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A Study on Growth and Development Information and Growth Prediction Model Development Influencing on the Production of Citrus Fruits

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Abstract The purpose of this study is to develop the growth prediction model that can predict growth and development information influencing on the production of citrus fruits. The growth model was developed to predict the floral leaf ratio, number of fruit sets, fruit width, and overweight fruits depending on the main period of growth and development by considering the weather factors because the fruit production is influenced by weather depending on the growth and development period. To predict the outdoor-grown citrus fruit production, the investigation result for the standard farms is used as the basic data; in this study, we also understood that the influence of weather factors on the citrus fruit production based on the data from 2004 to 2013 of the outdoor-grown citrus fruit observation report in which the standard farms were targeted by the Agricultural Research Service and suggested the growth and development information prediction model with the weather information as an independent variable to build the observation model. The growth and development model for outdoor-grown citrus fruits was assumed by using the Ordinary Least Square method (OLS), and the developed growth prediction model can make a prediction in advance with the weather factors prior to the observation investigation for the citrus fruit production. To predict the growth and development information of the production of citrus fruits having a great ripple effect as a representative crop in Jeju agriculture, the prediction result regarding the production applying the weather factors depending on growth and development period could be applied usefully.

Keyword production, outdoor grown citrus fruits, floral leaf ration, number of fruit set, fruit width, overweight, weather factor, prediction

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1 Introduction

To accurately predict the production of the outdoor grown citrus fruits is the important data in performing the citrus fruit-related policy including the citrus fruit production plan, land use improvement, agricultural management improvement, agricultural income estimation, citrus fruit price stability, distribution measures, etc. The outdoor-grown citrus fruit is a crop with a severe biennial bearing, and its fruit set cannot maintain the regular pattern due to the unusual weather according to temperature rising; the low quality citrus orchard increases when passing the receiving date. Therefore, the quantity change becomes larger depending on each year so that the difficult situation when the price plunge occurs in the year of over-bearing fruits; in the year of under-bearing fruits, the quantity decreases, the fruits are extremely large, and its sugar content decreases as well (Cary, 1970; Kim et al., 2004).

The Jeju citrus fruit industry takes 53% of the Jeju agriculture and is in absolute position, and its effort to save oneself such as reconstruction is required according to the liberalization of imports. Therefore, starting with the establishment of the long-term development plan for the citrus fruit improvement in 1991, the citrus fruit production

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control policy was enforced to properly produce high quality citrus fruits in 1997. For production control, the harvest by thinning, fruit thinning, fruit selecting, etc. of citrus fruit trees was actively promoted. As a part of this project, in the citrus fruit industry development indicator, the cultivating area was adjusted to less than 20,000 ha, and the production was adjusted to less than 600,000 ton by organizing the orchard corresponding to the area that is not appropriate for the citrus fruit cultivation (Sunwoo Kim, et al., 2012).

The production of the citrus fruits influences on the price and is closely related to the farm income source and the nation's gross benefit. After 2000, the change of the citrus fruit price supporting policy such as the gross benefit deviation of citrus fruits was necessary for this time period. The policy inducing high quality citrus fruit production such as the introduction of the citrus fruit distributing order system, encouragement of thinning, etc. appears, and the measures controlling the distribution such as the establishment of Agricultural Products Processing Center (APC), etc. is introduced. As a plan to minimize the damage from Korea-China FTA, Jeju currently has the assignment to achieve high-level, high-quality, price competition of Jeju citrus fruits, etc. (Iksoo Jeon et al., 2013).

The price increase of the agricultural products such as the citrus fruit is not a temporary phenomenon, and the price change is deepened due to the influence of the supply and demand of agricultural products by an abnormal weather phenomenon such as localized heavy rain, drought, etc. As the price of oranges increased and the import quantity decreased because of the poor harvest of oranges produced in the U.S. in 2006, the price of the Onju mandarin orange (Citrus unshiu Marc.) rose to the highest level on February 2007.

In this background, the observation system predicted the future by collecting and analyzing the information related to the production, supply, and price of the agricultural product and allowed to make a reasonable decision in establishing a farming plan and adjusting the shipment through this result (Gwangho Kim, et al., 2003).

The data predicting the production of the agricultural product is investigated and announced from the Korea Rural Economic Institute (KREI) observation center, each provincial government of producing area, and National Statistical Office. The Korea Rural Economic Institute (KREI) provides the observation data by estimating the price of various economic crops for price stability. The observation data could help the price stability of the agricultural product by inducing the shipping period control of farmers. However, there are some limitations to predict the supply and demand of agricultural products since the observation data of KREI is based on the interview with farmers (Lee et al., 2004). Therefore, as the necessity to systemically predict the production of agricultural products is on the rise, the production-observing investigation for outdoor-grown citrus fruits (Onju mandarin orange [Citrus unshiu Marc.]) had been conducted from 1999 according to the ordinance Article 4 policy about production and distribution of citrus fruits; the provincial governor was asked to conduct the citrus fruit production-observing investigation on May, August, and November and notify the observation result to the mayor, county governor, and shipment alliance chairman. The mayor and county governor were asked to report to the provincial governor to establish the production plan by consulting with the producer group according to the observing investigation result (Sangsoon Lee et al., 2005).

The production of the agricultural products is different depending on the cultivating area and the production per unit area (crop yield) decided by the farmers' opinion. The crop yield is greatly influenced by the technical condition and weather changes (Lee et al., 2005). Therefore, this study investigates the correlation between the weather factors influencing on the citrus fruit production and enhances the suitability of the growth information prediction model based on this.

2 Materials and Method

2.1 Citrus Fruit Production and Weather Information

The productivity of the crop is decided by the genetic features of the cultivating crop, cultivating technique, and the cultivating environment. Although many varieties and producing techniques are going through development due to the efforts of agricultural experts and cultivating technicians, the weather environment among cultivating environments could not be artificially controlled so that it has a very close relationship with the production. The citrus fruit cultivated in the Jeju area has been appropriately evolved for natural characteristics passing the adjustment process regarding regional climate. Due to global warming, the average temperature of Seogwipo-si and Jeju-si were respectively 17.1℃ and 16.2℃, after increasing by 2℃ and 1℃. The amount of rainfall has gradually increased to 2,400mm in 2010 so that many changes occur in the citrus fruit cultivating environment (Yongho Kim, 2011). As the weather in the Jeju area continuously changes, the citrus fruit cultivating environment is expected to alternate as well. For instance, if the cultivating producer is changed, the alternative crop with high sugar content can be produced. It could be thought that the weather change has a close relationship with the development of the Jeju citrus fruit industry with various factors.

If the weather is similar with that of the average climate, the growth and development of the crop will change every year; depending on its level, the damage could be severe. There were enormous economic losses due to bad harvesting of the main cereal crop by the low summer temperature phenomenon in 1980 and 1993 as well as small and large climatic damages every year (Gyomoon Shim, 2003). Recently, the green houses were damaged due to a record-breaking snow storm from late December 2010 to early 2011, and there were freezing damages on wintering citrus fruits and stored citrus fruits due to the low temperature phenomenon from January to April. Particularly, there were damages on outdoor-grown citrus fruits because leaves were withered and darkened so it resulted to some of these falling, and a germinating period of spring started five days late compared to that of last year (Sangsoon Lee et al., 2011).

Like other general crops, citrus fruit agriculture also depends on the weather in many aspects; however, it does not completely depend on it. It is necessary to increase the amount of sunlight by organizing the windbreak actively using production technology, to conduct the thinning out in case of many bearing flowers by checking the amount of flowers to avoid biennial bearing, and to prevent the rain from collecting on the ground while it is raining. When the accurate weather information is converged with IT technology based on this artificial producing technology, the synergy could be amplified in growth and development information management.

2.2 Data Collection

In this study, the production of citrus fruits refers to outdoor-grown Onju mandarin oranges (Citrus unshiu Marc.) and the line of the Onju mandarin orange in Heungjin and Goongcheon.

The growth and development information influencing on the production of citrus fruits includes the floral leaf ratio, number of fruit sets, and the fruit width as important factors. The floral leaf ratio refers to the ratio of flowers per old leaf, and the fruit setting refers to the remaining flower that did not fall and became a fruit. In other words, the fruit setting refers to the phenomenon of producing fruits through blooming and pollinating of the citrus fruit tree. Therefore, the number of fruit sets refers to the number of fruits on the citrus fruit tree; if the number of fruit sets is large, the production of that year will be plentiful.

Because the citrus fruit production is represented with a ton ever year, the number of fruits is calculated by converting it to weight. To obtain the weight of a fruit, the fruit width becomes the main variable. The fruit width refers to the horizontal length of the fruit, and the number of citrus fruits can be obtained by calculating the number of fruit sets and the weight of the fruit.

To obtain the growth and development information influencing on the production of the citrus fruit, we actively used the annual citrus fruits observing the investigation report of Jeju, the main producing district. Jeju-do has conducted the production-observing investigation about outdoor-grown cultivating citrus fruits since 1999 according to the Act on Citrus Fruit Production and Distribution Chapter 2 Article 5. The citrus fruit observation method of the Jeju Agricultural Research Service is performed based on a scientific method in the investigating aspect. Various methods are used for the investigation, and the possibility of an error for one investigation is greatly reduced because the investigating period varies such as May, August, November, etc. However, in spite of the large amount of low data investigated, there are limitations on the systematical use of the database. The observation of the citrus fruit production was conducted by the Jeju Citrus Fruit Agricultural Cooperative from the early 1980s to 1990, and the Jeju Agricultural Research Services has taken over since 1991. The main investigation contents include cumulative temperature depending on each area, change of germinating and blooming period depending on each area and year, prediction of blooming period based on the temperature before blooming, flower setting and fruit setting depending on each area, distribution of the average temperature depending on each area and month, cumulative temperature after full bloom, enlargement survey on fruit diameter by regional field, weight investigation, sugar content change, acid content, etc.

The data used in this study is from the observation report between ten years (2004 ~ 2013). The reason for using the data from 2004 is that the new method was used from 2004 according to the ‘Research on the improvement of Citrus Fruit Production Observing Investigation Method’ in 2003. Although it is not possible to automatically collect and save the citrus fruit data unlike the weather data, the Agricultural Research Service annually issues the report of citrus fruits observing investigation result to use for the analysis of the prediction of the weather and citrus fruit production.

2.3 Growth and Development Characteristics of Citrus Fruits in Jeju-si and Seogwipo-si and Weather Data Collection

The nearest automatic weather stations (AWS) located at Jeju-si and Seogwipo-si are station numbers 184 AWS in Jeju-si and 189 AWS in Seogwipo-si. Between 2004 and 2013 in Jeju-si, the average annual temperature was 16.1℃, the lowest temperature was –1.8℃, and the highest temperature was 34.7℃; in Seogwipo-si, the average annual temperature was 17.0℃, the lowest temperature was –2.2℃, and the highest temperature was 33.9℃; therefore, there was only a difference of ±1℃ in average between the two areas. However, in the temperature of each step of growth and development period, Seogwipo-si showed more than a 1℃ of regional difference compared to Jeju-si.

Table 1 Annual investigating table for the floral leaf ratio, number of fruit sets, and fruit width in Jeju-do

Category		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Floral leaf ratio	Jeju-si	0.89	0.92	0.84	0.77	0.69	0.95	0.74	0.90	1.17	0.74
	Seogwipo-si	1.00	0.90	0.72	0.85	0.50	1.04	0.41	1.04	0.76	0.88
	Whole	0.91	0.94	0.77	0.81	0.59	1.00	0.57	0.97	0.96	0.81
Number of fruit sets	Jeju-si	0.89	0.92	471	754	545	740	565	588	949	509
	Seogwipo-si	668	488	559	819	482	943	542	700	770	730
	Whole	580	466	515	786	514	842	554	644	860	620
Fruit width	Jeju-si	37.5	42.0	42.1	41.6	43.7	44.6	40.6	42.8	38.0	40.9
	Seogwipo-si	36.5	42.3	42.6	40.4	43.2	42.7	41.4	41.4	40.5	42.0
	Whole	37.0	42.3	42.4	41.0	43.5	43.6	41.0	42.1	39.3	41.5

Data Agricultural Research Service, "Observing Investigation Report for Outdoor-Grown Citrus Fruit Production", each year

When using the weather information for prediction, it is important to analyze and apply the weather data of growth and development time because the use of the annual average data is not appropriate. In bloom of the citrus fruit tree, the flower bud is physiologically divided from September ~ October of the previous year; the flower bud is morphologically divided around March, and the flower blooms on early/middle of May. The number of citrus fruits is decided by how many flowers bloom, if the physiological fruit drop amount is large or small after blooming, and the amount of fruits enlargement. Like this, the weather environment greatly influences on the flower bud division, physiological fruit drop, and fruit enlargement. In the flower bud dividing period, the temperature has the most important role starting from the low temperature period. If the lowest temperature passes more than 7.5 hours at –5℃, 80% of the stem and 35% of the leaf are frozen.

If severe low temperature is sustained, it is difficult to expect the production since the tree itself will be withered. As a result of investigating the blooming condition of the citrus flower by selecting the sample enumeration district among the citrus orchard in Jeju, the production is predicted by investigating the floral leaf ratio that is the number of blooming flowers per leaf of a citrus tree. For the floral leaf ratio, the number of old leaves and flowers of a branch is investigated after selecting and marking branches from four cardinal directions. The factors deciding the production of citrus fruits per 10a are the floral leaf ratio, number of fruit sets, fruit width, weather condition, biennial bearing phenomenon, and technique change (Haeryong Han et al., 1992). However, for receiving distributions and variety distributions, the date from the observing investigation report was maximally used because it was difficult to obtain the opened data. The citrus fruit tree is a subtropical evergreen fruit tree so that each flower blooms from the branch of the previous year and some of them are remained for fruits to be harvested. To bloom the flower, the flower bud is physiologically divided from September ~ October of the previous year and morphologically divided around March, and then the flower blooms on early/middle of May. Therefore, the temperature to bloom the flower greatly influences on the flower bud division. Particularly, the average temperature, highest temperature, and lowest temperature on March ~ April have the high correlation with the number of fruit sets.

3 Research Method

To analyze the correlation between the growth and development information and weather information influencing on the citrus fruit production, the weather information for ten years between 2004 and 2013 was obtained from the Korea Meteorological Administration. The weather information is extracted from the Automatic Weather Service (AWS) in Seogwipo-si and Jeju-si which are administrative districts of Jeju-do, and it is analyzed by using five weather factors including annual rainfall, humidity, annual average temperature, annual average highest temperature, and annual average lowest temperature. The observance of the citrus fruit production is conducted by analyzing the statistical data of a demonstrating farm's tree to investigate according to the growth and development period. On March, the month of the observation preparing step, the decision of investigating field number, the decision of investigating lot position and investigation tree, etc. are conducted, and the final prediction or harvest amount investigation is conducted on late May and after late August.

When the floral leaf ratio is investigated on May, the month of the actual observation step, the number of fruits in the specific time is predicted by the predictive function of the number of fruits per 10a. The fruit width of the harvesting time is predicted by the fruit width predictable function of a specific time; when this fruit width is decided, the weight of one fruit is decided by the predictable function per fruit weight of harvesting time; it is multiplied by the number of fruit obtained, and the production per 10a is predicted.

As a structure, after the investigation for the number of fruits and the fruit width is conducted after late August, the fruit width is predicted by applying the fruit width enlargement ratio of the harvesting time; through this, the production per 10a is predicted by a fruit's weight of the harvesting time. After late August, the fruit width investigation is conducted focusing on survey field on the 10th day of every month or once a month; it is relatively accurate to predict how the future citrus fruit production changes by observing the growth and development result of citrus fruits and the change of fruit width. Based on the past date obtained in this way, in this study, the production change of citrus fruits is understood by predicting the investigating items of growth and development time depending on each step, and the correlation with weather factors at the time of each growth and development step is analyzed. The weather factors used here are average values in Korea.

For this, the outdoor-grown citrus fruits were the subject; the weather data from 2004 to 2013 was used by classifying the weather factors into average rainfall, humidity, annual average temperature, sunshine amount, annual average highest temperature, and annual average lowest temperature. In addition, the growth and development information in the observing report of outdoor-grown citrus fruits was used during this period. The analyzing targets were Seogwipo-si and Jeju-si with all the data because there were many cases of no data by region in some years. The correlation was analyzed with the data after 2004 through the multivariate analysis using SPSS IBM 20.0.

4 Prediction Model for Growth and Development Information

4.1 Floral Leaf Ratio

The floral leaf ratio is the important factor to predict the harvest of the corresponding year since it shows the number of flower sets per leaf. In the change of the floral leaf ratio depending on each area investigated by the citrus fruit observing report for the last 10 years(2004 ~ 2013), the average floral leaf ratios were 0.86 in Jeju-si and 0.81 in Seogwipo-si. In the average floral leaf ratio each year, the highest floral leaf ratio of Jeju-si and Seogwipo-si was respectively 1.17 in 2012 and 1.01 in 2009 and 2011, and the production at that time was high as well. When the floral leaf ratio was high, the production was also high; however, while the floral leaf ratio was as high as 1.17 in 2012, the production was appropriately 558,000 ton so that it meant that the production was adjusted by political variables or other variables. The estimation equation of the floral leaf ratio was estimated by applying the Ordinary Least Square Equation using the data for 10 years from 2004 to 2013. The estimation equation of the floral leaf ratio was made with Jeju-si and Seogwipo-si as a basic point in the standard of administrative district because the weather data was different depending on the area.

In the estimation equation of the floral leaf ratio, as a result of checking the weather data of Jeju-si, the floral

Table 2 Estimating result of the floral leaf ration of Jeju-si

Variable	Standard coefficient value	s.e.	t-value	p-value
Constant term (α)	-0.801	0.405	-1.978	0.104
Highest temperature in February (β_1)	0.076	0.022	3.459	0.018
Average temperature in February (β_2)	-0.099	0.038	-2.591	0.048
Germinating period (β_3)	0.001	0.003	3.781	0.012
Flower setting level (β_4)	0.723	0.122	5.902	0.001
R^2	0.895		DW	1.464
Adj. R^2	0.811		F value	10.715

Table 3 Estimating result of the floral leaf ration in Seogwipo-si

Variable	Standard coefficient value	s.e.	t-value	p-value
Constant term (α)	0.551	0.428	1.285	0.245
Average temperature in January (β_1)	-0.114	0.024	-4.629	0.003
Germinating period (β_2)	-0.017	0.004	-4.061	0.006
Flower setting level (β_3)	0.380	0.107	3.553	0.012
R^2	0.949		DW	0.967
Adj. R^2	0.923		F value	37.034

leaf ratio had correlations with the weather of January and February and the germinating period. Based on these correlations, the prediction model of the floral leaf ratio was set, and the result of the estimation is as follows:

$$y = \alpha + \beta_1(x_1) + \beta_2(x_2) + \beta_3(x_3) + \beta_4(x_4)$$

Here, y = Floral leaf ratio of Jeju-si
x_1 = Highest temperature in the first ten days of the month (February)
x_2 = Lowest average temperature (February)
x_3 = Germinating period
x_4 = Flower setting

The determination coefficient of the prediction model of the Jeju-si floral leaf ratio is R^2=0.895, and the independent variables explain 85.9% of the floral leaf ratio, the dependent variable.

The coefficient (0.076) of the highest temperature in February and the coefficient(-0.099) of the average temperature in February influence on the floral leaf ratio; it is judged that the flower-setting level gave the largest influence on the floral leaf ratio because the coefficient (0.732) of the flower setting level was the largest. The regression line model is appropriate because the F value was 10.715 and the significant probability was 0.001 ($p<0.05$).

As a result of analyzing the weather data, the estimation equation of Seogwipo-si showed the influence of the average weather of January, the germinating period, and the flower setting level. As a result of inputting the average temperature of January, the germinating period, and the flower setting level as independent variables and substituting the floral leaf ratio as a dependent variable, the determination coefficient R^2=0.949, and it was possible to explain 94.9% of the independent variables explained the model explaining the prediction of the floral leaf ratio.

$$y = \alpha + \beta_1(x_1) + \beta_2(x_2) + \beta_3(x_3)$$

Here, y = Floral leaf ratio of Seogwipo-si
x_1 = Average temperature in January
x_2 = Germinating period
x_3 = Flower setting level

It is thought that the coefficient (0.380) of the flower setting level in the Seogwipo area influenced more on the floral leaf ratio because it was larger than the coefficient of the January average temperature (-0.114) and the coefficient of the germination period (-0.017). It was verified that there was a correlation because the t-value of the estimation equation was larger than ±1.96 and the p-value was also satisfied with the condition of $p<0.05$. The regression line was suitable because the f-value was 37.034 and the significant probability was 0.01 satisfied with the $p<0.05$ condition.

Table 4 Estimating result of the number of fruit sets in Jeju-si

Variable	Standard coefficient value	s.e.	t-value	p-value
Constant term (α)	1930	841.11	2.294	0.008
Average temperature (β_1)	2056	540.23	3.806	0.018
Highest temperature (β_2)	-1087.3	278.69	-.901	0.017
Lowest temperature (β_3)	-1014.6	244.73	4.146	0.014
Floral leaf ratio (β_4)	614.5	208.53	2.947	0.042
R^2	0.919		DW	0.894
Adj. R^2	0.837		F value	11.296

Table 5 Estimating result of the number of fruit sets in Seogwipo-si

Variable	Standard coefficient value	s.e.	t-value	p-value
Constant term (α)	-2439	266.61	-9.148	0.000
Average temperature (β_1)	332.17	58.18	5.709	0.004
Highest temperature (β_2)	-473.77	110.99	-4.268	0.012
Lowest temperature (β_3)	273.59	53.18	5.143	0.006
Floral leaf ratio (β_4)	293.65	52.52	5.590	0.005
R^2	0.982		DW	1.188
Adj. R^2	0.965		F value	56.19

4.2 The Number of Fruit Sets

The correlation was calculated to analyze at which point the number of fruit sets that one of the important factors that influence on the production of citrus fruits has a high relation with the weather factor. To know the number of fruit sets, the data investigated during the middle of August in citrus fruit observing investigation was used. Based on the number of fruit sets investigated for 10 years (2004~2013) in citrus fruits observing report as basic data, in the change of the number of fruit sets by region, the average number of fruit sets was 598 in Jeju-si and 670 in Seogwipo-si. In the average number of fruit sets by year, the highest numbers were 949 in Jeju-si in 2012 and 943 in Seogwipo-si in 2009. It was shown that when the floral leaf ratio was high, it influenced on the number of fruit sets, and the year of the high floral leaf ratio was the same with the year of the high number of fruit set. It can be expected that the floral leaf ratio is one of the factors that influences on the number of fruit sets. In this study, the correlation between the floral leaf ratio and the number of fruit sets was 0.467, and it was verified that there was an influence of the floral leaf ratio on the number of fruit sets.

Between the blooming period and May ~ early June of the preliminary physiological fruit drop period, the amount of rainfall and sunlight greatly influence the weather. If the sunlight is not sufficient during the preliminary physiological fruit drop period, the preliminary physiological fruit drop increases more due to the lack of nutrient supply by suppression of photosynthesis so that it influences the final quantity (Gwangho Kim el al., 2003). With the preliminary physiological fruit drop period, the secondary physiological fruit drop period from late June to the middle of July is the important period to decide the quantity of the Onju mandarin oranges (Citrus unshiu Marc.) of the corresponding year. In this period, the secondary physiological fruit drop largely occurs and starts between late June and early July. The lack of sunlight during the physiological fruit drop period fosters the physiological fruit drop more so that it plays a very decisive role in the quantity.

The number of fruit sets is influenced by the weather factors between May and July; the followings are the results by establishing and estimating the number of fruit set models based on the correlation during this period by region: as a result from the correlation analysis of the average temperature, highest temperature, lowest temperature, daily temperature range, floral leaf ratio, rainfall, sunlight, and the number of fruit sets to understand the relation among variables. The correlation coefficient between the average temperature and rainfall was a significantly high negative value of – 0.593. The correlation coefficient between the number of fruit sets and the rainfall was 0.1041, resulting in weak correlation. While the correlation coefficient between the average temperatures and the sunlight was as high as 0.7313, the correlation with the number of fruit sets was a negative relation as low as -0.247. From this, it is shown that although the rainfall and sunlight are important factors for growth and development, they seem to have an indirect influence rather than a direct influence when applying the variables of the model consisting of the number of fruit sets that is one of the growth and development information. Therefore, the independent variables used to predict the number of fruit sets consist of the average temperature, highest temperature, lowest temperature, and the floral leaf ratio.

For the estimation equation for the number of fruit sets of Jeju-si, the weather data from June 10 to July 20 was used, and the determination coefficient of the number of fruit sets during this period was R^2 =0.918 and provided a sufficient explanation through the weather data used as the independent variable and the floral leaf ratio. In addition, the t-value and p-value were satisfied with the condition; the F-value was 11.296 in the 0.01 of significant probability by satisfying the $p<0.05$, and it explained the regression equation.

$$y = \alpha + \beta_1(x_1) + \beta_2(x_2) + \beta_3(x_3) + \beta_4(x_4)$$

Here, y = The number of fruit set of Jeju-si
x_1 = Average temperature
x_2 = Highest temperature
x_3 = Lowest temperature
x_4 = Floral leaf ratio

The temperature of the Seogwipo area was 1℃ higher than that of the Jeju area; the weather factor of May, the month of the preliminary physiological fruit drop period, influenced more on the number of fruit sets; based on the correlation during this period, the fruit set number model was installed and estimated. To understand the relationship between these variables, as a result of analyzing the correlation with the average temperature, highest temperature, lowest temperature, daily temperature difference, floral leaf ratio, rainfall, sunlight, and the number of fruit sets, the correlation coefficient was more than 0.807, the average, highest, and lowest temperatures, and there was an extremely weak correlation of – 0.199 in rainfall. The correlation coefficient between the sunlight and the number of fruit sets was as low as 0.35, and there was a somewhat high correlation of 0.596 with the floral leaf ratio. The correlation between the sunlight and the highest temperature was as high as 0.633. To build the same prediction model for the number of fruit sets of Seogwipo with that of the Jeju area, it is thought that the sunlight gives an indirect influence rather than a direct influence; therefore, the prediction model was made by selecting the variables with more than a correlation of 0.5 and by deciding the average temperature, highest temperature, lowest temperature, and the floral leaf ratio as the same independent variables as the Jeju area.

Table 6 Estimation result of fruit width of Jeju-si

Variable	Standard coefficient value	s.e.	t-value	p-value
Constant term (α)	149.964	20.013	7.493	0.000
Middle June average temperature (β_1)	-2.911	0.564	-5.323	0.003
Late June average temperature (β_2)	-1.302	0.346	-3.761	0.013
Early July average temperature (β_3)	2.610	0.514	5.077	0.003
Late July average temperature (β_4)	-2.961	0.490	-6.044	0.001
R^2	0.895		DW	1.912
Adj. R^2	0.811		F value	10.681

Table 7 Estimation result of fruit width of Seogwipo-si

Variable	Standard coefficient value	s.e.	t-value	p-value
Constant term (α)	102.80	8.842	11.628	0.000
June average temperature (β_1)	-1.874	0.374	-5.001	0.002
Late July average temperature (β_2)	-0.739	0.223	-3.312	0.016
R^2	0.943		DW	2.532
Adj. R^2	0.890		F value	24.320

In the estimation equation for the number of fruit sets of Seogwipo-si, the average temperature of May among the weather data of Seogwipo-si, the floral leaf ratio, and the number of fruit sets were used as independent variables; to explain the number of fruit sets with the determination coefficient R^2 =0.982 for the prediction model, there was a 98.2% of explanation ability. The model was significant because the t-value between the variables was larger than ±1.98 and the p-value was smaller than 0.05. It was suitable for the regression line model because the F-value was 56.19 and the significant probability was 0.000.

$$y = \alpha + \beta_1(x_1) + \beta_2(x_2) + \beta_3(x_3) + \beta_4(x_4)$$

Here, y = The number of fruit sets of Seogwipo-si
x_1 = Average temperature
x_2 = Highest temperature
x_3 = Lowest temperature
x_4 = Floral leaf ratio

The weather data of May was high overall in all of the average temperature coefficient (329.97), the highest temperature coefficient(-471.78), and the lowest temperature coefficient (273.61); the coefficient of the floral leaf ratio (297.89) was also high; therefore, it is thought that all of the variables used for an estimation influenced on the number of fruit sets.

4.3 Fruit Width

As one of the factors greatly influencing on the maturing of the citrus fruits is the temperature, the enlargement of fruit is promoted by the high temperature during the summer that is the growth and development period of the citrus fruits. As a result analyzing the temperature between June and July to predict the fruit width, it was verified that middle and late June and early and late July had an influence. To predict the fruit width as the dependent variable, the independent variables showed a high result of the determination coefficient R^2 =0.895 in explaining the model.

In addition, the t-value and the p-value explaining the relationship between the dependent and independent variables were larger than ±1.96 and satisfied the $p<0.05$ condition. It was suitable for the regression line model because the F-value was 10.681 and the significant probability was 0.001, satisfying the $p<0.05$ condition.

$$y = \alpha + \beta_1(x_1) + \beta_2(x_2) + \beta_3(x_3) + \beta_4(x_4)$$

Here, y = Fruit width of Jeju-si

x_1 = Middle June average temperature

x_2 = Late June average temperature

x_3 = Early July average temperature

x_4 = Late July average temperature

As the determination coefficient of the fruit width estimation equation was R^2 5=0.890, the weather data of the independent value explained the 89%. The t-value of –5.001 of the average temperature of June was larger than ±1.96, and the 0.002 of the significant probability satisfied the $p<0.05$ condition. The regression line model was suitable because the F-value was 24.320 and the significant probability was 0.001.

$$y = \alpha + \beta_1(x_1) + \beta_2(x_2)$$

Here, y = Fruit width of Seogwipo-si

x_1 = June average temperature

x_2 = Late July average temperature

4.4 Fruit Weight

The quantity of the citrus fruits can be obtained by the number of fruit sets and the weight of the fruits, and the annual quantity can be calculated by investigating the number of planted hills per unit area and yield per tree. The fruit weight cannot be measured in the condition of the fruit set but can be indirectly estimated by the size of the fruit, the width and longitudinal length. Therefore, the quantity was estimated through the size of the fruit extracted for sampling, and the average enlargement ratio was calculated by analyzing the fruit width of August and October from 2006 to 2013.

The late enlargement ratio increases due to the rainfall and high temperature after late August and close to the maturing period so that the latitudinal enlargement becomes more longitudinal enlargement. The average enlargement ratios of Jeju-si and Seogwipo-si were respectively 1.45% and 1.44%, and the fruit width of October can be expected by multiplying the fruit width of August by enlargement

Table 8 Width analyzing by region

Year	Jeju-si			Seogwipo-si		
	Fruit width of Aug.	비대율	Fruit width of Oct.	Fruit width of Aug.	비대율	Fruit width of Oct.
2006	42.1	1.49	62.8	42.6	1.46	62.1
2007	41.6	1.45	60.3	40.4	1.49	60.1
2008	43.7	1.38	60.3	43.2	1.38	59.7
2009	44.6	1.35	60.3	42.7	1.38	58.8
2010	40.6	1.49	60.6	41.4	1.49	61.6
2011	42.8	1.47	62.8	41.4	1.47	60.9
2012	38.0	1.44	54.7	40.5	1.42	57.6
2013	40.9	1.55	63.3	42.0	1.43	59.9

Table 9 Estimation result of the citrus fruit weight of Jeju-si

Variable	Standard coefficient value	s.e.	t-value	p-value
Constant term (α)	-89.304	16.882	-5.290	0.0023
Fruit width of Jeju-do (β_1)	2.911	0.277	10.511	0.000
R^2	0.974		DW	1.861
Adj. R^2	0.948		F value	110.48

ratio. The correlation between the fruit weight and the fruit width was as high as 0.973.

The estimation equation was made to estimate the fruit weight in the standard of the average fruit width of the Seogwipo-si and Jeju-si areas. The determination coefficient of the corresponding estimation equation was R^2 =0.948, and the weather data of the independent variable provided 94.8% of the explanation. The t-value of the fruit width of Jeju-do was 10.511 and larger than ±1.96, and the significance probability was 0.000 and satisfied the condition of $p<0.05$. It was suitable for the regression line model as the F-value was 110.48 and the significance probability was 0.000.

5 Conclusion

The purpose of this study is to develop the model to predict factors influencing on the production according to the growth and development step for the prediction of the citrus fruit production. To make a model to predict the growth and development information according to each growth and development step, it was built focusing on the influence of weather information. Among coefficients calculated by the model of each step, if the correlation coefficient was lower than the 0.05 level although it was the factor influencing on the growth and development indirectly, it was excluded from the variables. Through the growth and development information made in the observing investigation for the citrus fruit production for the last 10 years, the relation between the growth and development factors and the weather was specified, and the growth and development model was completed based on this. As a result of analyzing the correlation according to the weather information and the growth and development step of citrus fruits, the growth and development of citrus fruits was generally influenced by the average temperature, lowest temperature, highest temperature, rainfall, and sunlight. However, while the rainfall and sunlight closely influenced on each step of growth and development, the correlation was low so that it seemed to give an indirect influence compared to the other weather data; among the weather data, the average temperature, highest temperature, and lowest temperature showed a high correlation. Therefore, in this study, based on the correlation between the variable applications as premise, the prediction model was built through the variable combination of the weather data with a high correlation.

To predict the production amount, the number of planted hills per unit area and the quantity per unit area were calculated by multiplying the cultivating area; the quantity per unit area was calculated by using the number of fruit sets per tree, predictable fruit weight in harvest, and planting number value per unit area. Therefore, we made the prediction model for the fruit width regarding the number of fruit sets, the floral leaf ratio influencing on the number of fruit sets, and the fruit width to predict the fruit weight by separating the Seogwipo and Jeju areas using the growth and development information and the weather information.

There are limitations of this study: first, it is to make the prediction equation by separating only the Seogwipo and Jeju areas. It is not possible to predict an accurate production amount if the weather data provided as the consistent agricultural weather data, which is not the corresponding weather information by region, is substituted as the same way. There is a difference in the weather of eup, myeon, and dong units of Jeju-do, and there is a large difference between the weather of the middle of Halla mountain and the coastal area. However, the model could not be made in detail in the eup and myeon units because the observing report of outdoor-grown citrus fruits was made by separating the Seogwipo and Jeju areas that were the administrative districts; in a further study, it could be possible to make the prediction model in detail by separating them into the eup and myeon units.

Second, the model currently developed was predicted by only using the observation data investigated for ten years after the "Study on Improvement of Observing Investigation Method for Citrus Fruit Production in 2003" to increase suitability and application. To increase the accuracy of the prediction model, thedatashouldbesystemicallymanaged andapplied,andtheobservinginvestigationdatashouldbes ystemicallymanagedbythedatabase . It could be possible to make an effective decision by building the system to predict the citrus fruit harvesting amount through the DB of observation data and supporting the predictable service in the Jeju provincial government, farms, merchants, etc.

This study shows that if the weather data which is a big data is analyzed from various angles, the matching variables will be found and the predictable production will be suggested by applying the pattern, the production can be predicted through the big data analysis without the observing investigation requiring many human resources each year.

It is necessary to consistently supplement the prediction model to reflect the changed data according to the continuous weather change. In addition, to use the growth and development information, it is required to prepare the application method for measurement data related to the various types of growth change. If the data changed by the weather change is systematically built as the database and applied to the growth and development model, the scenario can be made in long-term and the production can be predicted by this method.

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