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Evaluation of Mathematical Algorithm to Increase the Crop Yielding of Asparagus in an Agricultural Industry of Mexicali Valley, Baja California, México

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Abstract - A scientific study was made to evaluate the crop yielding of the asparagus in the Mexicali Valley, as is part of the Mexicali city in the Baja California State, Mexico; being an arid zone, which is located in the northwest of Mexican Republic, and is a border region with the California State of the United States of America (USA), where asparagus is highly coveted in the nutritious diet of the population of these two states (Baja California-Mexico and California-USA). This investigation was made in two steps, being the first action an analysis with the evaluation of three parameters, being the soil pH, water pH utilized in the irrigation of the asparagus crop process and the electrical conductivity of soil and water, as the basic factors of the soil fertilization. In the first step was used utilized the Scanning Electron Microscopy (SEM) to evaluate as at microscopy level, the quality of soil, where was cropped the asparagus, and with this, obtain an increase of the fertilization action and increase the crop yielding of the asparagus. The second step action was an administrative method as analysis of the logistic process as administrative process to evaluate the supply chain of the harvest process, inspection, cleaning, packaging and distribution of asparagus grown in this agricultural area of our country. Only in the second step, were utilized mathematical algorithms to evaluate at detail these specific actions, obtaining an increase in the productivity and quality levels of this agricultural industry where was made this investigation in 2022.

Keywords: Mathematical algorithm, agricultural industry, administrative-logistic process.

1.INTRODUCTION

The crop yielding of asparagus was evaluated to determine the principal factor in the soil fertilization using the SEM technique to detect when soil was deteriorated by the lack of irrigation process, and developed a new automatized system to maintain the humidity of the soil evaluated in this region of the Mexican Republic (Ortiz, 2012). This was to determine the principal factor that was relevant and had a positive effect in the productivity and quality levels of the asparagus crop, being as both as the pH and electrical

conductivity, the important aspects to increase the productivity and quality indices of the asparagus crop (Fuentes et al, 2009).

1.1 Mexicali Valley

Is an important productive region in the Mexican Republic, being relevant in the Gross Domestic Product (GDP) of our country with industrial and agricultural activities. This zone has very interest in the agricultural products, being similar as other zone of the Baja California State in Mexico (San Quintin region), as is very important in the crop of some agricultural products, as the asparagus, as in Mexicali Valley (Grijalva, 2008), as is mentioned in this scientific study, where in table 1 is showed the principal agricultural products cropped in this agricultural zone (SEMARNAT, 2022).

Table -1: Principal crops in the Mexicali Valley (2022)

Characteristics / Crops	Cultivation Area, Hectares	Price per ton, Mexican Pesos	Ton per Hectare
Wheat	40,881	6,801.00	3.50
Fodder Oats	8,901	4,090.00	4.42
Chives	3,155	7,998.00	40.00
Rye-Grass	1,708	31,000.00	60.00
Grain Corn	283	5,800.00	Yellow: 9.50 / White 11.00
Asparagus	158	39,720.00	5.80
Barley	70	12,200.00	3.00

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Table 1 shows the three main characteristics of the principal crops of the Mexicali Valley, where was observed that the higher cultivation area is the wheat with a round of 74% of the total agricultural products cropped in this northwest region of Mexico. Other relevant characteristic is the price of asparagus, being the highest priced and a nutritive vegetal required in all homes of families. And the third characteristics illustrated is the ton per hectare, being the major the rye-grass. As is observed in table 1, asparagus is an important vegetable cropped in the Mexicali Valley (Moreno et al, 2005; Walsh, 2007).

1.2 Characteristics of asparagus

Asparagus are considered food products of plants called asparagus, which contain tender stems, and whose plant can grow up to a height of 1.5 meters from the ground (Kellegöz et al, 2015). This food is part of the Liliaceae family, and according to research, it is believed that its origin comes from the banks of the Tigris and Euphrates rivers in the current region of the country of Iraq. The first versions of asparagus cultivation date back to the Egyptians from 6000 BC, and from that region it spread to the European zone of Greece and Italy, in later years (Słupski et al, 2010). One of the main characteristics of asparagus is its composition, one of its components being the rootlets that have the function of absorbing water and nutrients from the soil so that they are contained in the storage organs that contain the nutrients (Cheng et al, 2018). Another relevant factor in asparagus is its difference in color, with white asparagus being the

one that grows underground without receiving sunlight, green asparagus the one that contains chlorophyll, which is a component in the nutritional diet, and purple asparagus, which contains an edible pigment called anthokinin. When the growth of asparagus is developing, three phases are mainly taken into account, which help to obtain an efficient harvest of this vegetable, explained below in table 2 (Mitchell et al, 2014).

Table -2: Characteristics of the growth of asparagus

Characteristics Phases	Plant Growth	Growing Period
1	Formation of the claws is generated	Is evaluated in the period of one to two years, in which the sowing and the formation of the plants are contemplated
2	The accumulation of reserves is developed, with the objective of generating the expansion of the vegetation and thus achieving the greatest number of nutritive substances in the asparagus and that are contained in the fleshy roots that are the main roots.	Is generating the process of accumulation of nutrients in a period of two to three years.
3	The productive stage of asparagus is obtained, three years after the start of phase 1, and is subdivided into three stages.	Phase3a. Harvest period of the shoots, being the fleshy shoots, formed in the head or claw; and when they grow, they are formed, being also called asparagus. Phase3b. Development period of the vegetable, which is generated in a period of 12 months, if it is direct sowing or nine months if it is sown in nursery (made to reproduce plants based on their seeds and is carried out in wooden boxes or trays with refined earth, placing the boxes on bricks in a well-covered place so that they receive sunlight (this process is carried out when the soils have fertility problems for this type of food product). This process consists of evaluating at the end of the asparagus harvest, the growth of the stems and leaves called cladioles, in order to promote photosynthesis and the plant achieves its maximum growth. Asparagus harvest periods are contemplated, described immediately: Period 1. In the first year of cultivation, asparagus is harvested every seven days. Period 2. In the second year, asparagus is harvested every 14 days. Period 3. In the third year, asparagus is harvested every three weeks or 21 days.

		Period 4. In the fourth year, asparagus is harvested every 30 or 36 days. The asparagus planting season is basically from March to May of each year, but sometimes it can extend from February to June of each year. Phase3c. It occurs in the autumn and winter period, being important to allow the plant to regenerate again to be used for cultivation, where the plants stop growing, their stems becoming narrower and their aerial organs dry up.

1.3 Development of mathematical algorithms in agricultural industry

They are very useful as part of the immediate or future solutions of simple or complex activities that sometimes cause controversial situations and can cause loss of material, low production performance and quality; to the possibility of a work accident that entails some acute or serious health symptom (Janardhanan et al, 2019). An example of the mathematical algorithm in the agricultural industry is illustrated in figure 1.

Fig -1: Mathematical algorithm of the harvest process in the agricultural industry evaluated.
Source Analysis of research literature

Figure 1 shows mathematical algorithm to the cultivation process with the optimal parameters to obtain the major yielding of the crop of the asparagus (Wang et al, 2013). The second step considers the flow

process of inspection, organize and pack the asparagus in boxes and stow of boxes of asparagus, to the delivery operation to send to clients of an agricultural industry located in the Valley of Mexicali, dedicated to the cultivation of this coveted vegetable. (Hamta et al, 2013). Based on the operations made in an industrial activity, including agriculture, an order and hierarchy of activities can be presented and thus have an efficient process flow that helps to obtain the adequate quantity of production, as well as quality indices. optimal for consumption (Fattahi et al, 2011). Being the agricultural activity, an industry, where a variety of complex situations can occur that can generate adversity in the productivity and quality indices, the optimal actions must always be considered too made the production processes with the production flows. required, without presenting alternatives to modify the process flow that an operation must follow (Cheng, 2017; Fattahi et al, 2011). In this investigation, mathematical algorithms were developed to obtain the best performance in the asparagus harvest, describing below the most relevant one that consists of the main process flow in the harvesting operation of this appreciated vegetable (Hamta et al, 2013).

1.4 Microscopy analysis

Is an important evaluation using diverse microscopy techniques, and being the most relevant the SEM analysis, which was utilized in this scientific study to evaluate the deterioration of soil. The deterioration of soil is for lack of moisture, when not are supplied the adequate quantity of water and with the climatic variations of relative humidity and temperature in the region where is located the Mexicali Valley, can add other important aspect to deteriorate very fast the soil. For this reason, specialized people of agricultural activities were made some analysis with soil with the SEM technique, showing in figure 2 some areas of soil deteriorated and need supports to improve the conditions of the soil to asparagus crop, as a microanalysis (Gustavo López et al, 2017).

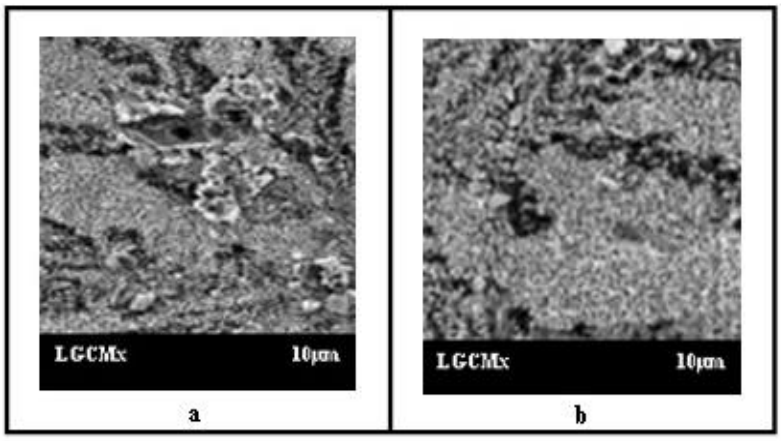

Fig -2: Microanalysis of deteriorated soil in the zone of the agricultural industry evaluated, analyzed without water at (a) two days and (b0 five days in the summer season

Source Analysis of research literature

Figure 2 represents a microphotographies of deteriorated soil at the zone of the harvest process in the agricultural industry evaluated, observing that in two and five days, was damaged, and illustrated in light zones (white) at two day without water supply the areas of this microphotography with a bit moisture and the dark zones without moisture, and the microphotography at five days, shows the dark zones in the

majorly of figure 3b, at 40 °C and 60% of relative humidity (RH) in the June month of 2022, generating an increase of the deterioration of this area of soil evaluated. This was important, because specialized people take care recommendations to conserve the moisture in all zones of the soil evaluated with this micro test.

1.5 Logistic activities

This an important thematic in any type of industrial process, analyzing from the supplier of raw materials, the operational process to the products manufactured or cropped and the distribution of the products of each industrial company (Janardhanan et al, 2019). One factor of this relevant thematic is the supply chain, which is very utilized in the industrial operations (O'Connor et al, 2020), were constantly is applied the continuous improvement. With this important aspect can have the structure of the operations with very strict organization and can obtain the major operative yielding of operation personnel of the operative functions, and of the industrial equipment and machinery, and also some industrial systems and devices utilized in the manufacturing and cropped process. In the agricultural industry, where was made the scientific study was used this factor (Oliveira et al, 2017), being illustrated in figure 3 the basic steps of the asparagus crop processes.

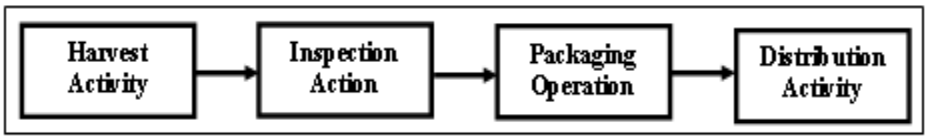

Fig -3: Operation flow process as a supply chain analysis
Source Analysis of research literature

The last figure presents the basic four steps, required for the asparagus crop, being evaluated with the supply chain action, with the purpose of generates the continuous improvement as the administrative and logistics functions, which was required in this investigation, observing that conforms advanced this scientific study, the productivity and quality levels, were increased by this relevant action, combined with the microanalysis of soil (Slatnar et al, 20180.

1.6 Productivity and quality indices

These relevant parameters were evaluated constantly in all months of the year when was made this scientific study (2022), observing that when was made the supply chain and the fertilization action of soil, maintaining the adequate moisture in the soil, these factors were increasing in each month of the investigation, begin the increment from second month (February 2022), to the final month of this scientific study (Hafizur et al, 2012). One of the applications that is widely used in the industry is the prediction or estimation of the productivity and quality factors, in diverse activities of interest that want be evaluated, with the aim of being able to know the possible events or occurrences that may occur and thus determine the possible actions to be considered for prevent industrial operations, whether simple or complex, from having any complicated situation. Some complicated situations can be, that delays in the production process, loss of material, or on occasions some type of accident or generation of some health symptom, even mild or serious, or disease that is reflected in the body of a person from the manufacturing area in particular, forever in his life (Conversa et al, 2009).

2. METHODOLOGY

The realization of this scientific study with the correct planification, organization, execution and control of the asparagus cultivation was supported by specialists of this investigation in agricultural, administrative and logistic thematic, obtaining interesting informacion to be constantly applying the continuous improvement and steadily increasing the productivity and quality levels of the asparagus cropped. This investigation was made in two steps that is expressed now:

a) Evaluation of the psychochemical aspects as the pH soil, pH water and electrical conductivity of soil and water, and also an evaluation of the use of the SEM technique.

b) Analysis of productivity and quality levels, correlating with the use of supply chain correctly as an administrative and logistic factor.

3. RESULTS

This investigation supported to people of the agricultural evaluated, which was suffer before made this scientific study, being relevant, because was solved complicated situations that was made presenting and increasing the productivity and quality levels, and was concerned by low indices of this important factors.

3.1 Evaluation of the psychochemical factors

This step was made to detect the action of the four interesting parameters of soil and water, which determine the soil fertilization process, evaluating these four parameters and showed in table 3, where is presented the maximum and minim values of the parameters analyzed.

Table -3: Analysis of physicochemical parameters (2022)

Factors / Months	pH Soil	pH Water	ECS, mS/cm	ECW, mm/cm	Factors / Months	pH Soil	pH Water	ECS, mS/cm	ECW, mm/cm
January	4.5	4.8	3.2	1100	July	7.1	7.5	0.8	530
February	5.8	5.6	2.2	850	August	7.5	7.1	0.7	580
March	6.5	6.0	1.5	750	September	7.3	7.0	0.6	600
April	6.9	6.6	1.2	660	October	6.9	7.4	0.7	640
May	7.2	6.9	1.1	580	November	7.4	7.0	0.5	710
June	7.0	7.3	0.9	550	December	7.6	6.8	0.5	760

Electrical Conductivity Soil (ECS), Electrical Conductivity Soil (ECW)
Soil: miliSiemens/cm (mS/cm): Very High (VH): > 3.0, High (H): 1.6-3.0, Medium (M): 0.8-1.6, Low (L); < 0.6
Water: mmhos/cm (mm/cm): High (H): 1000-1500, Medium (M): 500-1000, Low (L); < 500

Table 3 shows the values obtained of the investigation actions, where was presented the levels of four basic aspects evaluated, illustrating that in the first month of this scientific study, the levels not were appropriate, but from the second month; was improved, to generates better soil fertilization action, and with this improve the productivity and quality indices. Also, was made an evaluation of the SEM technique to determine the grade of effect, being positive and representing in table 4, where is observe that conforms advanced this

scientific study, the soil was better to the cultivation process of asparagus, being important in the increment of the productivity and quality indices.

Table -4: Evaluation of the use of SEM technique (2022)

Factors / Months	Soil State	Soil Deterioration	Factors / Months	Soil State	Soil Deterioration
January	B	H	July	G	L
February	R	M	August	G	L
March	G	M	September	G	L
April	G	L	October	G	L
May	G	L	November	G	L
June	G	L	December	G	L

Soil State. Good (G), Regular (R), Bad (B)
Deterioration Grade. High (H), Medium (M), Low (L)

3.2 Analysis of productivity and quality indices

The evaluation of these important parameters is illustrated in table 5, whit percentage levels, and presented from the first month of the investigation, and represented the increase of levels begin from less of 70% in the productivity level and less 60% in the quality indices; and increasing every month and was maintaining in some months to the finish of this scientific study, being relevant the improvement of soil and the supply chain.

Table -5: Analysis of productivity and quality levels (2022)

Factors / Months	Productivity, %	Quality, %	Factors / Months	Productivity, %	Quality, %
January	67	58	July	85	83
February	79	69	August	84	81
March	83	78	September	87	86
April	80	83	October	86	84
May	86	84	November	85	87
June	85	88	December	86	85

Also, was made an evaluation of the operations processes in the agricultural industry evaluated and was presented the production flow process type and the effect of the use of mathematical algorithm to improve the agricultural operations, obtaining positive results and observing in table 6.

Table -6: Evaluation of supply chain as a logistic aspect (2022)

Factors / Months	PFP	EL	Factors / Months	PFP	EL
January	Lineal	B	July	Lineal, U	G
February	Lineal, T	R	August	Lineal, G	G
March	Lineal, T	R	September	Lineal, G	G
April	Lineal, T	G	October	Lineal, G	G
May	Lineal, U	G	November	Lineal, G	G
June	Lineal, U	G	December	Lineal, G	G

Production Flow Process (PFP). Lineal, T, U, G
Effect Level (EL). G. Good, R. regular, B. Bad

The table 6 illustrates the process of evaluation of the necessity of change the production process flow, and having the majorly of the investigation a positive effect and an optimal result.

4. CONCLUSIONS

This investigation obtained interesting results, being supported by the new strategies implemented in the agricultural operations, from the harvest action, inspection and packaging activities and the distribution of the asparagus to the customers of this region, where were consumed. The physicochemical parameters analyzed was necessary to know the levels in the different period of the year, when was realized this scientific study. The specialists were applied the adequate strategies to all analysis elaborated and this was relevant to increase the productivity and quality indices, being important to consider to this agricultural industry to increase as industry and supports to workers in some human aspects as help to improve the medical care security, buy scholar supplies to maintain the personnel of all the areas of this agricultural company, in a way, in which the maximum operational performance is obtained.

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