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Economic-Environmental Management of Sugar Beet Fertilizer by Using Statistical Quality Control Technique

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ABSTRACT

Sugar Beet as a source of human nourishment contains about 30% of sugar consumption in the world. On the other hand, problems encountered in providing human food as well as environmental pollution caused by unbridled human interference in the normal process of nature have created serious anxiety among scholars and concerned organizations. Therefore, efforts to increase production along with improving the quality of strategic products, provided that the environment is protected and not polluted, is the only fundamental solution to this global problem. In conservative agriculture, using fertilizer for increasing sugar beet production must be planned on the bases of economic beneficiary and environmental conservation. Considering the robust growth of sugar beet in saline soils and low-quality land, it is imperative to conduct studies in this respect. Unaware of the fact that compliance with the principles of operation and maintenance of fertilizing soil quality can be significantly raised the yield of sugar beet. Since Fasa region is one of the leading sugar beet production regions in Iran, it was chosen as the statistical population example. The purpose of this study is to provide guidelines for optimal use of fertilizers to sugar beet using MINITAB software and quality control charts. For this purpose, 80 samples were recorded from the fields of excavation and their OC, K, and P were tested. Results were quantified. The paper is concluded with some practical strategy suggestions.

1. Introduction

The devastating environmental consequences that the present world faces are rooted in the unwise dealing of the human being with the environment and the over-exploitation of basic resources (Almasri, 2006; Shahraki et al., 2012; Sardar Shahraki, 2016). In the past decade, the application of chemical fertilizers has had adverse environmental impacts, such as water and soil pollution, as well as health problems for humans and other living organisms (Murty and Ladha, 1988; Ghost and Bhat, 1998).

Increasing demand for agricultural products has drawn attention to bolstering production. The use of chemical fertilizers has been considered a way to increase crop yields (Ayneband, 2014; Sardar Shahraki et al., 2018). Today, agriculture is an economic activity that accounts for an important part of the gross domestic product (GDP) of all countries by supplying food security for their people. On the other hand, agricultural activities may have several environmental side effects (Van Loon and Glik, 2004).

Most economic analyses only emphasize the economic well-being of farmers and neglect environmental issues. Thus, one can say that an efficient manager should consider several goals, both economic and environmental, simultaneously in the selection of agricultural activities (Mansouri and Kohansal, 2007). Many studies have shown that the conventional agricultural system ruins the environment and depletes the natural resources by excessive use of chemical inputs (Aghili et al., 2009).

Presently, bio-agriculture is growing at a rapid pace, and most countries, especially developed countries, have put the development of bio-agriculture in the agenda of their action plans (Lockeretz, 2007). As such, experts have growingly paid attention to agriculture sustainability. Agriculture is sustainable when it is technically feasible, economically valid, politically suitable, managerially executable, socially acceptable, and environmentally compatible (Kochaki, 1997; Sharma, 2003; Shaharoona et al., 2006). The goal in sustainability is not absolute maximization, but it is to maximize outputs and minimize inputs relatively and concurrently. This approach is closely associated with the role of sustainability, i.e. reducing or stopping the use of chemicals including fertilizers and herbicides and alleviating the deterioration of water and soil resources (Lara and Minasian, 1999).

In bio-agriculture, more rational ways have been put forth, such as the optimal use of fertilizers, to avoid the loss of products (Asadi Rahmani et al., 2012). Fertilizer use behavior of farmers is categorized among environmental behaviors because farmers' use of more biofertilizers and

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less chemical fertilizers means that they feel responsible about the environment.

Soil pollution in agricultural areas is a major environmental problem in developed and developing countries (Taghipour et al., 2013).

Today, the use of high-yielding agricultural inputs in the wrong, unbalanced and excessive way has not only damaged crop safety but it has also had detrimental effects on aquatic, plant, animal and human ecosystems. Indeed, the use of chemical fertilizers is damaging the environment irreparably. It should be noted that today's agricultural knowledge not only takes economic objectives into account, but it should also give a special attention to the environmental issues as agriculture is a source of injuries to the natural environments in different regions (Halkidis and Papadimos, 2007).

A growing interest for bio-refineries has resulted in a subsequent increase in publication of lifecycle assessments (LCA) of such systems in later years (Bernstad Saraiva, 2017).

Organic farmers argue that the use of synthetic pesticides and fertilizers is unnecessary and traditional farming practices can produce safe food with higher quality (Rai and Gaur, 1988; Mohammadi and Sohrabi, 2012). Therefore, it seems that the optimal management of chemical fertilizer use is the only way to achieve sustainable development in agriculture and accomplish the goals and policies anticipated for sustainable agriculture. The rate of fertilizer use in Iran has increased sharply in recent years. Irrespective of its environmental problems, the purchase of the fertilizers has been a huge burden on foreign currency (Torabian and Mahjori, 2001).

Beta vulgaris from the genus Phoenix is the species commonly known as sugar beet. Most species of this plant is ornamental. This plant is resistant against heat, soil salinity, and dehydration, and it grows better in sandy, limestone, and clay soils. Good ventilation of the soil is an important factor for the growth and development of this plant. It can be grown in warm weather and sunshine.

According to the latest statistics, the total harvesting area of industrial crops in the 2015-2016 growing season was about 490,200 ha, accounting for 4.17 percent of total harvesting area of all the crops in Iran. Of this area, 91.6 percent is irrigated and 8.4 percent is rain-fed. The first five leading industrial crops are sugar beet, sugarcane, cotton, soybean, and canola accounting for 22.5, 18.3, 14.4, 10.59, and 10.55 percent of this area, respectively, so that 76.5 percent of the total harvesting area of industrial crops is allocated to these five crops (Anonymous, 2016).

Fasa County is the largest producers of sugar beet in Fars province, Iran. Since, sugar beet plays an important role in economy, thus the correct use of fertilizers and agricultural operations can increase the quality and quantity of this crop.

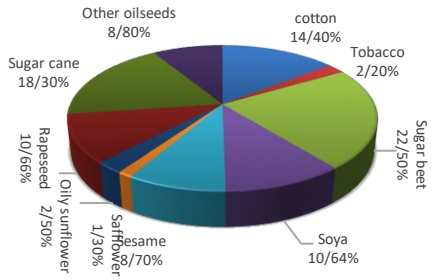


Fig. 1. Total acreage of industrial crops

The objective of this study is optimizing the consumption of fertilizers in Fasa County in 2017 (Statistical Yearbook of Agriculture Organization, 2017).

2. Research objectives

- To determine the optimum level important soil nutrients for sugar beet growing.
- To determine production functions for each of the fertilizers with respect to the optimal level of soil elements.

3. Materials and Methods

Statistical quality control was founded by Walter A. Shewhart in the 1920s. Although statistical techniques are necessary tools to control and improve quality, they should be an integrated component of a quality-committed management system in order to be the most effective. In fact, a management system should guide the quality improvement and ensure their application in all parts of an organization. The management framework to meet this goal is usually total quality management (TQM) (Besterfield, 1994).

Statistics is the science of decision making about a process or a population drawing on the analysis of data derived from a sample of that population. Statistical techniques are crucial for quality control so that they enable sampling, assessment, and the use of data derived from the sample to control and improve the production process (Wadsworth et al., 2002).

The quality of a product is usually determined with respect to the following three parameters:

- The quality of design
- The quality of compliance
- The quality of performance (Noghondarian, 2009)

The process of production refers to a combination of machines, methods, materials, and people who are used to produce a high-quality product, and control refers to the efforts to create and maintain specifications and standards. Control allows detecting undesirable changes, identifying the causes of the changes, and resolving these causes.

The ultimate goal of any production process is to make a product in compliance with acceptable specifications.

Control chart is a chart by which information derived from the performance of the production process is compared with the control limits drawn on the chart. The information on the performance of the production process is usually derived from samples that are taken from the consecutive steps of production (Montegomery, 1996).

Control charts are mainly used to figure out the causes of deviations detected in the production process. Deviations in the production process are divided into two groups:

1. The random single deviations caused by an event
2. Deviations with reasons to determine the possible causes (Debertin 1997).

When an observation is within the control limits of random deviations, it means that the production process is under control. If there are just random deviations in the production process, the process is uniform enough in which case it is possible to satisfy the overall quality of the production by sampling. It is assumed that a qualitative characteristic has a normal distribution with the mean μ and standard deviation σ, and both these quantities are known. If $x_1, x_2, \ldots, x_n$ is a sample with size n, the mean of the sample is equaled to:

$$\bar{x} = \frac{x_1, x_1, ..., x_n}{n} \tag{1}$$

since $\bar{x}$ has normal distribution with the mean μ and standard deviation is $\sigma_{\bar{x}} = \sigma / \sqrt{n}$. In addition, the probability that a mean sample is placed within:

$$\begin{cases} \mu + z_{\frac{\alpha}{2}} \sigma_{\bar{x}} = \mu + z_{\frac{\alpha}{2}} \dfrac{\sigma}{\sqrt{n}} \\ \mu - z_{\frac{\alpha}{2}} \sigma_{\bar{x}} = \mu - z_{\frac{\alpha}{2}} \dfrac{\sigma}{\sqrt{n}} \end{cases} \tag{2}$$

is $1-\alpha$ (Noghondarian, 2009).

If $x_1, x_2, \ldots, x_n$ is the size of an n-fold sample, then, the range of its variations is the difference between the largest and smallest sizes as below:

$$R = x_{Max} - x_{Min} \tag{3}$$

There is a known relationship between the variation range of a sample taken from a normal distribution and the standard deviation of the distribution. Now if it is assumed that $R_1, \ldots, R_m$ represents the values of the variation range of m samples, then average variation range will be as below:

$$\bar{R} = \frac{R_1 + R_2 + ... + R_m}{m} \tag{4}$$

In this case, the standard deviation of the process σ and the mean d_2 are estimated as below:

$$\hat{\sigma} = \frac{\bar{R}}{d_2} \tag{5}$$

If the $\tilde{x}$ is as an estimate for μ and $\frac{\bar{R}}{d_2}$ is as an estimate for σ, thus the around of $\bar{x}$ chart control is (Noghondarian, 2009):

$$\begin{aligned} UCL &= \tilde{x} + \frac{3}{d_2\sqrt{n}}\bar{R} \\ \tilde{x} &= Central\ \ line \\ LCL &= \tilde{x} - \frac{3}{d_2\sqrt{n}}\bar{R} \end{aligned} \tag{6}$$

Note that the amount of $A_2 = 3/d_2 n^{1/2}$ is constant and related to sample size. Thus, the definition of around control of $\tilde{x}$ charts is as a follow:

$$\begin{aligned} UCL &= \tilde{x} + A_2 R \\ \tilde{x} &= Central\ \ line \\ LCL &= \tilde{x} - A_2 R \end{aligned} \tag{7}$$

The range of sample is related to standard deviation in process. Therefore, we can survey process variability with drawing the amount of R on the chart control.

$$\sigma_R = d_3 \sigma \tag{8}$$

Since σ is unknown, σ_R can be estimated by the following equation:

$$\hat{\sigma}_R = d_3 \frac{\bar{R}}{d_2} \tag{9}$$

Consequently, the around of control with three standard deviations for R chart is (Noghondarian, 2009):

$$\begin{aligned} UCL &= \bar{R} + 3\hat{\sigma}_R = \bar{R} + 3d_3 \frac{\bar{R}}{d_2} \\ \bar{R} &= Central\ \ line \\ UCL &= \bar{R} - 3\hat{\sigma}_R = \bar{R} - 3d_3 \frac{\bar{R}}{d_2} \end{aligned} \tag{10}$$

Data were collected from a sample of 90 sugar beet farms in Fasa County based on soil studies. The sample was taken by randomization given the specifications of the statistical population. Data were analyzed using MINITAB software package to determine the statistical quality control in the samples.

4. Results and Discussion

We tested three main indicators including K, P, and OC for 80 samples of sugar beet crop. The results of quality control are presented here.

Table 1. Soil profile samples of sugar beet in the city of Fasa

No of samples	$P_{(ppm)}$	$K_{(ppm)}$	$OC_{(ppm)}$	No of samples	$P_{(ppm)}$	$K_{(ppm)}$	$OC_{(ppm)}$
1	1	290	1.9	41	5.8	150	1
2	1.4	150	0.2	42	5	160	1
3	1.2	320	0.03	43	7	180	0.2
4	3.2	180	1.5	44	0.8	90	0.3
5	1.2	870	2.3	45	10	100	1.2
6	3.1	230	3.4	46	22.8	100	1.6
7	2.3	650	0.03	47	3.6	95	1.8
8	1.3	230	0.05	48	1.1	100	1.5
9	1.7	210	0.8	49	1	120	0.6
10	2.3	130	0.7	50	6.4	420	0.8
11	3.1	70	0.9	51	0.4	180	0.8
12	5.8	300	0.1	52	4.6	130	0.7
13	2.7	150	0.1	53	1	180	0.9
14	2.3	200	0.1	54	3.6	140	2.5
15	1.3	160	0.02	55	2.8	220	2.9
16	3.7	80	0.08	56	3.2	210	2.7
17	4.5	50	0.5	57	5.4	360	2.5
18	11.2	90	0.6	58	0.6	470	2.6
19	4.2	140	0.7	59	5.4	200	0.1
20	1.2	250	0.8	60	3.2	100	0.2
21	1.8	60	0.2	61	8.6	100	0.6
22	3.5	130	0.2	62	11.6	90	0.7
23	6.5	110	0.21	63	0.2	80	0.8
24	1.2	190	0.23	64	5.8	70	0.9
25	1.7	200	0.56	65	1.8	120	1.2
26	2.1	80	0.78	66	1.1	150	2.6
27	7.9	140	0.81	67	2.2	110	0.5
28	1.5	130	0.92	68	5.4	130	3.2
29	2.6	180	0.25	69	3.6	550	6.5
30	3.9	220	0.82	70	8.7	350	4.1
31	5.4	180	0.14	71	6.5	320	2.3
32	2.6	190	0.36	72	3.4	410	2.2

33	2.1	330	0.58	73	1.3	320	3.2
34	5.9	410	0.96	74	2.6	250	1
35	7.8	250	0.14	75	5.6	140	1
36	18.9	120	1.3	76	7.8	210	1.1
37	15.3	80	2.1	77	4.1	220	1.2
38	12.3	90	2.2	78	6.5	100	3.2
39	12.6	120	5.6	79	4.1	80	0.23
40	11	100	4.1	80	2.3	90	0.58

Source: Research findings, (PPM: Parts per million)

A performance result of the sugar beet fertilizer consumption varies in different situations and a significant variation is observed in sugar beet yield. It should be noted that these variations in yield are constant considering all factors.

4.1. Potassium (K)

K is involved in almost all metabolic processes of the plants. K in its ion form is absorbed from the soil by spending energy and is responsible for establishing osmotic potential, activating enzymes (as a coenzyme), stabilizing pH, synthesizing protein, adjusting stomatal movements, cell expansion, photosynthesis, anionic equilibrium and so on in plants. K content is positively related to the synthesis of starch and sugars. K enhances diastasis activity and sugar synthesis in plants, thereby partially curbing intracellular freezing in plants. This is why it is said that K improves chilling resistance of the plants.

K is an element that is involved in plant resistance to diseases, high humidity, chilling and drought, absorbability of other nutrients, and fruit palatability and is key for the production of high-quality fruits. This element is highly mobile in plants and is required in high concentrations. A high content of N, P, and/or Ca may cause K deficiency. K is very effective in improving crop quality and the efficiency of the use of other nutrients. This element is known as a quality element in crops. Among macronutrients, K plays a vital role in root quality (sugar content) of sugar beets. Among the cations absorbed by sugar beets, K accounts for a large part. Other roles of K are (i) improving resistance to diseases, pests, drought, and chilling, (ii) non-linear direct relationship with root sugar content, (iii) competing with Ca, Mg, and Na cations during the process of uptake by sugar beets, and (iv) involvement in sugar beet nutrition so that K and Na cations are two necessary nutrients to accomplish maximum yield. Optimal K range in sugar beets is 120-180 ppm. The relevant results are illustrated in Figure 2.

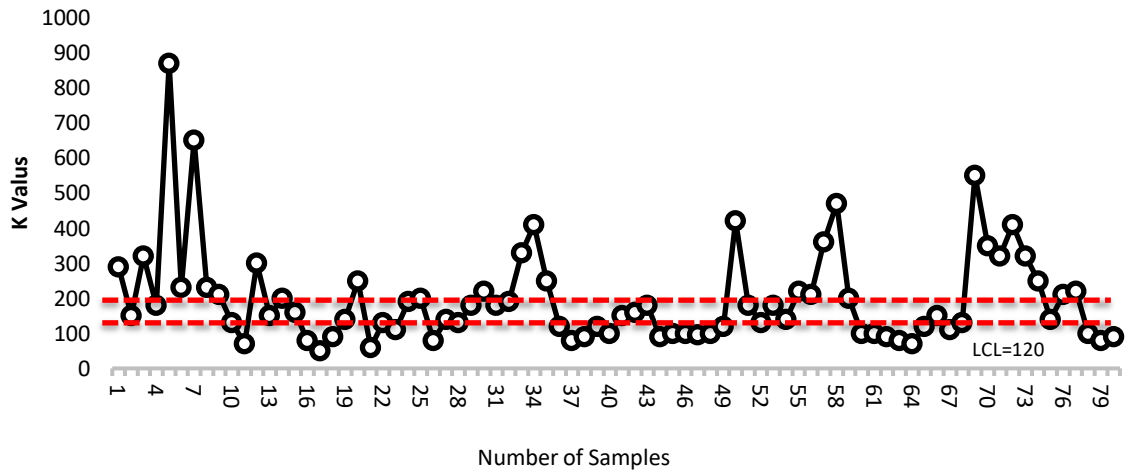


Fig. 2. UCL and LCL Limits of index *K*

According to Figure 2, the K level is not optimal in the studied samples. This impairs the quality of sugar beet crop. In this case, sugar beet yield is from 10.2 to 14.4. However, if the K value is over 180, it can go into the third economic phase. Only the range of 120 to 180 is the economic area of production.

4.2. Phosphorus (P)

Sugar beets does not relatively absorb a great deal of P from soil. The best way to determine P requirement of the plant is soil test. P deficiency postpones the full growth of the plant. Then, the leaves turn into dark green color. Optimal P for sugar beet is between 4.8 to 16.3 ppm. Figure (4) shows samples of phosphorus (P) index.

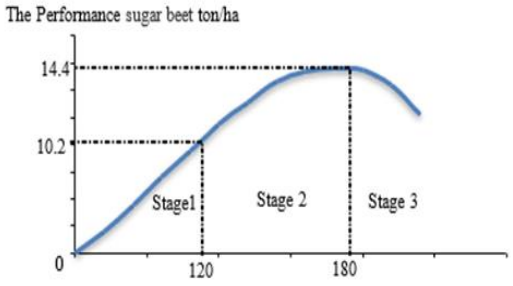


Fig. 3. Production function for index *K*

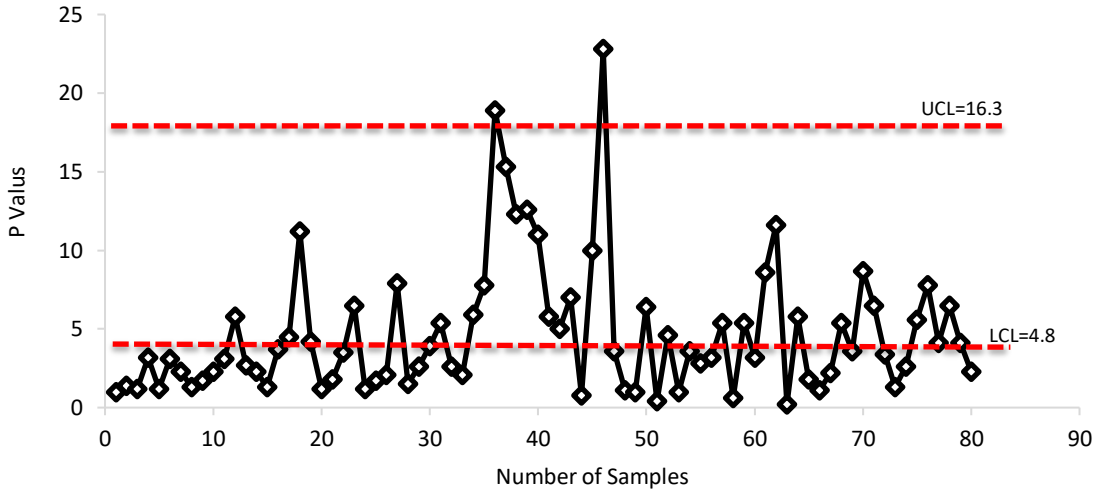


Fig. 4. UCL and LCL Limits of index *P*

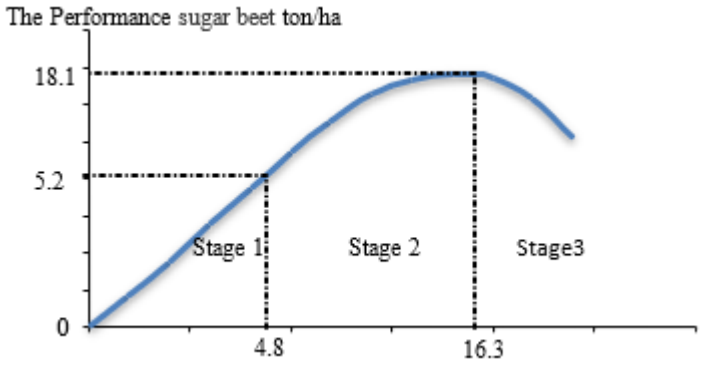


Fig. 5. Production function for index P

4.3. Soil Organic Carbon (OC)

Organic matter is very functional in soils as it is a source of minerals and energy for plants and soil organisms, maintains them in absorbable form in soil, increase the formation of particulates and root development, enhances water penetrability into soil and water use efficiency, and finally, improves the physical properties of soil, facilitating farming operations. Organic matter affects some features of soil including particulate stability, soil compaction, soil biology, and thermal regime. All these factors are very important for the dynamic and biotic medium of soil. The application of organic carbon greatly contributes to improving sugar beet yield.

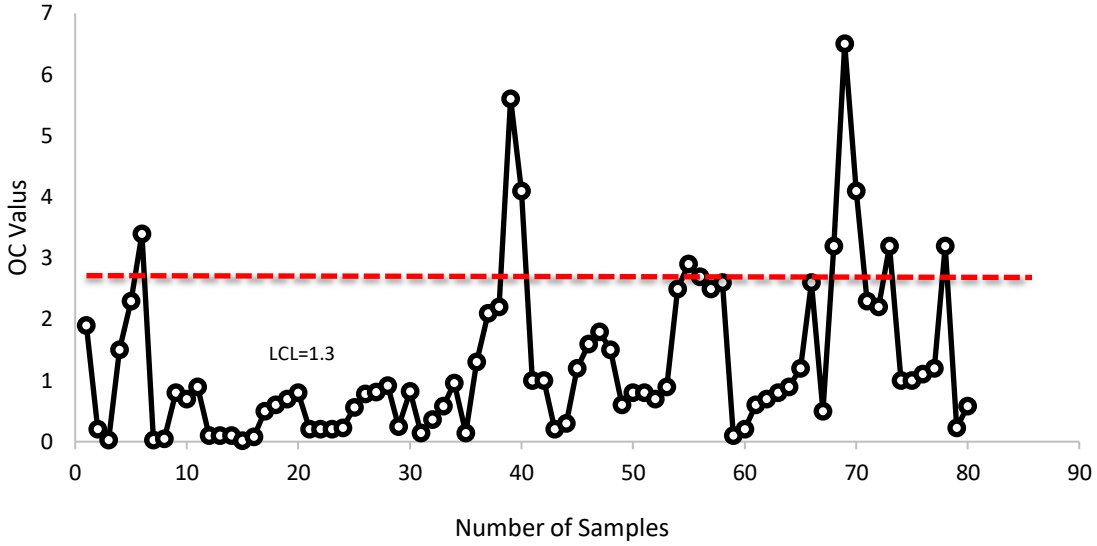


Fig. 6. UCL and LCL Limits of index *OC*

The optimal level of soil OC for sugar beet is between 1.3 and 2.8 ppm. Figure 6 shows the quality control of the samples.

Sugar beet performance in this situation varies from 9.9 to 28 tons per hectare. The results of production function are presented in Figure 7.

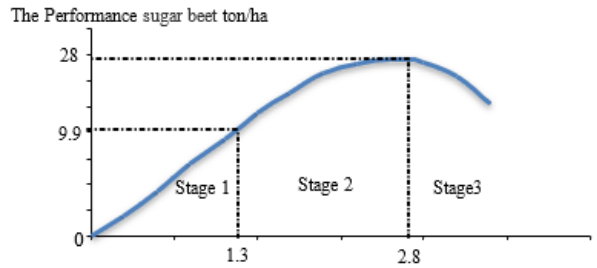


Fig. 7. Production function for index *OC*

According to the results of quality control, sugar beet yield varies in the range of 9.9 and 28 t ha^{-1}.

5. Conclusion and Suggestions

Quality control of soil and fertilizers applied to plants and crops are crucial. This can be considered from both economic and environmental perspectives. Since agriculture is one of the main components of economic development, it is imperative to give a special attention to this activity. On the other hand, the application of fertilizers and inattention to soil quality can have detrimental impacts on the environment. Sugar beet is a key crop in the agricultural, economic, and industrial sectors. This crop plays a major role in sugar production. So, the present study focused on Fasa County as a leading region of sugar beet production in Iran. We sampled 80 sugar beet farms and assessed the relevant indicators with respect to quality control charts.

The following recommendations can be drawn from the results:

- It is recommended to examine the results of the present study for all sugar beet growing regions of Iran. This can enhance agriculture economy to a great extent and alleviate detrimental environmental impacts.
- It is recommended to retest the studied samples in the study site every year and to compare the results. This can contribute to detecting the variation trend of the indicators over time.
- Governments should take actions as soon as possible to reduce the application of chemical fertilizers and pesticides. The reduction of their consumptions would not suffice without the support of the government. The government should take care of its role. Indeed, pests are not supposed to be eradicated because they are a part of the ecosystem, so their eradication will only disrupt the ecosystem. If the order of the ecosystem is maintained, the living organisms will automatically control one another and there will be no need for us to adopt practices to control them.
- It is recommended to stress out on the implementation of research-extension farms with respect to the effectiveness of bio fertilizers.
- It is recommended to manage the subsidy that granted to chemical fertilizers on the basis of their economic profitability and environmental impacts.

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