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Original Research Article

Comparative the impact of organic and conventional strawberry cultivation on growth and productivity using remote sensing techniques under Egypt climate conditions

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Abstract

Two years field experiment on strawberry plants (cv. Sweet Charlie) in Qalyubia Governorate, Egypt was carried out to study the effect of different growing conditions (organic and conventional) and the effect of some colors of plastic mulch such as clear, black, and silver on the quantitative and qualitative characteristics of the strawberry plantations using hyper spectral remotely sensed data. As the first step, spectral reflectance pattern for the different treatments (fertilization and colors of plastic mulch) was identified through in situ spectral measurements. It was found that silver plastic mulch recorded higher values with all observed vegetative and fruit traits, as compared with an organic strawberry growing systems without plastic mulch. Spectral reflectance parameters in form of vegetation indices (VIs) were examined as yield estimators and their correlation with leaf area index (LAI) was observed. Generated models with accuracy assessment were explained and the optimal vegetation index to estimate yield under each treatment was identified. Generally, it was found that fertilization has more effect on spectral characteristics than plastic mulch. Spectral vegetation indices (VIs) showed higher accuracy than LAI as yield estimators. (Spectral – yield) models showed the same trend with adequate correlation coefficient (r^2) exceeded (0.7) except the treatment of black plastic mulch conventional system that showed (r^2) less than (0.6) with two yield estimators. All generated models with an accuracy of each model are explained in the following sections.

Keywords: Strawberry, Spectral Reflectance, Vegetation Index, LAI, Yield

Introduction

In Egypt, Strawberry crop is the most important export vegetable crop. Egypt has increased its placement on global rank from number 9 in 2014 to number 5 in 2015 in terms of exports of frozen strawberries (OctoFrost Group 2016). Because of the importance of strawberry for local consumption and export, there is a high need for yield prediction system month/s before harvest. This system enables optimal management for strawberry production and exportation. Comparing conventional and organic production system and fruits quality depended on a large number of factors (Vallverdú-Queralt; Lamuela-Raventós, 2015). Palomaki et al. (2002) noticed that when they measured plant vegetative growth was less than in the conventional system .Organic growers employ cultural practices that support soil health for certification, to increase crop quality and yields, and to improve environmental sustainability. This increase is due to benefits of mulching such as an increase in soil temperature, reduced weed pressure, moisture conservation, reduction of certain insect pests, higher crop yields, and more efficient use of soil nutrients (Kyrikou and Briassoulis, 2007; Kasirajan and Ngouajio, 2012). The light color that is perceived by the plant can possibly influence the development of the plants including its physiological characteristics. Fatemi *et al*., (2013) reported that the chlorophyll content of *Cucurbita pepo* was increased when grown with colored polyethylene mulch. Plastic mulch and fertilization are two vital factors for the growth and productivity of strawberry (Abo Sedera *et al.*, 2010a and b). Significant effects of organic and plastic mulches on vegetative growth, flowering traits and yield and its components of strawberry plants have been reported by several investigators (Hasanein *et al* 2011; Abou El-yazied and Mady, 2012; Haroon *et al* 2014). Remote sensing (RS) for crop monitoring is a vital requirement for agricultural development locally and globally. It has been used for the assessment of physiological conditions, biophysical and biochemical parameters of the plants and their effect on crop yield (Sims and Gamon, 2002). RS techniques include different tools that assess spectral characteristics (SC) of plants (Zhang et al., 2010). Changes in (SC) during the growing season are based on different parameters including plant pigments, chlorophyll and water content (Jorgensen et al., 2006; Maire et al., 2004). (SC) in form of vegetation indices (Vis) were used to identify spectral reflectance characteristics in different spectral regions specifically, red, near infrared and green (Gitelson et al., 2005). They were used to estimate chlorophyll content (Gitelson, 2004). Among different (VIs), normalized difference vegetation index (NDVI) is the most common ones (Cabrera-Bosquetet al., 2011). The objective of this study was to evaluate the response of strawberry plants for organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch such as clear, black, and silver and their interactions on the quantitative and qualitative characteristics of the strawberry cv. Sweet Charlie and their effect of these treatments on spectral reflectance characteristics. It is essential for the proposed method to be applicable under local agricultural conditions that might be different from a country to another and sometimes are different even within the same country.

Material and Methods

Two years field experiment on strawberry plants (cv. Sweet Charlie) in Qalyubia Governorate, Egypt was carried out to study the effect of different growing conditions (organic and conventional) and the effect of some colors of plastic mulch such as clear, black, and silver on the quantitative and qualitative characteristics of the strawberry plantations using hyper spectral remotely sensed data. The transplants were dipped in Rhizolex solution at a rate of 2.0 g /l for 20 minutes as recommended for pathogen disinfection before transplanting. A soil sample was collected from the experimental field at the beginning of the experiment, where some physical and chemical properties of the experimental field was sandy loam in texture with EC of 1.67 ds/m and pH 7.80, N was 22.7 mg/kg soil, P was 17.1 mg/kg soil and exchangeable K was 129.4 mg/kg soil. On the other hand, the chemical analysis of used compost is presented in Table (1).

Transplanting was done on 20 and 24th of September in 2014- 2015 and 2015- 2016, respectively. Sprinkler irrigation was used in the first month after transplanting. The drip irrigation was used until the end of the season. Treatments were arranged in a split-plot design with four replicates. The plot area was 14 m^2 included one bed (175cm width and 8 meters long) each bed included four rows and the planting distance was 25 cm between transplants.

Table 1. Average chemical analysis of compost during the two seasons of study.

Organic materials	Sources of compost (Delta Bio Tec.Co.)	pH	Ec dS /m	O.M %	N %	P %	K %	C/N	Humidity %	Weight of m^3 (kg)
Botanical waste compost	AL wadi compost	6.6	1.6	58	1.4	0.65	0.79	18: 1	24	730

Treatments were as follows:

Growing conditions Systems:

Organic strawberry growing systems: 100 % recommended fertilizers. Compost 100 % N rate was used at (200 units N/ fed $^{-1}$ which were about 17.857 ton compost fed $^{-1}$ while potassium fertilizer rates (240 unit K_2O / fed $^{-1}$) which were about (17.857 ton compost fed $^{-1}$ plus 1199.5 kg from feldspar) while phosphorus rate was used at (90 units P_2O_5/ fed $^{-1}$.) which were about (17.857 ton compost fed $^{-1}$ plus 9.4 kg from rock phosphate). A source of P and K were added during soil preparation mixture with compost before agriculture. In each treatment, the content of compost, potassium, and phosphorus account calculated and completed to the required concentration by adding feldspar and rock phosphate.

I.

Conventional strawberry growing systems: 100 % recommended fertilizers (200 Kg N unit/fed., and80 Kg unit P2O5/fed., and 240 Kg unit K2O/fed.) Ditches were prepared in the sites of drip irrigation lines; calcium superphosphate added in the ditches then covered by soil. Ammonium sulfate (20.6 % N) was used as a source of nitrogen, calcium superphosphate (15.5 % P_2O_5) as a source of phosphorus and potassium sulfate (48 % K2O) was used as a source of potassium.

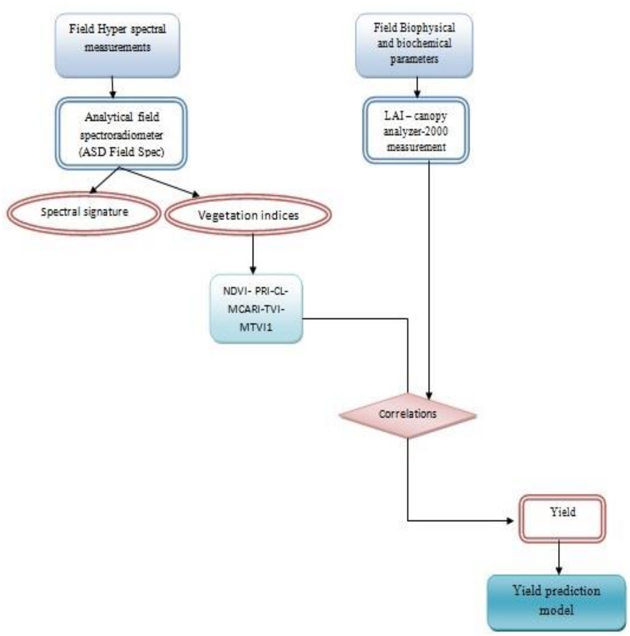

Figure1. Methodology Flowchart

Plastic culture strawberry production (using colored plastic mulches):

1. All plots were mulched with black plastic.
2. All plots were mulched with silver plastic.
3. All plots were mulched with clear plastic.
4. All plots were without Plastic Mulch.

The focus of this study is to identify spectroscopic characteristics of different samples under different fertilizer treatments and different colors of plastic mulches. The second step is to correlate spectroscopic parameters with biophysical and biochemical parameters and yield data to generate empirical models to retrieve these parameters through spectroscopic characteristics and to predict yield as well. Figure (1) is a flowchart that shows the whole methodology.

Study area

Experimental site was (933.8 square meters), a farm at El-Dair village, Qaluybia Governorate, Egypt, located between longitudes 30°22'10" and 30°22'12"E and latitudes 31°17'18" and 31°17'16" (figure 2).

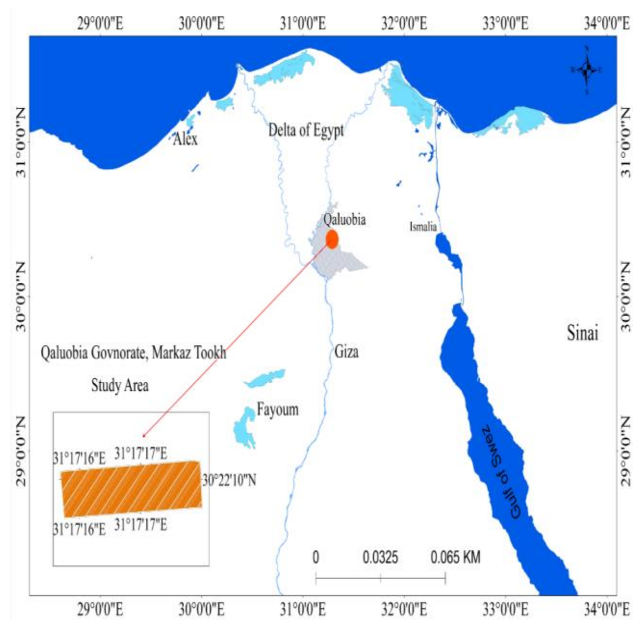

Figure2. Location of the study area

Data recorded: A random sample of five plants was randomly taken from each experimental plot on March 15 in the two seasons to determine the following data. Plant height (cm), Number of leaves/plant, Crown diameter (cm), Dry weight / plant (g) and Chemical compositions of plant foliage by Black et al.1981, Trough and Meyer 1939 and Brown and lilleland 1946 in both seasons, where early and total fruit yield (ton fed.-1), was determined as the weight of all harvested fruits at the 80-90% color stage and Fruit quality by AOAC (2000).

Biophysical data recorded

Field spectroradiometer was the tool for spectral reflectance measurements of strawberry ''sweet Charli" plant at 10:00 – 14:00 local time under cloud free weather conditions. Measurements were performed in a wide spectral range (350 - 2500 nanometer (nm)) covering visible, near infrared (NIR) and shortwave infrared (SWIR). The final sampling intervals for the output data are: (1.37 nm) for the wavelength range (350 – 1000 nm), 2 nm for the range (1000 – 2500 nm). Plant canopy analyzer (LAI-2000) was used for LAI measurements the same time with spectral measurements. The average LAI is calculated through measuring incoming radiation above the strawberry subplot and five below-canopy samples.

Spectral data analysis

The first step of the analysis was the identification of spectral reflectance pattern for strawberry plants cv. Sweet Charlie under different treatments. Second step, six (VIs) were calculated and used as estimators for crop yield. Finally, the optimal (VI) that could be used efficiently to predict yield with different treatments was identified after accuracy assessment process. Equations that were used to calculate the different vegetation indices and the references for each index are explained in table (2).

Table 2. Vegetation Indices (VI) calculated

No.	**Index description**	Equations	**Reference**
1	NDVI (Normalized difference vegetation index)	R_{800}-R_{680}/R_{800}+R_{680}	Rouse *et al.*, 1974
2	PRI(Photochemical reflectance index)	R_{531}-R_{570}/ $R_{531+}$$R_{570}$	Gamon *et al.*, 1992
3	CL (Chlorophyll Index)	$R_{750}/(R_{700} + R_{710})-1$	Gitelson *et al.*, 2005
4	MCARI (Modified chlorophyll absorption ratio index)	$[(R_{700} - R_{670}) - 0.2*(R_{700} - R_{550})] (R_{700}/R_{670})$	Daughtry *et al.*, 2000
5	TVI (Triangular vegetation index)	$0.5[120(R_{750}-R_{550})-200(R_{670}-R_{550})]$	Broge and Leblanc, 2000
6	MTVI1 (Modified Triangular Vegetation Index)	$1.2 \times [1.2 \times (R_{800} - R_{550}) - 2.5 \times (R_{670} - R_{550})]$	Haboudane *et al.*, 2004

*R is relative reflectance at their respective wavelengths

Statistical analysis:

Data of the present study were statistically analyzed using (M Stat). The differences between the means of the treatments were considered significantly when they were more than least significant differences (LSD) at the confidence level of 5% level according to Snedecor and Cochran (1980). Spectral reflectance analysis and yield production modeling was carried out SPSS software.

Results and Discussion

Vegetative Growth Characters:

Effect of growing conditions Systems:

The effect of organic and conventional growing systems under different treatments of fertilization on some vegetative growth characteristics of strawberry plants is presented in tables (3 and 4) show that vegetative growth character of strawberry plants were significantly affected by conventional strawberry growing systems under different treatments of fertilization. The highest values of the above-mentioned growth characters which in turn increased the number of leaves/ plant, crown diameter, leaf area and dry weight/plant were obtained with a conventional strawberry growing system under different treatments of fertilization. On the other hand, the lowest values were obtained with the organic strawberry growing systems under different treatments of fertilization. These findings were significant and true in both experimental seasons. These results are in agreement with Organic manure plays a direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization and improve physical and chemical properties of soils (Chaterjee *et al.*, 2005). Rodas *et al.*, 2013 Indicated that plant growth characters of the cultivar 'Aromas', such as plant height, a number of leaves/ plant, crown diameter, and dry weight/plant were influenced by combined doses of N and K applied through fertigation. On the other hand, those reported by Abo Sedera *et al.*, 2010, Abd El-Mawgoud *et al.*, 2010, Spinelli *et al.* 2010, Yadav *et al.*, 2010 and Hazarika *et al.*, 2015. On strawberry reported a positive response for using such organic compounds on plant growth characters as expressed by plant height, number of leaves/ plant, crown diameter and dry weight/plant of strawberry cultivars.

Effect of plastic culture strawberry production (using colored plastic mulches):

As shown in tables (3 and 4) show that the application treatments of strawberry plants with plastic culture strawberry production (using colored plastic mulches) significantly affected plant growth characters as expressed by plant height**,** number of leaves/ plant, crown diameter, and dry weight/plant compared with untreated plants (without Plastic mulch)**.** The highest values of plant height**,** number of leaves/ plant, number of crown diameter and dry weight/plant were obtained with silver Plastic mulch compared all treatments in both seasons of study. These results, generally, are matched with those reported by Hasanein *et al.*, 2011; Abou El-yazied and Mady, 2012; Haroon *et al.*, 2014.

Effect of the interaction between growing conditions Systems and Plastic culture strawberry production (using colored plastic mulches):

Results in tables (3 and 4) show that vegetative growth parameters of strawberry plants were significantly responded to the interaction between growing conditions Systems and Plasticulture strawberry production (using colored plastic mulches) resulted in the highest values of plant growth characters as expressed by plant height**,** number of leaves/ plant, crown diameter, leaf area and dry weight / plant were obtained with a conventional strawberry growing systems under different treatments of fertilization combined with silver Plastic Mulch. On the other hand, the lowest values of the above-mentioned plant growth characters as expressed by plant height**,** number of leaves/ plant, crown diameter, leaf area and dry weight/plant were recorded with an organic strawberry growing systems under different treatments of fertilization combined with untreated plants (without Plastic mulch). The above-mentioned findings were true in both experimental seasons. Significant differences were detected among these interaction treatments in both seasons. The obtained results seemed to complement with those reported by Abo Sedera *et al.,* 2010a and b**;** Abou El-yazied and Mady, 2012; Haroon *et al.,* 2014.

Chemical compositions of plant foliage:

Effect of growing conditions Systems:

It was clear from table 5 show that significant difference among the tested plant foliage in the percentage of total nitrogen, phosphorus and potassium increased by conventional strawberry growing systems under different treatments of fertilization. The highest values of the above-mentioned growth characters were obtained with a conventional strawberry growing system under different treatments of fertilization. On the other hand, the lowest values were obtained with an organic strawberry growing system under different treatments of fertilization. Preusch *et al*., (2004) who reported that leaf- N, P, and K was greater in strawberry plants grown in a salty soil which was amended with composted and fresh poultry litter than synthetic fertilizer, but there were no differences in leaf- N in plants grown in clay and sandy soils. Brandt and Molgaard, 2001, Abo Sedera *et al.*, 2010, Abd El-Mawgoud *et al.*, 2010, Spinelli *et al.*, 2010, Yadav *et al.*, 2010 and Hazarika *et al.*, 2015. On strawberry reported a positive response for using such organic compounds on plant foliage in the percentage of total nitrogen, phosphorus, and potassium and leaf chlorophyll content of strawberry cultivar. On the other hand, Rodas et al. (2013) indicated that plant growth characters of the cultivar 'Aromas', such as plant height, a number of leaves/ plant, crown diameter, and dry weight/plant were influenced by combined doses of N and K applied through fertigation.

Plastic culture strawberry production (using colored plastic mulches):

It was obvious from table 5 show that the application plastic culture strawberry production (using colored plastic mulches) significantly affected chemical compositions of plant foliage as expressed by total nitrogen, phosphorus, and potassium content compared with untreated plants (without plastic mulch)**.** The highest values in the percentage of total nitrogen, phosphorus and potassium were obtained with silver Plastic mulch compared all treatments in both seasons of study. These results were true and similar in the two seasons of the experiment. These results seemed to be in general agreements with those reported by Hasanein *et al.*, 2011; Abou El-yazied and Mady, 2012; Haroon *et al.*, 2014.

Effect of the interaction between growing conditions Systems and Plastic culture strawberry production (using colored plastic mulches):

Interaction of interaction between growing conditions systems and plastic culture strawberry production (using colored plastic mulches) statistically affected N, P and K percentages in the plant foliage of strawberry. The highest N, P and K percentage in the plant foliage were obtained by the combined effect of conventional strawberry growing systems under different treatments of fertilization combined with silver plastic mulch in Table 5. On the other hand, the lowest N, P and K percentages were obtained by organic strawberry growing systems under different treatments of fertilization combined with untreated plants (without Plastic mulch). The obtained results are in general accordance with those reported by Abo Sedera *et al.*, 2010a and b; Abou El-yazied and Mady, 2012; Haroon *et al.*, 2014.

Total fruit yield

Effect of growing conditions Systems:

It was evident from data in tables (6 and 7) show that conventional strawberry growing systems under different treatments of fertilization had a significant effect on early fruit yield, exportable fruit yield, marketable fruit yield and total fruit yield. The highest values of early fruit yield, exportable fruit yield, marketable fruit yield and total fruit yield were obtained by application of conventional strawberry growing systems under different treatments of fertilization, while the lowest values in all studied fruit yield traits were obtained by application of organic strawberry growing systems under different treatments of fertilization. Meanwhile, the conventional strawberry growing systems under different treatments of fertilization decreased unmarketable fruit yield. It was clearly evident that all treatments that conventional strawberry growing systems under different treatments of fertilization recorded higher values in all studied fruit yield traits when compared with an organic strawberry growing systems under different treatments of fertilization. In this regard, Brandt and Molgaard, 2001 and Abo Sedera *et al*. (2010).

Plastic culture strawberry production (using colored plastic mulches):

Data presented in tables (6 and 7) show that the application of plastic culture strawberry production (using colored plastic mulches) significantly affected early fruit yield, exportable fruit yield, marketable fruit yield and total fruit yield.The highest values early fruit yield, exportable fruit yield, marketable fruit yield and total fruit yield compared with untreated plants (without plastic mulch) during both seasons of study. Whereas, silver plastic mulch recorded the highest early fruit yield, exportable fruit yield, marketable fruit yield and total fruit yield. Meanwhile, silver plastic mulch recorded decreased unmarketable fruit yield. These results were in agreement with those reported by Abu-Zahra and Tahboub (2008) and Abo Sedera *et al*., (2010).

Effect of the interaction between growing conditions Systems and Plasticulture strawberry production (using colored plastic mulches):

Interaction of interaction between growing conditions systems and plastic culture strawberry production (using colored plastic mulches) increased most of the total fruit yield and its components tables (6 and 7). the combined effect of conventional strawberry growing systems under different treatments of fertilization combined with silver plastic mulch gave the highest values of early fruit yield, exportable fruit yield, marketable fruit yield and total fruit yield compared with untreated plants (without plastic mulch). Early fruit yield, exportable fruit yield, marketable fruit yield and total fruit yield trait recorded the highest values with a conventional strawberry growing systems under different treatments of fertilization combined with colored plastic mulches comparing with untreated plants (without plastic mulch). Meanwhile, the combined effect of conventional strawberry growing systems under different treatments of fertilization and silver plastic mulch decreased unmarketable fruit yield. These findings appeared to be in general accordance with those reported by several investigators Abo Sedera *et al.*, 2010a and b; Abou El-yazied and Mady, 2012; Haroon *et al.*, 2014.

Fruit quality

Effect of growing conditions Systems:

The data tabulated in tables (8, 9, 10 and 11) show that conventional strawberry growing systems under different treatments of fertilization significantly affected most of the physical quality, i.e., average length, diameter, weight and firmness of fruits and chemical constituents of fruit, i.e., TSS%, vitamin C, titratable acidity, anthocyanin and total sugars. The highest values in all measured fruit traits were obtained by application of conventional strawberry growing systems under different treatments of fertilization, while the lowest values in all measured fruit traits were obtained by application of organic strawberry growing systems under different treatments of fertilization. These results are in agreement with those reported by Brandt and Molgaard, 2001, Abu-Zahra and Tahboub, 2008 and Abo Sedera *et al*., (2010).

Plastic culture strawberry production (using colored plastic mulches):

The results shown in tables (8, 9, 10 and 11) show plastic culture strawberry production (using colored plastic mulches) significantly effect on physical quality, i.e., average length, diameter, weight and firmness of fruits and chemical constituents of fruit, i.e., TSS%, vitamin C, titratable acidity, anthocyanin and total sugars. The highest values of average fruit length, diameter, weight, firmness, TSS%, vitamin C, titratable acidity, total sugars and anthocyanin compared with untreated plants (without plastic mulch) during both seasons of study. Whereas, silver plastic mulch recorded the highest values of average fruit length, diameter, weight, firmness, TSS%, vitamin C, titratable acidity, total sugars, and anthocyanin. These results were in agreement with those reported by Fatemi *et al*., 2013 and Haroon *et a.,l* 2014.

Effect of the interaction between growing conditions Systems and Plasticulture strawberry production (using colored plastic mulches):

Interaction of interaction between growing conditions systems and plastic culture strawberry production (using colored plastic mulches) increased all measured fruit traits Tables (8, 9 and 10, 11) conventional strawberry growing systems under different treatments of fertilization and colored plastic mulches gave the highest values of physical quality, i.e., average length, diameter, weight and firmness of fruits and chemical constituents of fruit, i.e., TSS%, vitamin C, titratable acidity, anthocyanin and total sugars comparing with an organic strawberry growing systems under different treatments of fertilization plus untreated plants (without plastic mulch) during both seasons of study. Average fruit length, diameter, weight, firmness, TSS%, vitamin C , titratable acidity, total sugars and anthocyanin traits recorded the highest values with a conventional strawberry growing systems under different treatments of fertilization and silver plastic mulch comparing with an organic strawberry growing systems under different treatments of fertilization combined with untreated plants (without plastic mulch) during both seasons of study. These results were obtained in the two seasons of the experiment. Similar results were obtained by Abo Sedera et al., 2010a and b; Abou El-yazied and Mady, 2012; Fatemi *et al*., 2013 and Haroon *et al.*, 2014.

Spectral reflectance characteristics

Generally, (NIR) spectral region (700-1300 nm) is dependent on the internal leaf structure, the space amount in the mesophyll, cell shapes, number of cell layers, cell size and contents as reported by (Gausman, 1974; Gausman,1977; Slaton et al., 2001). Shortwave infrared (SWIR-1 and SWIR-2) regions (1300 - 2500 nm) are characterized by the light absorption by the leaf water. Shortwave infrared (SWIR-1 and SWIR-2) regions (1300 -2500 nm) are characterized by the light absorption through leaf water content. Reflectance’s increase when leaf liquid water content decreases. Visible spectral region (400-700 nm) is the absorption region of leaf pigments.

Analysis of the spectral reflectance characteristics for cultivar Sweet Charlie in the organic system under three colored plastic mulch with control (without mulch) is shown in figure (3).

Plants under black plastic mulch showed the highest spectral reflectance in (NIR) and (SWIR) spectral regions. Plants under silver plastic mulch showed the highest reflectance in visible and moderate in (NIR) and (SWIR). Plants with clear plastic mulch showed the lowest reflectance in (NIR) and moderate reflectance in (SWIR) and visible. Plants without plastic mulch showed the lowest spectral reflectance in visible and (SWIR) spectral regions and moderate reflectance in (NIR).

Analysis of the spectral reflectance characteristics for cultivar Sweet Charlie in the conventional system under three colored plastic mulch with control (without mulch) is shown in figure (4).

Plants under silver plastic mulch showed the highest spectral reflectance in visible and (NIR) and (SWIR) spectral regions. Plants without plastic mulch showed the lowest reflectance in (NIR) and moderate spectral reflectance in visible and (SWIR). Plants under clear and black plastic mulch showed moderate spectral reflectance in all regions.

Generated models

Generated models NDVI and yield under different treatments.

Were explained in the table (12). As shown from these results that the highest correlation coefficient (0.99) was found with the treatment of yield prediction of the treatment (organic with black mulch), however, other treatment showed also sufficient correlation coefficient. **g)**

Generated models PRI and yield under different treatments

Were explained in table (13) showed high correlation coefficient except with the treatment of (clear plastic mulch conventional) that showed low correlation coefficient (0.24).The highest correlation coefficient was observed with the treatment (without plastic mulch organic).

h)

Generated models CI and yield under different treatments

Were explained in table (14) as shown that the relatively low correlation coefficient was found with the treatments of black plastic mulch conventional and silver plastic mulch conventional while other treatment showed acceptable correlation coefficients.

Generated models MCARI and yield under different treatments

Correlation coefficients of the generated (MCARI – yield) models were high with all treatments (higher than 0.95) with all treatments as shown in the table (15).

Generated models TVI and yield under different treatments

Among generated (TVI – yield) models, treatment of (black plastic mulch conventional) showed the lowest correlation coefficient (0.582) while the highest correlation coefficients were found with the treatments of (silver plastic mulch organic and black plastic mulch organic) as shown in the table (16).

Generated models MTVI1 and yield under different treatments

The Same trend was found also with (MTVI1 – yield) models. Treatments of (black plastic mulch conventional)and (silver plastic mulch conventional) showed relatively low correlation coefficient (0.627) and (0.7924) while the highest correlation coefficients were found with the treatments of (silver plastic mulch organic and black plastic mulch organic) as shown in the table (17).

Generated models LAI and yield under different treatments

Generated models to predict yield through measured LAI are shown in the table (18). The lowest correlation coefficient was found with the treatment (black plastic mulch conventional). Treatment (silver plastic mulch conventional) showed relatively low correlation coefficient while the high correlation coefficient was found with the treatment (clear plastic mulch organic).

Generated models LAI and NDVI under different treatments

Models to retrieve LAI from NDVI are shown in the table (19). A sufficient model to retrieve LAI from NDVI was found with the treatment (clear plastic mulch organic) while the treatments (black plastic mulch conventional) and (silver plastic mulch conventional) were not sufficient to retrieve LAI from NDVI as they showed low correlation coefficients (0.500) and (0.630).

As shown from all generated models that organic treatments were more correlated with spectral characteristics than conventional treatments. The optimal vegetation index to observe plants under each treatment is explained in the table (20). It is clear that fertilizer treatment may have more effect on spectral reflectance characteristics than plastic mulch as the same color of plastic mulch showed different sensitivity to spectral characteristics according to different fertilization treatments. Field observation of the different vegetative parameters was carried out with field spectral measurements to understand the correlation between different biological and biophysical factors that may affect crop yield separately or binary.

Table 3. Effect of organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch and their interactions on vegetative growth of strawberry plants in 2014/2015season.

Treatments		Plant Length (cm)	Number of leaves /plant	Crown diameter (cm)	Dry weight (g)
Strawberry growing systems (A)	**Colors of plastic mulch (B)**				
Organic cultivation		23.96	18.71	2.87	13.67
Conventional cultivation		28.36	24.11	3.22	15.81
LSD 0.05 value		1.94	0.88	0.88	1.18
	Without	23.18	20.13	2.72	13.38
	Clear	25.93	20.90	3.01	14.45
	Black	26.77	21.42	3.07	15.07
	Sliver	28.75	23.18	3.38	16.07
LSD 0.05 value		1.48	2.07	0.31	1.45
Organic cultivation	**Without**	20.30	17.20	2.50	12.33
	Clear	23.43	18.00	2.89	13.97
	Black	25.37	18.90	2.89	13.40
	Sliver	26.73	20.73	3.22	15.00
Conventional cultivation	**Without**	26.07	23.07	2.94	14.43
	Clear	28.43	23.80	3.12	14.93
	Black	28.17	23.93	3.25	16.73
	Sliver	30.77	25.63	3.56	17.13
LSD 0.05 value		2.10	2.92	0.44	2.05

Table 4: Effect of organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch and their interaction on vegetative growth of strawberry plants in 2015/2016 season.

Treatments		Plant Length (cm)	Number of leaves /plant	Crown diameter (cm)	Dry weight (g)
Strawberry growing systems (A)	**Colors of plastic mulch (B)**				
Organic cultivation		24.92	19.45	3.28	14.64
Conventional cultivation		29.66	26.67	4.28	14.96
LSD 0.05 value		1.16	2.75	0.39	1.95
	Without	25.77	20.77	3.29	14.25
	Clear	26.32	21.68	3.52	14.52
	Black	27.50	24.43	4.04	14.97
	Sliver	29.57	25.37	4.27	15.46
LSD 0.05 value		1.58	2.86	0.41	3.04
Organic cultivation	**Without**	23.17	17.27	2.85	14.83
	Clear	22.20	17.50	3.17	13.00
	Black	25.63	21.23	3.42	15.20
	Sliver	28.67	21.80	3.69	15.53
Conventional cultivation	**Without**	28.37	24.27	3.73	13.67
	Clear	30.43	25.87	3.87	16.03
	Black	29.37	27.63	4.67	14.73
	Sliver	30.47	28.93	4.85	15.40
LSD 0.05 value		2.23	4.04	0.57	4.29

Table 5. Effect of organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch and their interaction on Chemical compositions of plant foliage of strawberry plants in Two seasons.

Treatments		Season 2014/2015			Season 2015/2016		
Strawberry growing systems (A)	**Colors of plastic mulch (B)**	**Nitrogen %**	**Phosphorus %**	**Potassium %**	**Nitrogen %**	**Phosphorus %**	**Potassium %**
Organic cultivation		2.67	0.52	1.52	2.92	0.61	1.64
Conventional cultivation		3.01	0.66	1.71	3.36	0.73	1.78
LSD 0.05 value		0.08	0.04	0.11	0.05	0.04	0.04
	Without	2.65	0.49	1.49	2.83	0.54	1.58
	Clear	2.74	0.55	1.56	3.05	0.63	1.65
	Black	2.88	0.62	1.66	3.17	0.71	1.75
	Sliver	3.09	0.71	1.76	3.51	0.81	1.87
LSD 0.05 value		0.10	0.04	0.04	0.10	0.04	0.04
Organic cultivation	**Without**	2.5	0.41	1.41	2.72	0.44	1.52
	Clear	2.59	0.47	1.46	2.83	0.57	1.56
	Black	2.69	0.55	1.56	2.92	0.66	1.68
	Sliver	2.89	0.64	1.68	3.19	0.76	1.81
Conventional cultivation	**Without**	2.8	0.58	1.58	2.94	0.64	1.63
	Clear	2.88	0.63	1.66	3.26	0.69	1.74
	Black	3.06	0.68	1.76	3.41	0.76	1.82
	Sliver	3.30	0.76	1.84	3.83	0.85	1.92
LSD 0.05 value		0.14	0.06	0.06	0.14	0.06	0.06

Table 8. Effect of organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch and their interaction on Physical Fruit quality of strawberry plants in 2014/2015season.

Treatments		**Average fruit weight (gm)**	**Average Fruit diameter (cm)**	**Average Fruit length (cm)**	**Fruit firmness (g/cm^2)**
Strawberry growing systems (A)	**Colors of plastic mulch (B)**				
Organic cultivation		18.58	3.29	4.88	11.08
Conventional cultivation		21.14	3.95	4.92	10.81
LSD 0.05 value		5.09	1.18	0.44	0.25
	Without	17.08	3.04	4.05	9.94
	Clear	20.64	3.21	4.65	10.59
	Black	20.188	4.08	5.05	11.16
	Sliver	21.53	4.17	5.86	12.09
LSD 0.05 value		2.57	0.89	0.89	0.26
Organic cultivation	**Without**	16.22	2.62	4.35	10.18
	Clear	20.27	3.08	4.58	10.66
	Black	18.04	3.63	5.12	11.42
	Sliver	19.81	3.87	5.64	12.07
Conventional cultivation	**Without**	17.96	3.45	3.75	9.71
	Clear	21.02	3.32	4.73	10.51
	Black	22.32	4.54	4.98	10.90
	Sliver	23.26	4.48	6.08	12.11
LSD 0.05 value		3.63	1.26	1.26	0.37

Table 9. Effect of organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch and their interaction on Physical fruit quality of strawberry plants in 2015/2016 season.

Treatments		Average fruit weight (gm)	Average Fruit diameter (cm)	Average Fruit length (cm)	Fruit firmness g/cm2
Strawberry growing systems (A)	**Colors of plastic mulch (B)**				
Organic cultivation		20.34	3.93	5.17	11.44
Conventional cultivation		20.78	4.38	5.45	10.94
LSD 0.05 value		2.27	1.47	0.01	0.16
	Without	18.59	3.23	4.22	9.91
	Clear	20.01	4.32	4.87	10.79
	Black	20.24	4.17	5.82	11.6
	Sliver	23.42	4.89	6.33	12.47
LSD 0.05 value		3.30	0.74	0.56	0.16
Organic cultivation	**Without**	18.14	3.22	3.82	10.37
	Clear	20.46	3.90	4.91	11.21
	Black	20.22	3.84	5.76	11.68
	Sliver	22.55	4.74	6.21	12.51
Conventional cultivation	**Without**	19.04	3.24	4.63	9.46
	Clear	19.54	4.74	4.83	10.36
	Black	20.27	4.52	5.88	11.51
	Sliver	24.29	5.04	6.46	12.43
LSD 0.05 value		4.67	1.04	0.79	0.23

Table 10. Effect of organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch and their interaction on Chemical fruit quality of strawberry plants in 2014/2015 season.

Treatments		TSS %	Titratable acidity %	Total sugar (mg/ g F.W)	Anthocyanin (mg/100g F.W)	Vitamin C (mg/100g F.W.)
Strawberry growing systems (A)	**Colors of plastic mulch (B)**					
Organic cultivation		9.84	0.73	7.45	85.55	46.13
Conventional cultivation		10.1	0.81	7.65	86.47	46.52
LSD 0.05 value		0.34	0.04	0.05	0.29	0.04
	Without	9.4	0.69	7.19	84.61	45.71
	Clear	9.76	0.74	7.44	85.04	46.10
	Black	10.18	0.80	7.65	85.94	46.46
	Sliver	10.55	0.86	7.91	88.45	47.04
LSD 0.05 value		0.25	0.04	0.21	0.19	0.33
Organic cultivation	**Without**	9.32	0.64	7.12	84.51	45.63
	Clear	9.72	0.70	7.28	84.63	45.87
	Black	9.99	0.76	7.55	85.42	46.23
	Sliver	10.34	0.83	7.84	87.62	46.79
Conventional cultivation	**Without**	9.49	0.74	7.27	84.71	45.78
	Clear	9.79	0.78	7.61	85.45	46.32
	Black	10.37	0.84	7.75	86.46	46.68
	Sliver	10.77	0.89	7.97	89.29	47.30
LSD 0.05 value		0.36	0.06	0.30	0.27	0.47

Table 11. Effect of organic and conventional strawberry growing systems under different treatments of fertilization, some colors of plastic mulch and their interaction on Chemical fruit quality of strawberry plants in 2015/2016 season.

Treatments		TSS %	Titratable acidity %	Total sugar (mg/ g F.W)	Anthocyanin (mg/100g F.W)	Vitamin C (mg/100g F.W.)
Strawberry growing systems (A)	**Colors of plastic mulch (B)**					
Organic cultivation		10.1	0.75	7.84	87.46	46.62
Conventional cultivation		10.5	0.82	8.13	88.87	46.88
LSD 0.05 value		0.08	0.04	0.16	0.09	0.09
	Without	9.51	0.70	7.59	86.51	45.97
	Clear	10.03	0.77	7.76	87.70	46.54
	Black	10.51	0.81	8.10	88.45	46.88
	Sliver	11.15	0.87	8.50	90.01	47.62
LSD 0.05 value		0.28	0.04	0.16	0.45	0.25
Organic cultivation	**Without**	9.38	0.69	7.55	86.31	45.62
	Clear	9.64	0.74	7.70	86.93d	46.44
	Black	10.27	0.77	7.88	87.39	46.75
	Sliver	11.09	0.83	8.22	89.23	47.67
Conventional cultivation	**Without**	9.63	0.71	7.63	86.71	46.31
	Clear	10.43	0.81	7.81	88.47	46.63
	Black	10.72	0.84	8.31	89.52	47.00
	Sliver	11.20	0.91	8.77	90.78	47.57
LSD 0.05 value		0.39	0.06	0.23	0.64	0.36

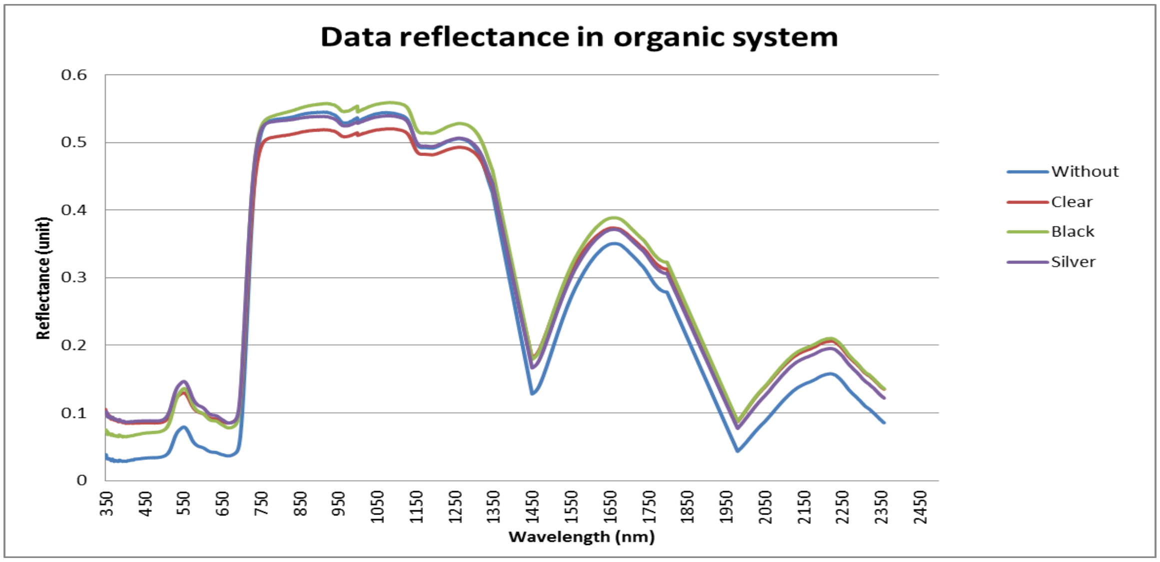

Figure 3. Spectral reflectance of organic system under different plastic mulch

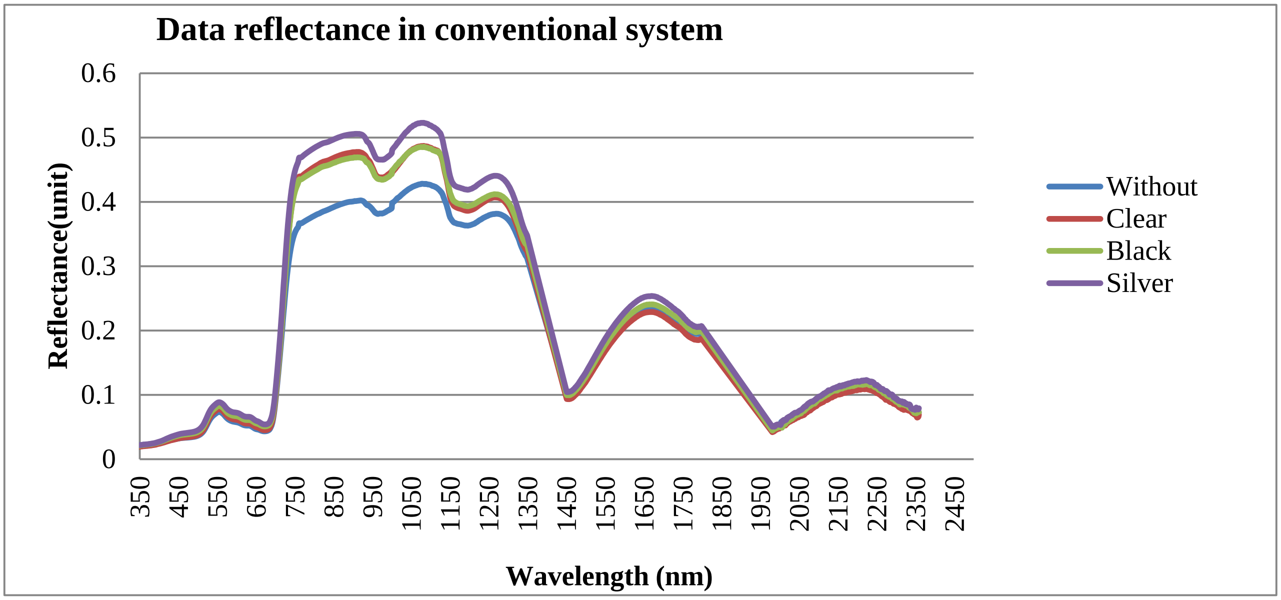

Figure 4. Spectral reflectance of conventional system under different plastic mulch

Table 12. Generated models between vegetation index NDVI and yield under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 2157.2\ _{NDVI} - 1847.5$	0.917
Clear plastic mulch organic system	$y = 57.802\ _{NDVI} - 18.363$	0.962
Black plastic mulch organic system	$y = 120.23\ _{NDVI} - 66.699$	0.995
Silver plastic mulch organic system	$y = 78.051\ _{NDVI} - 32.667$	0.729
Without plastic mulch conventional system	$y = 44.47\ _{NDVI} - 13.626$	0.809
Clear plastic mulch conventional system	$y = 54.873\ _{NDVI} - 22.089$	0.951
Black plastic mulch conventional system	$y = 153.16\ _{NDVI} - 98.399$	0.974
Silver plastic mulch conventional system	$y = 297.18\ _{NDVI} - 211.95$	0.935

Table13. Generated models between vegetation index PRI and yield under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 1003.6\ _{PRI} + 5.8193$	0.996
Clear plastic mulch organic system	$y = 2974.7\ _{PRI} - 37.704$	0.971
Black plastic mulch organic system	$y = 874.47\ _{PRI} + 12.8$	0.982
Silver plastic mulch organic system	$y = 214.73\ _{PRI} + 21.183$	0.754
Without plastic mulch conventional system	$y = 266.34\ _{PRI} + 9.6987$	0.985
Clear plastic mulch conventional system	$y = 179.72\ _{PRI} + 15.247$	0.240
Black plastic mulch conventional system	$y = 3.9519\ _{PRI} + 22.123$	0.942
Silver plastic mulch conventional system	$y = 558.75\ _{PRI} - 0.6093$	0.687

Table 14. Generated models between vegetation index CI and yield under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 200.5_{CI} - 195.59$	0.996
Clear plastic mulch organic system	$y = 24_{CI} + 12.488$	0.956
Black plastic mulch organic system	$y = 53.578_{CI} + 2.8012$	0.996
Silver plastic mulch organic system	$y = 43.477_{CI} + 8.9684$	0.966
Without plastic mulch conventional system	$y = 14.641_{CI} + 14.564$	0.984
Clear plastic mulch conventional system	$y = 8.3732_{CI} + 16.577$	0.990
Black plastic mulch conventional system	$y = 12.127_{CI} + 15.611$	0.719
Silver plastic mulch conventional system	$y = 28.245_{CI} + 6.9157$	0.771

Table15. Generated models between vegetation index MCARI and yield under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 1085.3_{MCARI} - 70.513$	0.960
Clear plastic mulch organic system	$y = 385.05_{MCARI} - 2.0054$	0.961
Black plastic mulch organic system	$y = 379.94_{MCARI} - 16.059$	0.995
Silver plastic mulch organic system	$y = 96.512_{MCARI} + 14.093$	0.982
Without plastic mulch conventional system	$y = 62.305_{MCARI} + 16.06$	0.973
Clear plastic mulch conventional system	$y = 50.743_{MCARI} + 18.008$	0.964
Black plastic mulch conventional system	$y = 79.554_{MCARI} + 16.351$	0.988
Silver plastic mulch conventional system	$y = 202.27_{MCARI} + 5.4801$	0.994

Table 16. Generated models between vegetation index TVI and yield under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 36.473_{TVI} - 1078.1$	0.985
Clear plastic mulch organic system	$y = 2.0657_{TVI} - 31.403$	0.953
Black plastic mulch organic system	$y = 3.1156_{TVI} - 67.09$	0.996
Silver plastic mulch organic system	$y = 2.0883_{TVI} - 35.609$	0.998
Without plastic mulch conventional system	$y = 0.344_{TVI} + 14.692$	0.832
Clear plastic mulch conventional system	$y = 0.571_{TVI} + 8.4664$	0.861
Black plastic mulch conventional system	$y = 0.4196_{TVI} + 13.29$	0.582
Silver plastic mulch conventional system	$y = 0.9272_{TVI} + 1.4279$	0.791

Table 17. Generated models between vegetation index MTVI1 and yield under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 1638.6_{MTVI1} - 1264.4$	0.972
Clear plastic mulch organic system	$y = 81.168_{MTVI1} - 32.663$	0.955
Black plastic mulch organic system	$y = 120.35_{MTVI1} - 68.55$	0.995
Silver plastic mulch organic system	$y = 76.446_{MTVI1} - 33.014$	0.999
Without plastic mulch conventional system	$y = 12.717_{MTVI1} + 14.743$	0.848
Clear plastic mulch conventional system	$y = 23.034_{MTVI1} + 7.2616$	0.835
Black plastic mulch conventional system	$y = 17.039_{MTVI1} + 12.427$	0.628
Silver plastic mulch conventional system	$y = 35.323_{MTVI1} + 0.825$	0.792

Table 18. Generated models between vegetation index LAI and yield under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 2.4404_{LAI} + 12.19$	0.818
Clear plastic mulch organic system	$y = 4.1172_{LAI} + 6.0093$	0.926
Black plastic mulch organic system	$y = 10.036_{LAI} - 24.893$	0.899
Silver plastic mulch organic system	$y = 15.971_{LAI} - 53.904$	0.893
Without plastic mulch conventional system	$y = 1.793_{LAI} + 15.548$	0.869
Clear plastic mulch conventional system	$y = 2.3336_{LAI} + 18.975$	0.807
Black plastic mulch conventional system	$y = 9.4204_{LAI} + 2.4941$	0.578
Silver plastic mulch conventional system	$y = 32.383_{LAI} - 28.459$	0.738

Table 19. Generated models between vegetation index LAI and NDVI under different treatments

Treatments	Prediction equation	R^2
Without plastic mulch organic system	$y = 0.0011_x + 0.8622$	0.815
Clear plastic mulch organic system	$y = 0.0676_x + 0.4363$	0.868
Black plastic mulch organic system	$y = 0.0818_x + 0.3558$	0.867
Silver plastic mulch organic system	$y = 0.1575_x - 0.0439$	0.726
Without plastic mulch conventional system	$y = 0.0337_x + 0.6778$	0.752
Clear plastic mulch conventional system	$y = 0.0417_x + 0.7495$	0.818
Black plastic mulch conventional system	$y = 0.0536_x + 0.676$	0.500
Silver plastic mulch conventional system	$y = 0.0974_x + 0.6364$	0.630

Table 20. Optimal vegetation index for different treatments

Treatment	Optimal VI
Without plastic mulch organic system	PRI and CI
Clear plastic mulch organic system	PRI
Black plastic mulch organic system	CI and TVI
Silver plastic mulch organic system	MTVI
Without plastic mulch conventional system	PRI
Clear plastic mulch conventional system	CI
Black plastic mulch conventional system	MCARI
Silver plastic mulch conventional system	MCARI

Conclusions

This study observed the effect of different growing conditions of strawberry cv. Sweet Charlie (organic and conventional under different treatments of fertilization and some colors of plastic mulch such as clear, black, and silver on the quantitative and qualitative characteristics of plantations through remote sensing tools. Conventional strawberry growing systems under different treatments of fertilization and silver plastic mulch recorded higher values with all observed plants and fruit traits comparing with an organic strawberry growing systems under different treatments of fertilization combined with untreated plants (without plastic mulch). Field remotely sensed hyperspectral measurements were carried out to identify spectral reflectance signature for different samples. Different (VIs) were generated from spectral measurements and were examined with measured leaf area index (LAI) as estimators for yield through statistical-empirical models. Three replicates for the measurements (spectral reflectance measurements and LAI) of each treatment during the two growing seasons (2014 – 2015) and (2015 – 2016) represented the dataset for the statistical analysis. It was found that fertilization has more effect on spectral characteristics than plastic mulch. All (LAI – yield) and (spectral- yield) models were tested to spectrally identify the optimal model for each treatment. Adequate accuracy was observed with most of the generated yield prediction models as the correlation coefficient between observed and modeled yield reached more than (0.7) with most of the generated models except (LAI – yield) and (TVI - yield) models that showed accuracy less than (0.7) with the treatment (black plastic mulch conventional system). According to the correlation coefficient between modeled and observed yield, the optimal model to predict yield for each treatment was identified. The generated model could be the base of using remotely sensed data for yield prediction of strawberry yield under local conditions and local agricultural treatments in Egypt.

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