Engineering and Applied Science Research

Double exponential smoothing and Holt-Winters methods with optimal initial values and weighting factors for forecasting lime, Thai chili and lemongrass prices in Thailand

Thitima Booranawong[1] and Apidet Booranawong*[2]

[1]Faculty of Management Sciences, Nakhon Si Thammarat Rajabhat University, Nakhon Si Thammarat 80280, Thailand
[2]Faculty of Engineering, Thaksin University, Phatthalung Campus, Phatthalung 93210, Thailand

Abstract

In this paper, the Double Exponential Smoothing (DES), the Multiplicative Holt-Winters (MHW) and the Additive Holt-Winters (AHW) methods with optimal initial values and weighting factors are presented to forecast lime, Thai chili, and lemongrass prices in Thailand. Since these plants are important economic plants in Thailand, knowing their market prices or trends before selling them would be very useful for Thai agriculturists to appropriately plan their work and sales. In this paper, lime, Thai chili and lemongrass prices from January 2011 to September 2016 were gathered from the website's database of Simummuang market used and as input data. This is one of the biggest markets in Thailand. Our study reveals that the DES method with optimal initial values and weighting factors provides the smallest forecasting error measured by the Mean Absolute Percentage Error (MAPE) when forecasting Thai chili and lemongrass prices, while the MHW and the AHW methods show better performance on forecasting lime price data which present seasonality patterns. The forecasted prices of lime, Thai chili and lemongrass during October 2016 to December 2016 are also provided.

Keywords: Forecasting, Double exponential smoothing, Holt-Winters, Lime, Thai chili, Lemongrass

1. Introduction

Lime, Thai chili and lemongrass, as illustrated in Figure 1, are currently important economic plants in Thailand. This is because they are integral to many Thai foods and beverages. Their selling prices are consistently high making them attractive to Thai agriculturists. Therefore, projecting market prices and trends is very useful for Thai agriculturists, allowing them to properly plan their planting and sales schedules.

In this paper, the well-known DES, MHW and AHW time series methods [1-3] are used to forecast lime, Thai chili and lemongrass prices in Thailand for the period of October 2016 to December 2016. The input data from January 2011 to September 2016 were gathered from the website database of Simummuang Market, Thailand. Although forecasting time series data using the DES, MHW and AHW methods is not a new approach, various studies applied these methods due to their simplicity, low computational complexity, and algorithm efficiency [4-5]. The DES method is appropriately used when the data to be forecasted shows a trend, while the MHW and the AHW methods are often used when the data show both a trend and seasonality patterns [6-9].

To the best of our knowledge, there is no work in the literature that applies the DES, MHW and AHW methods to forecast these commodity prices in Thailand. The main contributions of our paper are twofold. First, to forecast lime,

Figure 1 a) Lime, b) Thai chili and c) lemongrass.

*Corresponding author. Tel.: +6684 581 7864
Email address: apidet.boo@gmail.com

Thai chili and lemongrass prices, optimal initial values and weighting factors assigned for the DES, the MHW and the AHW methods were rigorously determined. They significantly minimize the forecasting error. Second, sales prices and trends of these economic plants are revealed. This information is very useful to Thai agriculturists.

This paper is organized as follows. Section 2 explains the materials and methods used, including details of the input data, the forecasting techniques and the performance metrics. Section 3 describes results and presents a discussion. Finally, conclusions are drawn in Section 4.

2. Materials and methods

2.1 Input data

Lime, Thai chili and lemongrass prices from January 2011 to September 2016 were gathered from the website of the Simummuang market. This is one of the big markets in Thailand. It is located in Pathum Thani Province, Thailand. Monthly prices for limes, Thai chili and lemongrass, in Thai baht, are given in Tables 1, 2 and 3, respectively.

Table 1 The monthly lime prices in Thai Baht units.

Months	Monthly lime prices from the year 2011 to 2016
	2011	2012	2013	2014	2015	2016
1	71.77	265.16	235.67	236.13	261.94	210.00
2	110.00	369.66	320.00	337.14	314.29	200.00
3	269.35	502.90	558.06	505.00	398.21	320.00
4	184.83	561.33	676.67	745.00	544.83	421.67
5	169.68	336.45	542.19	622.41	581.10	500.00
6	149.33	173.00	281.67	373.33	298.33	473.33
7	113.55	163.23	251.61	187.10	200.00	264.52
8	92.90	267.74	309.35	211.29	182.26	183.87
9	84.67	295.00	300.00	289.33	200.00	270.59
10	140.00	209.03	235.45	370.97	232.26	-
11	140.00	200.00	196.00	326.33	218.33	-
12	187.00	204.84	169.03	222.58	200.00	-

Table 2 The monthly Thai chili prices in Thai Baht units.

Months	Monthly Thai chili prices from the year 2011 to 2016
	2011	2012	2013	2014	2015	2016
1	42.06	121.33	54.53	93.55	94.06	61.00
2	40.36	83.31	89.11	91.79	122.14	67.50
3	43.23	49.87	89.97	58.67	114.29	73.76
4	47.66	60.13	110.60	48.03	107.59	141.00
5	39.44	43.61	110.78	55.45	98.06	181.61
6	43.4	28.23	68.07	62.07	125.67	120.50
7	76.29	36.58	73.74	64.74	117.00	50.97
8	97.90	62.00	85.03	71.48	111.61	61.45
9	55.20	44.70	65.80	60.17	80.34	66.25
10	48.86	35.52	75.16	49.23	81.61	-
11	48.86	37.43	79.80	51.73	53.17	-
12	85.75	29.23	93.55	61.87	57.42	-

Table 3 The monthly lemongrass prices in Thai Baht units.

Months	Monthly lemongrass prices from the year 2011 to 2016
	2011	2012	2013	2014	2015	2016
1	64.68	249.68	105.67	189.68	120.32	177.83
2	65.00	236.72	100.00	252.50	127.14	172.86
3	65.24	251.94	90.65	296.67	120.00	199.00
4	67.50	249.33	108.67	283.00	119.66	226.00
5	64.84	220.65	103.44	273.79	109.03	204.52
6	62.58	182.00	98.67	264.67	100.00	200.00
7	56.58	145.16	100.00	238.39	100.00	179.68
8	55.00	106.45	100.00	185.81	92.58	147.74
9	55.00	90.00	100.00	141.33	87.59	128.24
10	102.5	87.42	122.90	124.52	87.74	-
11	102.5	90.00	151.00	126.00	96.33	-
12	145.5	96.13	172.26	123.87	121.29	-

2.2 Forecasting methods

2.2.1 The DES method

The DES method, also known as Holt's Linear Exponential method, is suitably used to forecast data which shows a trend [4-6]. The DES method includes a trend factor in the equation. There are three relationships incorporated in this method as presented in Eq. (1-3). L_i is an estimate of the level of the data series at the sample number i, X_i is the input value (i.e., the product price) as shown in Tables 1 to 3, b_i is the estimate of the trend of the data series, α and β are the weighting factors with values between 0 and 1, and Y_{i+m} is the forecasted value (i.e., the forecasted price) for the period $i + m$ (where $m > 0$).

$$L_i = \alpha X_i + (1-\alpha)(L_{i-1} + b_{i-1}) \tag{1}$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \tag{2}$$

$$Y_{i+m} = L_i + mb_i \tag{3}$$

As suggested by [4-7, 10], to set the initial values for L_i and b_i, we used Eq. (4-6). For b_i, a value that gives the minimum forecasting error is chosen. Additionally, optimal values of α and β are also determined. They are selected to minimize the forecasting error [4-5, 7, 10]. In this work, the minimization problem is automatically solved using the Solver function in Microsoft Excel (Version 2013) [10]. α and β are determined by minimizing the MAPE.

$$L_1 = X_1 \tag{4}$$

$$b_1 = 0 \tag{5}$$

$$b_1 = (X_n - X_1)/(n-1) \tag{6}$$

2.2.2 The Holt-Winters method

The Holt-Winters method is more suitable when the data series to be forecasted show a seasonality pattern [4-6]. The Holt-Winters method is often used when both trend and seasonality patterns are present in the data series. It incorporates three equations: the first for the level, the second for the trend, and the third for seasonality. In general, there are two Holt-Winters methods, the MHW method and the AHW method, depending on whether the seasonality is modeled in multiplicative or additive forms, respectively.

The MHW method is shown in Eq. (7-10). Equation (8) is identical to Eq. (2), where S_i is the multiplicative seasonal component, γ is the weighting factor with a value between 0 and 1, and n is the seasonality length (i.e., 12, number of months in a year).

$$L_i = \alpha\left(\frac{X_i}{S_{i-m}}\right) + (1-\alpha)(L_{i-1} + b_{i-1}) \tag{7}$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \tag{8}$$

$$S_i = \gamma\left(\frac{X_i}{L_i}\right) + (1-\gamma)S_{i-n} \tag{9}$$

$$Y_{i+m} = (L_i + mb_i)S_{i-n+m} \tag{10}$$

As suggested by [4-7, 10], to initialize the level, we used Eq. (11) ($n = 12$ months). To initialize the trend, we use the Eq. (5-6). The one that gives the minimum forecasting error was chosen. Finally, to initialize the seasonal components, we used Eq. (12), where $i = 1, 2, 3, \ldots, 12$.

$$L_n = (X_1 + X_2 + \cdots + X_n)/n \tag{11}$$

$$S_i = X_i/L_n \tag{12}$$

The AHW method is expressed in Eq. (13-16). Equation (14) is identical to Eq. (8) and (2).

$$L_i = \alpha(X_i - S_{i-m}) + (1-\alpha)(L_{i-1} + b_{i-1}) \tag{13}$$

$$b_i = \beta(L_i - L_{i-1}) + (1-\beta)b_{i-1} \tag{14}$$

$$S_i = \gamma(X_i - L_i) + (1-\gamma)S_{i-n} \tag{15}$$

$$Y_{i+m} = L_i + mb_i + S_{i-n+m} \tag{16}$$

To initialize the level, Eq. (11) is used. To initialize the trend, Eq. (5-6) are used. The one that yields the minimum forecasting error was chosen. The initial values for the level and the trend are identical to those for the MHW method. Finally, to initialize the seasonal components [4-6, 10], we used Eq. (17), where $i = 1, 2, 3, \ldots, 12$.

$$S_i = X_i - L_n \tag{17}$$

For both the MHW and the AHW methods, optimal values of α, β and γ are automatically determined and chosen when the forecasting error is minimized [4, 7-8]. The minimization problem is solved using the Solver function in Microsoft Excel, Version 2013, where the parameters α and β were determined by minimizing the MAPE.

2.3 Performance metric

To evaluate the performance of the forecasting methods presented above, the forecasting error represented by the Mean Absolute Percentage Error (MAPE) [11] was chosen as the performance metric. It is given by Eq. (18), where N denotes the number of data samples, e_i denotes the forecasting error from $\acute{Y}_i - Y_i$, $\acute{Y}_i$ is the observed data, and Y_i is the forecast data. The 95% confidence interval (CI) is also provided for average results.

$$MAPE = \frac{\sum_{i=1}^{N}\left|\frac{e_i}{\acute{Y}_i}\right|}{N} \times 100, \text{where } e_i = \acute{Y}_i - Y_i \tag{18}$$

3. Results and discussion

Figures 2, 3 and 4 show the MAPE of lime, the Thai chili and the lemongrass prices by the DES, the MHW and the AHW methods, respectively. The results indicate that in the cases of the Thai chili and lemongrass prices, the DES method had a significantly smaller MAPE than the MHW and the AHW methods, while for lime prices, the MHW and the AHW methods showed better performance. Our study also reveals that the initial value in Eq. (5) gives a significantly smaller forecasting error than using the initial value in Eq. (6). We note that for the DES method, when using the initial values in
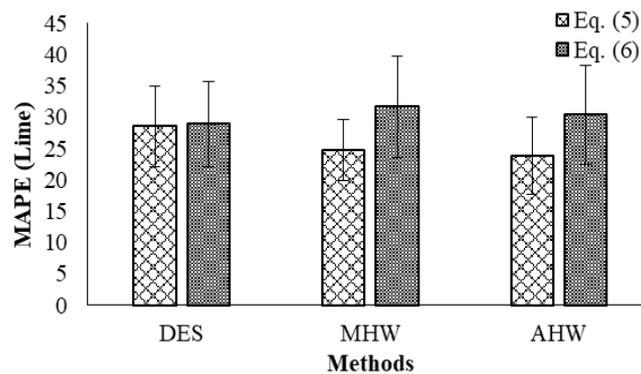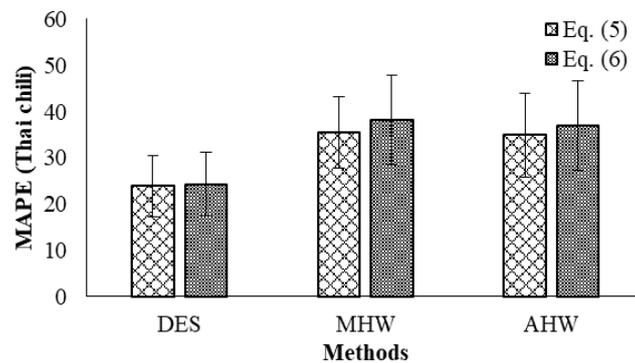
Figure 2 The MAPE of the lime prices.

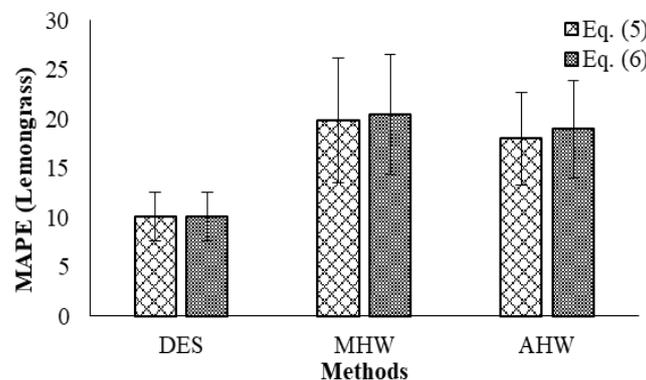**Figure 3** The MAPE of the Thai chili prices.

Figure 4 The MAPE of the lemongrass prices.

Eq. (5-6), the MAPE was not significantly different in any of the cases.

The comparison of the lime, the Thai chili and the lemongrass prices in Thai baht are presented in Tables 1, 2 and 3 and the forecast data determined by the DES, the MHW and the AHW methods with an initial value in Eq. (5). The optimal weighting factors are shown in Figures 5, 6 and 7, respectively. The optimal weighting factors that give the minimum MAPE and forecast prices for October to December 2016 are listed in Tables 4-6. The results support our previous discussion. Moreover, the results also show that the monthly lime prices are very high during the summer (i.e., March to May) every year. Thai chili prices vary throughout the year, and the monthly lemongrass prices showed a cyclical pattern from January 2011 to September 2016.

The patterns of the forecast prices (e.g., peak values, trends, scales) are shown in Figures 5, 6 and 7. They directly depend on the input values (prices of products) presented in Tables 1, 2 and 3 and the forecasting equations presented in Section 2.2. For example, in the DES method, the forecast price (Y_{i+m}) in Eq. (3) is determined by considering the estimated level (L_i) and the estimated trend (b_i) of the data series at sample number i, where the input value (X_i) is a component of L_i. So, Y_{i+m} varied based on changes of X_i, L_i and b_i. Additionally, for the result in Figure 5(a), the forecast price was determined by the DES method with $\alpha = 1$, $\beta = 0$, and $b_i = 0$. Since the estimate of the trend was equal to zero and the estimate of the level in Eq. (1) was equal to $L_i = X_i$, the forecast price in Eq. (3) is then equal to $Y_{i+m} = L_i$. As a result, the pattern in Figure 5(a) indicates a lag of one period in the graph.
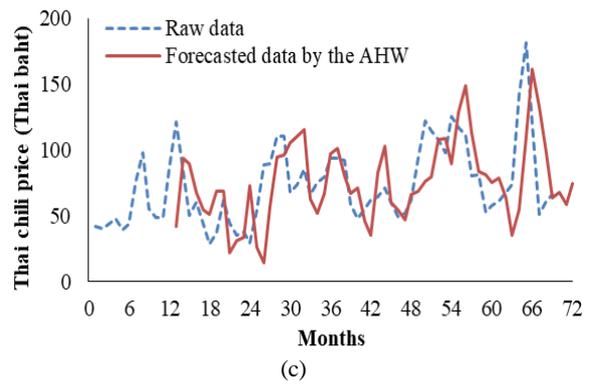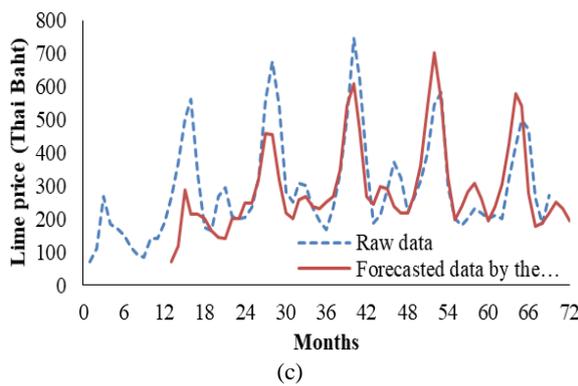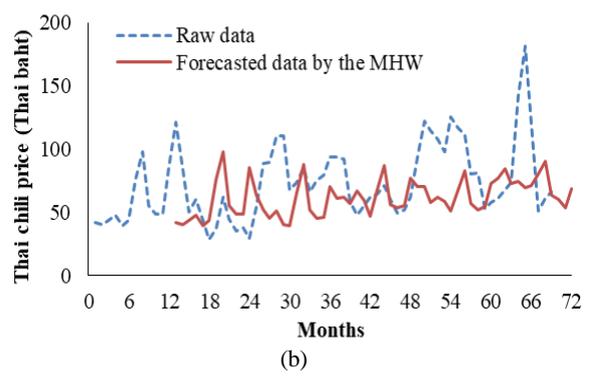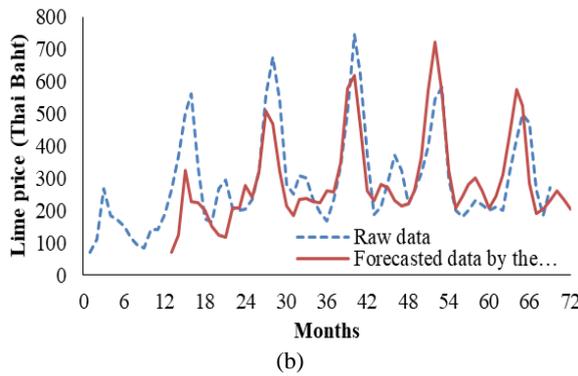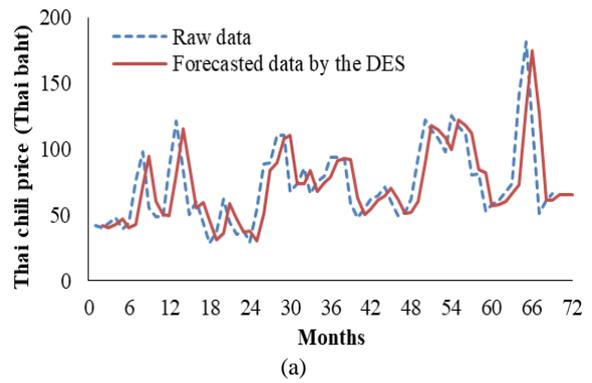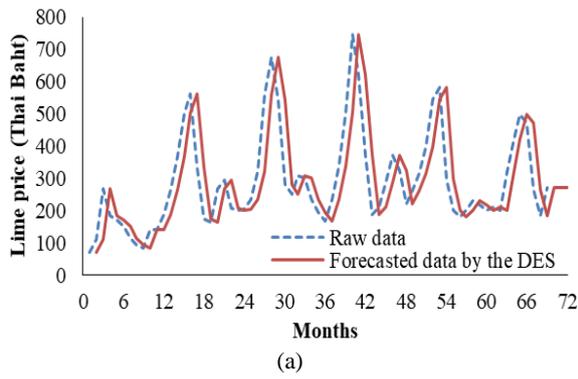
Figure 5 Comparison of lime prices as observed data and forecast data determined by a) the DES, b) MHW and c) AHW methods with an initial value in Eq. (5) and the optimal weighting factors in Table 4.

Figure 6 Comparison of Thai chili prices as observed data and forecast data determined by a) the DES, b) MHW and c) AHW methods with an initial value in Eq. (5) and the optimal weighting factors in Table 5.

Table 4 The optimal weighting factors for the DES, MHW and AHW methods and forecast prices from October 2016 to December 2016 for lime prices.

Lime						
Methods	Optimal weighting factors			Forecasted prices (2016)		
	α	β	γ	Oct.	Nov.	Dec.
DES	1	0	-	270.590	270.590	270.590
MHW	0.04250	0	0.54890	259.750	236.156	203.195
AHW	**0.04522**	**≈0**	**0.62631**	**252.417**	**229.753**	**192.843**

Table 5 The optimal weighting factors for the DES, MHW and AHW methods and forecast prices from October 2016 to December 2016 for Thai chili prices.

Thai chili						
Methods	Optimal weighting factors			Forecasted prices (2016)		
	α	β	γ	Oct.	Nov.	Dec.
DES	**0.86380**	**0**	**-**	**65.596**	**65.596**	**65.596**
MHW	0	0.40700	0.27340	60.283	53.875	68.460
AHW	0.66935	0	1	67.931	58.523	74.919

Table 6 The optimal weighting factors for the DES, MHW and AHW methods and forecast prices from October 2016 to December 2016 for lemongrass prices.
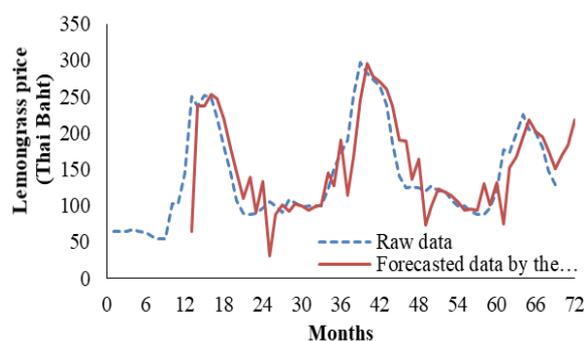
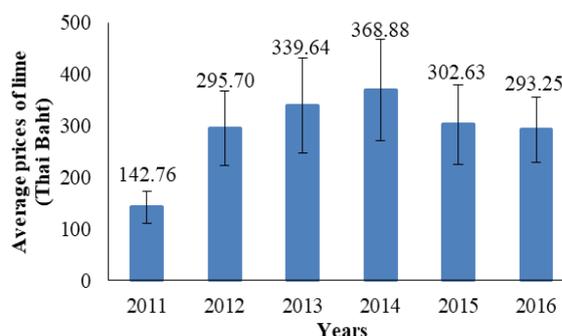| Lemongrass						
Methods	**Optimal weighting factors**			**Forecasted prices (2016)**		
	α	β	γ	Oct.	Nov.	Dec.
DES	**0.93605**	**0.89103**	**-**	**105.549**	**83.485**	**61.422**
MHW	0.95590	0	1	215.416	246.746	335.030
AHW	0.92822	≈ 0	1	169.870	183.320	218.269
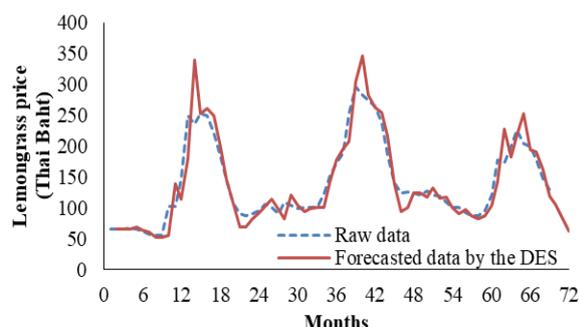
(a)
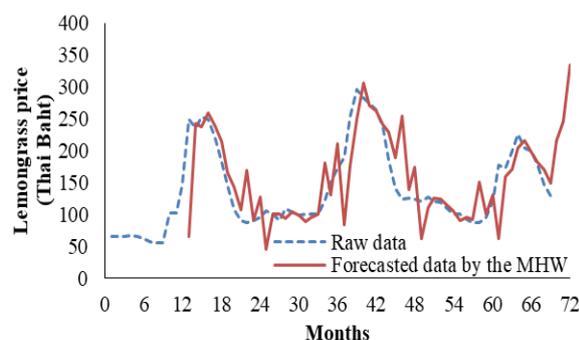
(b)

(c)

**Figure 7** Comparison of lemongrass prices as observed and forecast data determined by a) the DES, b) MHW and c) AHW methods with the initial value in Eq. (5) and the optimal weighting factors in Table 6.
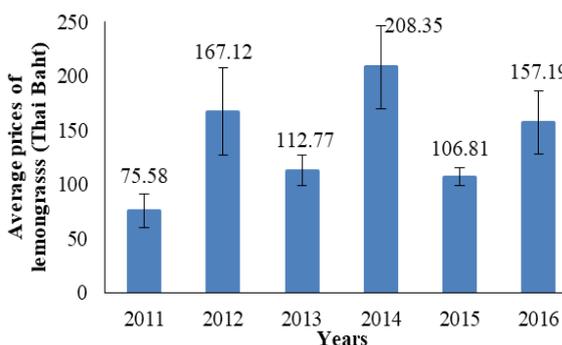
Figures 8, 9 and 10 show the year's average prices for limes, Thai chili and lemongrass during the years of 2011 to 2016. For 2016, we used raw data (i.e., January 2016 to September 2016) in the last columns of Tables 1 to 3 and the forecast data (i.e. October 2016 to December 2016) determined by the forecasting method which gave the smallest MAPE in Tables 4-6 (i.e., the bolded data). The results revealed that lime prices increased from 2011 to 2014 and decreased from 2014 to 2016. Thai chili prices seemed to

Figures 8 The year's average prices for limes.
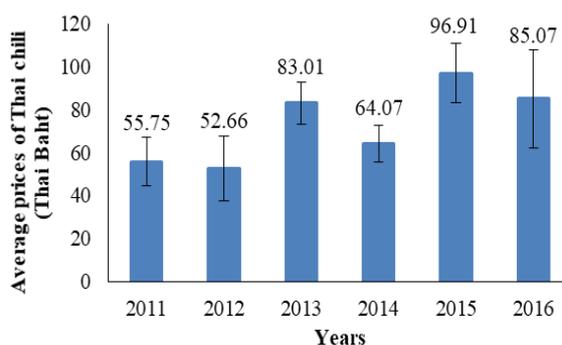
Figures 9 The year's average prices for Thai chili.

Figures 10 The year's average prices for lemongrass.

to increase from 2011 to 2016. Finally, lemongrass prices cyclically increased and decreased from 2011 to 2016.

4. Conclusions

The DES, MHW and AHW methods were used to forecast lime, Thai chili, and lemongrass prices in Thailand. Optimal initial values and weighting factors assigned for those methods are introduced. Our study revealed that the DES method

provides better performance than other methods forecasting Thai chili and lemongrass prices. Monthly Thai chili prices varied throughout the year, and the yearly trend of the average price seemed to increase from 2011 to 2016, while the yearly trend for lemongrass prices was cyclic. Lime prices exhibited a seasonality pattern, and the MHW and AHW methods showed better performance. Lime prices were very high during the summer, and the yearly trend of average price increased from 2011 to 2014 and decreased from 2014 to 2016. We believe that this research methodology can be applied to forecast next year's lime, Thai chili and lemongrass prices. These results are useful for Thai agriculturists in planning their work and sales.

In future work, to further reduce the forecasting error and to find more appropriate forecasting methods, extension or modification of the DES, the MHW and the AHW methods will be studied, and their performance compared with other forecasting methods. Additionally, forecast prices with longer periods (i.e., more than three months) should be determined.

5. Acknowledgements

6. References

[1] Brown RG. Exponential smoothing for predicting demand. The 10th National Meeting of the Operations Research Society of America; 1956 Nov 14-15; San Francisco, USA. San Francisco: Little; 1956.

[2] Hunter JH. The exponentially weighted moving average. J Qual Tech. 1986;18:203-10.

[3] Winters PR. Forecasting sales by exponentially weighted moving averages. Manag Sci. 1960;6(3):324-42.

[4] Montgomery DC, Jennings CL, Kulahci M. Introduction to time series analysis and forecasting. Wiley Series in Probability and Statistics. New Jersey, USA: John Wiley and Sons; 2008.

[5] Kalekar PS. Time series forecasting using Holt-Winters exponential smoothing. Mumbai: Kanwal Rekhi School of Information Technology; 2004.

[6] Holt CC. Forecasting seasonals and trends by exponentially weighted moving averages. Int J Forecast. 2004;20(1):5-10.

[7] Dhakre DS, Sarkar KA, Manna S. Forecasting price of Brinjal by Holt Winters method in west Bengal using MS excel. Int J Bio-res Env Agril Sci. 2016;2(1):232-5.

[8] Gardner ES. Exponential smoothing: the state of the art. J Forecast. 1985;4(1):1-28.

[9] De Gooijer JG, Hyndman RJ. 25 years of time series forecasting. Int J Forecast. 2006;22:443-73.

[10] Tratar LF, Srmcnik E. The comparison of Holt-Winters method and regression methods: a case study. Energy. 2016;109:266-76.

[11] Chatfield C. Time-series forecasting. New York: Chapman & Hall; 2001.