The factors affecting time series fluctuations of pistachio yield

Mohammad Abdolahi-Ezzatabadi (PhD)[1*], Ali Esmaeilpour (PhD)[1] , Reza Sedaghat (PhD)[2] , Bahman Panahi(PhD)[2]

[1]*Assistant Professor of Pistachio Research Center, Horticultural Sciences Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Rafsanjan, Iran*

[2]*Associate Professor of Pistachio Research Center, Horticultural Sciences Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Rafsanjan, Iran*

Information

Article Type:
Original Article

Article History:

Received: 05.01.2021
Accepted: 25.03.2021

Doi: 10.22123/phj.2021.279568.1089

Keywords:
Pistachio
Yield fluctuations
Orchard management
Natural hazards

Corresponding Author:
Mohammad Abdolahi-Ezzatabadi

Email: abdolahi@pri.ir

Tel: +98-9131917728

Abstract

Introduction: One of the issues in pistachio orchards is the wide range of fluctuations of crop yield in different years. These fluctuations have resulted in different yield of dry crop per hectare in different years. Thus, the two indicators i.e. pistachio yield average and pistachio yield fluctuations are effective in creating a suitable and reliable income for farmers; it is important to identify the factors affecting these two indicators.
Materials and Methods: In this study, by using 9-year-old data (2010-2018) of 286 pistachio orchards from 4 commercial pistachio cultivars; Ahmad Aghaei, Akbari, Kaleghoochi, and Ohadi in two cities i.e. Anar and Rafsanjan in Kerman province, it was attempted to investigated different factors affecting time series fluctuations of pistachio yield. In this regard, two indices i.e. coefficient of variation and probability of yield loss to less than long-term average, 1000 kg of dry pistachio per hectare, were used.
Results: In terms of crop yield's coefficient of variation, Ohadi (cultivar) had the least fluctuation, Kaleghoochi showed the highest fluctuation, and Akbari and Ahmad Aghaei were reported to have an average fluctuation. As for probability of crop yields falling to less than a certain level of yield (1000 kg per hectare), Ahmad Aghaei had the lowest risk, Akbari had the highest risk, and the two other cultivars, Ohadi and Kaleghoochi, were reported to have an average level of risk. The management factors affecting the pistachio yield fluctuations include: water quality and quantity, irrigation time and system; type, quantity and time of the fertilizers consumed; number, quality, time, and dose of pesticides; and pruning. Pistachio spring frost damage resulted in increased crop yield fluctuation in all cultivars, and lack of chilling requirement had significant effect on crop loss only in Akbari cultivar i.e. it did not affect other cultivars.
Conclusion: Factors such as pistachio cultivar, soil and water quality, climatic conditions, and pistachio orchard management affect two indices i.e. pistachio yield average and pistachio yield fluctuations over different years. This has made it impossible to estimate a specific order, including biennial bearing cycles, in the time series fluctuations of pistachio yield.

►Please cite this article as follows:

abdolahi-Ezzatabadi A, Esmaeilpour A, Sedaghat R, Panahi B. The factors affecting time series fluctuations of pistachio yield. Pistachio and Health Journal. 2021; 4 (1): 30-50.

1. Introduction

One of the main issues in pistachio orchards is the wide range of crop yield fluctuations in different years. These fluctuations have resulted in different yield of dry crop per hectare in different years. This has created numerous problems for both farmers and the Agricultural Insurance Fund; sometimes, for more than two or more years, the unpredictable fluctuations in crop yield make the farmers face low yields, and this makes them not even afford the current expenditures of their orchards. This has also increased the insurance premium of this crop; in some cases, the insurance premium is impossible to be paid by pistachio growers. Moreover, in high-risk years, the Agricultural Crops Insurance Fund is faced with a large number of gardeners whose damages are required to be compensated; this brings about numerous financial problems for the fund [1].

As for crops such as pistachios that have biennial bearing, in addition to crop production fluctuations arising from biennial bearing having genetic origins, there are changes in natural factors (climatic conditions) as well. In addition, orchard management can also affect the fluctuations of pistachio yield over time. For example, using a specific nutritional pattern not only affects the average yield but it can also influence the yield variance of pistachio crop per hectare over time [2]. Thus, determining the contribution of each of the three factors including genetic, natural and managerial factors is of high significance. The natural hazards factor is required to be managed by insurance and the use of related technologies. In terms of rules, genetic factors can be managed by selecting and changing the appropriate rootstock and cultivar. The garden management factor cannot be covered by insurance. In other words, the pattern of coping with each of these three phenomena is different [1]. Therefore, determining the significance of each of the three factors can guide planners and policy makers to determine future plans. In addition, by identifying appropriate management patterns and introducing them to gardeners, it is likely to decrease the yield fluctuations arising from orchard management.

Various studies have been conducted in different areas on the factors affecting the fluctuations of pistachio yield. Given the importance of delay in flowering in pistachio-rich regions of Iran, in order to prevent the risk of spring frosts, the date of flower opening can be adjusted by using paclobutrazol [3]. In Semnan province, Abbas Ali cultivar is the most resistant and Shahpasand cultivar is the most sensitive one to spring frost, and Khanjari cultivar is semi-resistant [4]. Due to the annual phenomenon of biennial bearing, the long-term average yield of pistachio crop per hectare is not affected by spring frost, yet it results in the increased risk of yield. Moreover, the results of the aforementioned study indicated that in the presence of the biennial bearing and the absence of increase in average yield (due to the application of frost control tools), there will not be sufficient willingness to use this tool. In such conditions, applying different plants such as crop insurance is recommended to eliminate all income fluctuations arising from frost and biennial bearing at the same time [5].

As for role of pistachio cultivars and rootstocks, different studies have indicated that khinjuk rootstock (Pistacia khinjuk) is less resistant to frost than Atlantica rootstock (*Pistacia atlantica*) [6]. Different cultivars of pistachio have different biennial bearing intensities. The biennial bearing intensity is high in Ahmad Aghaei, Sefid Peste Nough, and

Fandoghi cultivars, and it is low in Jandaghi, Shah Pasand and Italian cultivars. The biennial bearing intensity is average in Kaleghoochi and Ohadi cultivars [7]. Moreover, in another study, it was attempted to introduce and investigate the Iranian and commercial cultivars of pistachio in Faizabad of Khorasan Razavi province, and as many as 5 Iranian cultivars and 11 non-Iranian cultivars. In the aforementioned study, while introducing the history of the cultivars in question, it was attempted to describe other characteristics such as morphology, flowering and fruiting, yield, ecological needs, reaction to salinity, principles of cultivation, and the economic justification of planting for each of the mentioned cultivars [8].

Although extensive studies have been conducted to investigate the role of different management methods on the average yield of pistachio, no study has been yet conducted on their effect on the variance of yield of this crop over time (especially orchard management factors). Moreover, a comprehensive study investigating the time fluctuations of pistachio yield (in three areas of genetics, natural hazards, and management) has not yet been conducted. Thus, the present study can answer different questions in this field.

2. Materials and methods

The data used in the present study are related to 286 pistachio orchards. The data were collected from 2010 to 2018, in three time periods (2012, 2015 and 2018) by using a questionnaire by the Pistachio Research Center. Thus, information about the 9 years of each orchard is available. For the initial selection of the orchards, the samples were selected from the Anar and Rafsanjan in Kerman province in southeastern Iran. The sampling method was multistage random sampling. From the total villages of the two cities mentioned above, a number of samples have been selected by using a random sampling method. In the next stage, from the list of gardeners living in the selected villages, a number of gardeners were selected by applying a random sampling method. The final sample size was measured to be 286. The information in question are provided in the following paragraphs.

To measure yield fluctuations per hectare in the investigated pistachio orchards, we have used the criterion of variance, coefficient of variation, and number of years (9 years of being investigated) in which the yield of dried pistachio orchard is less than the long-term average yield (1000 kg of dry produce per hectare). For this purpose, gardeners were first asked about the yield per hectare of each orchard for 9 consecutive years (2010 to 2018). Using this information, the yield mean and variance per hectare of the pistachio orchard were calculated. Then, by dividing the root of variance (standard deviation) by the mean, the coefficient of variation of each orchard was calculated. This number is the mean change of yield in each orchard in 9 years. The larger the number, the greater the changes and fluctuations.

For each orchard, in addition to information about the yield of the pistachio produce, it was also attempted to collect information about garden characteristics, pistachio cultivar, various inputs used, the presence of lack of natural disasters, different patterns of irrigation management, nutrition, pests, diseases, and breeding operations.

Regarding the measurement of orchard characteristics, the gardeners were asked about soil texture based on their own perceptions and opinions [9]. In this regard, gardeners were asked to classify the soil texture of their orchard into three categories: light, medium and heavy. Water salinity was used according to electrical

conductivity (EC). In order to measure the amount of water consumed annually per hectare of orchard, the gardeners were asked about the number of times and duration of each irrigation cycle. Then the flow trend of the irrigation well used was measured as well. For this purpose, according to the existing conditions, if water was flowing in the pipe, the flow trend measured by using the set square method. Moreover, if the flow was done in the canal, the flow trend was measured using a floating object and the average speed of water movement in the canal and the measurement of the cross-section of the water existing in the canal. Finally, the annual water consumption was calculated in cubic meters per hectare.

For measuring different irrigation management patterns of pistachio orchards, the gardeners were asked about the irrigation method. For example, these patterns include the type of irrigation system used, the quality of water used, the amount of water used, the time of water used, deficit irrigation pattern, the pattern of water distribution in the orchard, the area of irrigation plots, and the width of the strips.

To measure the different management patterns of pistachio orchards, the gardeners were asked about nutritional methods used. For example, these patterns include using only chemical fertilizers, using only animal fertilizers, using both chemical and animal fertilizers, and foliar application. Moreover, using a special type of fertilizer can be conducted in different methods i.e. spraying, soil drench, and injection; this is likely to increase the number of nutrition management patterns. The selected method is based upon the diagnosis stage and analysis of the current status of orchard nutrition management in the food monitoring model [10].

To measure different management models of pest control in pistachio orchards, the gardeners were asked about different pest control methods they had applied. For example, these patterns include the use of pesticides according to the classification of insecticides, herbicides, etc., the use of pesticides at different times, the number of pesticides used, and the use of other pest control methods (agricultural, biological, and physical). In each of the models used, the gardeners were also asked about factors such as cost and crop yield. The selected method is based on the model used in the study conducted by Vitonde et al [11].

As for disease management, the gardeners were also asked about various methods of controlling diseases in the investigated pistachio orchards. Moreover, they were asked about breeding operations including pruning as well.

To investigate the effect of various factors including pistachio cultivar, natural disasters, and various management patterns on crop yield fluctuations, three methods have been used: correlation coefficient, analysis of variance, and regression function.

To calculate the biennial bearing intensity of different pistachio cultivars, the following formula was applied [12].

$$I = \frac{1}{n-1}\left(\frac{a2-a1}{a2+a1} + \frac{a3-a2}{a3+a2} + \cdots + \frac{an-an-1}{an+an-1}\right)$$

In this formula, I represents the biennial bearing index, n represents the number of years the crop has existed, and a represents the amount of crop in each year. The closer the numerical value biennial bearing index (I) is to zero, the lower the biennial bearing of the cultivar. Moreover, the closer this index is to number one, the higher biennial bearing intensity of the cultivar.

3. Results

Table 1 shows the time trend of crop yields of the studied pistachio orchards over 9 years from 2010 to 2018. As the results of this table indicate, it is not possible to determine a specific trend for changes in the average yield over 9 years in the investigated orchards. From among the 9 years investigated, 2014 and 2017, with a yield of more than 1600 kg per hectare per year, accounted for the highest production. Also, following 2014, in 2015, a relatively good yield of 1222 kg has been recorder. However, following 2017, in 2018, a very low yield of 73 kg per hectare per year was recorded; this sharp decrease of yield was owing to excessive temperature rise in March and April exactly when male and female trees of different cultivars started flowering. Of the total 9 years investigated, the crop yield is less than the average 9-year yield in years (2011, 2012, 2016 and 2018). Out of these four years, in 2011 and 2012, the rainfall rate was extremely low in Anar and Rafsanjan. According to the statistics released by the Meteorological Department of the aforementioned cities, in 2010-2011 crop year, the annual rainfall in Anar and Rafsanjan were 32 and 54 mm, respectively, and in 2011-2012 crop year, it was 5 and 41 mm, respectively. In 2016, spring frosts occurred, and in 2018, there was heatstroke and chilling requirement was not met. Generally speaking, it can be stated that the non-uniformity of pistachio orchards in terms of creating “on” and “off” years, on the one hand, and the effects of climatic factors on the other hand, has made it impossible to extract the biennial bearing cycle from the average garden yield. Table 1 also indicates that the minimum yield of the investigated pistachio orchards is zero in all years. However, maximum yield varies from year to year. Out of the total 9 years investigated, 5 years indicated a maximum yield in the range of 7000 kg per hectare per year.

Table 1: Time trend of crop production in the investigated pistachio orchards (kg per hectare per year)

Year	Minimum yield	Mean Yield	Maximum yield	Standard deviation of yield
2010	0	1307	6666	1289
2011	0	988	12000	1257
2012	0	1029	7200	1228
2013	0	1300	7000	1219
2014	0	1626	8400	1489
2015	0	1222	7500	1289
2016	0	1054	7500	921
2017	0	1633	7200	1517
2018	0	73	3800	365
Nine-year mean	83	1166	4438	845

Table 2 compares the mean yield per hectare of crop in the investigated pistachio orchards between 4 commercial pistachio cultivars (Ahmad Aghaei, Akbari, Kaleghoochi and Ohadi). The last row of this table indicates that Ahmad Aghaei cultivar has the highest yield compared to the other 3 cultivars. Akbari, Kaleghoochi and Ohadi cultivars have an equal nine-year-yield. Investigating the trend of yield changes over a nine-year period indicates that only Ohadi cultivar has an approximate biennial bearing rhythm. As it is known, in Ohadi cultivar, each "on" year is followed by one "off" year. However, this trend is disrupted in 2016. The reason for this is the occurrence of spring frost this year. This means that 2016 was not a high-yield year, and instead it was a low-yield one. The existence of two low-yield years (2015 and 2016) resulted in the dramatic increased yield of Ohadi pistachio in 2017. This high yield in 2017, as well as unfavorable weather conditions in 2018, resulted in the decreased yield of Ohadi pistachio in this year. Generally speaking, it can be said that if there had not been a spring frost in 2016 and there had not been a heatstroke in 2018, Ohadi pistachio crop would have experienced a complete biennial bearing cycle.

For further investigation, the time trend regression of crop yield of different cultivars was estimated. In this regression, this year's crop yield variable was a function of last year's yield and 1/0 weather conditions variable. The weather conditions variable in 2016 and 2018 was set to be one. Estimating this regression function for the four cultivars indicated that it is significant only for Ohadi cultivar. In other words, only Ohadi cultivar shows the biennial bearing. The estimated regression results for Ohadi cultivar are given in Equation 1.

$$Y_t = 2290.17 - 502.07\text{weather} - 1.05Y_{t-1}$$ Equation 1

7.49(0.001) -2.87(0.035) -3.86(0.012)

$R^2 = 0.86$ adjust $R^2 = 0.81$ $F = 15.88$ (0.007)

In equation 1, Y_t and Y_{t-1} respectively show the Ohadi pistachio yield of the current year and previous one. "weather" indicates the weather conditions; if the conditions are favorable, it is zero and, if the conditions are unfavorable, it is one. The numbers written below the coefficients represent the t-statistic and the numbers in parentheses indicate the significance level of the t-statistic. As it is clear, all coefficients are significant at the level of 5% and less. Moreover, F-statistic is significant at the level of one percent. The adjusted R^2 and R^2 values are 81% and 86%, respectively; this shows a good index of regression estimation. The negative sign of last year's yield variable indicates that this year's yield is inversely to last year's yield. If last year's yield was high, this year's yield will be low and vice versa. In Formula 1, if we replace Y_{t-1} with biennial bearing yield, it will indicate how "off" year will be like in both good and bad weather conditions. For example, if the yield of the crop in the "on" year is 1500 kg per hectare, the yield of the "off" year will be 715 kg per hectare in favorable weather conditions and 213 kg per hectare in unfavorable conditions. Moreover, if we replace the Y_{t-1} with the yield of the "off" year, it will indicate what the "on" year will be like in both good and bad weather conditions. For example, if the yield of "off" year is 500 kg per hectare, the yield of the "on" will be 1765 and 1263 kg per hectare in good and bad weather conditions, respectively.

Table 2: Comparison of the mean yield of 4 commercial pistachio cultivars in the investigated orchards (kg per hectare per year)

Year	Ahmad Aghaei	Akbari	Kaleghoochi	Ohadi	Significance level F statistic
2010	1576	1288	1156	1245	0.405
2011	1123	1213	764	939	0.196
2012	1343	1013	760	1138	0.048
2013	1556	1359	1190	1069	0.198
2014	2257	1560	1450	1256	0.003
2015	1777	829	1298	791	0.000
2016	1074	1325	1058	859	0.131
2017	1960	923	1667	1735	0.008
2018	104	29	80	72	0.798
Nine-year mean	1435	1011	1139	1072	0.253

Table 3 compares the yield changes of 4 commercial pistachio cultivars. The first row of this table (mean yield) indicates an index of average pistachio production, regardless of changes and production time risk. As it is clear, based on this index, Ahmad Aghaei cultivar is superior to the other three cultivars, and the other three cultivars i.e. Akbari, Kaleghoochi , and Ohadi are not significantly different in this regard. The second and third rows represent the changes in pistachio production. The coefficient of variation is calculated by dividing the standard deviation by mean. Moreover, the third row represents the number of years out of 9 years in which each garden has a yield below the mean yield. If no factor affects yield other than biennial bearing, this number must be 4.5. In other words, the yield is less than mean 9-year yield in half of the years, and it is higher in the other half. These two variables represent changes in production and indicate the risk and time fluctuations of pistachio production. As it is evident, in this regard, Ohadi cultivar has the lowest risk and production fluctuations; it enjoys a lower risk compared to other cultivars.

In this regard, Ahmad Aghaei and Akbari cultivars are average; they have nearly the same risk. However, Kaleghoochi cultivar with the highest coefficient of variation, and the highest number of years of having a yield below the 9-year mean, represents the highest production risk. The last row of Table 3 indicates both the mean index and production changes. 1000 kg has been considered as the mean long-term yield

of pistachio cultivars in the investigated area. This yield can be used as one of the indicators to determine the guaranteed yield in the insurance plan of pistachio. The index of the number of years in which the crop yield is below 1000 kg indicates two criteria. The first criterion is the mean crop yield and the second criterion is time changes or production risk. Thus, the crop yield of cultivars with fewer years of experiencing 1000 kg are less likely to suffer from damages; it will thus be less likely to receive compensation from insurance funds.

As the last row of Table 3 indicates, Ahmad Aghaei cultivar is the best one in terms of the probability of crop fall (to less than 1000 kg). It can be observed that in 48% of the years, the yield of this cultivar is less than 1000 kg, and in 52% of the years, it is more than 1000 kg. In this regard, Akbari cultivar has the highest risk of crop fall compared to the yield of 1000 kg. As can be seen, in 64% of the years, it is less than 1000 kg, and in 37% of the years, it is more than 1000 kg. Kaleghoochi and Ohadi cultivars are average in terms of crop fall.

In such conditions that environmental factors and climatic conditions can largely affect crop yield, cultivars sensitive to environmental factors are not able to provide biennial bearing annuals. The calculation of biennial bearing by using the formula of biennial bearing intensity [12] indicated that that biennial bearing is not significantly different in the 4 commercial cultivars investigated. The biennial bearing calculated with this formula for Ohadi, Kaleghoochi , Akbari, and Ahmad Aghaei cultivars were 0.1, 0.09, 0.14 and 0.1, respectively. Thus, using this formula is useful only in conditions where the pistachio plant is safe from damages caused by natural factors; it enjoys normal climatic conditions.

Table 3: Comparison of 9-year yield changes of pistachio in 4 commercial pistachio cultivars

Variable	Ahmad Aghaei	Akbari	Kaleghoochi	Ohadi	Significance level F statistic
9-year mean (kg per hectare per year)	1435	1011	1139	1072	0.253
9-year coefficient of variation (percent)	83	85	94	77	0.038
The number of years with a mean yield below the long-term mean yield (out of nine years)	5.18	5.19	5.29	5.13	0.937
The number of years with a yield below 1000 kg (out of nine years)	4.30	5.81	5.45	5.70	0.094

Tables 4 and 5 presents different management factors affecting the coefficient of variation of pistachio yield (the mean of 4 commercial cultivars i.e. Ahmad Aghaei, Akbari, Kaleghoochi and Ohadi). In these two tables, the correlation coefficients are significant at the level of 10% and less. Moreover, only variables whose difference is significant at the level of 10% and less are presented in Table 5. In other words, it has been avoided to present variables that were not statistically significant.

As Table 4 indicates, the amount of water consumed per hectare per year is one of the influential variables. As the water consumption increases, the coefficient of variation of pistachio yield decreases. As it is evident, increasing the amount of water consumed results in the increase of both mean and standard deviation of crop yield, yet the increase rate of mean yield is larger than the increase rate of standard deviation. This causes the coefficient of variation to decrease overall. In other words, increasing water consumption per hectare reduces production fluctuations of the crop. Another variable that is significant in Table 4 is irrigation cycle. The longer the interval between irrigations, the higher the coefficient of variation of the yield. As it is evident, increasing the irrigation cycle reduces the mean and standard deviation of yield, yet the decrease rate mean yield is larger than the decrease rate of standard deviation, and it will ultimately increase the yield's coefficient of variation. In general, it can be stated that increasing the irrigation cycle will result in increased production fluctuations.

The results of Table 4 indicate that increasing the number of pesticides increases its standard deviation without affecting the mean yield of the crop, and as a result, it will increase the coefficient of variation. This indicates that if instead of consuming a few quality pesticides, the strategy of consuming a variety of low quality pesticides is followed, the damages caused by pistachio pests will increase; the production risk will increase as well. Table 4 also indicates that the amount of pesticide consumption in each spraying time (for fighting with pistachio pests) is negatively related with the coefficient of variation. In other words, the higher the dose of the pesticides, the higher the mean and standard deviation of the yield. However, the increase rate of mean is larger than the increase rate of standard deviation, and the coefficient of variation has thus decreased. In other words, the denominator of the fraction has increased more than the numerator of the fraction, and the coefficient of variation (standard deviation divided by the mean) has thus decreased. This generally shows that the average dose of pesticide to control the pests is less than the average dose recommended by experts. This is conducted to reduce the cost of pest consumption. However, consuming a lower dose of pesticide (which is less than the recommended dose) has increased the risk of crop production.

Table 4: Correlation coefficient between management variables and 9-year coefficient of variation, mean, and standard deviation for pistachio yield

Management variable	Correlation coefficient between 9-year coefficient of variation of crop yield and management variables	Correlation coefficient between 9-year mean of crop yield and management variables	Correlation coefficient between 9-year standard deviation of crop yield and management variables
Water consumption (cubic meter per hectare per year)	-0.223	+0.349	+0.263
Irrigation cycle	+0.264	-0.308	-0.222
The number of pesticides to control pistachio psylla	+219	-	+0.153
The amount of pesticide used at each pesticide spraying time to control the pistachio pests (liter of pesticide in 1000 liter of water)	-0.258	+0.321	+0.234

As Table 5 shows, using pressurized irrigation systems reduces the coefficient of variation and this will thus reduce the production risk. As it is evident, using pressurized irrigation systems increases both mean and standard deviation of yield in comparison to traditional irrigation system. Since the increase of yield mean is larger than the increase of standard deviation, the overall coefficient of variation decreases. In Table 5, the two variables of how cattle and poultry manures are consumed over time in pistachio orchards are significant. In conditions where both poultry and cow manures are consumed every year, the mean and standard deviation of crop yield increases, yet the rate of increase of the mean is larger than that of the standard deviation. This will thus reduce the yield coefficient of variation. In other words, consuming these two fertilizers every year reduces the production risk. In other words, for a certain amount of cattle and poultry manures, it is better that they are consumed annually rather than being used every other year.

The last two rows of Table 5 confirm that gardeners who are familiar with the pistachio chain pest and have used non-chemical methods to control pistachio twig borer moth (Kermania pistaciella) have a lower yield coefficient of variation. This has been done without affecting the mean yield and only by reducing the standard

deviation of the yield. In general, it can be stated that a better pest management has less effect on the mean crop; it is more likely to reduce the risk of pistachio production.

Table 5: Comparison of mean coefficient of variation, mean and standard deviation of 9-year pistachio crop yield; two different types of management

Management variable	9-year coefficient of variation of crop yield (percentage)		9-year mean of crop yield (kg per hectare per year)		9-year standard deviation of crop yield (kg per hectare per year)	
	When the management variable is zero	When the management variable is one	When the management variable is zero	When the management variable is one	When the management variable is zero	When the management variable is one
Pressurized irrigation system is used	87	71	1091	1927	896	1292
The annual consumption of poultry manure	93	80	1151	1677	991	1241
The annual consumption of cattle manure	88	76	990	1849	834	1338
Being familiar with pistachio *Idiocerus stali*	107	82	-	-	1295	879
Non chemical method of controlling pistachio twig borer moth (Kermania pistaciella)	97	76	-	-	1043	846

In Tables 6 and 7, the effect of different factors affecting the variable of number of years (out of 9 years), -when the crop yield is below 1000 kg-has been investigated as an index of the mean and crop yield risk. In this regard, only variables are presented whose effects on the coefficient of variation (Tables 4 and 5) have not been investigated. For example, the variables related to water management presented the same results as shown in Tables 4 and 5, so they were avoided to be presented here again.

As Table 6 shows, the amount using cattle and poultry manures has a negative effect on the number of years (out of 9 years) when the yield is below 1000 kg. In other words, the higher the amount of these two types of manures per hectare, the less likely it will be that the yield will decrease to less than 1000 kg. Table 6 also indicates that the increased consumption of three chemical fertilizers i.e. nitrogen, phosphate, and potash, reduces the probability of pistachio crop yield fall to less than 1000 kg per hectare per year. Moreover, potash fertilizer is more effective than the other two chemical fertilizers.

Table 6 indicates that as the number of foliar application against pistachio psylla increases, the probability of yield fall of this product (to less than 1000 kg) decreases. In other words, in the years of psylla outbreak, this pest plays an important role in damaging the crop. Table 6 also indicates that the later the spraying against pistachio psylla at the beginning of the year, the higher the likelihood of crop yield fall (to less than 1000 kg). This indicates that delays in controlling psylla are an important factor in intensifying the damage of this pest. In addition, Table 6 indicates that the more knowledge the gardeners have about pistachio pest control, the less likely it is that the crop yield will fall to less than 1000 kg.

Table 6: Correlation coefficient between management variables and the number of years (out of 9 years) when pistachio yield is less than 1000 kg per hectare

Management variable	Correlation coefficient between management variables and the number of years (out of 9 years) when pistachio yield is less than 1000 kg per hectare	Significance level
The amount of consuming poultry manure (ton per hectare per year)	-0.394	0.000
The amount of consuming cattle manure (ton per hectare per year)	-0.329	0.000
The amount of consuming nitrogen fertilizer (kg per hectare per year)	-0.164	0.060
The amount of consuming potash fertilizer (kg per hectare per year)	-0.359	0.000
The amount of consuming phosphate fertilizer (kg per hectare per year)	-0.148	0.088
The number of psylla spraying in one year	-0.370	0.000
Starting psylla spraying at the beginning of every year	+0.246	0.007
The score of controlling pistachio pests (out of 20)	-0.468	0.032

Table 7 indicates that using cattle and poultry manures (in comparison to avoiding their consumption) reduces the likelihood of yield loss of pistachio to less than 1000 kg. As Table 7 indicates, the annual consumption of nitrogen fertilizer and consuming it twice a year will reduce the likelihood of crop yield fall to less than 1000 kg per hectare. In other words, better time distribution and consuming smaller amounts of nitrogen fertilizer reduces the risk and increases the yield of pistachio. Table 7 also indicates that the consumption of potash fertilizer (in comparison to avoiding its consumption) and its annual consumption (in comparison to consuming it every other year) will reduce the likelihood of pistachio crop yield fall to less than 1000 kg. Regarding the usage of micro fertilizers, especially zinc and calcium fertilizers, Table 7 reports that their consumption reduces the likelihood of pistachio crop yield fall to less than 1000 kg per hectare per year. The data in this table also indicate that the controlling spring pistachio pests reduces the likelihood of crop yield fall to less than 1000 kg.

According to the results of Table 7, in pistachio orchards suffering from frost, the likelihood of pistachio crop fall to less than 1000 kg is higher. Table 7 also shows that pistachio orchards that did not have any problems of water scarcity and weather and soil conditions were less likely to experience crop yield fall to less than 1000 kg. In other words, it is not only orchard management issues that can affect the likelihood of pistachio crop fall but other non-managerial factors are effective as well. In addition, Table 7 indicates that the three operations, loading the garden before planting the tress, using soft sand and gypsum can also reduce the likelihood of pistachio crop yield fall to less than 1000 kg.

Table 7: Comparison of the mean number of years (out of 9 years) when pistachio crop yield is less than 1000 kg per hectare; two different types of management

Nutritional management variable	When the management variable is zero	When the management variable is one	F-statistic value	F-statistic significance level
Consumption of cattle manure	7.29	5.09	13.07	0.000
Consumption of poultry manure	6.41	4.77	13.58	0.000
The annual consumption of nitrogen fertilizer	6.36	5.09	5.27	0.023
Consumption of nitrogen fertilizer twice a year	5.70	4.54	5.18	0.025
Consumption of potash fertilizer	5.80	4.95	3.82	0.053
The annual consumption of potash fertilizer	5.53	4.35	3.11	0.083
Foliar spraying of micro elements	6.06	4.59	12.16	0.001
Spraying of zinc fertilizer	5.60	4.43	6.03	0.015
Spraying of calcium fertilizer	5.49	3.95	6.87	0.010
Controlling the spring pests of pistachio	6.89	5.63	6.55	0.002
The orchard suffers from frost	4.46	5.49	3.33	0.070
The orchard doesn't have any problems	5.83	4.67	7.34	0.008
Loading the garden	6.19	4.75	7.31	0.000
Soft sand has been used in the orchard	5.91	4.98	4.17	0.043
Gypsum has been used in the orchard	5.56	4.22	5.58	0.020

The comparison of mean indicated that using Volk oil reduces the yield coefficient of variation only for Akbari cultivar. The coefficient of variation of crop yield for 9 years is 97% in conditions when Volk oil is not used, yet it decreases to 84% in conditions when Volk oil is used; this difference is statistically significant. Further studied indicated that using Volk oil increases the mean and standard deviation of yield, but the rate of increase in mean yield is higher; the coefficient of variation will thus decrease. Volk oil also reduces the likelihood of yield loss to less than 1000 kg. Orchards that did not use Volk oil had a yield of less than 1000 kg during all 9 years of being investigated. This issue shows that in none of the investigated years, the chilling requirements Akbari cultivar have not been met. However, only in 5.39 years (out of 9 years) the yield reached below 1000 kg for orchards using Volk oil. This shows that despite the problems caused by using Volk oil, in the current situation, the production of Akbari pistachio is not possible without using Volk oil. However, the use of Volk oil for other pistachio cultivars did not have a significant effect on the coefficient of variation and the likelihood of yield fall to less than 1000 kg.

As the trees grow older, the likelihood of yield fall to less than 1000 kg increased for Akbari pistachio. The related regression is as equation 2 below:

Num = 2.69 + 0.158Age
Equation 2.

2.69(0.013) 3.36(0.003)

$R^2 = 0.32$ adjust $R^2 = 0.29$ F = 11.31 (0.003)

In Equation 2, Num (number) is the number of years (out of 9 years) during which the yield of Akbari pistachio is below 1000 kg, and Age is the age of Akbari tree. As it is obvious, the coefficient sign of the independent variable is positive. In other words, as the Akbari tree grows older, the number of years it will experience yield fall below 1000 kg will increase. If the dependent variable is replaced by number 9, the age variable of tree is measure to be 40. In other words, if the Akbari pistachio tree is over forty years old, its yield will not exceed 1000 kg. However, the tree age variable has not turned out to be significant for Ohadi, Kaleghoochi and Ahmad Aghaei cultivars; it indicates that Akbari pistachio cultivar reaches old age earlier than the other three cultivars. The two negative characteristics i.e. “failing to meet the chilling requirements” and “early aging” of Akbari pistachio have not stopped the expansion of this cultivar in areas with saline water such as Anar; yet it has increased, and cultivars such as Ohadi and Kaleghoochi are grafted to Akbari. This is owing to two reasons. First, the problem of failing to meet the chilling requirements has been solved by using Volk oil. The second issue is related to the resistance of Akbari cultivar against salinity. In high-salinity waters where the other three cultivars of pistachio do not have economic yield, Akbari cultivar is capable of having economic yield. Thus, its cultivation is recommended in areas with saline water, despite problems such as failing to meet the

chilling requirements and early aging. Therefore, it is recommended not to cultivate Akbari pistachio in fresh water and soil conditions due to the problems mentioned earlier. However, in saline water conditions, Akbari cultivar is the most frequently recommended cultivar among the four commercial cultivars.

In Equation 3, the regression of the effect of water EC on the number of years with a yield of less than 1000 kg has been measured for Kaleghoochi cultivar:

Num = 6.77 – 0.00027Water + 0.00018EC – 0.054Gyp Equation 3.

7.29(0.000) -3.29(0.0002) 2.74(0.010) -2.88(0.007

R^2 = 0.40 adjust R^2 = 0.35 F = 7.55 (0.001)

In Equation 3, Num, Water, EC and Gyp are respectively, the number of years in which the yield of Kaleghoochi pistachio is less than 1000 kg, the amount of water consumed (cubic meter per hectare per year), the electrical conductivity of water (micromhos per centimeter), and the amount of gypsum consumed (tons per hectare per year). The negative sign of the water variable coefficient indicates that as the amount of water consumed increases, the likelihood of the crop fall to less than 1000 kg will decrease. Moreover, by consuming agricultural gypsum, the likelihood of crop yield fall can be reduced as well. However, as water EC increases, the likelihood of crop yield fall increases. If, in Equation 3, the current amount of water consumed (9000 cubic meters per hectare per year) and gypsum are both replaced by zero, and the dependent variable is equal to 9, the water EC will be thus equal to 25000 micromhos per centimeter. In other words, if the water EC is higher than 25000 micromhos per centimeter, it is not possible to produce Kaleghoochi pistachio with a yield of more than 1000 kg per hectare. However, as the volume of water gypsum consumed increase, crop production can be increased to some extent. For example, if in such conditions, 10 tons of gypsum is consumed per hectare in each hectare of a Kaleghoochi pistachio orchard, the yield of the crop will exceed 1000 kg in one year (out of the 9 years).

Statistical analysis indicated that in conditions where a permanent worker is used for pruning, the number of years during which the yield of Ohadi cultivar is less than 1000 kg is 3.83 (out of 9 years). This number is less than 4.5. As it has been mentioned earlier, if no factor other than biennial bearing affects the fluctuations of pistachio crop yield, the number reaches 4.5 (out of 9 years). In the previous sections of the article, it was indicated that Ohadi cultivar has the least affected one by climatic conditions, and its temporal yield changes are the closest to the biennial bearing cycle. It was also indicated here that increased pruning skills reduces biennial bearing. In general, biennial bearing can be reduced only if other factors affecting the fluctuations of pistachio crop yield (such as weather conditions and management) are eliminated, and then the biennial bearing can be adjusted by operations such as pruning.

4. Discussion

The two indicators of mean and time series fluctuations of pistachio yield are effective in providing a suitable and reliable income for gardeners. Sometimes, gardeners prefer to have a lower income but with low temporal fluctuations. In other words, having a lower yet secure income is preferable to having a high risky income. Thus, it is important to identify the factors affecting both mean and fluctuations of pistachio yield.

The results of this study indicated that the effect of environmental factors such as drought, frost, heatstroke, failing to meet the chilling requirements, and differences in "on" and "off" years of different orchards have led to the inability to determine biennial bearing cycles as reported in different studies for the mean harvest of pistachio in the United States [13]. However, among the 4 pistachio cultivars investigated, Ohadi cultivar shows better biennial bearing cycles since it was less affected by environmental factors. However, as for Akbari cultivar, in addition to these two environmental factors, the factor of not meeting the chilling requirements has caused less biennial bearing cycles to occur. Thus, it was possible to estimate the biennial bearing regression only for Ohadi cultivar, and it was conducted.

Comparison of 4 pistachio cultivars indicated that in terms of mean yield, Ahmad Aghaei cultivar was superior to the other three cultivars and there was no significant difference between the remaining three cultivars i.e. Akbari, Kalehghoochi and Ohadi. This is in line with the result of the study conducted by Esmailpour et al [14]. Moreover, in terms of the time series fluctuations of the crop yield periods, Ohadi cultivar has the least fluctuations, Kaleghoochi cultivar shows the most fluctuations, and Akbari and Ahmad Aghaei cultivars are in an average range (in terms of fluctuations). However, all 4 pistachio cultivars investigated show more fluctuations than biennial bearing fluctuations. This means that the yield fluctuations of all 4 pistachio cultivars investigated, besides biennial bearing, were also affected by environmental and managerial factors, yet Ohadi cultivar was the least affected and Kaleghoochi cultivar had the most affected. However, if the risk phenomenon is considered from the point of view of the likelihood of crop yield fall to less than a certain level, the index that is considered as guaranteed yield in the product insurance plan, Ahmad Aghaei cultivar is faced with the lowest risk, and Akbari is faced the highest risk. Ohadi and Kaleghoochi cultivars are in an average range (in terms of risk). In other words, the insurance premium to be paid is required to be determined according to the pistachio cultivar.

Investigating the factors affecting the fluctuations of pistachio yield indicated that in the field of management, irrigation, nutrition, pest control, and orchard pruning operations are effective. As for the environmental factors affecting the time series fluctuations of pistachio crop yield, the results of the study reported that spring frosts of pistachios increase the likelihood of crop yield fall to less than 1000 kg. Moreover, as

for the damages caused by the lack of meeting the chilling requirements, only Akbari cultivar has a significant effect on crop yield; lack of meeting the chilling requirements does not affect other cultivars.

Regarding the differences between different cultivars (as a genetic factor) in creating yield fluctuations and production risk, the results of the study showed that Akbari cultivar has two weaknesses and one strong point. The first weakness of Akbari cultivar was the lack of meeting the chilling requirement in all 9 years of investigation; lack of using Volk oil has caused the yield to fall below 1000 kg in all these 9 years. In other words, if the weather conditions are the same as in the past 9 years, it is not possible to produce Akbari pistachios without consuming Volk oil. Another disadvantage of Akbari cultivar is the early aging of its tree. In comparison to the other three cultivars, it reaches old age earlier; the lack of economic production is initiated earlier as well. The results of this study showed that in Akbari pistachio, at the age of over 40 years, the likelihood of providing a yield above 1000 kg is almost zero. Despite these two main drawbacks, the resistance of Akbari cultivar to soil and water salinity has resulted to its spread in areas with saline soil and water such as Anar. Kaleghoochi cultivar is sensitive to salinity. Moreover, Ohadi cultivar is less affected by climatic conditions. Ahmad Aghaei is a cultivar with high yield and quite suitable for conditions with salty and fresh soil and water. As for the fluctuations of pistachio crop yield and the factors affecting it, no study has yet been conducted, and therefore it can be said that the results of this study are the unique.

5. Conclusion

In general, the results of this study indicated that the effectiveness of environmental factors has disrupted the biennial bearing of pistachio; it is not possible to observe a specific order regarding fluctuations in crop yield. Factors affecting the yield fluctuations of pistachio crop in different years are affected by not only biennial bearing (having a genetic origin) but also the environmental conditions and orchard management. As for the effects of environmental conditions, from among the four commercial pistachio cultivars, Ohadi cultivar was the least affected cultivar, and Akbari cultivar was the most affected one.

Conflict of interest

The authors of the article express no conflict of interest in the publication of this study.

Acknowledgements

This article has been extracted from a research project conducted at the Pistachio Research Center. Hereby, the authors express their sincerest thanks to the manager and colleagues working at the Pistachio Research Center.

References

1- Abdolahi-Ezzatabadi M, Najafi B. Investigation of income fluctuation of Iranian pistachio producers. Agricultural Sciences and Industries. **2002**; *16(2): 169-179.*

2- Davarinezhad GH, Azizi M, Akherati M. Effect of foliar nutrition on quality, quantity and of alternate bearing of Pistachio (Pistacia vera L.). Journal of Horticulture Science (Agricultural Sciences and Technology). **2009**; *23(2): 1-10.*

3- Javanshah A, Arzani K, Dehghani Shouraki Y, Paula K. Delaying flowering of pistachios to deal with spring frosts. Research and Construction. **2000**; *13(4): 18-21.*

4- Afshari H, Hokmabadi H, Ebadi AG, Arab HA, Ghorbanian AR. The study of spring frost resistance of some comercial Damghan pistachio (Pistacia Vera) cultivar. Plant and Ecosystem. **2009**; *5(18); 60-76.*

5- Abdolahi-Ezzatabadi M. Measuring farmers' willingness to pay for frost protection when there is alternate bearing: a case study of pistachio in Rafsanjan. Agricultural Economics. **2009**; *3(4): 31-44.*

6- Mohammadi H, Nemati SH. Evaluation of biochemical and physiological changes of two pistachio cultivars *Pistacia khinjuk* and *Pistacia atlantica* in the face of frost stress under controlled conditions. Ninth Congress of Horticultural Sciences. Ahwaz. **2015**.

7- Esmailpour A. Evaluation of alternate bearing intensity in Iranian pistachio cultivars. Options Mediterraneennes Serie A. **2005**; *63:29-32.*

8- Sherafati AM, Hokmabadi H. Mahvalat pistachio, a review of the characteristics and challenges of pistachio processing in Feizabad (pistachio production center in Khorasan Razavi). Agricultural Research, Education and Extension Organization, Deputy of Extension. 2018. Manuscript, *204* pages.

9- Tittonell P, Vanlauwe B, Leffelaar PA, Shepherd KD, Giller KE. Exploring diversity in soil fertility management of small holder farms in western Kenya II. Within –farm variability in resource allocation, nutrient flows and soil fertility status. Agriculture, Ecosystems and Environment. **2005**; *110: 166-184.*

10- De Jager A, Nandwa SM, Okoth PF. Monitoring nutrient flows and economic performance in African farming system (NUTMON) I. concepts and methodologies. Agriculture, Ecosystem and Environment. **1998**; *71: 37-48.*

11- Vitonde AK, Vaidkar RD, Chorey AA. Integrated pest management techniques in cotton production- an economic analysis. New Agriculturist. **2008**;*19(1,2):159-162.*

12- Wood BW. Pecan production respons to root carbohydrates and rootstock. Journal of the American Society for Horticultural Science. **1989**;*114: 223-228.*

13- Ferguson L, Haviland DR. Pistachio Production Manual. University of California. Agriculture and Natural Resources Publication. **2016**.

14- Esmailpour A, Emami SY, Basirat M, Tajabadipour A, Hosseinifard SJ, Haghdel

M, Hokmabadi H, Shaker Ardakani A, Sedaghat R, Sedaghati N, Alavi SH, Mohammadi AM, Hashemi Rad H. Iran Pistachio. Pistachio Research Center, Horticultural Sciences Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Rafsanjan, Iran. **2020**.