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Economic assessment of colored shade net: growth and yield improvement in mango cv. Keitt

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Abstract

Colored shade net is an effective tool for sustainable agricultural production. Shade nets of five colors (white, yellow, red, blue, and black), in comparison to open field conditions, were studied in mango cv. Keitt. The aim of the study was to explore the profitability of different colored shade nets (white, yellow, red, blue, black, and control) on the yield of 'Keitt' mango during the period of 2016-2020. The results showed that the use of white colored shade net increased the yield $2000 \cdot m^{-2}$. The average yield of the trees under white colored shade net was about 7.3 $kg \cdot tree^{-1}$, compared to about 6.3, 5.8, 5.1, 4.3, 4.3 $kg \cdot tree^{-1}$ for yellow, red, blue and black colored shade nets and control, respectively. The black colored shade net had the lowest economical profit. Thus, growing mango under a white colored shade net is useful to increase marketable and exportable yield, as well as to improve the quality of mangoes compared to other treatments.

Keywords: *Mangifera indica*, colored shade net, 'Keitt' mango, ratio of revenues to costs, unit costs of production.

Introduction

In 2020, the total cultivated area of fruit in Egypt was 1.63 million acres, while the total cultivated area of mango reached 310 thousand acres, representing about 19 % of the total cultivated fruit area with an average yield of 4.37 tons per acre, and a total production of 1.2 million tons (MALR, 2020). India is the largest producer of mangoes, with 24.75 million tons, which represented about 45.2 % of the global production of mango in 2021 (United Nations Department of Economic and Social Affair, 2021). The second-largest producer of mangoes is Indonesia, with 3.62 million tons, representing about 6.61 % of the global production of mango in 2021. Other important mango growing countries include Mexico (4.34 %), China (4.33 %), Pakistan (4.28 %), and Brazil (3.9 %). Thailand was positioned as the top mango exporter when looking at trade value, with about $571 million in 2020. Mexico was followed by the Netherlands with almost $460 million and $416 million, respectively (United Nations, 2021). The export value of Egyptian mango was $44.98 million, which represented about 1.2 % of the global market. The top importer of Egyptian mango was Saudi Arabia, followed by Jordan and the United Arab Emirates, with export shares of 31.06, 15.49, and 13.91 % respectively (United Nations Department of Economic and Social Affair, 2021).

Abbasnia Zare, et al. (2019) found that the usage of colored shade nets gives the plants better growth conditions than when they were not used. In addition to that, the cultivation of some fruit crops, such as peach, under greenhouse conditions, will lead to modifying environmental conditions, such as temperature and wind speed of the trees, thus improving yield, shelf life and quality of the fruit (Martínez-Gómez et al., 2021). It also provides physical protection (e.g. birds, hail, insects, excessive radiation) (Pérez et al., 2006). Besides, the environmental advantages of shade net greenhouses, Mohamed & El-Nagger (2018) displayed the profitability of cultivating the 'Keitt' mango and 'Navel' orange under shade net greenhouses using these particular assumptions, such as production cost, farm gate prices, total revenue and net return.

A simple and inexpensive greenhouse has been introduced (Mohamed & Medany, 2015) whereby, the greenhouse is covered by white shade net on an area of 4 200 m^2 with local

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materials from the domestic market reached a total cost of 26 000 Egyptian pounds (EGP[1]). This kind of greenhouse has been referred to as a new technique used to protect the trees from insects and fruits from the hot sun and wind. The development of architectures, technology, and cultivation of 'Navel' orange and 'Keitt' mango in the greenhouse model was such a smashing success, which generated a positive impact on fruit quality and the farmers' income compared to open field cultivation. Moreover, Mohamed & Medany (2015) revealed that the annual net return from the 'Keitt' mango growing in the open field is 50 % lower than that of the shade net. The objective of this on-going study was to evaluate the profitability of different colored shade net (white, yellow, red, blue, black and control) and open field on 'Keitt' mango yields.

Materials and methods

Location of the experiment

The experiment was undergone at the Agricultural Research Centre farms, located in km 80 Cairo–Alexandria Desert Road, in Behira Governorate, Egypt (Figure 1).

Greenhouse infrastructure

Mango seedlings (*Mangifera indica*) cv. Keitt were planted in a "multi-tunnel" greenhouse with an area of 10,000 m^2 (80 m length x 125 m width) in June 2009. The greenhouse was covered by five sequential colored shade net sections (white, yellow, red, blue, and black). Each section covered 80 m (North-South direction) and about 25 m (East-West direction) with a total area of 2 000 m^2. The number of trees per treatment was 333 trees·2000 m^2. Mango seedlings (a year and a half old) were provided by the Central Laboratory for Agricultural Climate farm in El-Behaira Governorate, Egypt. 'Keitt' mango was planted at 3 m x 2 m. The soil texture was sandy. The cell diameter of the shade net was 0.28 mm, and the cell size was 3.0 x 7.4 mm.

Orchard management

The trees were irrigated with a drip sytem. The amount of water supplied to the trees was determined according to the reference crop evapotranspiration (ET0) ($mm \cdot d^{-1}$), which was calc lated using the methodologies of Penman-Monteith (Allen, et al., 1998) using daily weather data from the automatic weather station inside the farm.

Mango trees under greenhouse conditions were fertilized with 10 tons of compost. Each ton of compost needs 100 kg of ammonium sulfate and 50 kg of sulfate during land preparation and after the harvesting of fruit. On the other hand, mango trees under open field were fertilized with 2 tons of compost, considering that each ton of compost needs 100 kg of ammonium sulfate and 50 kg of sulfate during land preparation and after the harvesting of fruit. For each treatment, the same amount of fertilizer (N, P_2O_5, and K_2O) was applied with irrigation two times per week for each cropping season.

Data analysis

The statistical analysis consists of one-way ANOVA and two-way ANOVA with a confidence level of 95 %, followed by the comparison of means using Tukey's post-hoc test at $P \leq 0.05$ to understand which treatments differed. All data were processed using IBM® SPSS® Statistics v. 25.

Results and discussion

Total yield and production

Table 1 shows the number of fruit per tree under different color net treatments. The white color net helped increase the amount of fruit compared to the other treatments.The yield per tree was about 0.25 kg in 2011 and reached the maximum yield in the eighth year of planting, with 12 $kg \cdot tree^{-1}$. The results in Table 2 indicate that the yield per tree under the white net was significantly different at 5 % level of significance. The results also indicate that the annual change was 1.33 $kg \cdot tree^{-1}$ during the study period. Henceforth, it can be concluded from the results of the yellow net that the average yield was about 6.3 $kg \cdot tree^{-1}$. The yield of a tree ranged between a minimum of 0.20 $kg \cdot tree^{-1}$ in 2011 and a maximum of 10.2 $kg \cdot tree^{-1}$ in 2018 (Table 1). The results in Table 2 indicate that the annual change was 1.14 $kg \cdot tree^{-1}$ during the study period. Meanwhile, the average yield of the red net treatment was about 5.8 $kg \cdot tree^{-1}$, where the yield of the tree ranged between a minimum of 0.19 $kg \cdot tree^{-1}$ in 2011 and a maximum of 9.9 $kg \cdot tree^{-1}$ in 2018 (Table 1). The results in Table 2 indicate that the annual change was 1.08 $kg \cdot tree^{-1}$ during the period of the study. With regard to the blue net treatment, the average yield was 5.1 $kg \cdot tree^{-1}$, the yield of a tree ranged between a minimum of 0.17 $kg \cdot tree^{-1}$ in 2011 and a maximum of 9.6 $kg \cdot tree^{-1}$ in 2018 (Table 1). The results in Table 2 indicate that the annual change was 1.04 $kg \cdot tree^{-1}$ during the study period. The average yield for the black net was about 4.3 $kg \cdot tree^{-1}$, the yield of a tree ranged between a minimum of 0.1 $kg \cdot tree^{-1}$ in 2011 and a maximum of 7.4 $kg \cdot tree^{-1}$ in 2018 (Table 1). The results in Table 2 also indicate that the annual change was 0.83 $kg \cdot tree^{-1}$ during the study period. On the other hand, the average yield under open field conditions (Control treatment) was less than the colored net treatments (white, yellow, red, and blue), except for the black net. The results in Table 1 show that the average yield for the control treatment was 4.3 $kg \cdot tree^{-1}$, the yield of a tree ranged between a minimum of 0.5 $kg \cdot tree^{-1}$ in 2013 and a maximum of w7.9 $kg \cdot tree^{-1}$ in 2018. The results in Table 2 indicate that the annual change was 0.95 $kg \cdot tree^{-1}$ during the period of study.

[1]Code for the Egyptian Pound according to the International Organization of Standardization ISO 4217.

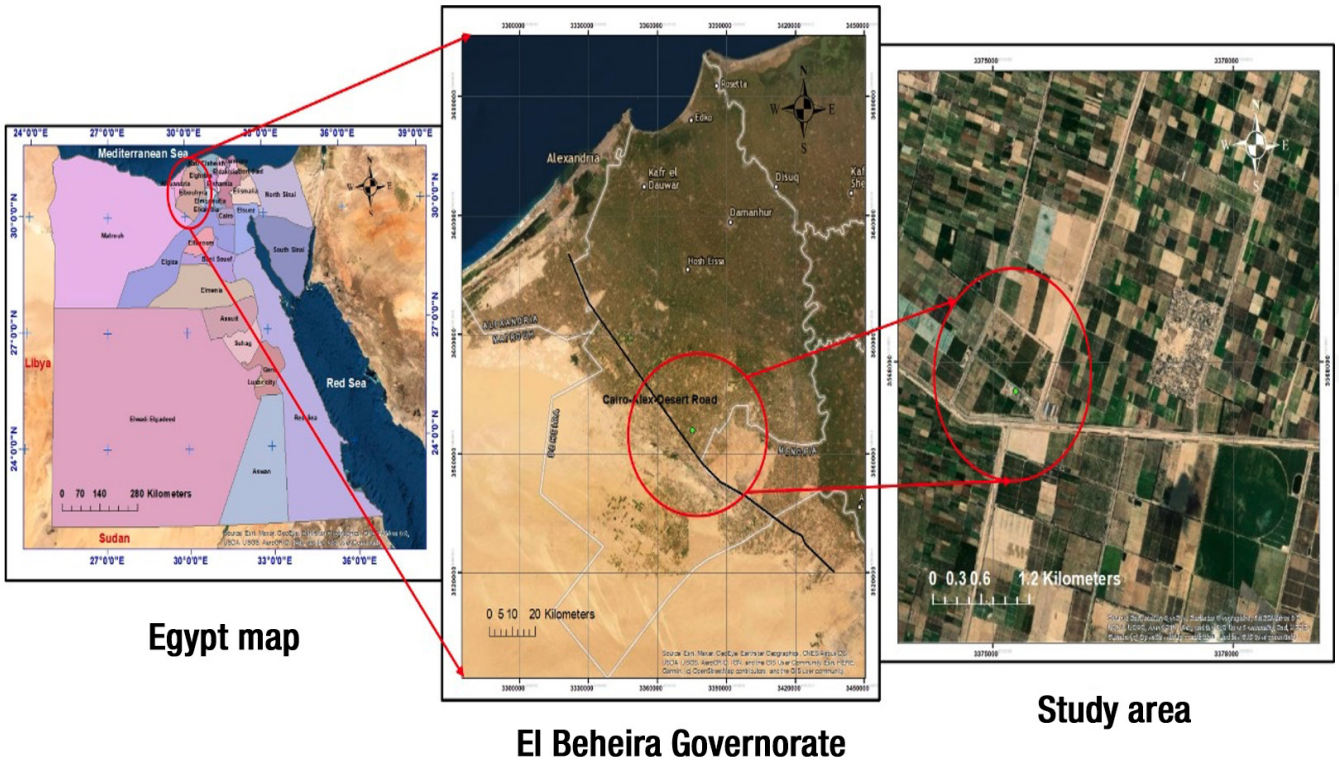

Figure 1. Location of the study area in Egypt.

Table 1 shows the total production of 'Keitt' mango under the different color net treatments. It can therefore be concluded that the white net treatment has the highest total yield with 2.4 thousand kg, followed by the yellow net treatment with 2.08 thousand kg, the red net treatment with 1.9 thousand kg, the blue net treatment with 1.69 thousand kg, and the black net treatment with 1.42 thousand kg. On the other hand, the control treatment had the lowest total production compared to all treatments of colored shade nets with 1.41 thousand kg.

One-way analysis of variance

The results of the one-way analysis of variance between yields of the 'Keitt' mango trees in different treatments are presented in Table 3. The results show that p-value ($P < 0.05$) is equal to 0.000, which confirmed that there were significant differences between yields of the 'Keitt' mango trees in different treatments, and to determine the source of the differences, additional tests should be used.

The results of the Tukey's test in Table 4 indicate that there were significant statistical differences between the average yield of the 'Keitt' mango trees under the white net treatment compared to the average yield under the different colored net treatments (yellow, red, blue, and black), in addition to the average yield in the open field. The difference between the yield of the white net treatment and the yield of the black net treatment ranked first, followed by the difference between the average yield of the white net treatment and the average yield in open field. Followed by the average yield of the white net treatment with the other treatments blue, red, and yellow respectively.

Two-way analysis of variance

The results in Table 5 show that the result of the two-way analysis of variance is similar to the results of the one-way analysis of variance. The significance of the effect during the years is shown in Table 5, where the p-value is equal to 0.0001, which is smaller than 0.05. Therefore, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted, which proves that there are two or more averages which are unequal.

The results of the analysis of variance (F_{test}) confirm that there were significant differences between treatments and to determine the source of these differences, a Tukey's test should be used. Table 6 shows the results of the Tukey's test which indicate that there were significant differences between the average yield of the 'Keitt' mango trees under the white net treatment compared to the average yield under the different colored treatment (yellow, red, blue, and black), in addition to the average yield in the open field (control). The difference between the yield of the white net treatment and the yield of the black net treatment ranked first, followed by the difference between the average yield of the white net treatment and the average yield in the open field (control); these were followed by the average yield of the white net treatment with the other

Table 1. Number of fruit and total production (kg) of 'Keitt' mango under different treatments during 2011-2020.

Year	White		Yellow		Red		Blue		Black		Control	
	YpT	Total production	YpT	Total production	YpT	Total production	YpT	Total production	YpT	Total production	YpT	Total production
2011	0.25	83.25	0.2	66.6	0.2	63.3	0.2	56.6	0.1	33.3	-	-
2012	2.5	832.5	2.0	666	1.8	599.4	1.5	499.5	1.2	399.6	-	
2013	3.0	999.0	2.4	799.2	2.1	699.3	1.75	582.75	1.4	466.2	0.5	166.5
2014	5.0	1665.0	4.1	1365.3	3.9	1298.7	2.1	699.3	1.9	632.7	2.1	699.3
2015	7.0	2331.0	6.6	2197.8	5.8	1931.4	5.2	1731.6	4.7	1565.1	4.9	1631.7
2016	11.0	3663.0	9.8	3263.4	9.1	3030.3	7.3	2430.9	6.5	2164.5	6.8	2264.4
2017	10.0	3330.0	9.2	3063.6	8.8	2930.4	7.5	2497.5	7.2	2397.6	7.5	2497.5
2018	12.0	3996.0	10.2	3396.6	9.9	3296.7	9.6	3196.8	7.4	2464.2	7.9	2630.7
2019	10.6	3529.8	8.8	2930.4	8.1	2697.3	7.6	2530.8	6.1	2031.3	6.3	2097.9
2020	11.2	3729.6	9.4	3130.2	8.8	2930.4	8.1	2697.3	6.3	2097.9	6.5	2164.5
Aver.	**7.3**	**2415.9**	**6.3**	**2087.9**	**5.8**	**1947.7**	**5.1**	**1692.3**	**4.3**	**1425.2**	**4.3**	**1415.3**

YpT: Yield per tree.

Table 2. Results of the trend of 'Keitt' mango yields under different treatments during 2011-2020.

Color	β	T_{test}	R^2	Rate of change (%)	Averag	% aver. for Control	No.
White	1.33	7.61	0.88	18.3	7.3	69.8	1
Yellow	1.14	6.45	0.84	18.2	6.3	46.5	2
Red	1.08	6.36	0.83	18.5	5.8	34.9	3
Blue	1.04	7.05	0.86	20.5	5.1	18.6	4
Black	0.83	5.71	0.80	19.5	4.3	0.0	5
Control	0.95	5.56	0.79	22.2	4.3	0.0	6

R^2: ratio of 'explained' variance to the 'total' variance of the dependent variable 'Yield'. The coefficient of determination indicating goodness-of-fit of the regression. T = T- Test, test on individual regression coefficients.

Table 3. One-way analysis of variance ($P \leq 0.05$) results of different treatments during 2016-2020.

Source of variation	Sum of squares	Degrees of freedom	Mean square	F	Signif.
Between Groups	64.622	5	12.924	26.602	.000**
Within Groups	11.660	24	.4860		
Total	76.282	29			

P-value: expresses the results of the hypothesis test as a significance level. P-values smaller than 0.05 are taken as evidence that the population coefficient is nonzero, the more evidence there is in the sample data against the null hypothesis and for the alternative hypothesis. Source: calculated from data of Table 1.

treatments blue, red, and yellow respectively. This observation is similar to the aforementioned in the one-way analysis of variance.

Results in Table 7 show significant differences between the average yield of the 'Keitt' mango trees under shade net in the third year (2018), compared to the average yield of the 'Keitt' mango trees in other years (2016, 2017, 2019, 2020). Results indicate that the difference between the average yield of the third and fourth year came first, followed by the average yield differences of the third and fifth year, also followed by the average yield differences of the second and first season.

Economic assessment

White net treatment

Table 8 shows the difference between the total net revenue of the white net treatment and the open field, it ranged between a minimum of about 1 605 Egyptian Pounds (EGP) in 2 017 and a maximum of about EGP 10 190 in 2020, with an average of about EGP 6 634 during the study period. According to the unit costs of production, the average cost per kilogram in white net treatment was about EGP $4.5 \cdot kg^{-1}$ compared to about EGP $5.5 \cdot kg^{-1}$ in the open field. Whereas the unit cost of production in white net treatment ranged between a minimum of about EGP $4.0 \cdot kg^{-1}$ in 2016 compared to about EGP $4.8 \cdot kg^{-1}$ in the open field for the same year. Additionally, a maximum of about EGP $5.0 \cdot kg^{-1}$ in 2019 compared to about EGP $6.6 \cdot kg^{-1}$ in the open field for the same year. As for the ratio of revenues to costs, it ranged between a minimum of about 1.4 % in 2017, which was similar to the 1.4 % in the open field, and a maximum of about 2.3 % in 2018, compared to about 1.9 % in the open field, with an average of about 1.8 %, compared to about 1.5 % in the open field.

Yellow net treatment

Table 9 illustrates the differences between the total net revenue of the yellow net treatment and the open field, it ranged between a minimum of EGP 2 525 in 2016 and a maximum of about EGP 4 794 in 2018. The net revenue was a negative value in 2017, estimated at EGP 124. For the unit costs of production, the average cost per kilogram in yellow net treatment was about EGP $5.2 \cdot kg^{-1}$, compared to about EGP $5.5 \cdot kg^{-1}$ in the open field. Meanwhile, the unit cost of production in the yellow net treatment ranged between a minimum of about EGP $4.5 \cdot kg^{-1}$ in 2016, compared to about EGP $4.8 \cdot kg^{-1}$ in the open field for the same year and a maximum of about EGP $6.1 \cdot kg^{-1}$ in 2019, compared to about EGP $6.6 \cdot kg^{-1}$ in the open field for the same year.

As for the revenue to cost ratio, it ranged between a minimum of about 1.3 % in 2017, compared to 1.4 % in the open field, and a maximum of about 1.9 % in 2018, compared to about 1.9 % in the open field, with an average of about 1.6 %, compared to about 1.5 % in the open field.

Red net treatment

Table 10 presents differences between the total net revenue of the red net treatment and the open field, it ranged between a minimum of EGP 1 071 in 2016, with an increase of about 32.4 % compared to the open field, while the maximum net revenue was EGP 2 997 in 2020, with an increase of about 59 % compared to the open field treatment. The average total net revenue was EGP 1 497 during the study period. In addition, the net revenue was a negative value in 2017, estimated at EGP 992. For the unit costs of production, the average unit cost of production per kilogram was about EGP $5.5 \cdot kg^{-1}$, in both treatments, while the unit cost of production in the red net treatment and the open field treatment ranged between a minimum of about EGP $4.8 \cdot kg^{-1}$ in 2016, and a maximum of about EGP $6.6 \cdot kg^{-1}$ in 2019, for both treatments. As for the revenue to cost ratio, it ranged between a minimum of about 1.2 % in 2017, for both treatments, and a maximum of about 1.8 % for the red net treatment in 2018, compared to about 1.9 % in the open field, with an average of about 1.7 %, compared to about 1.5 % in the open field.

Blue net treatment

The differences shown in Table 11 between the total net revenue of the blue net treatment and the open field ranged between a negative value of EGP 3 806 in 2017, and a

Table 4. Tukey test results ($P \leq 0.05$) of the different treatments on the yield of 'Keitt' mango during 2016–2020.

(I) Group	(J) Group	Mean difference (I-J)	Std. Error	Signif.	95 % confidence interval	
					Lower Bound	Upper Bound
White	Yellow	1.48000*	0.44083	0.028	0.1170	2.8430
	Red	2.02000*	0.44083	0.001	0.6570	3.3830
	Blue	2.94000*	0.44083	0.000	1.5770	4.3030
	Black	4.26000*	0.44083	0.000	2.8970	5.6230
	Control	3.96000*	0.44083	0.000	2.5970	5.3230
Yellow	White	-1.48000*	0.44083	0.028	-2.8430	-0.1170
	Red	.540000	0.44083	0.821	-0.8230	1.9030
	Blue	1.46000*	0.44083	0.031	0.0970	2.8230
	Black	2.78000*	0.44083	0.000	1.4170	4.1430
	Control	2.48000*	0.44083	0.000	1.1170	3.8430
Red	White	-2.02000*	0.44083	0.001	-3.3830	-0.6570
	Yellow	-0.54000	0.44083	0.821	-1.9030	0.8230
	Blue	0.92000	0.44083	0.327	-0.4430	2.2830
	Black	2.24000*	0.44083	0.000	0.8770	3.6030
	Control	1.94000*	0.44083	0.002	0.5770	3.3030
Blue	White	-2.94000*	0.44083	0.000	-4.3030	-1.5770
	Yellow	-1.46000*	0.44083	0.031	-2.8230	-0.0970
	Red	-0.92000	0.44083	0.327	-2.2830	0.4430
	Black	1.32000	0.44083	0.062	-0.0430	2.6830
	Control	1.02000	0.44083	0.227	-0.3430	2.3830
Black	White	-4.26000*	0.44083	0.000	-5.6230	-2.8970
	Yellow	-2.78000*	0.44083	0.000	-4.1430	-1.4170
	Red	-2.24000*	0.44083	0.000	-3.6030	-0.8770
	Blue	-1.32000	0.44083	0.062	-2.6830	0.0430
	Control	-0.30000	0.44083	0.982	-1.6630	1.0630
Control	White	-3.96000*	0.44083	0.000	-5.3230	-2.5970
	Yellow	-2.48000*	0.44083	0.000	-3.8430	-1.1170
	Red	-1.94000*	0.44083	0.002	-3.3030	-.5770
	Blue	-1.02000	0.44083	0.227	-2.3830	.3430
	Black	0.300000	0.44083	0.982	-1.0630	1.6630
Tukey criterion (HSD) = 1.362						

* It means that there are significant differences between the two averages. ** The mean difference is significant at 5% level of significance.

Table 5. Two-way analysis of variance ($P \leq 0.05$) results of the different treatments during 2016–2020.

Tests of between-subject effects Dependent variable: average yield kg per tree					
Source	**Sum of squares**	**Degrees of freedom**	**Mean square**	**F**	**Signif.**
Treatments	64.622	5	12.924	76.100	0.000*
Years	8.263	4	2.066	12.164	0.000*
Error	3.397	20	0.170		
Total	76.282	29			

* Indicates significant difference at the 0.05 level.

Table 6. Tukey test results ($P \leq 0.05$) of the treatments on the yield of 'Keitt' mango during 2016–2020.

(I) Group	(J) Group	Mean difference (I-J)	Std. Error	Signif.	95 % confidence interval	
					Lower Bound	Upper Bound
White	Yellow	1.4800*	0.26064	0.000	.6607	2.2993
	Red	2.0200*	0.26064	0.000	1.2007	2.8393
	Blue	2.9400*	0.26064	0.000	2.1207	3.7593
	Black	4.2600*	0.26064	0.000	3.4407	5.0793
	Control	3.9600*	0.26064	0.000	3.1407	4.7793
Yellow	White	-1.4800*	0.26064	0.000	-2.2993	-0.6607
	Red	0.5400	0.26064	0.340	-.2793	1.3593
	Blue	1.4600*	0.26064	0.000	.6407	2.2793
	Black	2.7800*	0.26064	0.000	1.9607	3.5993
	Control	2.4800*	0.26064	0.000	1.6607	3.2993
Red	White	-2.0200*	0.26064	0.000	-2.8393	-1.2007
	Yellow	-0.5400	0.26064	0.340	-1.3593	0.2793
	Blue	0.9200*	0.26064	0.022	.1007	1.7393
	Black	2.2400*	0.26064	0.000	1.4207	3.0593
	Control	1.9400*	0.26064	0.000	1.1207	2.7593
Blue	White	-2.9400*	0.26064	0.000	-3.7593	-2.1207
	Yellow	-1.4600*	0.26064	0.000	-2.2793	-0.6407
	Red	-0.9200*	0.26064	0.022	-1.7393	-0.1007
	Black	1.3200*	0.26064	0.001	.5007	2.1393
	Control	1.0200*	0.26064	0.010	.2007	1.8393

Table 6. Tukey test results (P ≤ 0.05) of the treatments on the yield of 'Keitt' mango during 2016–2020. (cont.)

(I) Group	(J) Group	Mean difference (I-J)	Std. Error	Signif.	95 % confidence interval	
					Lower Bound	Upper Bound
Black	White	-4.2600*	0.26064	0.000	-5.0793	-3.4407
	Yellow	-2.7800*	0.26064	0.000	-3.5993	-1.9607
	Red	-2.2400*	0.26064	0.000	-3.0593	-1.4207
	Blue	-1.3200*	0.26064	0.001	-2.1393	-.5007
	Control	-0.3000	0.26064	0.854	-1.1193	0.5193
Control	White	-3.9600*	0.26064	0.000	-4.7793	-3.1407
	Yellow	-2.4800*	0.26064	0.000	-3.2993	-1.6607
	Red	-1.9400*	0.26064	0.000	-2.7593	-1.1207
	Blue	-1.0200*	0.26064	0.010	-1.8393	-0.2007
	Black	0.3000	0.26064	0.854	-.5193	1.1193
Tukey criterion (HSD) = 0.819						

* It means that there are significant differences between the two averages. ** The mean difference is significant at 5% level.

Table 7. Tukey test results (*P* ≤ 0.05) between the years on the yield of 'Keitt' mango during 2016–2020.

(I) Years	(J) Years	Mean difference (I-J)	Std. Error	Signif.	95 % confidence interval	
						Upper Bound
Year 1	Year 2	0.0500	0.23793	1.000	-0.6620	0.7620
	Year 3	-1.0833*	0.23793	0.002	-1.7953	-0.3714
	Year 4	0.5000	0.23793	0.258	-0.2120	1.2120
	Year 5	0.0333	0.23793	1.000	-0.6786	0.7453
Year 2	Year 1	-0.0500	0.23793	1.000	-0.7620	0.6620
	Year 3	-1.1333*	0.23793	0.001	-1.8453	-0.4214
	Year 4	0.4500	0.23793	0.353	-0.2620	1.1620
	Year 5	-0.0167	0.23793	1.000	-0.7286	0.6953
Year 3	Year 1	1.0833*	0.23793	0.002	0.3714	1.7953
	Year 2	1.1333*	0.23793	0.001	0.4214	1.8453
	Year 4	1.5833*	0.23793	0.000	0.8714	2.2953
	Year 5	1.1167*	0.23793	0.001	0.4047	1.8286

Table 7. Tukey test results ($P \leq 0.05$) between the years on the yield of 'Keitt' mango during 2016–2020. (cont.)

(I) Years	(J) Group	Mean difference (I-J)	Std. Error	Signif.	95 % confidence interval	
					Lower Bound	Upper Bound
Year 4	Year 1	-0.5000	0.23793	0.258	-1.2120	0.2120
	Year 2	-0.4500	0.23793	0.353	-1.1620	0.2620
	Year 3	-1.5833*	0.23793	0.000	-2.2953	-0.8714
	Year 5	-0.4667	0.23793	0.319	-1.1786	0.2453
Year 5	Year 1	-0.0333	0.23793	1.000	-0.7453	0.6786
	Year 2	0.0167	0.23793	1.000	-0.6953	0.7286
	Year 3	-1.1167*	0.23793	0.001	-1.8286	-0.4047
	Year 4	0.4667	0.23793	0.319	-0.2453	1.1786
Tukey criterion (HSD) = 0.780						

* It means that there are significant differences between the two averages. ** The mean difference is significant at the 0.05 level.

Table 8. Economic indicators of 'Keitt' mango under white net treatment compared to open field during 2016–2020.

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·2000 m^{-2}	Total revenue EGP·2000 m^{-2}	Net revenue EGP·2000 m^{-2}	Unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
2016						
White	3663	14566	22894	8328	4.0	1.6
Control	2264.4	10850	14153	3303	4.8	1.3
Deviation from control	1398.6		8741	5025	-0.8	0.3
(%) Deviation from control	61.8		61.8	152.2	-17.0	20.5
2017						
White	3330	15206	21645	6439	4.6	1.4
Control	2497.5	11400	16234	4834	4.6	1.4
Deviation from control	832.5		5411	1605	0.0	0.0
(%) Deviation from control	33.3		33.3	33.2	0.0	0.0
2018						
White	3996	16756	37962	21206	4.2	2.3
Control	2630.7	12950	24992	12042	4.9	1.9
Deviation from control	1365.3		12970	9164	-0.7	0.3
(%) Deviation from control	51.9		51.9	76.1	-14.8	17.4
2019						
White	3529.8	17756	33533	15777	5.0	1.9
Control	2097.9	13950	19930	5980	6.6	1.4

Table 8. Economic indicators of 'Keitt' mango under white net treatment compared to open field during 2016–2020. (cont.)

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·2000 m^{-2}	Total revenue EGP·2000 m^{-2}	Net revenue EGP·2000 m^{-2}	Unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
Deviation from control	1431.9		13603	9797	-1.6	0.5
(%) Deviation from control	68.3		68.3	163.8	-24.4	32.2
2020						
White	3729.6	18296	33566	15270	4.9	1.8
Control	2164.5	14400	19481	5081	6.7	1.4
Deviation from control	1565.1		14086	10190	-1.7	0.5
(%) Deviation from control	72.3		72.3	200.6	-26.3	35.6
Average						
White	3649.7	16516	29920	13404	4.5	1.8
Control	2331.0	12710	19481	6771	5.5	1.5
Deviation from control	1318.7		10440	6634	-0.9	0.3
(%) Deviation from control	56.6		53.6	98.0	-17.0	18.2

Table 9. Economic indicators of 'Keitt' mango under white net treatment compared to open field during 2016–2020.

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·2000 m^{-2}	Total revenue EGP·2000 m^{-2}	Net revenue EGP·2000 m^{-2}	Unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
2016						
Yellow	3263.4	14566	20394	5828	4.5	1.4
Control	2264.4	10850	14153	3303	4.8	1.3
Deviation from control	999		6241	2525	-0.3	0.1
(%) Deviation from control	44.1		44.1	76.5	-6.8	7.3
2017						
Yellow	3063.6	15206	19916	4710	5.0	1.3
Control	2497.5	11400	16234	4834	4.6	1.4
Deviation from control	566.1		3682	-124	0.4	-0.1
(%) Deviation from control	22.7		22.7	-2.6	8.7	-8.0
2018						
Yellow	3396.6	16756	32272	15516	4.9	1.9
Control	2630.7	12950	24992	12042	4.9	1.9
Deviation from control	765.9		7280	3474	0.0	0.0
(%) Deviation from control	29.1		29.1	28.8	0.2	0.0

Table 9. Economic indicators of 'Keitt' mango under white net treatment compared to open field during 2016–2020. (cont.)

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·2000 m^{-2}	Total revenue EGP·2000 m^{-2}	Net revenue EGP·2000 m^{-2}	unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
2019						
Yellow	2930.4	17756	27835	10079	6.1	1.6
Control	2097.9	13950	19930	5980	6.6	1.4
Deviation from control	832.5		7905	4099	-0.6	0.1
(%) Deviation from control	39.7		39.7	68.5	-8.9	9.7
2020						
Yellow	3130.2	18296	28170	9874	5.8	1.5
Control	2164.5	14400	19481	5081	6.7	1.4
Deviation from control	965.7		8690	4794	-0.8	0.2
(%) Deviation from control	44.6		44.6	94.4	-12.1	13.8
Average						
Yellow	3156.8	16516	25717	9201	5.2	1.6
Control	2331.0	12710	18958	6248	5.5	1.5
Deviation from control	825.84		6760	2954	-0.2	0.1
(%) Deviation from control	35.4		35.7	47.3	-4.0	4.4

Table 10. Economic indicators of 'Keitt' mango under white net treatment compared to open field during 2016–2020.

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·2000 m^{-2}	Total revenue EGP·2000 m^{-2}	Net revenue EGP·2000 m^{-2}	unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
2016						
Red	3030.3	14566	18939	4373	4.8	1.3
Control	2264.4	10850	14153	3303	4.8	1.3
Deviation from control	765.9		4787	1071	0.0	0.0
(%) Deviation from control	33.8		33.8	32.4	0.3	0.0
2017						
Red	2930.4	15206	19048	3842	5.2	1.2
Control	2497.5	11400	16234	4834	4.6	1.4
Deviation from control	432.9		2814	-992	0.6	-0.2
(%) Deviation from control	17.3		17.3	-20.5	13.7	-12.0
2018						
Red	3296.7	16756	31319	14563	5.1	1.8
Control	2630.7	12950	24992	12042	4.9	1.9

Table 10. Economic indicators of 'Keitt' mango under white net treatment compared to open field during 2016–2020. (cont.)

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·2000 m^{-2}	Total revenue EGP·2000 m^{-2}	Net revenue EGP·2000 m^{-2}	unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
Deviation from control	666		6327	2521	0.2	-0.1
(%) Deviation from control	25.3		25.3	20.9	3.3	-3.1
2019						
Red	2697.3	17756	25624	7868	6.5	1.4
Control	2097.9	13950	19930	5980	6.6	1.4
Deviation from control	599.4		5694	1888	-0.1	0.0
(%) Deviation from control	28.6		28.6	31.6	-1.0	0.0
2020						
Red	2930.4	18296	26374	8078	6.2	1.4
Control	2164.5	14400	19481	5081	6.7	1.4
Deviation from control	765.9		6893	2997	-0.4	0.0
(%) Deviation from control	35.4		35.4	59.0	-6.2	6.6
Average						
Red	2977.0	16516	24261	7745	5.5	1.5
Control	2331.0	12710	18958	6248	5.5	1.5
Deviation from control	646.02		5303	1497	0.0	0.0
(%) Deviation from control	27.7		28.0	24.0	0.0	0.0

maximum net revenue of EGP 1 572 in 2018. For the unit costs of production, the average cost per kilogram in the blue net treatment was about EGP 6.2·kg^{-1}, compared to about EGP 5.5·kg^{-1} in the open field, while the unit cost of production in the blue net treatment ranged between a minimum of about EGP 5.2·kg^{-1} in 2018, compared to about EGP 4.9·kg^{-1} in the open field for the same year, and a maximum of about EGP 7.0·kg^{-1} in 2019, compared to about EGP 6.6·kg^{-1} in the open field for the same year. As for the revenue to cost ratio, it ranged between a minimum of about 1.0 % in 2016, compared to 1.3 % in the open field, and a maximum of about 1.8 % in 2018, compared to about 1.9 % in the open field, with an average of about 1.3 %, compared to about 1.5 % in the open field.

Black net treatment

As shown from data presented in Table 12 the average differences between the total net revenue of the black net treatment and the open field were a negative value (EGP 4 624). The results in the same table emphasized that the production of 'Keitt' mango under the black net treatment is economically unprofitable. For the unit costs of production, the average cost per kilogram in the black net

Table 11. Economic indicators of the 'Keitt' mango under blue net treatment compared to open field during 2016–2020.

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·(2000 m^{-2})	Total revenue EGP·(2000 m^{-2})	Net revenue EGP·(2000 m^{-2})	unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
2016						
Blue	2430.9	14566	15193	627	6.0	1.0
Control	2264.4	10850	14153	3303	4.8	1.3
Deviation from control	166.5		1041	-2675	1.2	-0.3
(%) Deviation from control	7.4		7.4	-81.0	25.1	-20.0
2017						
Blue	2497.5	15206	16234	1028	6.1	1.1
Control	2497.5	11400	16234	4834	4.6	1.4
Deviation from control	0		0	-3806	1.5	-0.4
(%) Deviation from control	0.0		0.0	-78.7	33.4	-25.0
2018						
Blue	3196.8	16756	30370	13614	5.2	1.8
Control	2630.7	12950	24992	12042	4.9	1.9
Deviation from control	566.1		5378	1572	0.3	-0.1
(%) Deviation from control	21.5		21.5	13.1	6.5	-6.1
2019						
Blue	2530.8	17756	24043	6287	7.0	1.4
Control	2097.9	13950	19930	5980	6.6	1.4
Deviation from control	432.9		4113	307	0.4	-0.1
(%) Deviation from control	20.6		20.6	5.1	5.5	-5.2
2020						
Blue	2697.3	18296	24276	5980	6.8	1.3
Control	2164.5	14400	19481	5081	6.7	1.4
Deviation from control	532.8		4795	899	0.1	-0.1
(%) Deviation from control	24.6		24.6	17.7	2.0	-7.4
Average						
Blue	2670.7	16516	22023	5507	6.2	1.3
Control	2331.0	12710	18958	6248	5.5	1.5
Deviation from control	339.66		3065	-741	0.7	-0.2
(%) Deviation from control	14.6		16.2	-11.9	13.4	-10.6

Table 12. Economic indicators of the 'Keitt' mango under black net treatment compared to open field during 2016–2020.

Statement	Yield (kg·2000 m^{-2})	Total costs EGP·(2000 m^{-2})	Total revenue EGP·(2000 m^{-2})	Net revenue EGP·(2000 m^{-2})	unit costs of production EGP·kg^{-1}	Ratio of total revenue to costs
2016						
Black	2164.5	14566	13528	-1038	6.7	0.9
Control	2264.4	10850	14153	3303	4.8	1.3
Deviation from control	-99.9		-624	-4340	1.9	-0.4
(%) Deviation from control	-4.4		-4.4	-131.4	40.4	-28.8
2017						
Black	2397.6	15206	15584	378	6.3	1.0
Control	2497.5	11400	16234	4834	4.6	1.4
Deviation from control	-99.9		-649	-4455	1.8	-0.4
(%) Deviation from control	-4.0		-4.0	-92.2	38.9	-28.0
2018						
Black	2464.2	16756	23410	6654	6.8	1.4
Control	2630.7	12950	24992	12042	4.9	1.9
Deviation from control	-166.5		-1582	-5388	1.9	-0.5
(%) Deviation from control	-6.3		-6.3	-44.7	38.1	-27.6
2019						
Black	2031.3	17756	19297	1541	8.7	1.1
Control	2097.9	13950	19930	5980	6.6	1.4
Deviation from control	-66.6		-633	-4439	2.1	-0.3
(%) Deviation from control	-3.2		-3.2	-74.2	31.5	-23.9
2020						
Black	2097.9	18296	18881	585	8.7	1.0
Control	2164.5	14400	19481	5081	6.7	1.4
Deviation from control	-66.6		-599	-4495	2.1	-0.3
(%) Deviation from control	-3.1		-3.1	-88.5	31.1	-23.7
Average						
Black	2231.1	16516	18140	1624	7.4	1.1
Control	2331.0	12710	18958	6248	5.5	1.5
Deviation from control	-99.9		-818	-4624	2.0	-0.4
(%) Deviation from control	-4.3		-4.3	-74.0	35.8	-26.4

treatment was about EGP 7.4·kg^{-1}, compared to about EGP 5.5·kg^{-1} in the open field. As for the revenue to cost ratio, the average for the study period in the black net treatment was 1.1 % while in the open field was 1.5 %.

Conclusions

The shade net represents a new technology to overcome the constraints that the production sector has faced within the last years. Shade nets created a higher level of protection for mango trees and improved the production. The use of white shade nets was very effective to improve yield and this result could encourage investments in fruit crop cultivation under protected cultivation, especially at new reclaimed lands in the 2.5 million feddan national project. In addition, mango production under blue and black colored net is not economically profitable.

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