, we need 800-960 workers to farm the same area (11). Studies have shown that the use of mechanized methods for planting eggplant, tomatoes and peppers saved 28.03%, 24.8% and 42.42% compared to the manual method (1). In a study, it was found that when the number of seedlings was increased from 40 to 50 to 60 seedlings per line per minute, the overall planting success rate reached 98.6%, 97.2% and 96.5% respectively (19).

The researcher (16) indicated that the mechanical process of planting onion seedlings contributes to reducing the labor force and helps to increase the productivity of the onion crop. (14)) concluded that the tractor-pulled rice planting machines increase the productivity of the labor force by 32.22 times and achieve a saving of 66.69% of the average cost of planting compared to the traditional method. The researcher concluded (13)) that modern vegetable cultivation machines are more suitable for planting vegetable seedlings compared to the traditional method. Studies have shown that the use of agricultural machines increases the number of annual working hours with lower labor costs compared to the manual method, as was found in crop (10). The researcher (8) concluded that seedling planting machines greatly reduce the labor force and thus increase the economic return in the agricultural process.

II. Materials and Methods

General Design of the Semi-Autonomous Planting Machine

This study illustrates the components of the semi-autonomous, self-propelled planting machine, as shown in Figure (1). The machine mainly consists of the machine frame, the metal rod, the metal plate, the planting mechanism, the feeding mechanism, the motor, the two burying wheels, and the two burying wheels.

1- **Body:** The body is made of hollow iron to maintain light weight and at the same time the strength of the body. The body is also equipped with a chair for the worker and a place to put the seedling trays.
2- **Horizontal bar:** A horizontal bar made of solid iron, which resists bending when subjected to loads, is attached to the frame. A set of gears of varying diameters and different numbers of teeth are attached to this bar to maintain the speed of each part to which motion is to be transmitted. Motion is transmitted to the bar via chains connected to a gear on the ground wheel.

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Figure (1) Components of the planting machine

3- The main metal plate: It is considered one of the most important parts in the machine because it receives the circular motion from the ground wheel and converts it into a reciprocating and vertical motion in order to deliver it to the planting hopper. The excess part was cut at a 45-degree angle to reduce the total weight of the machine, as three holes were made in it, the first and second of which are horizontal, and the first and second are perpendicular to the two holes. First and second, to avoid friction between the bars when rotating, four holes were made around each hole to fix the vertical base bearing seats to the level of the bearing seat by means of fixing screws. A bar was placed inside each bearing seat and a gear was placed on it. The gear was installed to receive the movement through the transmission chains from the gears located on the bar as in Figure (2).

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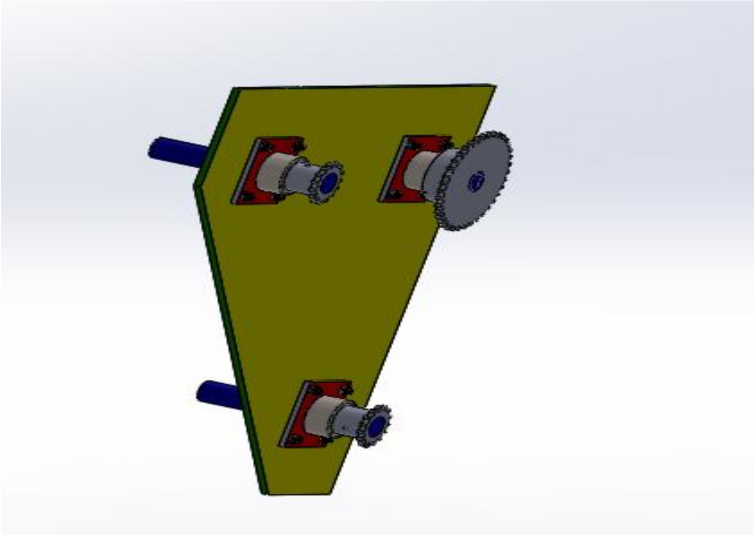

Figure (2) Metal plate

4- **The insertion mechanism:** The insertion mechanism is fixed on the rod at the bottom and top, located inside the gears in the metal plate, where an arm is placed in each metal rod located in the main metal plate and is fixed in its center of gravity to rotate with the rods that rotate inside the bearing seats, and an eccentric elbow is fixed on each arm, the benefit of which is to convert the circular motion into a vertical motion in one of the arms and the other arm. To convert it into an elliptical shape by attaching the bearing seats to a metal plate at the end of which is fixed the planting hopper holder, the planting jaws and the conical funnel to receive the seedlings.

5- **Feeding mechanism:** The feeding mechanism is designed with a gearbox that converts horizontal circular motion into vertical motion. A metal rod is attached to it, penetrating one tray and securing it to the other. Two trays were created for the feeding mechanism, one large and the other smaller in diameter. A set of cups were installed on each tray, into which the seedlings were placed by workers. A hole was drilled in the larger tray, allowing the seedlings to fall through it upon reaching the planting mechanism. The machine is equipped with a motor and gearbox to provide the required movement and speed to the ground tires, which in turn transmit it to the horizontal bar.

6- **2-1-2 How the Machine Works**

When the engine is running and the movement is transmitted to the gearbox, through the differential located under the machine, the movement reaches the tires. When they rotate, the gear fixed to the wheel frame rotates with them, and through the chains, the movement is transmitted to the horizontal bar which In turn, the movement is transferred to the feeding mechanism and the mechanism located on the metal plate. When the movement reaches the feeding mechanism, the tray with the cups rotates through its connection to the column, which takes its movement from a box that converts the horizontal movement into vertical movement, which transfers the seedlings that the worker has placed in the cups.

When the seedling reaches the opening in the tray, it will fall due to gravity at the top connected to the planting hopper On the other hand, and at the same time, the horizontal rod transmits the movement to the gears in the metal plate, which causes it to rotate, and thus rotates the arms of the first and second attachments together, as the arm at the bottom makes an elliptical movement for the planting mechanism,

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which moves the planting hopper away from the internal structure. When it moves away, a wire pulls it, opening the jaws of the hopper, and this is done when the planting is done. The pointed end of the hopper is in the soil and when the mechanism moves away due to the elliptical movement, the drag on the hopper jaws decreases between the hopper jaws, which pulls the two ends together and closes them together. During this same cycle, the other crank arm raises the hopper up and down at the appropriate time for the seedling to fall from the feeding tray for the purpose of receiving the seedling. When it descends, the hopper jaws open in the soil, and when the machine moves, there are two wheels that work at an angle to the ground in order to compress the soil on both sides of the seedling in order to stabilize it, as in Figure (6).

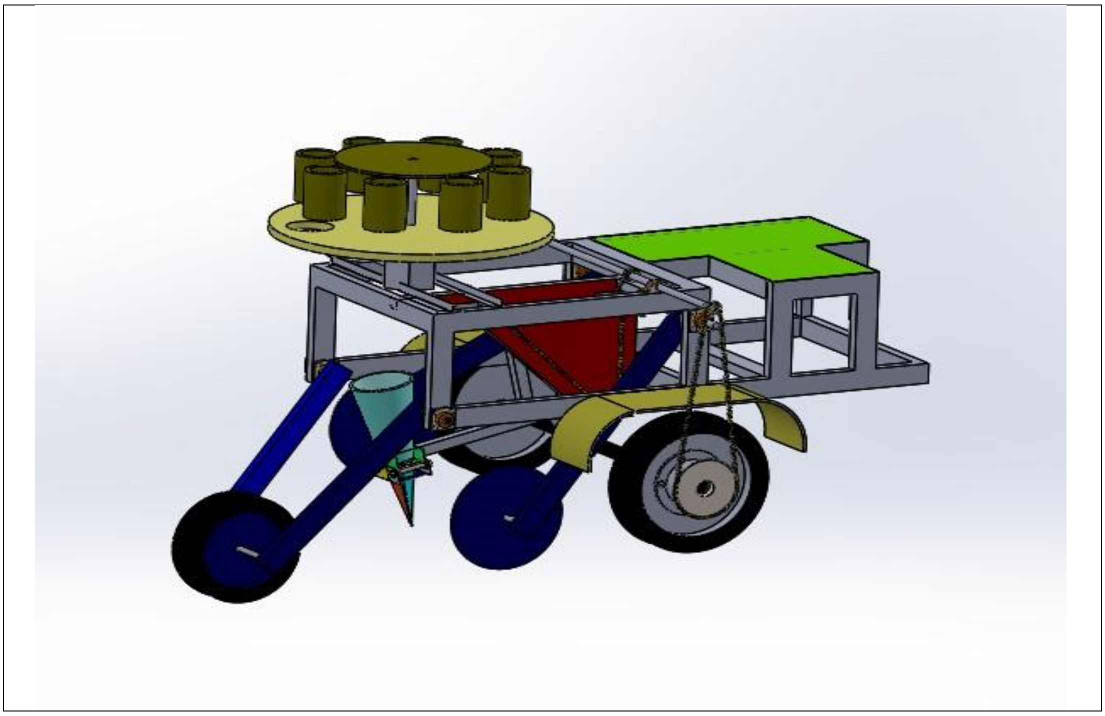

Figure (3) shows the machine's operation

3- Results and Discussion

3-1 Successful Transplanting Rate

Figure (3-1) illustrates the effect of the interaction between planting depth and machine forward speed on the successful planting rate. The results showed that a depth of 40 mm and a speed of 1.75 km/h gave the lowest planting success rate of 65%, while a depth of 100 mm and a forward speed of 0.85 km/h gave the highest successful planting rate of 95%. The reason for the increased planting rate at a depth of 100 The forward speed of 0.85 km/h is due to allowing enough time for the planting parts to fully perform their tasks and then the planting hopper to pierce the soil and place the seedling at its appropriate depth.

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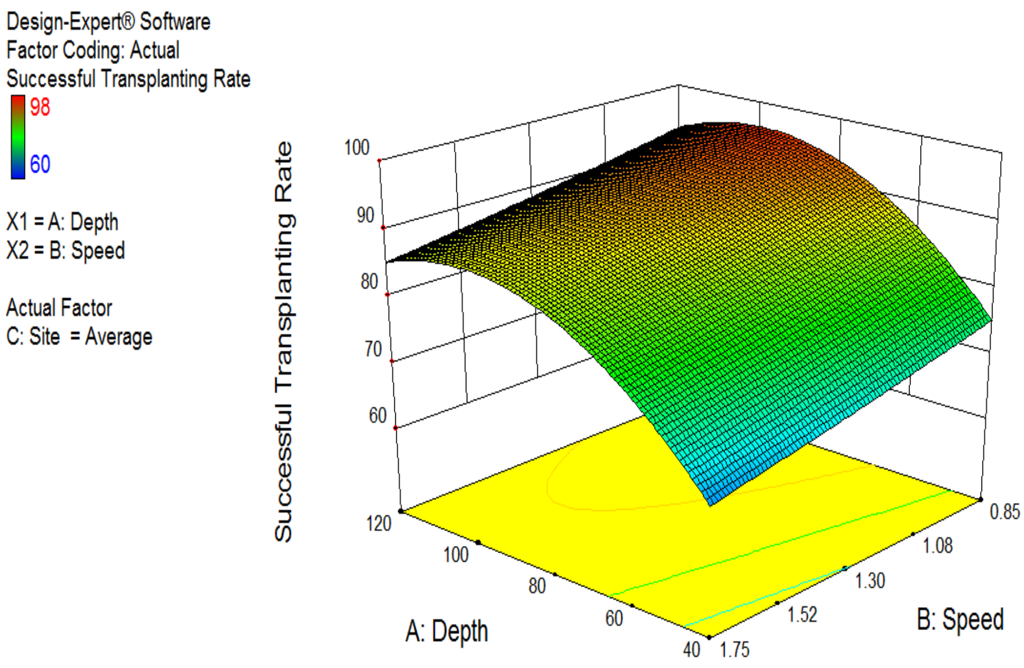

Figure (3-1) The effect of the interaction between planting depth and forward speed on the percentage of successful planting.

Figure (3-2) shows the effect of the interaction between planting depth and soil type (soil texture) on the percentage of successful planting. When the planting depth was 40 mm and the soil type was silty clay, the lowest planting percentage was recorded for silty clay soils at 73%, and the percentage increased with increasing depth to a depth of (95-100) mm, where the percentage of successful planting reached 95%. As for sandy soils, the lowest planting percentage was at a depth of 40 mm, reaching 67%. The percentage also increased with increasing planting depth to a depth of 95-100 mm, where the highest percentage of successful planting reached 88%. The reason for the difference between the planting percentages in the two soils is due to the difference in the physical properties of the soil. Also, the increase in both soils increases the stability of the seedling in the hole prepared for it by the planting hopper.

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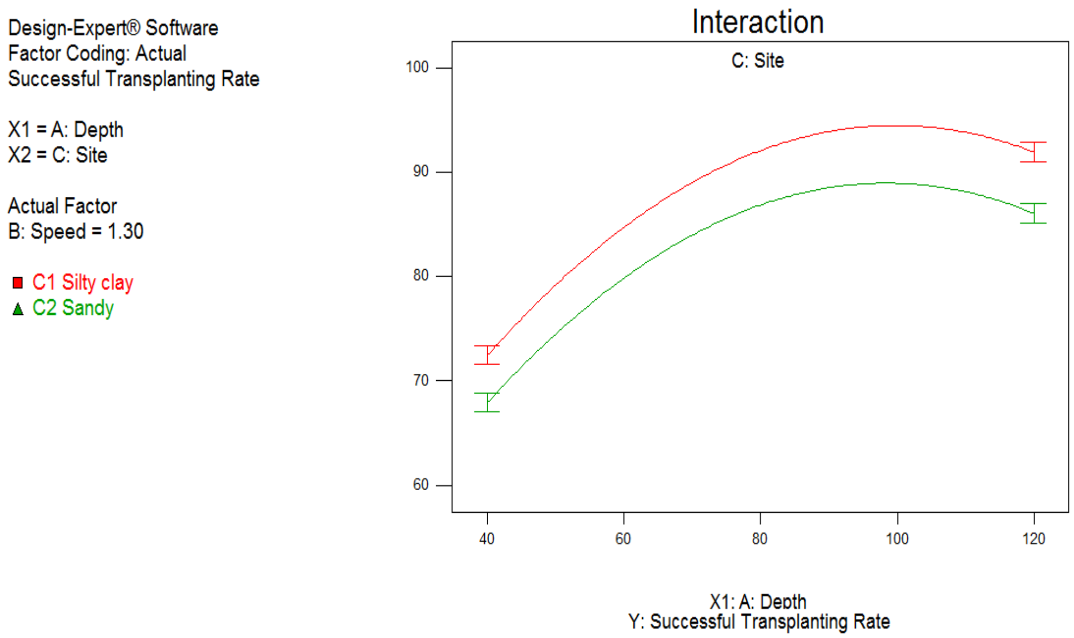

Figure (3-2) The effect of the interaction between planting depth and soil type on the percentage of successful planting.

Figure (3-3) shows the importance of each factor in the study on the successful planting rate. The results showed that the factor that had the greatest impact on the successful planting rate was the planting depth up to 100 mm, and its impact on the successful planting rate was estimated at 22.22%. After that, its impact was negative, followed by forward speed, which had an opposite impact with an impact rate of 11.76%.

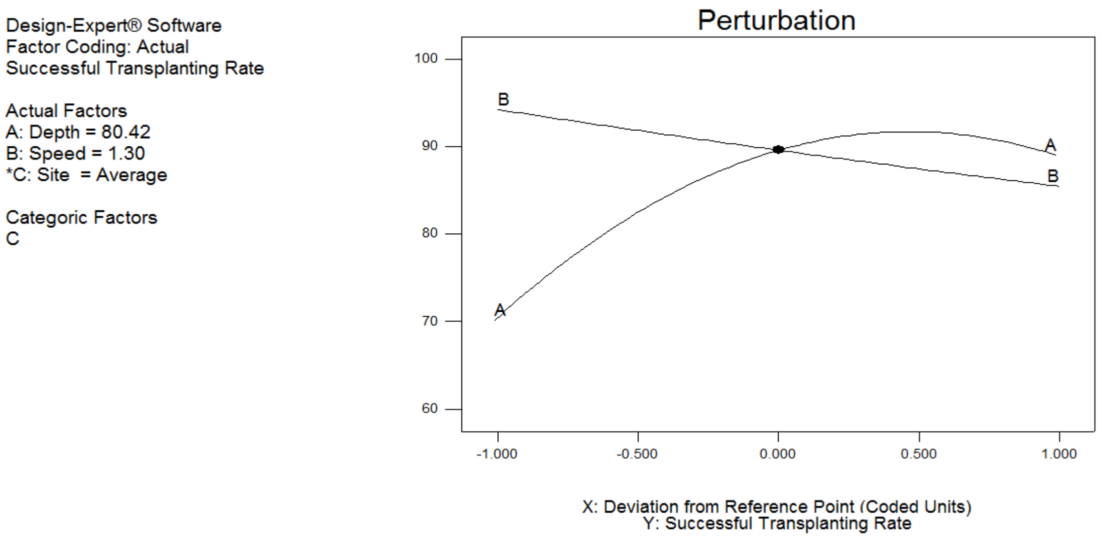

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Figure (3-3) The extent to which successful planting is affected by changing any of the studied factors.

3-1-1 The relationship between the percentage of successful planting calculated in the field and the predicted one

Figure (3-4) illustrates the mathematical relationship between the planting success rates in the field and the expected rate. The planting success rate values were found by identifying all the main factors in the experiment, which consist of (soil type, planting depth, forward speed of the machine and the interaction between them). This mathematical relationship is expressed in the form of an equation with the three studied factors, as in equation No. (3-1), where the best predictive performance was when the coefficient of determination $R^2 = 0.9779$.

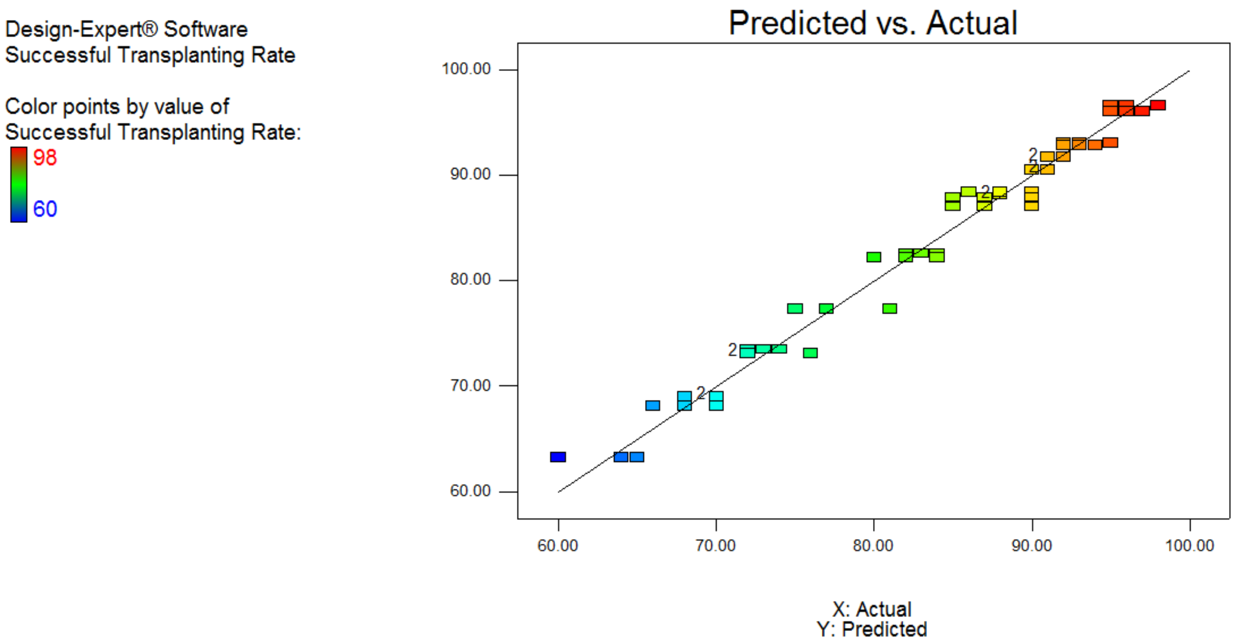

Figure (3-4) The relationship between the predicted successful planting rate and the field-calculated successful planting rate.

Final Equation in Terms of Actual Factors:

1) Site : Silty clay

Successful Transplanting Rate = + 49.75291+1.20395 * Depth - 14.56591 * Speed + 0.02209*Depth * speed - 6.18056E – 003*Depth^2+1.31473*Speed^2

2) Site : Sandy

Successful Transplanting Rate = + 46.84693 + 1.18729 * Depth - 15.31265*Speed + 0.022099 *Depth * Speed - .18056E – 003* Depth^2 +1.31473 * Speed^2

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1-2-3Machine productivity

Figure (3-5) illustrates the effect of the machine's forward speed, planting depth, and the interaction between them on the actual productivity of the planting machine. It was found that the maximum actual productivity rate was when the forward speed was 1.75 km/h and the planting depth was 40 mm, reaching 0.92 hectares/hour. On the other hand, the lowest actual productivity rate achieved was when the forward speed was 0.85 km/h and the planting depth was 40 mm, reaching 0.40 hectares/hour. This is consistent with the findings of (15).

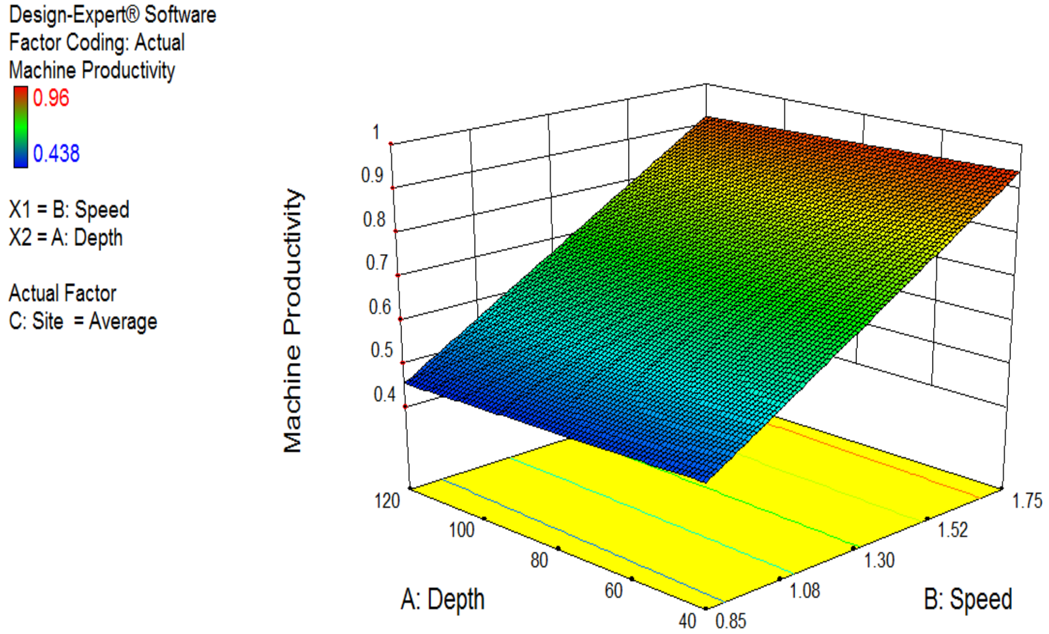

Figure (3-5) The effect of the interaction between planting depth and forward speed on machine productivity.

Figure (3-6) illustrates the importance of soil type, planting depth, and their interaction on the actual productivity of the machine. The results showed that the lowest productivity value was in sandy soil at a depth of 120 mm, at 0.68 hectares per hour, while the highest productivity was in clay soil at a depth of 40 mm, at 0.715 hectares per hour.

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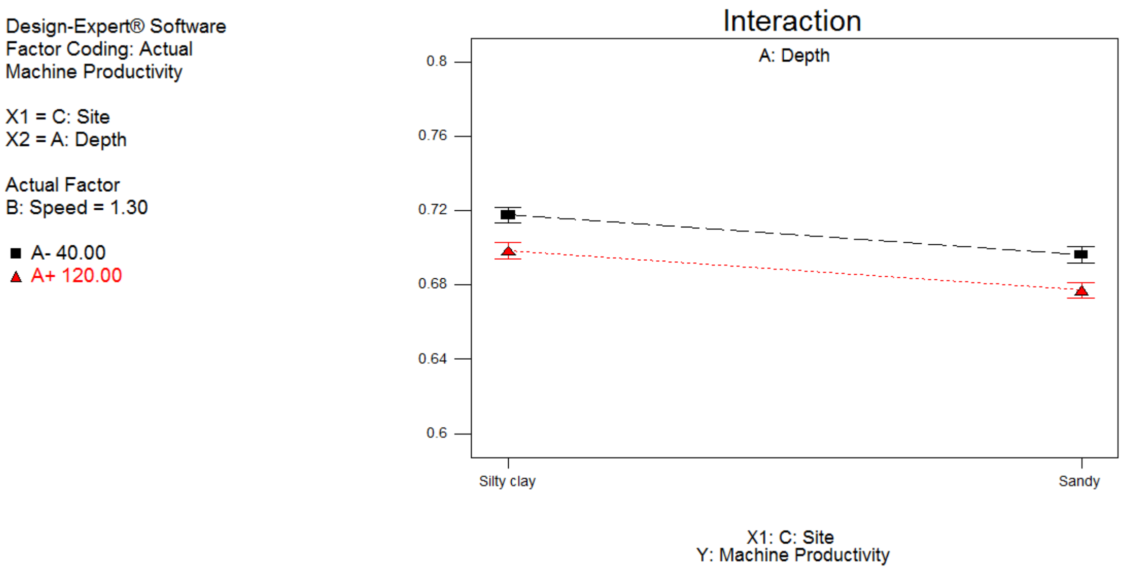

Figure (6-3) Effect of the interaction between soil type and planting depth on machine productivity

Figure (7-3) illustrates the importance of soil type, forward speed, and the interaction between them on field productivity. The lowest productivity rate was recorded in sandy soil at a speed of 0.85 km/h, with a rate of 0.48 hectares/hour, while the highest productivity was recorded in clay soil at a speed of 1.75 km/h, with a rate of 0.92 hectares/hour.

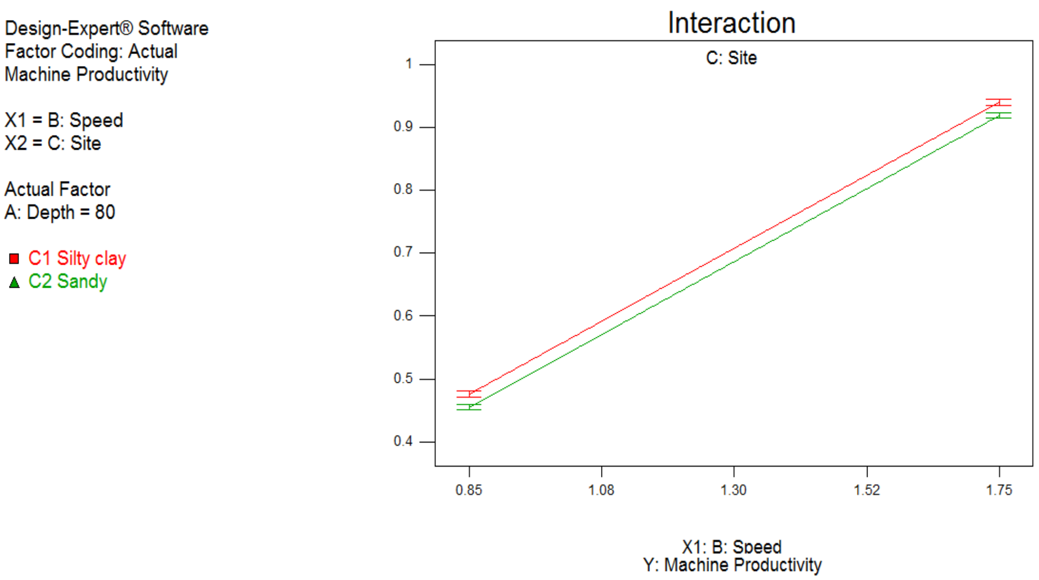

Figure (7-3) Effect of the interaction between soil type and machine forward speed on actual productivity

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Figure (3-8) illustrates the importance of all study factors on actual productivity. The analysis results revealed that the most influential factor on actual productivity was planting depth, with an influence of 2.24%, followed by forward speed, with a influence of 2.13%.

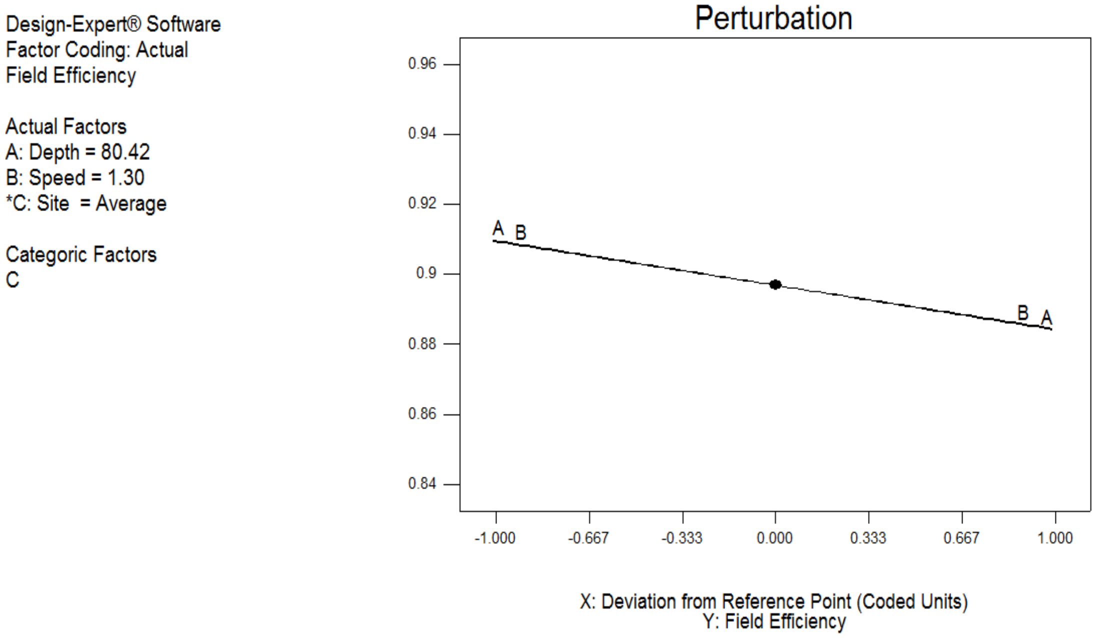

Figure (3-8) shows the extent to which actual productivity is affected by changes in any of the studied factors.

1-2-3The relationship between actual productivity calculated in the field and predicted productivity

Figure (3-9) reveals the relationship between field productivity calculated in the field and predicted productivity values. It was found that productivity values after determining all the study factors, consisting of soil type, machine forward speed, and planting depth, along with their interactions, were lower. The relationship between these factors can be represented through an equation for all of these factors, as in equation No. (3-2), and it had the best predictive performance when the coefficient of determination $R^2 = 0.9964$.

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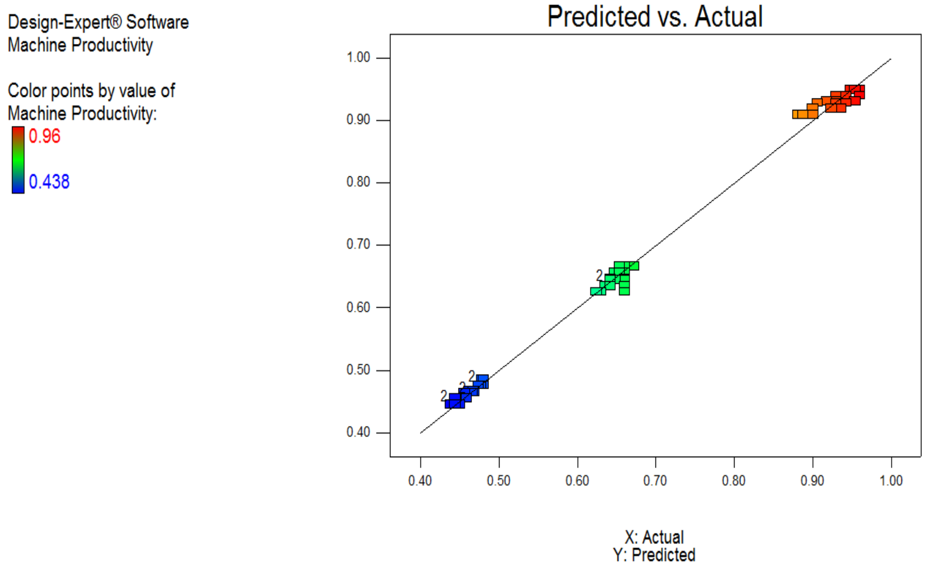

Figure (3-9) The relationship between the predicted field efficiency and the field-calculated field efficiency

Final Equation in Terms of Actual Factors:

1) Site : Silty clay

Machine Productivity = + 0.056990 - 2.39167E - 004 * Depth + 0.51559 * speed

2) Site : Sandy

Machine Productivity = + 0.035656 - 2.39167E - 004 * Depth + 0.51559 *speed

(2-3)

III. Conclusion

The analysis results showed that the planting depth factor was influenced by the interaction between speed and planting depth on the success rate. The lowest success rate was at a depth of 100 mm and a forward speed of 0.85 km/h (65%). The highest success rate was at a depth of 100 mm and a forward speed of 0.85 km/h. The interaction effect between soil type and planting depth was observed, with the highest planting percentage being in clay soils at a depth of 95-100 mm, and the lowest planting success rate being 67% in sandy soils at a depth of 40 mm.

It was also observed that the interaction between forward speed and planting depth had the highest effect at forward speed of 1.75 km/h and planting depth of 40 mm, with a percentage of 0.92 hectares/h or less..(%95) The effect at forward speed of 0.85 km/h and planting depth of 40 mm was 0.40 ha/h. While the interaction between planting depth and soil type reached the maximum effect in silty clay soils and planting depth of 40 mm at a rate of 0.715 ha/h and the lowest effect level in sandy soils at planting depth of 120 mm and was 0.68 ha/h, while the interaction between soil type was The forward speed is greatest in silty clay soils with a forward speed of 1.75 km/h at a rate of 0.93 hectares/h and the lowest effect is when the sandy soils have a forward speed of 0.85 km/h at a rate of 0.48 hectares/h.

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