Data Engineering Analysis of Fruit Bug Characteristics for Pear Cultivation

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***Abstract*—Several kinds of fruits are covered with fruit bags until harvesting to protect them from insects, birds, disease, agrochemical, etc. It is called as the preharvest bagging. There may be negative effect of the fruit bag used in the preharvest bagging, because humidity in the fruit bag is possible to rise. In this paper, the inner-bag temperature and humidity are directly measured at hourly intervals for four months from infancy to harvesting. During measurement, six different types of fruit bags are used. The collected measurement data are statistically analyzed, and difference is significantly disclosed among these inner-bags for humidity.**

***Index Terms*—fruit bag, pear, sensing technology, statistical analysis, precision agriculture**

I. Introduction

Imported from France to Niigata in the early 20th century, Le Lectier pear trees have flourished in Niigata prefecture ever since. Today it is cultivated around Niigata City's Minami Ward, Sanjo City, Kamo City, and so on. Le Lectier is known as "The Lady of All Pears". One of the most serious issues in Japanese agriculture is aging of the farmers. Since the number of farmers is decreasing and young generation avoid being engaged in agriculture, the average age of Japanese farmers is beyond 66 in 2016. Keeping the quality of Le Lectier by the efforts of the aging farmers is a quite tough problem.

Recently and rapidly, Information and Communications Technology (ICT) such as sensing technologies and cloud computing has been introduced in the agriculture area [1]-[5]. This new style of agriculture supported by ICT is often called as Precision Agriculture or Smart Agriculture.

The quality of Le Lectier greatly depends on its outlook because it is often used as gifts. Therefore, the fruit bags are used in preharvest bagging, that is covering the whole fruit by a bag after artificial fertilization until harvesting. The preharvest bagging is said to be an effective way to protect the fruits from insects, birds, disease, agrochemical, etc. On the other hand, there is some anxiety about negative effect for fruit size, maturity, skin color, and stains by preharvest bagging to a greater or lesser degree. A cause of stains is sometimes said to come from humidity in the fruit bag. However, relationship between the stains and humidity or humidity and the fruit bag is not known well yet. One of the causes that degrade the outlook is said to be the preharvest bagging, namely, the inner environment of the bag may affect the fruit outlook.

Before the advent of Precision Agriculture, the effect of preharvest bagging were mainly evaluated by physical and/or chemical methods. As a typical work in this category, Amarante *et al*. [6] used micro-perforated polyethylene bags for pear fruits and found that there was no effect on compositional and quality attributes of the pears at harvest. Understandably, the preharvest bagging is also used for other fruits such as apples, peaches, and grapes. Qin *et al*. [7] compared three different types of bag for preharvest bagging of 'Red Fuji' apple. They also compared bagged and non-bagged fruits from the viewpoint of the epiphyte community structure. More recently, Liu *et al*. [8] tested several types of fruit bag to overcome the poor peach fruit color problem. Those were non-woven polypropylene fruit bags in different color. One result from their studies is that the fruit bag with white non-woven polypropylene is an ideal replacement for a widely applied yellow paper one for peach cultivation. These works judged the fruit bag performance through postharvest analysis, since it was difficult to measure the inner-bag environment of the closed bag. So far, there is few studies to clarify the relationship between the bag characteristics and the inner-bag environment directly.

Thanks to advancement of sensor technologies, monitoring of the inner-bag environment has become realized. Humidity sensing is specifically interesting to the farmers, because humidity can be a cause of outlook degradation. In this paper, as application of Precision Agriculture to Le Lectier, clarification of the relationship between the bag characteristics and the inner-bag humidity is targeted. Six different types of fruit bags are used to experiment in real pear fields in collaboration with a pear farmer. For humidity measurement, a small sensing logger is used to carry out the measurement of humidity in fruit bags. After continuous measurement for about four months, the collected data are statistically analyzed and difference among multiple kinds of inner-bags is disclosed.

II. Inner-Bag Environment Measurement for Pear Cultivation

A. Measurement Experiments

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We have carried out inner-bag environment measurement experiments in the fields shown in Fig. 1 between June 7 and October 15 in 2016. The fields are located at Sanjo city, Niigata prefecture in Japan. One tree from each field was selected and total 34 Le Lectier fruits were picked out from two selected trees as the samples of measurement. A small temperature and humidity sensor with a diameter of 1.7cm and a weight of 3.3g is available on the market. The sensor is shown in Fig. 2 and compared with the Japanese one-yen coin.

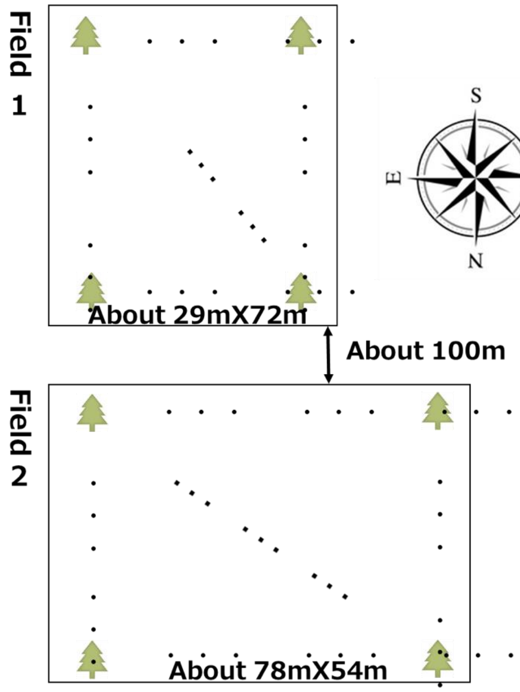

Figure 1. Experimental field.

Figure 2. A temperature and humidity sensor used for the inner-bag environment measurement experiments.

Six types of bags were used for the experiment and the small sensor was set inside each experimental bag not to damage the fruit carefully during the experimental period. The small sensor plays the role of data logging, so that the measured data were automatically recorded inside the sensor until the end of experiment. The data were collected every hour during the experimental period. The field temperature and humidity were also measured by the sensor shown in Fig. 3. This sensor was connected to a data logger placed in the field. The data logger has a 3G (the third generation of mobile telephony) communication line, so that the collected data are available from a specific Web site.

Figure 3. Field temperature and humidity sensor.

The bags are shown in Fig. 4 and have a double layer structure. Table I shows the properties of six fruit bags. All the bags have a double layer structure and Bags A, B, C, D, and E are products of a company, while Bag F comes from another company.

Figure 4. Six fruit bags used for the inner-bag environment measurement experiments.

TABLE I. PROPERTIES OF SIX FRUIT BAG USED IN THE 2016 EXPERIMENTS

Bag type	Size (Wide x Height) (mm)	Characteristics
Bag A	144 x 195	
Bag B	155 x 195	
Bag C	142 x 195	Thick
Bag D	142 x 195	Rough paper
Bag E	142 x 195	Rough paper
Bag F	142 x 195	

B. Measurement Results

The average temperature and humidity are depicted for each bag type as well as the pear field in Fig. 5 and Fig. 6 respectively. In Fig. 5 and Fig. 6, the horizontal axis is the season; we divided one month into the beginning (from the first to 10th days), the middle (from the 11th to 20th days), and the ending (from the 21th to the end days) periods and each period corresponds to the season in this paper. For example, E-Jun. represents the ending period of June, B-Jul. represents the beginning period of July, M-Aug. represents the middle period of August, and so on. The vertical axis of Fig. 5 is the temperature and that of Fig. 6 is the humidity. It is found that there is no big difference of the temperature change for the six fruit bags and change tendency corresponds to the outside temperature change collected from the weather information from the Meteorological Agency. On the other hand, difference is observed in the humidity change.

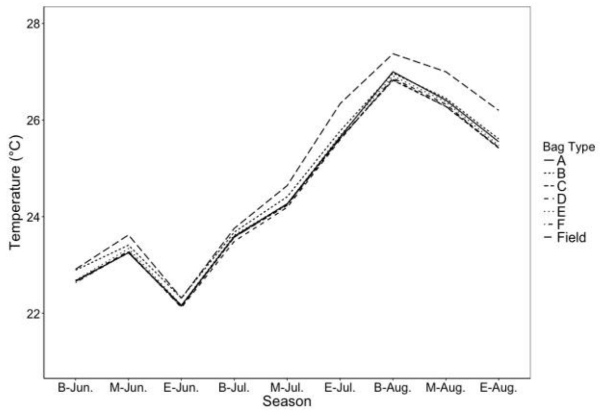

Figure 5. Temperature records in the experiments.

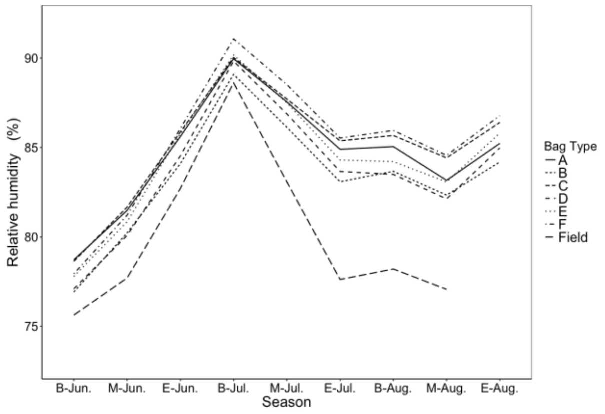

Figure 6. Humidity records in the experiments.

III. Differenciation of Fruit Bags by Humidity Data Analysis

A. Data Analysis through Whole Experimental Period

The difference of the inner humidity change in each fruit bag is verified statistically. As the fundamental statistics, the values of average, standard deviation, and median for all data collected through the whole experimental period are presented for six fruit bags and the pear field in Table II. Firstly, the Kruskal-Wallis test is used for the median values of six groups from Bag A to Bag F in Table II. The null hypothesis is that the medians of the six groups are equal. The results of the Kruskal-Wallis test are presented in Table III, where the chi-squared value is 104.75 with 5 degrees of freedom. Since the *p*-value is calculated as 0.000, the null hypothesis is rejected with a significance level of 0.01 (1%). Namely, it indicates that there is a 1% risk of concluding the medians of the six groups are not equal.

Then we apply the Holm-Bonferroni method (or the Holm's Sequential Bonferroni Procedure), one way of multiple hypothesis tests. It is a modification of the Bonferroni correction. The results of the Holm-Bonferroni method application to the inner-bag humidity data are shown in Table IV. Table IV is a matrix of 6 different fruit bags and an intersection of two kinds of bags indicates each pairwise comparison below the diagonal of the table. When there is significant difference of humidity for pairwise bags, ** or * is indicated depending on the significance level of 0.05 (5%) or 0.01 (1%). From these results, it is noticed that Bag B is significantly different from the others except for Bag D. Singularity of Bag B can be seen in Fig. 6 and Table II.

TABLE II. Properties of Six Fruit Bag Used in the 2016 Experiments

Bag type and field	Average	Standard Deviation	Median
Bag A	87.351	9.443	90.900
Bag B	86.221	10.318	90.050
Bag C	87.047	8.998	90.300
Bag D	84.683	11.274	89.075
Bag E	86.121	10.255	89.950
Bag F	87.622	10.424	91.483
Field	81.066	13.105	86.424

TABLE III. Results of Kruskal-Wallis test on Humidity

chi-squared	degrees of freedom	*p*-value
104.75	5	0.000

TABLE IV. Multiple Comparison of Humidity

	Bag A	Bag B	Bag C	Bag D	Bag E	Bag F
Bag A	—					
Bag B	**	—				
Bag C		**	—			
Bag D	*		**	—		
Bag E		**			—	
Bag F		**		**	*	—

**: significant difference (p<0.05), *: significant difference (p<0.01)

B. Data Analysis for Each Month

Since growth of fruits is different for each month, the humidity data in six fruit bags and from the pear field are analyzed monthly from June to August. As analyzed in the previous subsection, the Kruskal-Wallis test is applied to the median values of six groups for each monthly data. The null hypothesis is that the medians of the six groups are equal. The results of the Kruskal-Wallis test from June to August are presented in Table V - Table VII, where the degrees of freedom is 5 and the chi-squared values and the *p*-values are presented. While the null hypothesis is rejected with a significance level of 0.05 (5%) in the case of June as in Table V, it is rejected with a significance level of 0.01 (1%) in the cases of July and August as in Table VI and Table VII. It is seen that difference in the bag characteristics may become larger as time passes and fruits grow.

TABLE V. Results of Kruskal-Wallis Test on Humidity (June)

chi-squared	degrees of freedom	*p*-value
11.87	5	0.037

TABLE VI. Results of Kruskal-Wallis Test on Humidity (July)

chi-squared	degrees of freedom	*p*-value
55.61	5	0.000

TABLE VII. RESULTS OF KRUSKAL-WALLIS TEST ON HUMIDITY (AUGUST)

chi-squared	degrees of freedom	*p*-value
56.79.75	5	0.000

Then the Holm-Bonferroni method is applied to the monthly inner-bag humidity data to compare the fruit bags pair-wisely. Unfortunately, significant difference for humidity in respective fruit bags has not confirmed for June data. The results of the Holm-Bonferroni method application to the inner-bag humidity data of July and August are shown in Table VIII and Table IX. As in Table IV, the results are shown in a matrix form of 6 different fruit bags and an intersection of two kinds of bags indicates each pairwise comparison below the diagonal of the table. The notification of ** and * is the same as in Table IV. From the results in Table VIII, significant difference with the significance level of 0.01 is observed only between Bag B and F. On the other hand, the same significant difference is observed four pairs of fruits bags in Table IX. Again, it can be noted that difference in the bag characteristics becomes larger as the fruit growing period becomes longer.

Through the data analysis, it is clarified that Bag B has more distinguished characteristics for inner-bag humidity compared with the other fruit bags. From Table I, the characteristics of Bag B is its size. It means that a slightly larger size of fruit bag has a positive effect to suppress humidity in the bag. On the other hand, any outstanding effect for bag papers has not been clarified from the data analysis this time.

TABLE VIII. MULTIPLE COMPARISON OF HUMIDITY (JULY)

	Bag A	Bag B	Bag C	Bag D	Bag E	Bag F
Bag A	—					
Bag B	*	—				
Bag C		*	—			
Bag D				—		
Bag E					—	
Bag F		**		*		—

**: SIGNIFICANT DIFFERENCE (P<0.05), *: SIGNIFICANT DIFFERENCE (P<0.01)

TABLE IX. MULTIPLE COMPARISON OF HUMIDITY (AUGUST)

	Bag A	Bag B	Bag C	Bag D	Bag E	Bag F
Bag A	—					
Bag B		—				
Bag C		**	—			
Bag D			**	—		
Bag E					—	
Bag F		**		**		—

**: significant difference (p<0.05), *: significant difference (p<0.01)

IV. CONCLUSIONS

In this paper, continuous measurement and analytical results are presented for the inner-bag temperature and humidity for the preharvest bagging of Le Lectier pear. The inner-bag temperature and humidity are directly measured at hourly intervals for four months from infancy to harvesting. Also, the pear field temperature and humidity are recorded simultaneously. Since one of our research goals is to differentiate the characteristics of the various kinds of fruit bags, six different types of fruit bags are used for the experiments. We statistically analyzed the collected measurement data using the Kruskal-Wallis test and the Holm-Bonferroni method. The analyzed results showed that the size of fruit bag has a positive effect to suppress humidity in the bag. Moreover, the effect becomes clearer as the fruit growing period becomes longer.

These valuable data were able to be collected owing to development of sensor technologies. Also, data engineering has been combined with agriculture and data analysis has revealed significant characteristics of the different types of fruit bags. The analyzed results can contribute to improvement of fruit quality for pear cultivation. However, since the climate and soil conditions are different for each year, accumulation and analyzation of much larger data are requisite. In addition to this, real-time data collection using some communication technology is needed as a future study.

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