Australian Journal of Basic and Applied Sciences, 5(5): 334-340, 2011
ISSN 1991-8178

Using Experimental Designs in Order to Analyze the Affect of Effective Factors on Rice Seeds Weight

[1]Amir Moslemi, [2]Iman Ghaleh Khondabi

[1]Faculty of Industrial Engineering, Department of Engineering, Shahed University, Tehran, Iran.
[2]ETKA Center of Advanced Science and Technology, Tehran, Iran.

Abstract: Nowadays, there is an increasing demand for food in many countries due to the fast growing of technology, industry and population. Therefore, there is a need to using new methods and approaches in agriculture to obtain a high volume of high quality agricultural products. Beside modern machines and efficient workers, recognizing the effective factors in yield and productivity is vital. We want to study the effect of some controllable variables on rice. Design and analysis of experiments apply simple tools like analysis of variance (ANOVA) to survey the effect of some factors on a specific response like quantity of yield or time of growing for each plant. In this paper, we apply two common experimental design approaches: factorial design and Taguchi method where their results are compared, consequently. Taguchi method is common because it obtains good results with a fewer number of experiments and cost. In addition, screening experiments are used to obtain the effective factors, where three factors supposed to be effective. These three factors are: Time of adding fertilizer, amount of added fertilizer and adding barley stubble to agricultural field. The response that we want to measure is the weight of thousand seeds which is better to get a larger volume. Finally, we obtain the optimum levels of effective factors which consequent the maximum weight of thousand seeds.

Key words: Design and analysis of experiments; Factorial designs; Taguchi method; Fertilizer; Weight of thousand seeds.

INTRODUCTION

Development in agriculture can be categorized to two main clusters. First category is dedicated to utilizing modern technologies and machines, facilitate physical tasks and consequently decreasing number of workers by applying these modern tools. Second category is surveying the methods of reproducing new seeds or plants, methods of producing efficient fertilizers and the methods of product implanting and irrigation. By these approaches, productivity increases up to three or four times in some cases. So as the second category approaches are not as expensive as the first one, many researchers focus on this part of studies.

Recognition of affective factors forms an important part of studies. If we identify these factors and determine the best levels of performance, the procedure of growing crops is facilitated and the productivity is increased. One common and efficient tool to analyze the effect of different factors and survey the measure of effectiveness is design and analysis of experiments (DOE). In this approach, by applying statistical methods, especially analysis of variance (ANOVA), effect of each factor is obtained and the effective factors yield or any other responses can be found. As the next step, levels of effective factors are computed. Determination of effective factors is done by P-value in ANOVA test. Many different experimental designs are presented to analyze the factors such as completely randomized design, Latin squares design, factorial design, fractional factorial design and also new approaches like Taguchi method. In this study we use Taguchi design in order to show the effectiveness of this method instead of the lower number of performed experiments.

One of the most high usage foodstuffs in Iran is rice and it is the most strategic cereal after wheat. Especially, many fields are dedicated to rice growing in north of Iran. So, in this paper we concentrate on an important specification of this crop. In every experiment we can divide surveying factors into three main categories. First category is dedicated to controllable factors which can be identified by experimenter and also, experimenter can control the effect of these factors by fluctuating levels of them. Second group is nuisance factors that the experimenter can not exactly recognize them but can restrict the effect of them by blocking methods. The third category of factors is fixed variables that we don't survey them in this study because these factors are constant in every experiment.

Corresponding Author: Iman Ghaleh Khondabi, ETKA Center of Advanced Science and Technology, Tehran, Iran.
E-mail: ig.khondabi@gmail.com

Also, analysis of experiments results can be modeled as regression functions based on effective factors that can be optimized and be used in future decision makings. This procedure is called response surface methodology (RSM). Response surface methodology is a statistical procedure frequently used for a wide range of optimization studies. Mullen and Ennis (1979) used RSM to find the optimal working conditions by combining a small number of variables, resulting in fewer experiments.

Using design of experiments is surveyed in many researches; Madamba (2002) mentioned that optimization of the drying process is performed to recommend rapid processing conditions yielding an acceptable quality product and a high throughput capacity via manipulation of the amount of independent variables. For example, presented percentage of germination, normal seedling, vigor indices and other vigor traits are important seed quality factors for soybean seeds and the experiment is performed to optimize these factors. DOE was employed in optimizing drying operations and techniques (Barrozo, M.A.S. *et al*. 2005; Madamba, P. S. and Liboon, F.A. 2001; Madamba, P. S. and Lopez, R. I. 2002; Zhang, M. *et al*. 2003). It uses quantitative data from an appropriate experimental design to determine and solve multivariate problems, simultaneously. The equations that describe the effect of the test variables on the responses determine interrelationships among test variables and represent the combined effects of all test variables in the response. This approach enables us to make efficient exploration of a process or system.

Wiersma, D.W. *et al*. (1986) integrate the management of seeding dates and rates, row spacing, soil fertility, diseases, insects and lodging to maximize the grain yield. Alley, M.M. *et al*. (1999) surveyed effect of Nitrogen (N) fertilization and mentioned that it is crucial for economic wheat production and the protection of ground and surface waters. They presented Nitrogen fertilizer rate and timing are the major tools available after planting for manipulating wheat growth and developing to produce a greater grain yield per unit area.

New method presented by Taguchi is another common method using to survey effect of factors besides classical methods in design of experiment. Chen and Kitts (2008) determined conditions for nitric oxide synthesis in Caco-2 cells by using Taguchi methods and factorial experimental designs. Mohan *et al*. (2009) surveyed slurry contaminated soil with a metabolic function, using data enveloping analysis (DEA) and Taguchi design of experimental methodology (DOE).

In this paper the main purpose is to determine the effective factors on yield of rice growing by two methods: classic factorial design and Taguchi method. The paper is organized as follow: in Section 2 the case study is defined and the gathered data is given. Section 3 is dedicated to factorial design of our case study and its' analysis. In Section 4 Taguchi method is presented and its' computations are done. Finally, comparisons between two studied approaches and conclusions are proposed in section 5.

2. The Data:

The field experiments are conducted during the 2008-2009 growing season (spring and summer) at the experimental farm of Guilan research institute of rice (Rasht, Iran). To perform experiments, the field is divided to three main parts and each main part is divided to two subsets and finally, each subset is divided to four blocks. So we have 24 parts at all. The reason of this categorization will be described later. In the first step, field is divided into three parts which are different in time of adding fertilizer. Next category is for using barley stubble or not which causes two subsets for each of above parts. Finally, last categorization is performed due to four different levels of nitrogen fertilizer. Fig.1 better shows the procedure of grouping the main filed. We apply four kind of variables in this study which are explained as follow:

1. Response variables: In this paper we consider the weight of thousand seeds as a response variable which is surveyed by changes in controllable factors. Measuring response variable is done after harvesting and with digital scales. The higher weight of seed means that the crop is more nutritional. So, the variable is Larger-the better (LTB).
2. Controllable variables: By surveying these variables, effects of them on responses are computed. In this study, three controllable variables are selected. One important factor is using fertilizer. Moreover, amount of fertilizer and time intervals between using fertilizer are very important. The levels of time intervals are mentioned by three values: 10 days after planting, 20 days after planting, 30 days after planting. Volume levels of nitrogen fertilizer are mentioned by values: 0 kg in 10000 square meters, 50 kg in 10000 square meters, 100 kg in 10000 square meters, 150 kg in 10000 square meters. Using barley stubble as supplementary is another controllable variable.
3. Fixed variable: These factors are constant during the experiments and effect of them is equal for each experiment. The climate and agricultural machine are fixed variables in our study.
4. Nuisance factor: These variables are uncontrollable or in some cases experimenter does not interest in controlling them. There may be different value of organic materials or soil PH in different parts of our

experimental farm but studying the effect of these factors isn't important in our study. So, in order to eliminate the effect of unknown nuisance factors on the results of our experiments, random sampling is used and also three replicates are performed for each experiment.

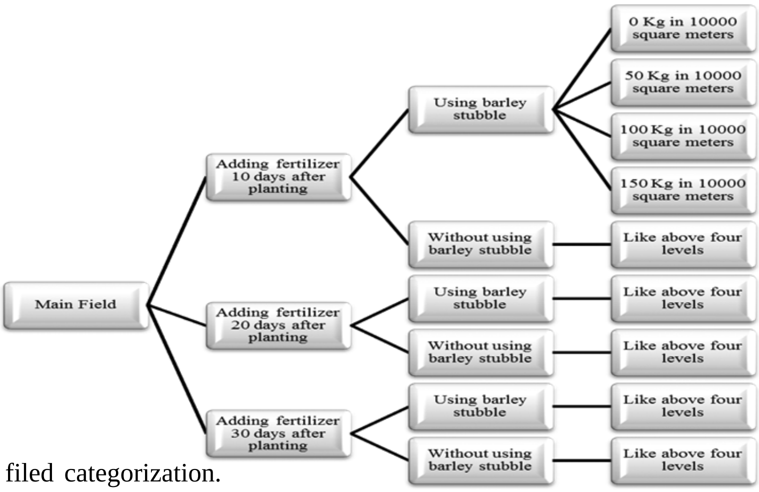

Fig. 1: Procedure of filed categorization.

Table.1 shows the results of performing experiments and the response variable which is weight of 1000 seeds. It is notable that all possible combinations for designing experiments are performed during the field study, but performing all of these experiments and analyzing them is so time consuming. So, the screening experiments are done to survey the effect of each factor on the response variable and obtain the effective factors in our study.

Table l: Experimental results.

Time of adding fertilizer	Using barley stubble	Amount of fertilizer	Replicate 1	Replicate 2	Replicate 3
10	Yes	0	24.5	24.8	24.2
10	Yes	50	22.5	22.7	22.3
10	Yes	100	22.1	22.3	21.7
10	Yes	150	20	20.3	19.7
10	No	0	23.8	24	23.6
10	No	50	23.1	23.4	22.8
10	No	100	21.7	22	21.4
10	No	150	14.9	15.2	14.6
20	Yes	0	20	20.2	19.6
20	Yes	50	18.8	19.1	18.5
20	Yes	100	17.7	17.9	17.4
20	Yes	150	16.6	16.9	16.4
20	No	0	18.8	19	18.6
20	No	50	19.6	19.8	19.3
20	No	100	17.1	17.3	16.8
20	No	150	15.8	16	15.5
30	Yes	0	19.7	20	19.4
30	Yes	50	20.2	20.5	19.9
30	Yes	100	17.7	18	17.3
30	Yes	150	15.5	15.8	15.1
30	No	0	18	18.4	17.7
30	No	50	18.7	19	18.4
30	No	100	16.8	17.1	16.4
30	No	150	15.4	15.7	15

3. Screening Experiments and Factorial Design:

After defining variables, in this section, we apply factorial design as a classical experimental design. In this model besides main effects, 2-way interactions and 3-way interactions are possible. The reason is shown in results of adequacy for supposed model. Now, as each treatment in this experiment has three replicate and total numbers of the experiments are 72, before analyzing by factorial design we use screening experiments in order to determine which parameters are effective. In order to perform screening experiments, for each controllable factor, two levels are mentioned. Finally, we have eight experiments in three replicates. Screening design of experiments and the response value for each design are shown in Table.2.

Table 2: Screening experiments results

	Time of adding fertilizer	Using barley stubble	Amount of fertilizer	Replicate 1	Replicate 2	Replicate 3
Experiment 1	10	Yes	0	24.5	24.8	24.2
Experiment 2	10	No	0	23.8	24	23.6
Experiment 3	10	Yes	150	20	20.3	19.7
Experiment 4	10	No	150	14.9	15.2	14.6
Experiment 5	30	Yes	0	19.7	20	19.4
Experiment 6	30	No	0	18	18.4	17.7
Experiment 7	30	Yes	150	15.5	15.8	15.1
Experiment 8	30	No	150	15.4	15.7	15

Performing ANOVA on Table.2 results that all surveyed factors are effective on the response variable. It is necessary to mention that we use the confidence level of 95% in all of our experiments. So, lower than 0.05 P-Values show the effectiveness of a factor on the response variable. Detailed process of ANOVA is presented in Table.3. Due to above explanations the effectiveness of all factors on response variable is obvious.

Table 3: Analysis of variance for obtaining the effective factors

Source	DF	Seq. SS	Adj. MS	F	P-Value
Time of using fertilizer	1	80.3	80.3	40.31	0
Using barley stubble	1	21.47	21.47	10.78	0.004
Adding nitrogen fertilizer	1	154.53	154.53	77.57	0
ERROR	20	39.84	1.99		
Total	23	296.15			

So as it is clear, all factors should be considered for more analysis. Table.4 shows the results of factorial design analysis. Also, existense of 2-way and 3-way interactions are surveyed in Table.4.

Table 4: Factorial design analysis

Source	DF	Seq. SS	Adj. MS	F	P-Value
Main Effects	3	394.47	131.49	79.39	0
2-way Interaction	3	13.27	4.42	2.67	0.055
3-way Interaction	1	14.16	14.16	8.55	0.005
Residual Error	64	106	1.65		
Lack of fit	16	101.9	6.36	74.56	0
Pure Error	48	4.1	0.08		
Total	71				

Analysis of adequacy must be done to determine that proposed factorial model is suitable for performed experiments datas or not. Fig.2 illustrates that our datas follow normal distribution and the residuals don't show a specific trend.

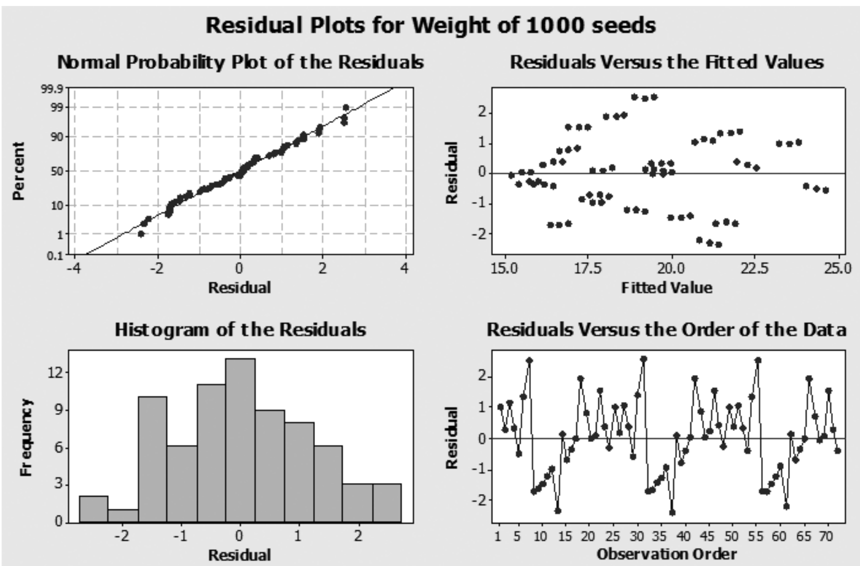

Fig. 2: Adequacy test of ANOVA model.

As it is obvious in Fig.2, all residuals have a normal dispersion and there is not a trend or outlier data in any of four graphs. In this model R-square = 79.92 % and R $^{(adj)}$-square = 77.72 % which are suitable values for model adequacy. These values confirm the coverage of about 80% of variations of model and about 20% of variations return to the factors which are not considered in presented model. To better analyze the model, the equality hypothesis of residual variances is surveyed by Bartlett's test and P-value confirms that the equality hypothesis is satisfied. Fig.3 demonstrates the result of equality hypothesis graphically.

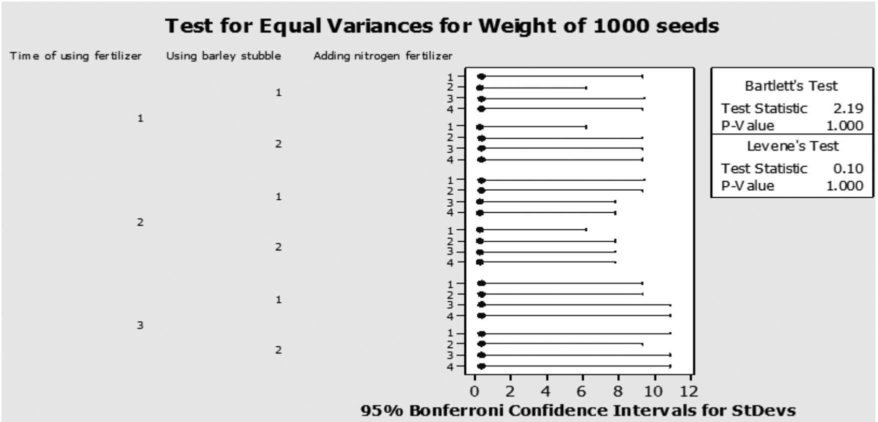

Fig. 3: Bartlett`s test result for equality test of residuals.

Until now, all the computations are about adequacy of the model and if the factors are effective or not, but these computations don't present any information about the optimal levels of any effective factors. Now, it is possible to obtain the optimal level of each factor due to proving the adequacy of presented model. To obtain best level of each factor the interaction plot must be used as Fig. 4.

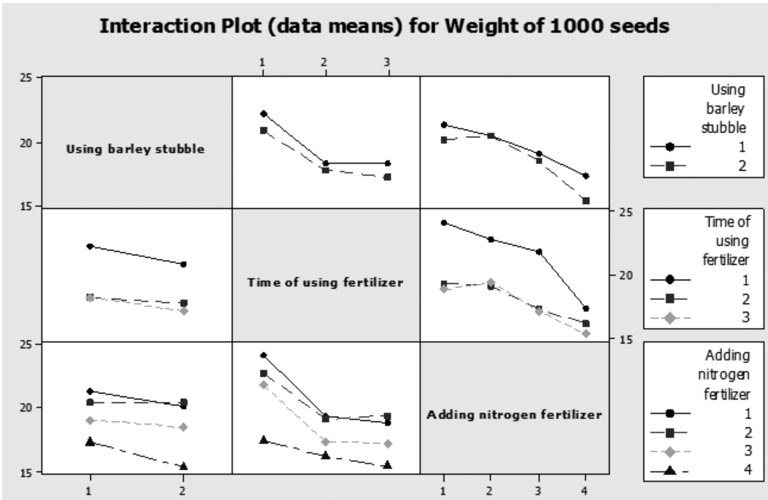

Fig. 4: Interaction plot.

As it is illustrated in Fig.4, best response is obtained while all factors are in their lowest level. More specifically, largest weight of 1000 seeds is obtained by using barley stubble and using no fertilizer. To better analyze this model, regression model can be computed and response surface can be analyzed by optimization methods.

4. Taguchi Method:

One important factor in design of experiment is number of performing experiments and also cost of performing them. In some cases, the constraint of experiments number is very important and maybe performing all experiments would not be possible. Therefore, professor Taguchi proposed some designs that reduce the number of experiments and consequently cost of performing experiments. These designs often focus on factors with same levels. So, we use the related design to screening experiments for three bi-level factors.

In the context of Taguchi design experimentation, suppose there are *m* experimental trials, and in each trial, quality losses of a set of *p* response variables are measured. Therefore, $L_{m\times p}$ will be the experimental data set. Taguchi [11, 12] categorized the response variables into three different types: the smaller the better, the larger the better, and nominal the best. The formulae for computing quality loss (Lij) for *j*th response corresponding to *i*th trial (i=1,2,..., m; j=1, 2,...,p) is different for different types of response variables and is computed through equations (1) to (3):

For smaller the better; $$L_{ij} = (\frac{1}{n}\sum_{k=1}^{n} y_{ijk}^2) \qquad (1)$$

For larger the better; $$L_{ij} = \frac{1}{(\frac{1}{n}\sum_{k=1}^{n} y_{ijk}^2)} \qquad (2)$$

For nominal the best; $$L_{ij} = (\frac{s_{ij}^2}{\bar{y}_{ij}^2}) \qquad (3)$$

Where, $\bar{y}_{ij} = \frac{1}{n}\sum_{k=1}^{n} y_{ijk}$ and $s_{ij}^2 = \frac{1}{n-1}\sum_{k=1}^{n}(y_{ijk} - \bar{y}_{ij})^2$.

n represents the number of repeated experiments, y_{ijk} is the experimental value of the *j*th response variable in *i*th trial at the *k*th replication, and L_{ij} is the computed quality loss for the *j*th response in *i*th trial.

However, the first quality losses are transformed into *SN* ratios. The *SN* ratio value (η_{ij}) for *j*th response in *i*th trial can be computed using the equation (4):

$$\eta_{ij} = -10\log_{10} L_{ij} \qquad (4)$$

The SN ratio is always expressed in decibel (*dB*) unit. On the other hand, since *log* is a monotone function, minimization of quality loss is equivalent to maximization of *SN* ratio.

In screening experiments, we presented three replicates for eight experiments, but for Taguchi design, four experiments are used for three bi-level factors. These experiments are shown in Table.5.

Table 5: Taguchi design experiments.

	Time of adding fertilizer	Using barley stubble	Amount of fertilizer	Replicate 1	Replicate 2	Replicate 3	Average	SNL
Experiment 1	10	Yes	0	24.5	24.8	24.2	24.5	27.78
Experiment 2	10	No	150	14.9	15.2	14.6	14.9	23.46
Experiment 3	30	Yes	150	15.5	15.8	15.1	15.46	23.78
Experiment 4	30	No	0	18	18.4	17.7	18.03	25.11

Since we want to maximize the value of response variable, *SNL* should be calculated. These values are computed in Table.5 and the effect of each factor is computed in Table.6.

Table 6: Effect of factors by Taguchi method

	Time of adding fertilizer	Using barley stubble	Amount of fertilizer
Effect of factor	-1.17	-1.49	-2.83

Using Table.5 and Table.6 it is possible to obtain the *SNL* estimating equation (5):

$$SNL = 25.03 - 0.58\times(time\,of\ adding\ fertilizer) - 0.74\times(u\sin g\,barley\,stubble) - 1.41\times(amount\,of\ fertilizer) \qquad (5)$$

SNL values should always be maximized due to Taguchi logic. So, all controllable variables in our study must be in their lowest value in order to maximize the *SNL* function. This result is as same as Section 3 despite of using a experimental design with less number of experiments. It is notable that the coefficients which are used in equation (5) are obtained from Tables 5 and 6. The constant coefficient 25.03 is the mean value of *SNL* values in Table.5. Other three coefficients 0.58, 0.74 and 1.41 are half of values in Table.6. The logic of calculating these coefficients is more explained in Kackar (1985).

5. Conclusion:

In this study, we surveyed the effect of controllable variables on the weight of thousand rice seeds using two approaches: Factorial design and Taguchi method. After applying these methods, results show that each factor should be at its lowest level in order to maximize the weight of rice seeds. For this study both factorial design and Taguchi method return same results. But Taguchi method needs a fewer number of experiments with lower cost and lower time consumption. So, by applying design of experiments methods simply effective factors are identified and optimal level of factors can be computed. As a future research, comparing other methods of experimental design is suggested. Also, development of this study to a multi response problem could be an attractive subject in the area.

ACKNOWLEDGMENT

The authors would like to thank ETKA Center of Advanced Science and Technology for financial and spiritual supports during the research process.

REFERENCES

Alley, M.M., D.E. Brann, J.L. Hammons and W.E. Baethgen, 1999. Nitrogen Management for Winter Wheat: Principles and Recommendations. Crop and Soil Environmental Sci., 424-429.

Barrozo, M.A.S., C.A.S. Felipe, A.F. Lacerda and M.H. Lisboa, 2005. Analysis of Soybean Seed Quality Related to Drying in Parallel Flow Sliding Bed. Seed Sci. Technol., 33: 675-685.

Chen, X.M., D.D. Kitts, 2008. Determining conditions for nitric oxide synthesis in Caco-2 cells using Taguchi and factorial experimental designs, Analytical Biochemistry, 381: 185-192.

Kackar, R.N., 1985. Off-line quality control, parameter design and the Taguchi method. J Qual Technol., 17: 176-188.

Madamba, P.S., 2002. The Response Surface Methodology: An Application to Optimize Dehydration Operations of Selected Agricultural Crops. LWT. Food Sci. Technol., 35: 584-592.

Madamba, P.S. and F.A. Liboon, 2001. Optimization of the Vacuum Dehydration of Celery (Apium graveolens) Using the Response Surface Methodology. Drying Technol., 19: 611-626.

Madamba, P.S. and R.I. Lopez, 2002. Optimization of the Osmotic Dehydration of Mango (Mangifera indica L.) Slices. Dry. Technol., 20: 1227-1242.

Mohan, S.V., B.P. Reddy, P.N. Sarma, 2009. Ex situ slurry phase bioremediation of chrysene contaminated soil with the function of metabolic function: Process evaluation by data enveloping analysis (DEA) and Taguchi design of experimental methodology (DOE), Bioresource Technology, 100: 164-172.

Mullen, K. and D.M. Ennis, 1979. Rotatable Designs in Product Development. Food Technol., 33: 74-80.

Wiersma, D.W., E.S. Oplinger and S.O. Guy, 1986. Environment and Cultivar Effects on Winter Wheat Response to Ethephon Plant Growth Regulator. Agron. J., 78: 761-764.

Zhang, M., C. Li, X. Ding and C.W. Cao, 2003. Optimization for Preservation of Selenium in Sweet Pepper under Lowvacuum Dehydration. Dry. Technol., 21: 569-580.