SVU-International Journal of Agricultural Sciences
Volume 5 Issue (3) pp.: 41-67, 2023
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2023.225051.1300
RESEARCH ARTICLE

Growth and production of cucumber plants as affected by colored shade nets and soil covering under Sharm El-Sheikh conditions

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Abstract

The experiment was conducted on a private farm in Sharm El Sheikh City, South Sinai Governorate, Egypt during the summer seasons of 2020 and 2021 to examine the effects of four different colors of shade nets (green, blue, grey, and black shading net) and four soil mulch materials (organic mulch and both black and silver plastic mulches, as well as without soil mulch) on shielding cucumber plants from high temperatures, improving microclimate as well as growth, quality, and fruit yield. The results demonstrated that the use of colored shade nets altered the microclimate around cucumber plants, resulting in a drop in average monthly both air temperature and light intensity as well as an increase in air relative humidity when compared to un-shaded treatment. Furthermore, the temperature of the soil was higher without mulch than it was with mulch. The findings showed that cucumber plants covered in green nets combined with organic soil mulch had the highest values of vegetative development features, such as root length, plant height, number of leaves, and both fresh and dry weight of plants, followed by black shade nets with organic soil mulch. Also, the outcomes revealed the highest values of yield per fed. were attained by green shade nets and/or black nets interacting with soil organic and/or black soil mulch. The results analysis indicate that P-fruit content created the most significant effect from the combination of grey shade nets with organic soil mulch. In terms of N-fruit content, cucumbers covered by green shade nets with organic soil mulch or/and black soil mulch had the greatest values.

Keywords: Colored shade nets; Cucumber plants; Soil mulches.

1. Introduction

Cucumber (*Cucumis sativus*) is a widely cultivated plant in the wide world and belongs to the family Cucurbitaceae. It is one of the most popular and consumer vegetable crops because its nutrition contains 19% vitamin K, 4% vitamin C, 3% vitamin B1, 5% pantothenic acid, 3% biotin, 12% molybdenum, 4% copper, 4% phosphorus, 3% potassium, 3% magnesium, and 3% manganese. In addition, Cucumber helps adjust adequate blood pressure and sugar, soothes skin, helps in digestion, reduces fat, and helps with weight loss. In addition, cucumber has several health-beneficial activities, such as antimicrobial properties, hydrating and detoxification, helping in digestion and weight loss, and preventing cancer and fragile bone diseases. (Chakraborty and Rayalu, 2021). Changes in climatic conditions to which the world is now exposed have greatly affected agricultural activities due to sharp changes in temperature, cold, drought, air relative humidity, solar radiation, etc., which affected the growth, quality, and production of vegetable crops, changes in the climatic conditions to which the world is currently exposed have had a significant impact on agricultural activities. Due to leaf wilting,

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Received: July 25, 2023; Accepted: September 3, 2023; Published online: September 4, 2023.

physical damage to plant parts like stems and root growth, physiological disturbances, and biochemical changes, higher temperatures significantly reduce agricultural yield (Fahad *et al.*, 2017). The average temperature was found to have increased by just 1°C, it was also mentioned. It results in a 4–10% reduction in agricultural output; hence it is vital to adopt new technology to keep crop yields stable in high-temperature environments. Also, heat stress, high solar radiation, drying winds, drought, and hail storms are considered some of the problems environmental and major causes of productivity determinants and nutritional quality of vegetables grown in open-field (Shahak *et al*., 2008). Many researchers reported that stress levels and variations in light quality can affect physio-chemical processes and metabolite profiles, which in turn has an impact on crop growth, productivity, and quality. The biosynthesis of bioactive chemicals in sweet pepper, for instance, has been demonstrated to be impacted by photo-selective nets (Mashabela *et al*., 2015; Selahle *et al*., 2015). The colored shad nets have a variety of effects, including reducing wind run and wind speeds, which in turn can change temperatures, relative humidity, and the microclimate of atmospheric gases. These changes can have an impact on processes such as respiration, transpiration, photosynthesis, and others. These effects depend on the amount of shading, the color of the nets, the location, the average daily temperature in the area, and the percentage of shading (Ili, and Fallik., 2017). The size, maturity, color, and flavor of the fruits are all improved by the use of shade, which encourages the best solar radiation distribution within or around the plant canopy (Ili *et al*., 2012; Ili *et al.*, 2017; Stamps, 2009). The production was 360 million tonnes of plastic manufactured worldwide in 2018. According to the following distribution around the globe, it was split as follows: 17% in Europe, 51% in Asia, 18% under the North American Free Trade Agreement (NAFTA), 7% in Africa, 3% in the Commonwealth of Independent States, and 4% in Latin America. The use of plastic in the agricultural sector, which includes mulching, is close to 4%. (Rajablariani *et al*., 2012). Colored plastic soil covers were manufactured to alter the micro-climate in the soil and around plants. The color of plastic soil mulches affects the spectral light balance in terms of quality and quantity, which can affect plants' growth and development as well as their yields. (Matsoukis and Gasparatos, 2015). Black, clear, and white plastic mulches were employed since they are commonly used in vegetable production. Today's most popular plastic hues include black, white, green, brown, red, silver, and blue. Changes in the color of plastic mulch will result in changes in the transmittance, reflectance, and absorption of both short-wave and long-wave radiation, which will have an impact on photosynthetically active radiation (PAR). Greater PAR reflection results in lower soil temperature and higher moisture content in plant roots. (Jagrity and Anis, 2022). The characteristics of the soil cover and types depend on the purposes for which it will be put to use; examples include polyethylene films, organic straw, wood, bark, or leaves; gravel, mulch, or hyacinth used singly or in combination; or live grass, rye, and alfalfa materials (Li Qiang *et al*., 2018; Sarkar *et al*., 2019). It should be noted that organic mulch is considered to be organic straw, which is one of the most widely used types of soil mulching in developing countries (Thankamani *et al.*, 2016). Numerous advantages of soil plastic mulches include modifying the quantity of radiation, controlling soil temperature, lowering water loss and hence improving water usage efficiency, reducing weed and insect infestations, and increasing the quality and yield of the crop (Amare, and Desta. 2021).

This study's goal was to identify the best interaction between different colors of shade nets and four soil mulch covering materials for protecting cucumber plants from high temperatures, improving microclimate and soil conditions, and increasing the growth, quality,

and fruit yield of cucumbers in Sharm El Sheikh City, South Sinai Governorate, Egypt.

2. Materials and methods

The experiment was carried out in the resort of Mövenpick Sharm El-Sheikh, overlooking Na'ama Bay, 2 km from the town center, Sharm El-Sheikh, South Sinai Governorate and located at 27°54'49.5"N 34°20'25.0" E, Egypt during the summer seasons of 2020 and 2021 to investigate the combined effect of different materials of soil mulching and the cultivation under different colored shading nets.

2.1. Preparation of the wooden net house

Structural characteristics of the net house are; wooden structure of 2.75m height oriented east to west, with 12 m in length x 8 m width resulting in 96 m^2 total area (Fig. 1), where, the top and sides of the structure's cladding are covered with shade net treatment cladding, which strikes a balance between cost and productivity while also providing a sound economic and environmental foundation (Kumar *et al*., 2021). Similar to how crops are supported in standard greenhouses, the crop was held aloft by wires and threads. Each treatment of shade net was separated from the others by 5 m of land to lessen the effect of scattered light inside adjoining color nets.

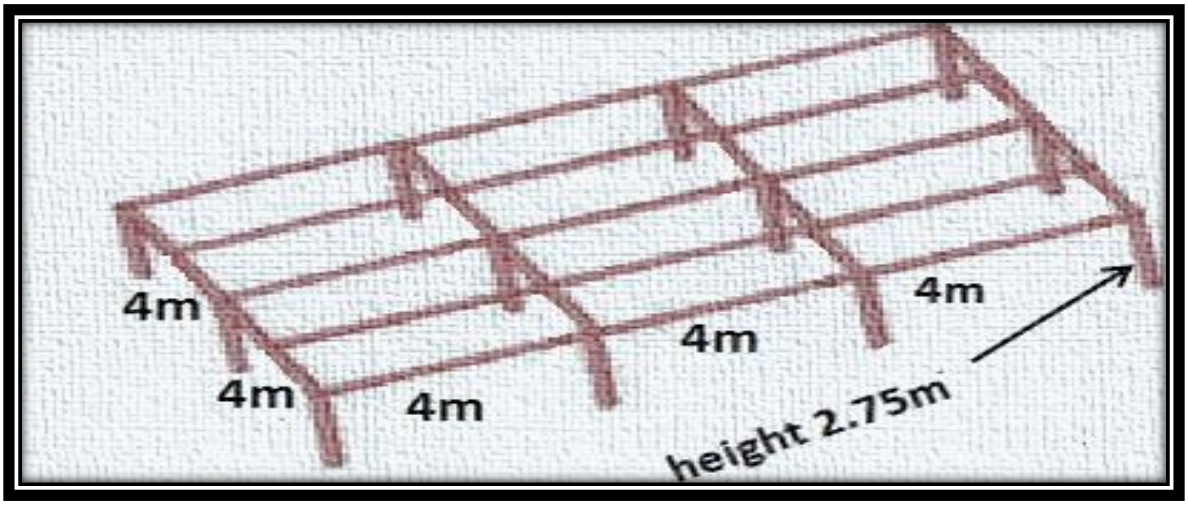


Figure 1. Illustration of the wooden net structure.

2.2. Plant material

Seeds of cucumber *cv* "the First hybrid" were planted in seedling trays on the 1st week of April and transplanting took place on the 1st week of May during both the 2020 and 2021 growing seasons.

2.3. Treatments

The experiment comprised of two factors: the first factor, which consisted of four colored shad nets of 40% shading (green, blue, grey, and black), and the second factor, which also included four covering materials, i.e., films of soil organic mulch (Its thickness was approximately 5 cm above the surface of the soil), two colored plastic mulches (black and silver of polyethylene 60 microns) and a non-mulched (control treatment). The treatments were set up randomly in a split-plot design in three replications where the four colored shading nets were placed randomly in the main plots and the four covering materials in the subplots (Table 1).

A week prior to transplanting, organic and plastic soil mulch is placed over the soil's surface. After 5 days of seedlings transplanting in both seasons, shade nets were then put in place above the wooden structure (0.5 m above the horizontal tutors). The experimental unit area consisted of individual beds, 10.0 m in length spaced 2 m

apart. To avoid the edge effect, space was left on each side of the four sides.

A drip irrigation line was placed on the soil surface at the center of each bed and plants were transplanted in a single row per bed at 0.50 m spacing. According to the instructions of the Ministry of Agriculture and Land Reclamation for cucumber plants, standard agricultural techniques were carried out. The experimental soil texture was sandy loam with pH 7.50, EC 0.70 dSm^{-1}, organic matter 0.08 %, and $CaCo_3$ 8.80 % (average of two seasons). However, chemical analysis of irrigation water had EC 2.11 dSm^{-1} and pH 7.6 (over two seasons).

Table 1. Colored shading nets and soil covering materials treatments used in the current study.

Main plot	Sub plot			
Shade net	Soil mulching materials			
Green SH	Control (NM)	OM	BPM	SPM
Blue SH	Control (NM)	OM	BPM	SPM
Grey SH	Control (NM)	OM	BPM	SPM
Black SH	Control (NM)	OM	BPM	SPM

SH: Shading nets; NM: Non-mulching; OM: Organic mulch; BPM: Black plastic mulch; SPM: Silver plastic mulch.

Anyway, organic mulch obtained from naturally growing plants in the study location was not crashed. The colored shade nets and plastic mulch were purchased from Al-Amir Company, Gharbeya Gov. and United Plastic Products, Sadat City, Menoufiya Gov., Egypt. Seeds of hybrid cucumber "the First" obtained from Technogreen for agricultural projects company, Heliopolis, Cairo, Egypt.

2.4. Data recorded

2.4.1. Microclimate parameters

A) Light intensity was monitored once every day at noon throughout the plant growth stages (June, July, August, September) using a Lux meter, (HI 97500,.001 to 199.9 Klux, Woonsocket, RI, USA).

B) Air temperature and relative humidity were monitored three times per day at 7:00 a.m., 1:00 p.m., and 6:00 p.m. during the plant growth phases. Using a digital thermometer device (TP50).

C) Soil temperatures were monitored in the soil at two depths (10 and 20 cm) under soil mulch and non-mulching treatments during plant growth stages every day at seven o'clock in the morning, one o'clock in the afternoon, and six o'clock in the evening whereas, all prior weather measurements were made using a digital thermometer protected by shade nets (Model: KCB-300).

2.4.2. Vegetative growth

A random sample of five plants was taken from each plot 90 days after transplanting (Plants located at the row end were not used for sampling) for recorded root length (cm), plant height (cm), number of leaves/plant and totally fresh and dry weight of plants. A Chlorophyll meter was used to measure the total chlorophyll content (SPAD) in the leaves 75 days after transplanting (SPAD-502, MINOLTA, CO. LTD. JAPAN)

2.4.3. Yield and its components

A) The samples necessary for yield measurements were taken for recording the data of average fruit weight (g) and yield/plot was calculated by weighing all plot fruits collected (kg), and then converted to yield of ton fed^{-1}),

B) A random sample of 16 fruits (from the four harvests) was taken from each treatment, to determine Fruit qualities, *i.e.*, Vitamin-C (mg/100 ml Juice), and TSS (%) according to A.O.A.C. (1990), and

C) Fruit physical measurements from the same 16 fruits were carried out on fruit length (FL. cm) and fruit diameter (FD. cm) using a caliper as well as fruit shape (FL/FD).

2.4.4. Chemical constituents

A) Total nitrogen was determined using the method described by Bremner and Mulvancy (1982),
B) Phosphorus content was determined using the method described by Ryan *et. al*. (1999), and
C) Potassium content was measured by flame photometer as described by Irri (1976).

2.5. Statistical analysis

Obtained data were subjected to statistical analysis of variance **(**Snedecor and Cochran, 1980). Duncan's multiple range test was used for comparison among means (Duncan, 1958).

3. Results and Discussion

3.1. Microclimate parameters

3.1.1. Light intensity

Data shows in Fig.2 the significant effects of colored shading nets on average light intensity values of the different day times (7 a.m., 1 p.m., and 6 p.m.) during the growth period of cucumber plants. In general, shaded plants exhibited the lowest values where Blue, Gray, Black, and Green shading nets caused an obvious reduction of light intensity by (33.8 & 36.3%), (45.0 & 44.2), (46.8 & 45.9%) and (48.1 & 47.9%) in the first and second seasons in descending order compared to the open field (unshaded) which recorded the highest light intensity values (107 and 115 Klux).

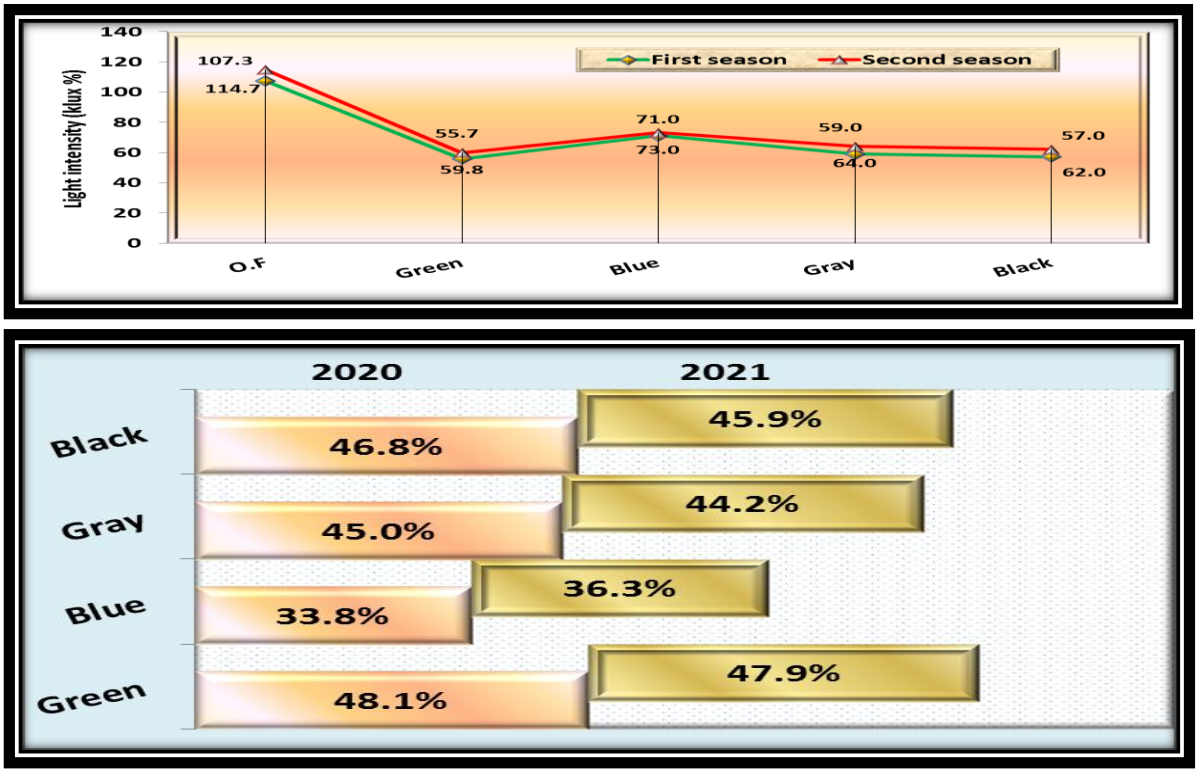


Figure 2. Average of light intensity (Klux, Up) and reduction percentage (%, Down) during the growth period of cucumber plants at three times in the day (7 am, 1 pm, 6 pm) under colored shade nets at both seasons.

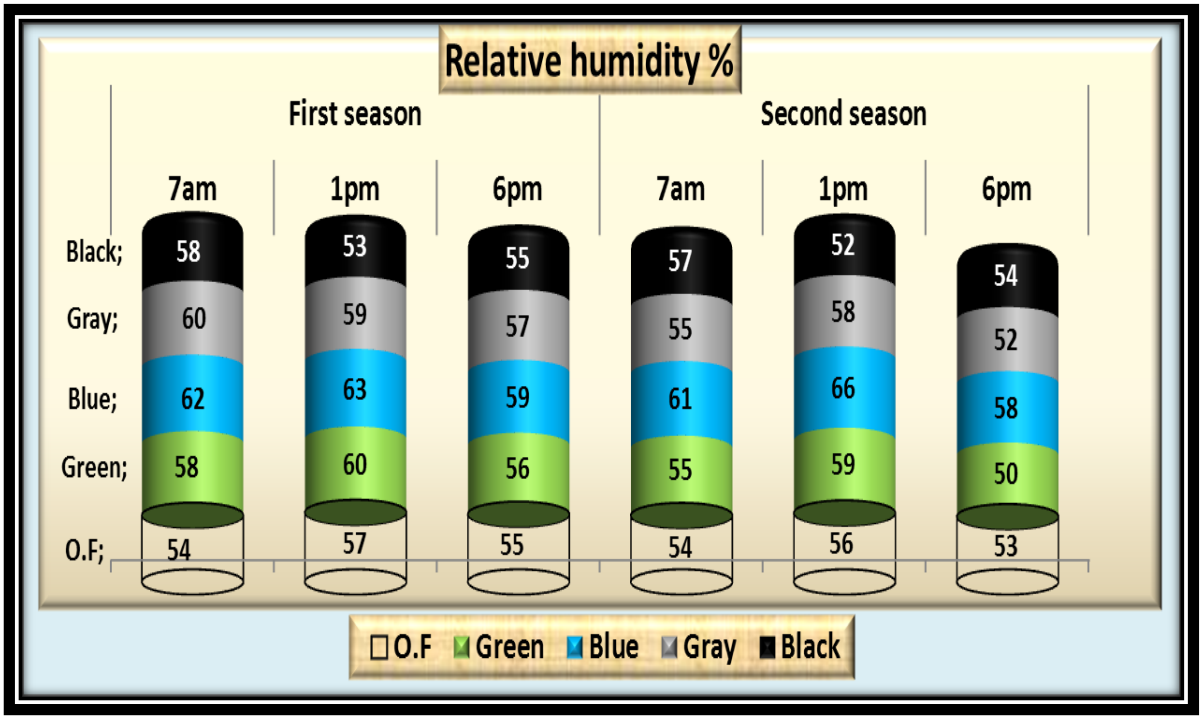
Rekha *et al.*, (2014) found that covering spinach plants with colored shade nets such as white, black, red, and green with a 40% percentage decreased light intensity compared to the control treatment. These results can be interpreted by (Gaurav *et al.*, 2016) who notice that the air temperature and relative humidity, in addition to the color of the net from factors that reduce radiation under a shade net; these results confirm our results. Also, Torres-Olivar (2016) reported

that light intensity above plant species adaptation limits combined with other stressors, can reduce photosynthetic activity; In contrast, the flux of photosynthetic photons was not a limiting factor for plants grown in a shade house because shading reduces irradiance.

3.1.2. Air relative humidity

Colored shade nets increased the measured relative air humidity at day times of 7 a.m., 1 p.m., and 6 p.m. during the growth period compared with open field (unshaded). Blue-shaded nets mostly achieved the highest air relative humidity percentage, i.e., 61, 66 and 58 % at 7 a.m., 1 p.m., and 6 p.m, respectively in the first season, and 62, 63 and 59 % in the ^{2}nd season followed by green shade nets at 1 p.m., in both seasons (Fig.3 Up and Fig.5). The relative humidity increased by 0.9–14.7% for all the shading nets treatments except black nets in which the RH% was significantly decreased at 1 p.m. (Fig.3 Down)

All the 4 colored shade nets at 7 am; each of the blue, green and grey shade nets at 1 p.m. and only blue shade net at 6 pm exhibited an increase in the relative humidity compared with the open field where the highest increment was recorded at peak time (1 p.m.) which could be due to the reflected increase of temperature in the open field, and the closed design of the shade nets. Thus, it impedes the air movement within the shade nets structure; furthermore, the experiment site is near the seawater in Sharm El-Sheik City, South Sinai Gov., however, these factors of the previous leads to an increase in relative humidity under the shading nets. Also, the relative humidity is often higher under the netting compared to the open fields due to the crop water vapor diffusion and reducing the mixing of dry air in the open field with the in-netting area **(**On disease fungi of *Leveillula Taurica* on Sweet Pepper plants by Elad *et al*., 2007, and on cucumber, Felipe *et al*. (2018). Furthermore, Momeni (2022) reported that relative humidity was higher than outdoors and that there was no significant difference between months. Moreover, Mditshwa *et al.* (2019) showed that depending on the type of nets, color and density of its texture, the relative humidity of the shading nets increased by 3.2–12.9%.



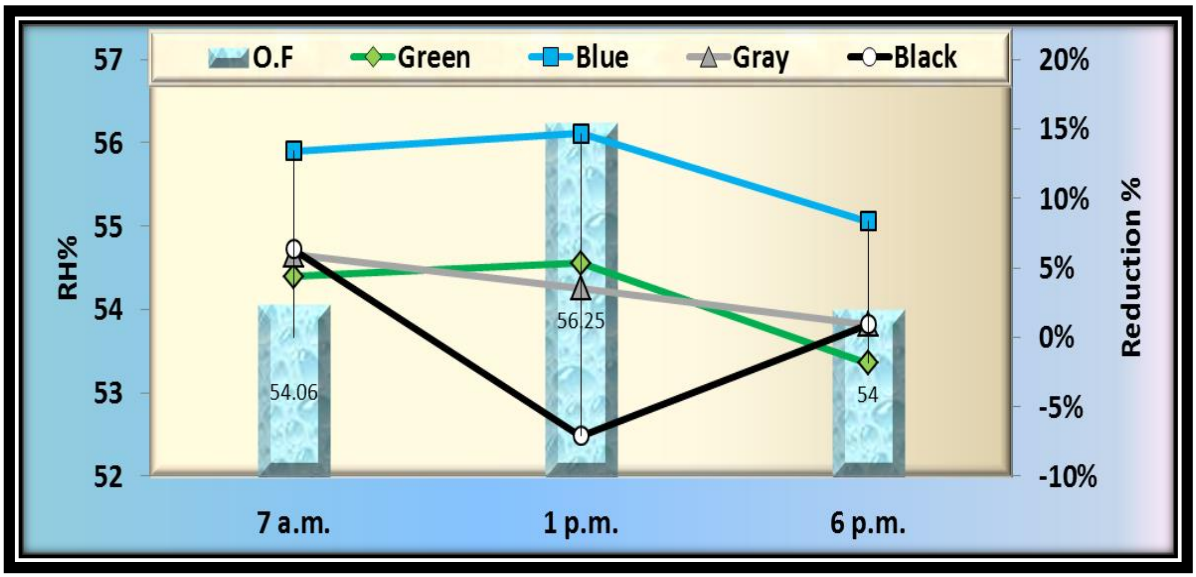


Figure 3. Average of relative humidity at the two seasons (Up) and reduction % comparing O.F (Down) during the growth period of cucumber plants at day times (7 am, 1 pm, 6 pm) under colored shade nets where, O.F: open field

3.2. Temperature

3.2.1. Air temperature

The average air temperature recorded the highest in the open field (unshaded) compared to the shade nets treatments in 3-times the day (7 a.m., 1 p.m., and 6 p.m.), during the growth period, *i.e.*, June, July, August, and September (Fig.4, and 5). The results in Fig. 6 indicated a decrease in average air temperatures under green shade nets (5.8 °C at 7 a.m., 6.7 °C at 1 p.m., and 5.5 °C at 6 p.m. in the average of both seasons and black (4.2 C at 7 a.m., 4.8 C at 1 p.m., and 5.0 °C at 6 p.m.) where the times at 6 a.m. and 7 a.m. has Lower air temperatures for all treatments compared to the time of 1 p.m. similar results were found by Smith *et al.* (1984). They reported that the air temperature under shade nets is lower than that of open fields, it depends on their shading intensity. Also, the maximum temperatures were high under open filed and decreased with shade color nets in the following order: white, red, green, and black, respectively (Mena *et al.*, 2014).

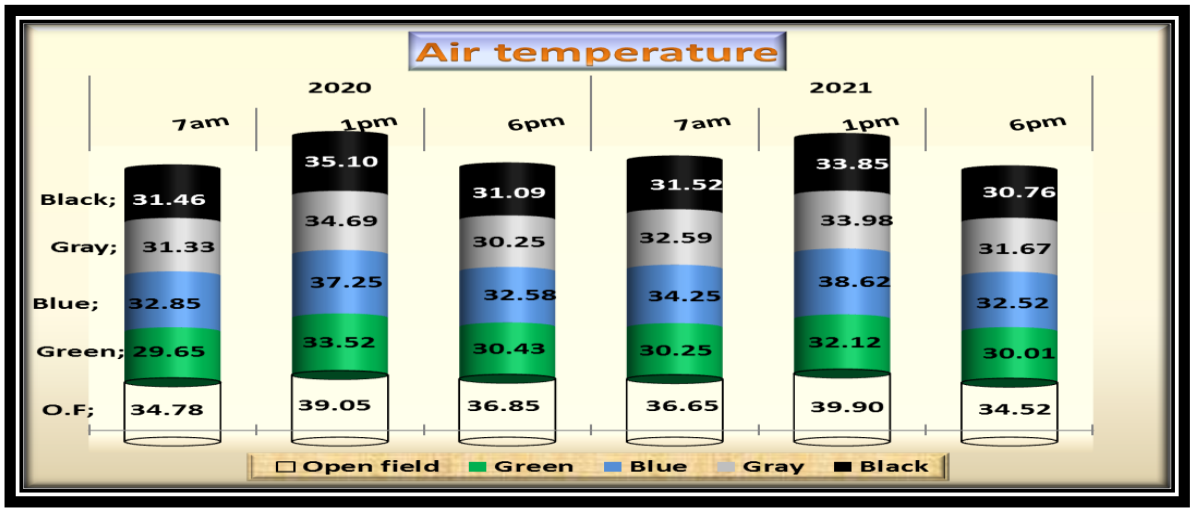


Figure 4. Average of air temperature at three times during the day (7am, 1pm, 6pm) under shade color nets during the two growing seasons.

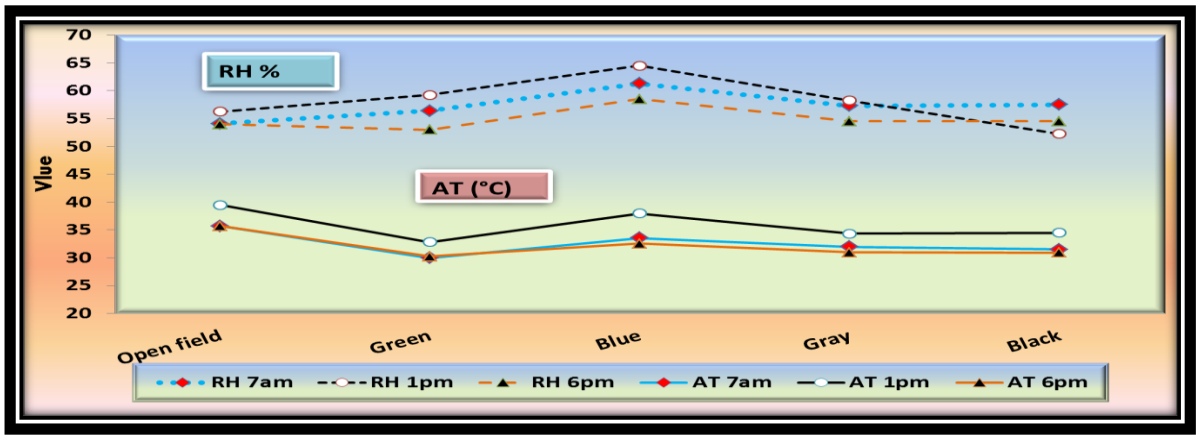


Figure 5. Both humidity and air temperature (average of both seasons) during the growth period of cucumber plants at three times (7 am, 1 pm, 6 pm) under open field and shade color nets

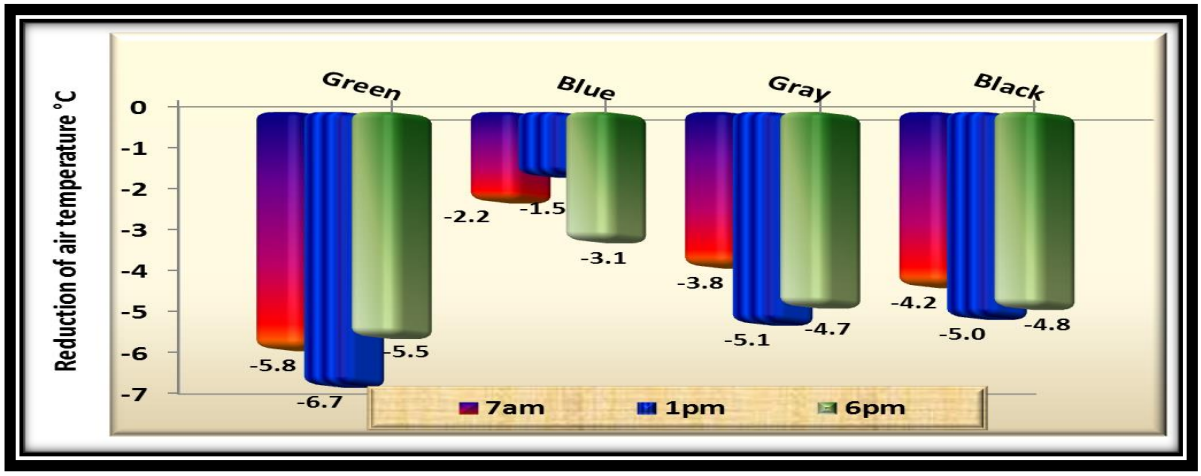


Figure 6. Air temperature reduction % comparing O.F during the growth period of cucumber plants at day times (7 am, 1 pm, 6 pm) under colored shade nets where, O.F: open field

3.2.2. Soil temperature

The interaction effects between colored shade nets and soil mulching treatments at 10 cm soil depth (as the average of two growing seasons) at 7 a.m., 1 p.m., and 6 p.m. along the season are shown in Fig. 7. The highest soil temperature degrees (35.9 °C) were recorded at 10 cm soil depth at 1 p.m. when cucumber plants were covered by black shade nets and silver-soil mulch. Silver or black soil mulching lead to an increment in the soil temperatures up to 4 °C at 10 cm depth under black or grey shade nets as well as at 20 cm under all colored shade nets at the three studied day times. All colored shade nets interacted with silver-soil mulch showed high soil temperatures at 1 p.m. and 6 p.m. compared with the corresponding control.

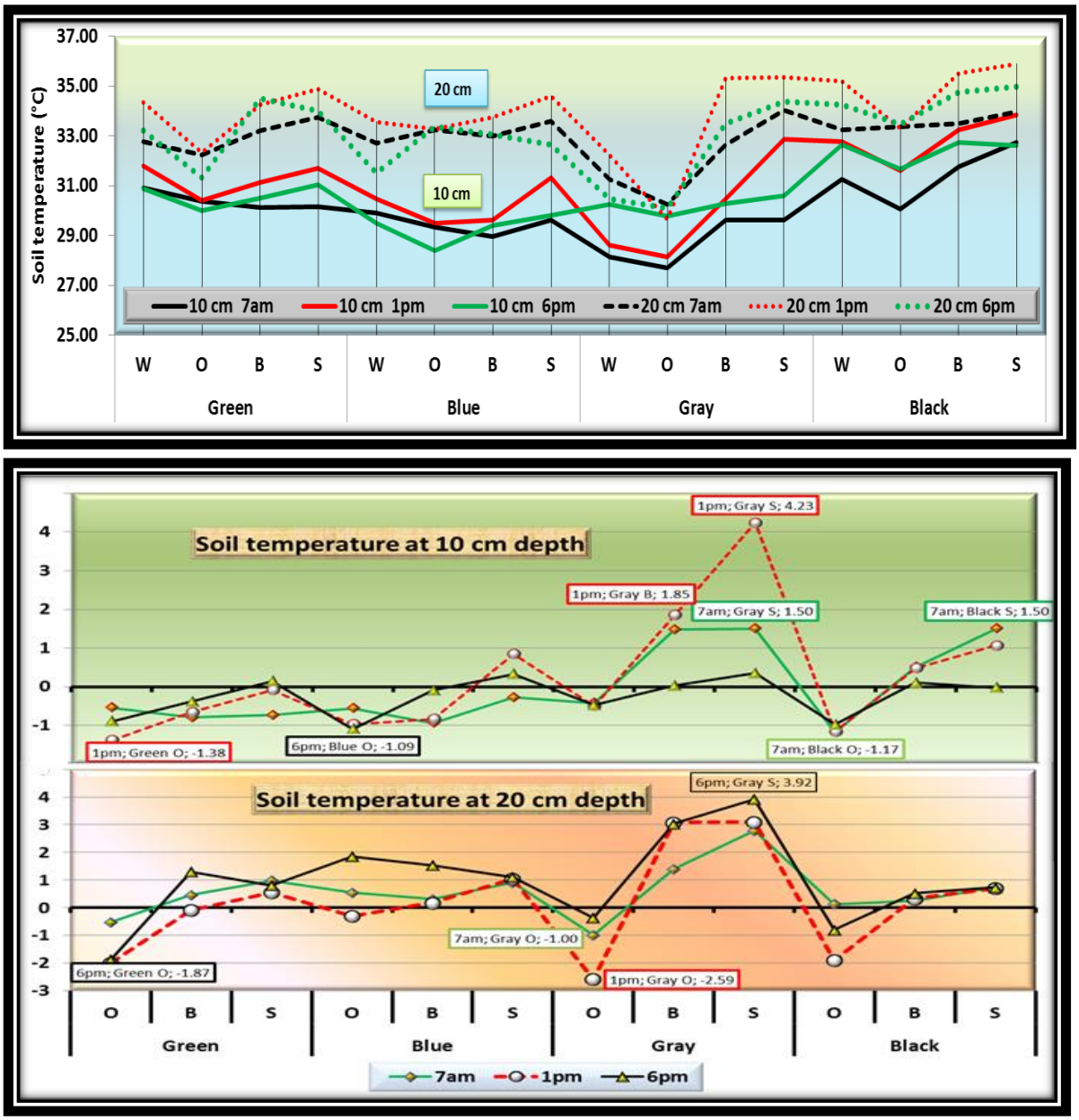


Figure 7. Average two seasons (2020-2021) of soil temperature (above) and reduction or increase over W treatment (lower) at 10 and 20 cm soil depth during the growth period of cucumber plants at three times (7 am, 1 pm, 6 pm) as affected by shade nets and soil mulching interaction (W: without, O: organic, B: black, S: silver)

Moreover, the lowest soil temperature degrees were observed at 10 or 20 cm soil depth (at 7 a.m., and 1 p.m.) with the interaction between gray shade nets and organic soil mulch were observed compared to corresponding un-mulching treatment. These results were similar to those of (Farias-Larios and Orozco-Santos, 1997; Gordon *et al*., 2010) reported that the highest temperature was recorded by black plastic mulch while the lowest was recorded by bare soil. A research report by (Shah *et al*., 2018) indicates that a higher temperature was recorded in the soil covered with black plastic mulch than in soil mulched with plastic color mulch of silver, blue, white, and organic mulch (pressed olive cake).

3.3. Vegetative growth traits

3.3.1. Effect of colored shade nets

Data presented in Fig. 8 show the effects among colored shade net treatments on vegetative growth traits, *i.e.*, root length, plant height, number of leaves, and both total weights of fresh and dry plants, as well as total chlorophyll of cucumber plants in both growing seasons.

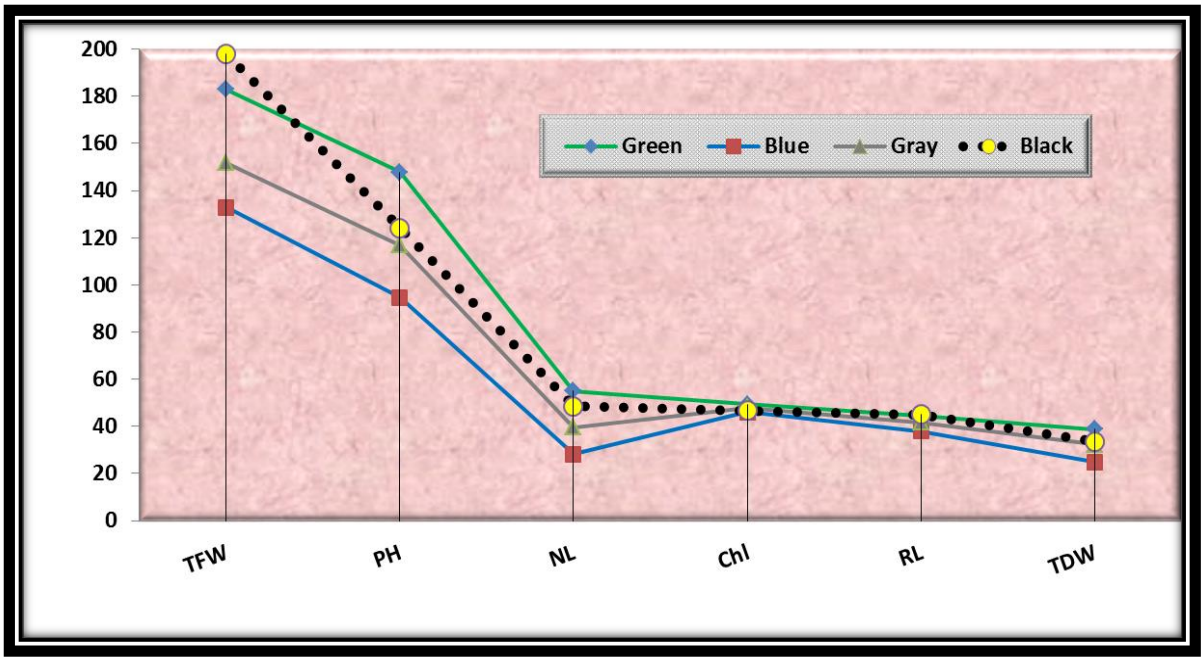


Figure 8. Effect of colored shade nets on vegetative growth and chlorophyll of cucumber plants in average of both 2020 and 2021 seasons.

(TFW: Total fresh weight, PH: Plant height, NL: Number of leaves, Chl: Chlorophyll, RL: Root length, TDW: Total dry weigh).

The results show that the effects of colored shade nets, *i.e.*, green, blue, gray, and black, on cucumber plants gave a significant effect for all vegetative growth traits, except root length and total chlorophyll in which no significant effects were observed under any colored shade net in both seasons. However, as for plant height, the number of leaves, and total dry weight, the highest values were observed using green shading nets whereas black shade nets were for the total fresh weight in both seasons. These results may be due to microclimate change *i.e.*, soil and air temperatures, relative humidity, and light intensity under colored shade nets (Figs. 2-7), where the microclimate affects properties of photo-selective (reduction of photo-synthetically active radiation, PAR), which affect the relationship between physiological responses, photosynthesis processing, and plant metabolism profiles, ultimately reflecting effects on plant growth. (Arthurs *et al.*, 2013) Noticed that the colored shade nets have many effects, such as reducing wind, air temperature, relative humidity, and the atmospheric gas microclimate. Consequently, these changes can affect processes such as respiration, evapotranspiration rate, photosynthesis, etc. These effects are related to the percentage of shading, the color of the netting, the location, and the prevailing temperatures throughout the day and the area (Ilic *et al.*, 2017).

3.3.2. Effect of soil mulch

The results presented in Figs. 9, and 10 show that the vegetative growth characteristics (root length; plant height; the number of leaves and both fresh and dry weight of plant as well as total chlorophyll) were strongly influenced by soil mulching with some different materials. Organic mulch surpassed the other treatments in all the studied traits during the two seasons of study with no significant differences between organic mulch and black plastic mulch for the Root length, Plant

height and plant fresh weight in 1st season and Chlorophyll in 2nd season, while the control treatment recorded the lowest values obtained in all the studied vegetative growth characteristics during the two study seasons. However, number of leaves exhibited the highest increment by 98.3% followed by TFW (54.0%), TDW (36.5%), RL (34.4%), PH (34.3%) and Chl (28.7%) in descending order (Fig.9) over the corresponding non-mulched treatment (control). That may be the organic soil mulch and black plastic mulch may be effective in keeping soil temperatures at an optimal level for root absorption, leading to improve plant growth compared to other soil treatments, which were less effective under experimental conditions.

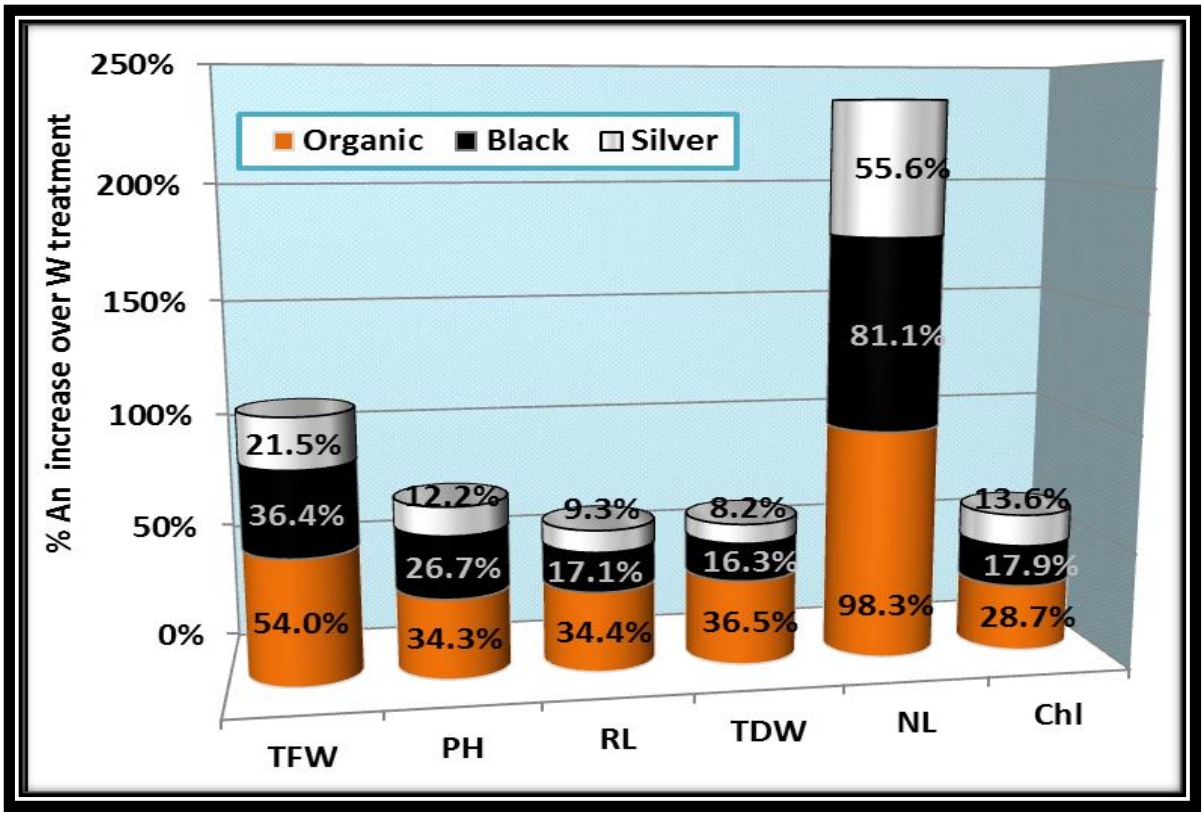


Figure 9. Changes percentage in vegetative growth traits as affected by soil mulch treatments in average of both seasons.

(TFW: Total fresh weight, PH: Plant height, RL: Root length, TDW: Total dry weigh, NL: Number of leaves, Chl: Chlorophyll).

Data of the soil temperatures under soil mulch (Figures 5, and 6) in 10 and 20 cm soil depths at different day times can be supported these results. Many researchers studied that the effect of soil mulching on some vegetable crops and found the plant growth characteristics of plants, viz., stem diameter, plant height, leaf length, leaf dry weight, stem dry weight, and plant dry weight, affected by the mean soil temperature (Torres-Olivar *et al.*, 2016; Sarkar *et al.*, 2019; Amare and Desta, 2021). However, transparent and green soil mulches lead to an increase in the growth and development of root traits, and leaf weight in radish plants compared to those without mulch (Lee and Park, 2020). The lettuce plants' traits, *i.e.*, number, length, and width of leaves, were highest when using black polyethylene, followed by white, blue, silver, and olive film (Shah *et al.*, 2018).

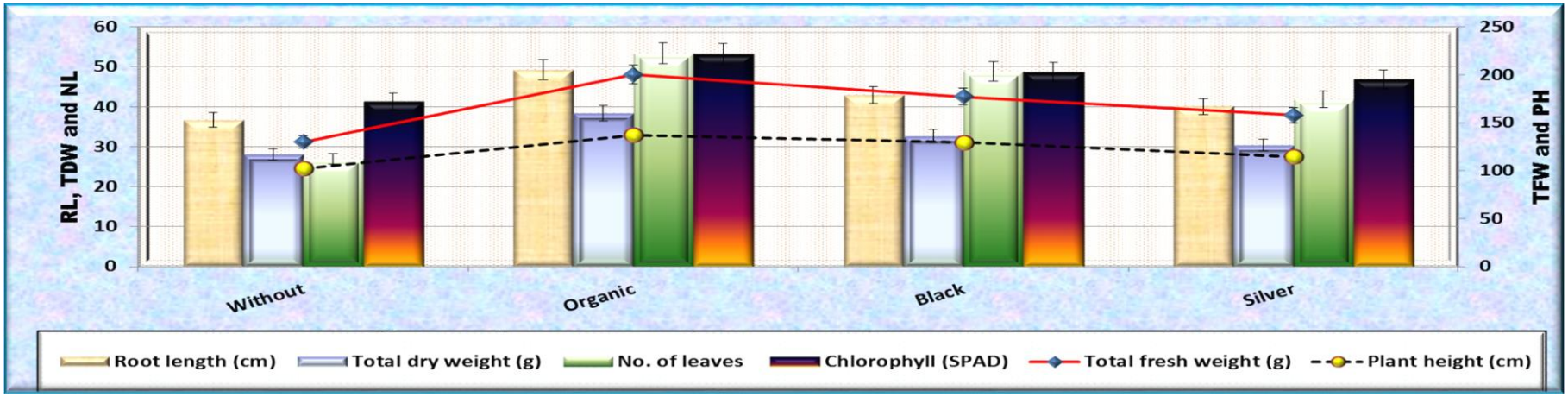


Figure 10. Effect of soil mulch materials on vegetative growth and chlorophyll of cucumber plants in average of both 2020 and 2021 seasons.

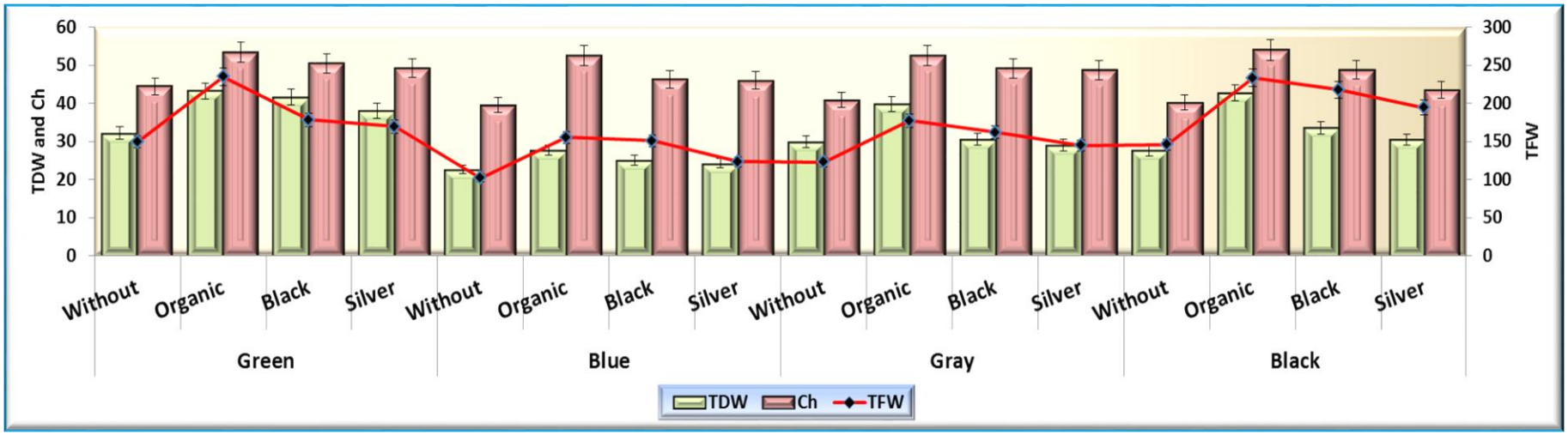


Figure 11. Effect of interaction between colored shade net and soil mulch on vegetative growth and chlorophyll of cucumber plants in average of both 2020 and 2021 seasons

Table 2. Effect of interaction between colored shade nets and soil mulch on vegetative growth and chlorophyll of cucumber plants in 2020 and 2021 seasons

Characters / Variables		Root length (cm)	Plant height (cm)	No. of leaves	Total fresh weight (g)	Total dry weight (g)	(SPAD) Chlorophyll
Shade Nets	Soil mulch			Season 2020			
Green	Without	40.33b-e	134.84b	28.63g-i	147.04de	31.74d	43.63fg
	Organic	49.81a	168.72a	69.52a	232.11a	40.20ab	53.13a
	Black	44.10a-c	144.05b	61.53b	177.12cd	38.46bc	49.58a-d
	Silver	42.24a-d	139.89b	55.54cd	168.24cd	34.12d	48.43b-e
Blue	Without	31.72f	80.59e	24.21j	96.04g	21.34i	35.64i
	Organic	42.87a-c	101.02d	30.17gh	158.18d	24.20gh	52.63ab
	Black	36.10c-f	97.49d	28.41hi	157.50d	23.06hi	46.40d-f
	Silver	34.66d-f	94.69d	24.17j	112.23fg	22.48hi	45.92d-f
Gray	Without	32.64e-f	93.33d	24.87ij	120.15eg	28.53ef	37.25i
	Organic	48.65a	135.75b	49.39ef	176.27cd	37.33c	49.70a-d
	Black	42.97a-c	133.80b	46.33f	160.25cd	29.20e	45.17e-g
	Silver	39.44b-f	97.11d	32.58g	143.62df	27.74ef	44.23e-g
Black	Without	39.67b-e	95.01d	25.33ij	144.20df	26.17fg	39.40h-i
	Organic	49.68a	139.38b	58.69bc	232.12a	42.30a	51.43a-c
	Black	44.63ab	136.67b	53.21de	216.51ab	32.89d	47.70c-f
	Silver	40.58b-e	118.90c	51.87de	192.26bc	29.18e	41.48gh
				Season 2021			
Green	Without	38.37d-f	136.98c	31.47h	151.45fg	32.60cd	45.36c-d
	Organic	55.84a	170.09a	71.46a	237.42a	46.25a	53.79ab
	Black	43.45b-d	146.12b	64.64b	179.76d	44.75ab	51.36a-c
	Silver	42.56b-e	141.41bc	56.52d	170.53de	41.94b	50.20b-d
Blue	Without	35.10f	83.29f	26.82i	108.46j	24.08h	43.47e
	Organic	45.96bc	103.02e	33.72gh	152.61fg	31.26c-e	52.57ab
	Black	39.30d-f	101.38e	31.15h	143.89gh	27.04fg	46.20c-e
	Silver	37.30ef	96.47e	26.15i	134.10hi	25.98gh	46.13c-e
Gray	Without	34.66f	98.33e	26.30i	125.56i	31.37c-e	44.51de
	Organic	47.81b	138.63bc	52.72e	178.33d	42.17b	55.34ab
	Black	45.33bc	135.49c	49.98f	163.88ef	31.91c-e	53.21ab
	Silver	41.72c-e	102.10e	34.90g	146.43gh	30.28de	53.20ab
Black	Without	41.01c-e	95.40e	27.87i	147.26gh	29.03ef	41.15e
	Organic	53.71a	141.63bc	61.71c	234.74a	43.13b	56.59a
	Black	47.70b	138.85bc	55.16de	219.68b	34.15c	49.82b-d
	Silver	42.25b-e	126.88d	53.61e	196.28c	31.70c-e	45.68c-e

Values having the same alphabetical letter(s) did not significantly differ at 0.05 levels of significance, according to Duncan's multiple range test.

3.3.3. Colored shade nets x soil mulch materials interaction

Vegetative growth and chlorophyll traits of cucumber plants (Table 2, and Fig.11) were significantly affected by interaction treatments. It is clearly noted that cucumber plants as shaded by any colored shade nets (green, blue, gray, and black) combined with organic or/and black soil mulch gave statistically equivalent or increase values in all vegetative growth traits *i.e.*, root length, plant height, number of leaves, and both fresh and dry weight of plants, as well as total chlorophyll of cucumber plants compared to the corresponding control treatments (Colored shade nets × non-mulched), indicating the efficient role of the studied soil mulching treatments to protect plants against frost. However, green shade nets followed by black shade nets interacted with

organic soil mulch treatment exhibited a highest value in all abovementioned traits. Under shade conditions, plants submit morphological changes to maximize light utilization, modifying the quality and quantity of the light spectrum through black or colored shade nets can serve as a physiological instrument to modulate the microclimate and promote plant growth. As for the soil treated by organic mulch with colored shade nets interaction, gave an increase in plant organ growth, which may be due to reflected of treatment which enhances soil aeration, gas exchange, water use efficiency, and nutrients retention better than colored plastic mulch under microclimate conditions which are enhanced by colored shade nets to balance the air and soil temperatures, humidity, light intensity. The colored shad nets have many effects, such as reducing wind run and wind speeds, and therefore can affect temperatures, relative humidity, and atmospheric gas microclimate accordingly; changes can affect respiration, transpiration, photosynthesis, and other processes. These effects are related to the percentage of shading, the color of the nets, the location, and the prevailing temperatures throughout the day and the region anyway the sweet pepper plants under shading nets gave the highest values for biomass, leaf area, chlorophyll content, and radiation utilization efficiency compared to the corresponding value without shading nets (Ilić *et al.*, 2017).

3.4. Fruit and yield traits

3.4.1. Effect of colored shade nets

Data presented in Fig. 12 show the effects among colored shade net treatments on physical fruit measures, average fruit weight, and cucumber yield traits of cucumber plants in both growing seasons.

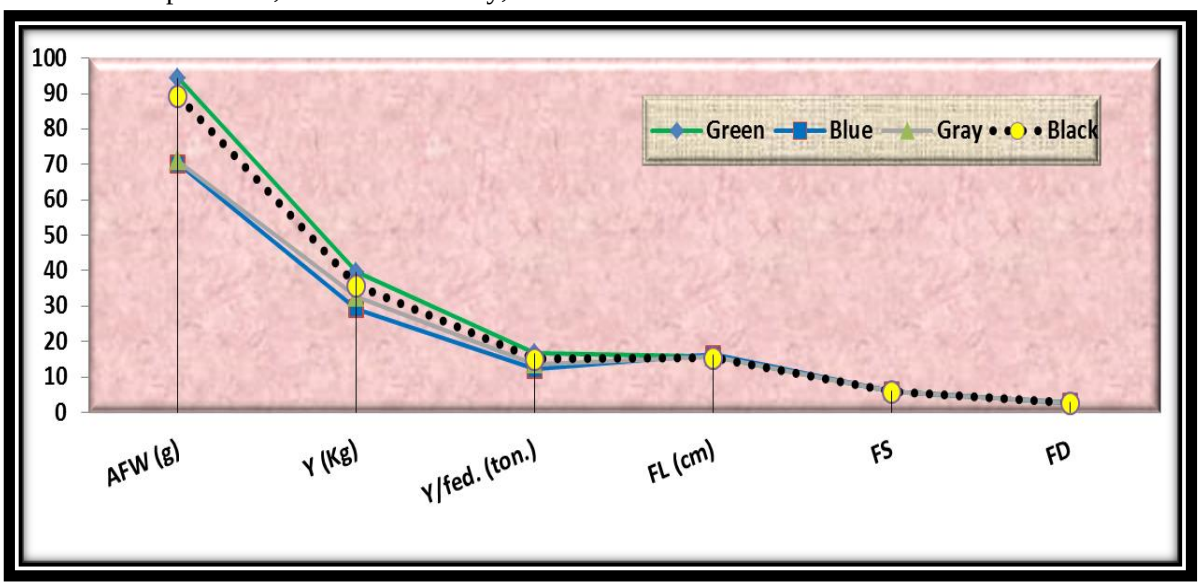


Figure 12. Effect of colored shade nets on fruit physical, average fruit weight and fruit yield of cucumber plants in average of both 2020 and 2021 seasons

(AFW: Average fruit weight, Y (kg):Yield/plots, Y/fed(ton.): Total yield, FL: Fruit length , FS: Fruit shape, FD: Fruit diameter).

The results show that the effects of colored shade nets, *i.e.*, green, blue, gray, and black, on cucumber plants gave a significant effect for the fruit traits, except, fruit length (L cm), fruit diameter (D cm), and fruit shape (L/D) in which no significant effects were observed under any colored shade net in both seasons. However, as for average fruit weight (g), yield (kg/plot) and total yield (ton/fed), the highest values were observed using green and black shading nets with no significant differences between them for

average fruit weight in both seasons. In a study involving some orchards and vineyards using photo-selective shade netting, It improved growth and thus increased yield and quality characteristics enhanced by the photosynthesis of carbohydrates and water use efficiency under color shade netting, in addition, in the same study the researchers mentioned that the effect of colored shade nets treatments namely, red, yellow, and pearl on pepper plants in comparison with the traditional black shade nets (equivalent shading capacity in PAR) led to increment the number of fruit per plant and the yield by 30-40% and 20-30%, respectively under the three photoselective nets, relative to the black net, as well as the average fruit size was different under all nets (Shahak *et al*., 2008). Also, Mena *et al.* (2014) on *Spinacia oleracea* in the summer season found that the yield under green shade net had nearly 66.4%, red 59%, black 23.8%, and white 22.1% more than the yield of control treatments.

3.4.2. Effect of soil mulch

The results presented in Figs. 13&14 show that average fruit weight, and cucumber yield/plot (kg) as well as total yield (ton/fed.) were strongly influenced by soil mulching with some different materials. However, fruit length, fruit diameter (D cm) and fruit shape (L/D) were not significantly affected in both growing seasons. Organic mulch surpassed the other treatments in average fruit weight, yield/plot (kg) and total yield (ton/fed.) during the two seasons of study, while both control and silver mulch treatments recorded the lowest values obtained in all the studied fruit and yield characteristics with no significant differences between the later during the two study seasons. However, average fruit weight exhibited the highest increment by 59% followed by total yield (34%), fruit diameter (4.9%) and fruit length (0.6%) as well as fruit shape which exhibited insignificant decreases (-4.5%) in descending order (Fig.12) over the corresponding non-mulched treatment (control).

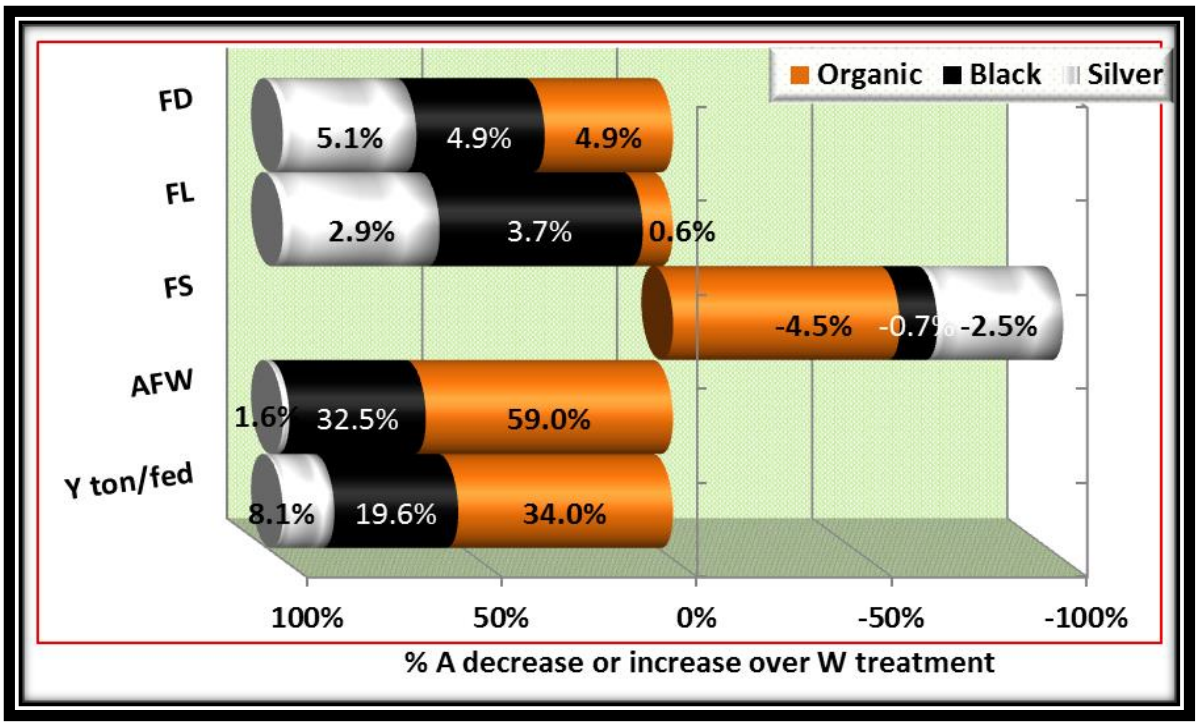


Figure 13. Changes percentage in fruit and yield traits as affected by soil mulch treatments in average of both seasons

(Y ton/fed: Total yield(ton/fed.), AFW: Average fruit weight, , FS: Fruit shape, FL: Fruit length, FD: Fruit dimeter).

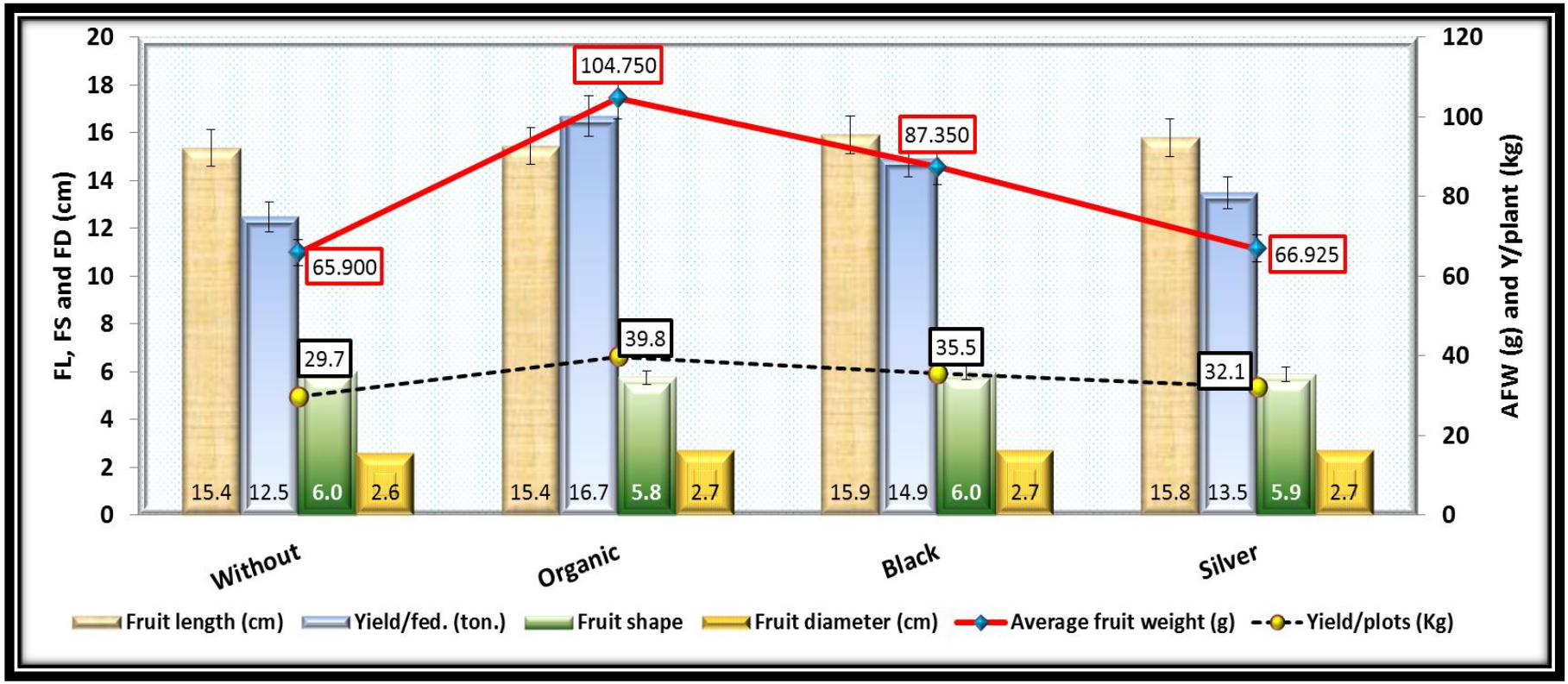
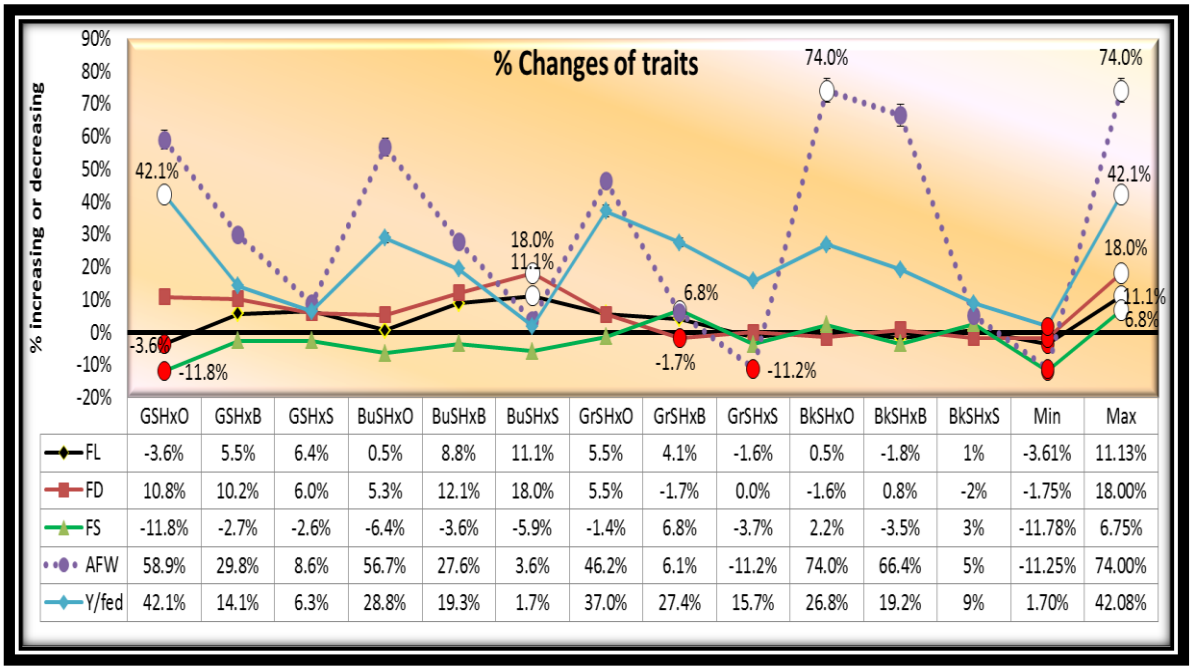


Figure 14. Effect of soil mulch materials on fruit length, diameter and shape as well as average fruit weight and fruit yield of cucumber plants in average of 2020 and 2021 seasons.

These results may be due to the effect of the organic mulch in achieving the appropriate temperatures in the root zone and thus achieving the highest efficiency for the absorption of water and nutrients, in addition to the accumulation of carbon dioxide that increases under soil mulch and around the root zone, which leads to increased photosynthesis and increased nutrient content in the leaves, resulting in better plant growth and yield productivity, which affect the physical characteristics and the best crop, compared with the other mulch treatments used under the experiment location conditions (high temperature, humidity, shad color nets) as shown in Figures (5 and 6 of soil temperature) . In addition, the researchers stated that the systems and processes involved in the soil are fundamentally dependent on nutrient uptake, water uptake, and root growth, thus affecting soil microorganism life, which depends too on the level of soil temperature (Kaspar *et al.*, 1992; Tapani *et al.*, 2015; Sabri *et al.*, 2018).

3.4.3. Colored shade nets x soil mulch materials interaction

Data presented of both seasons (Table 3) and average of the two seasons (Figs. 15 and 16) illustrated that the interaction effect between colored shade nets and soil mulch had a significant impact on most studied traits in both seasons, except fruit diameter (cm) in the first season had no significant effect with all interaction treatments. On the other hand, fruit characteristics did not record a fixed trend for these traits, but using blue shade with silver or black soil mulch recorded the best for fruit length (L) and fruit diameter (D) with no significant differences between silver and black soil mulches in this interaction in the two seasons. Data in the same table observed the significant effect interaction of shading color nets and soil mulch on yield per fed. (ton) where green and black shade nets combined with organic (19.56&15.69) and/or black (15.88&14.66) soil mulches achieved the highest values of yield per fed in [1]st season and 21.23&17.85 and/or 16.87&16.88, respectively in [2]nd season.



	GSHxO	GSHxB	GSHxS	BuSHxO	BuSHxB	BuSHxS	GrSHxO	GrSHxB	GrSHxS	BkSHxO	BkSHxB	BkSHxS	Min	Max
FL	-3.6%	5.5%	6.4%	0.5%	8.8%	11.1%	5.5%	4.1%	-1.6%	0.5%	-1.8%	1%	-3.61%	11.13%
FD	10.8%	10.2%	6.0%	5.3%	12.1%	18.0%	5.5%	-1.7%	0.0%	-1.6%	0.8%	-2%	-1.75%	18.00%
FS	-11.8%	-2.7%	-2.6%	-6.4%	-3.6%	-5.9%	-1.4%	6.8%	-3.7%	2.2%	-3.5%	3%	-11.78%	6.75%
AFW	58.9%	29.8%	8.6%	56.7%	27.6%	3.6%	46.2%	6.1%	-11.2%	74.0%	66.4%	5%	-11.25%	74.00%
Y/fed	42.1%	14.1%	6.3%	28.8%	19.3%	1.7%	37.0%	27.4%	15.7%	26.8%	19.2%	9%	1.70%	42.08%

Figure 15. percent yield traits increment or decrease as affected by the interaction between colored shade nets and soil mulch compared to the corresponding control treatments

Where G, Bu, Gr, Bk SH: green, blue, grey, black shade net, respectively; O, B, S: organic, black, silver soil mulch, respectively.

Table 3. Effect of interaction between colored shade nets and soil mulch on fruit length, diameter and shape as well as average fruit weight and fruit yield of cucumber plants in 2020 and 2021 seasons

Characters / Variables		Fruit length (cm)	Fruit diameter (cm)	Fruit shape	Average fruit weight (g)	Yield/plots (Kg)	Yield/fed. (ton/fed.)
Shade Nets	Soil mulch			Season 2020			
Green	Without	15.28b-d	2.53a	6.07ab	72.23e	30.99e	12.99e-g
	Organic	14.58d	2.83a	5.21b	115.45a	46.58a	19.56a
	Black	16.33ab	2.76a	5.93ab	97.53c	37.81b	15.88b
	Silver	15.42b-d	2.64a	5.85ab	83.92d	34.18cd	14.36c-e
Blue	Without	14.75d	2.50a	5.90ab	55.25g	23.78g	9.99h
	Organic	14.92cd	2.52a	5.92ab	92.73c	31.52e	13.24d-g
	Black	16.17ab	2.55a	6.34ab	70.32e	29.05f	12.21g
	Silver	17.21a	2.84a	6.01ab	55.01g	23.90g	10.04h
Gray	Without	15.25b-d	2.40a	6.36ab	62.17f	24.92g	10.47h
	Organic	15.42b-d	2.73a	5.67ab	92.63c	34.25cd	14.38c-e
	Black	16.05a-c	2.37a	6.92a	67.34ef	33.03d	13.87d-f
	Silver	15.67b-d	2.50a	6.34ab	54.40g	29.16f	12.25g
Black	Without	14.80d	2.42a	6.13ab	63.54f	29.49f	12.38fg
	Organic	14.92cd	2.50a	5.97ab	110.39ab	37.36b	15.69bc
	Black	14.71d	2.50a	5.98ab	107.68b	34.92c	14.66b-d
	Silver	14.92cd	2.43a	6.21ab	66.63ef	32.91d	13.82d-f
				Season 2021			
Green	Without	15.75b-e	2.67ab	6.15ab	59.83g	37.44cd	15.72cd
	Organic	15.33c-e	2.93a	5.57ab	94.33cd	50.54a	21.23a
	Black	16.41a-d	2.97a	5.96ab	73.90e-g	40.20bc	16.87bc
	Silver	17.60a-c	2.87ab	6.05ab	59.48g	38.49cd	16.16cd
Blue	Without	16.33a-d	2.39b	6.67a	79.96d-f	28.08f	11.79f
	Organic	16.33a-d	2.63ab	5.84ab	119.11a	35.29de	14.82de
	Black	17.66a	2.93a	5.78ab	102.18bc	32.81e	13.78e
	Silver	17.33ab	2.93a	5.82ab	85.01de	28.85f	12.11f
Gray	Without	15.66b-e	2.87ab	5.49ab	66.65fg	29.24f	12.28f
	Organic	17.20a-c	2.83ab	6.01ab	95.65cd	40.17bc	16.79bc
	Black	16.12a-d	2.81ab	5.73ab	69.35e-g	35.97de	15.11de
	Silver	14.75e	2.77ab	5.07b	59.93g	33.54e	14.08e
Black	Without	15.08de	2.73ab	5.49ab	67.55fg	33.53e	14.08e
	Organic	15.12de	2.57ab	5.91ab	117.71ab	42.51b	17.85b
	Black	14.62e	2.69ab	5.23b	110.49a-c	40.21bc	16.88bc
	Silver	15.14de	2.63ab	5.71ab	71.03e-g	35.70de	14.97de

Values having the same alphabetical letter(s) did not significantly differ at 0.05 levels of significance, according to Duncan's multiple range test.

Again, as average of both seasons (Fig. 16), the interaction between shading nets and soil covers showed many increases (although there were some decreases) in the different traits. However, the effect on average fruit weight ranged from -11.3% to 74.0%, followed by yield (1.70% to 42.08%), fruit diameter (-1.8% to 18.0%), and fruit length (-3.6% to 11.1). %) with average increases of 31%, 20.6%, 5.3%, and 3%, respectively as well as fruit shape (-11.8% to 6.8%), with an average decrease of 2.5%. Both Black SH and Green SH interaction with organic mulch showed the highest increment by 74% and 42.1% in average fruit weight (AFW) and yield, respectively followed by Blue SH x Silver mulch in both fruit diameter (18%) and fruit length (11.1%) as well as Grey SH x Black mulch (6.8%) in fruit shape.

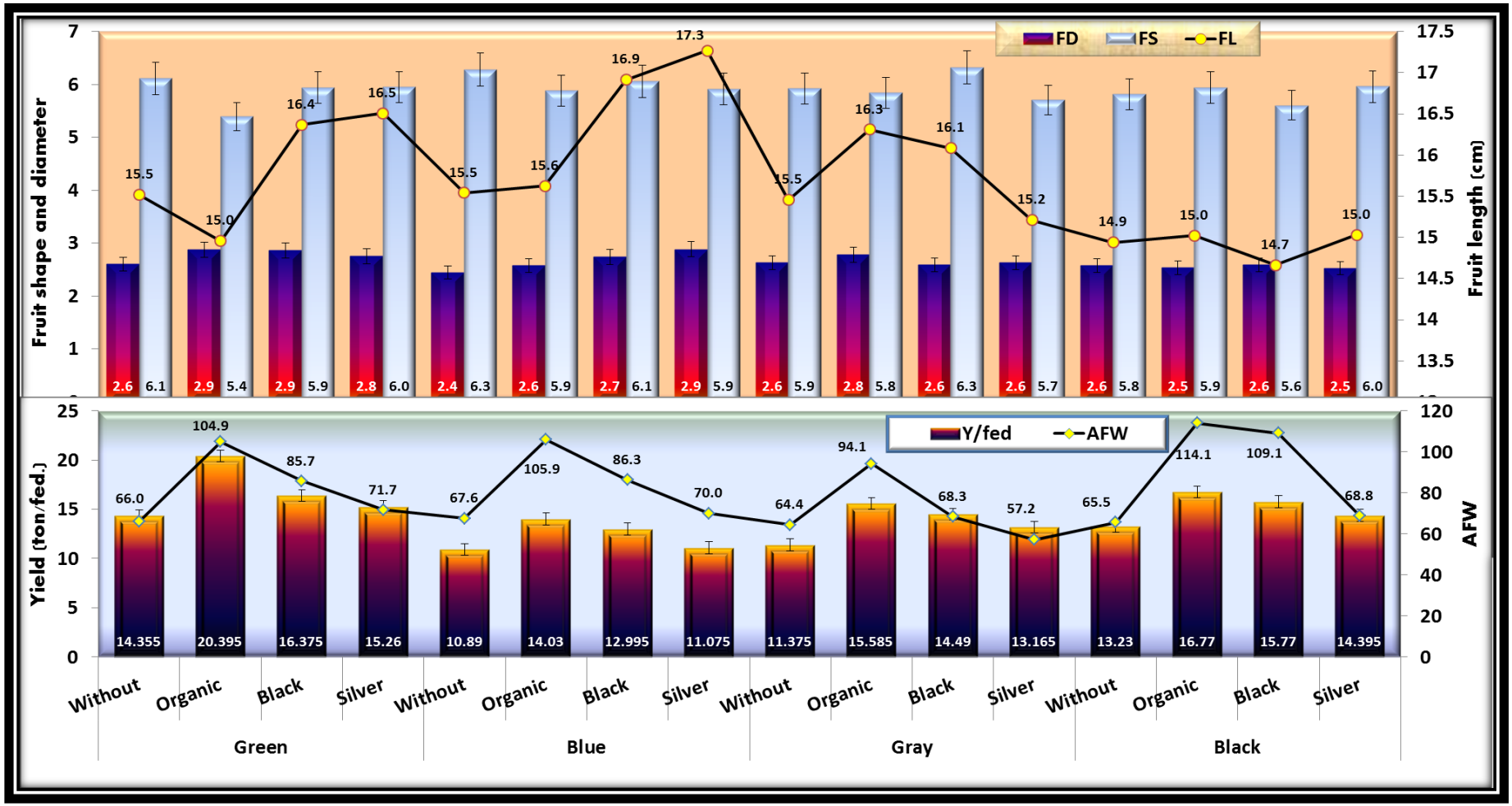


Figure 16. Effect of interaction between colored shade nets and soil mulch on fruit length, diameter and shape (above) as well as average fruit weight and fruit yield (Lower) of cucumber plants in average of both 2020 and 2021 seasons.

3.5. Fruit content of VC, TSS, and NPK

3.5.1. Effect of colored shade nets

Data presented in Fig. 17 show the effects among colored shade net treatments on fruit content traits, *i.e.,* Vitamin C, TSS, and NPK of cucumber plants in both growing seasons.

The results show that the effects of colored shade nets, *i.e.,* green, blue, gray, and black, on the contents of cucumber fruit gave a significant effect for all contents, except V.C in which no significant effects were observed under any colored shade net in both seasons. However, as for TSS, N and P%, the highest values were observed using green shading nets whereas black shade nets were for K% in both seasons with no significant differences between green and black shading nets in TSS, P and K%.

El-Gizawy *et al.* (1992) on fruit quality and yield of tomato found that tissue levels of N, P, and K increased with increasing shading level. On the contrary Liu *et al.* (2003) and Semida *et al.* (2017) stated that, for cucumber plants grown under different shade levels, lower shade conditions always cause a significant decrease in leaf mineral nutrients, *viz.*, N, P, and K.

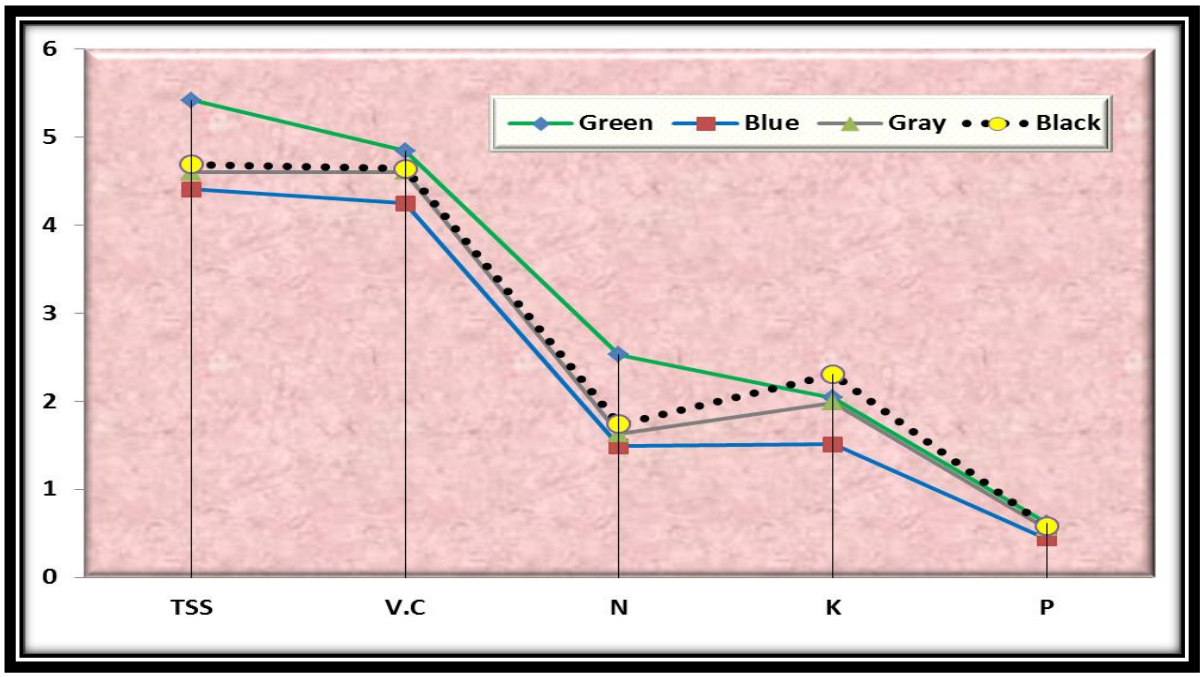


Figure 17. Effect of colored shade nets on V.C, TSS, N, P and K% of cucumber fruit in average of both 2020 and 2021 seasons.

3.5.2. Effect of soil mulch

The results presented in Figs. 18 &19 show the fruit contents (V.C, TSS, N, P and K %) influenced by soil mulch materials. N % content was significantly affected by soil mulch materials in both seasons whereas K and P% were in 1st and 2nd season, respectively. Both V.C and TSS were not significantly influenced by soil mulch materials in both seasons. Organic mulch and/or black plastic mulch surpassed the other treatments in all the studied traits during the two seasons of study with no significant differences between organic mulch and black plastic mulch in both seasons, while the control treatment recorded the lowest values obtained in N, P and K% contents during the two study seasons. As for average of both seasons, fruit K % content exhibited the highest increment by 26.8% under organic mulch treatment followed by N% (25.3%), P% (24%), TSS (7.2%) and V.C (2.1%) in descending order (Fig.18) over the corresponding non-mulched treatment (control).

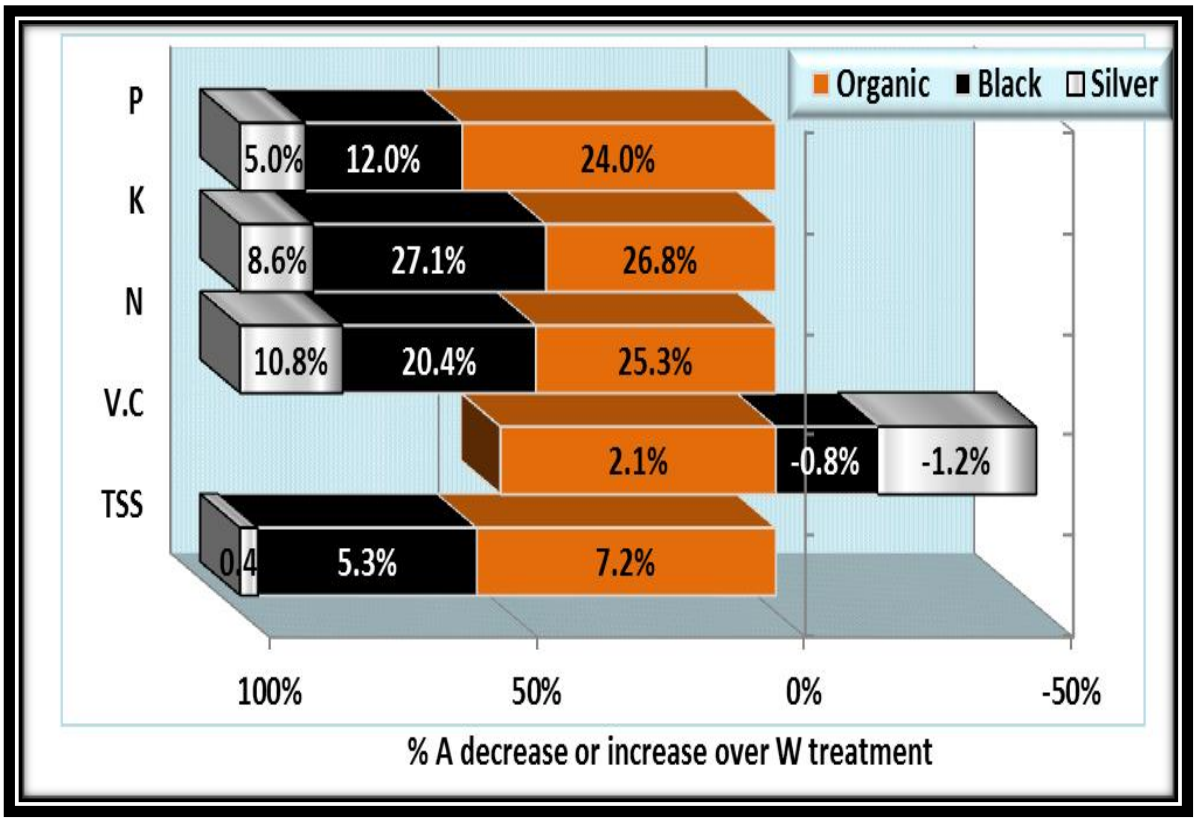


Figure 18. Changes percentage in V.C, TSS, N, P and K fruit content traits as affected by soil mulch treatments in average of both seasons.

In this respect, generally, the reason for the superiority of mulch treatment may be that it provides microclimate conditions suitable for plant growth by enhancing soil temperature, amending physical and chemical properties, decreasing water evaporation, improving water retention and nutrients, and increasing its uptake (Mahmoud *et al.,* 2002). Mulching the soil with black plastic mulch did not have a significant effect on the K-content leaves of okra plants, while N, P, and Ca were significantly affected (Kazem *et al.,* 2020).

3.5.3. Colored shade nets x soil mulch materials interaction

Data presented in Table 5, and Fig. 20 shows that the interaction between shade color nets and soil mulch nets has a significant effect on most studied traits except VC-content in cucumber fruits, which found no significant differences in both seasons. As for TSS content, a higher significant effect was observed in the first season with green shade nets and black soil mulch, and in the second season with green shade nets and organic mulch. Data in the same table also showed that a highly significant K-content was recorded when cucumber plants were covered with green shade nets and organic mulch in the first season, and with black shade nets and organic mulch in the second season. Additionally, no significant differences were found between organic and black soil mulches in most treatments and traits.

On the other hand, P-fruit content produced the best significant effect from gray shade nets' interaction with organic soil mulch; in the first (0.72) and second (0.75) seasons, respectively. As for N-fruit content, cucumbers covered by green shade nets with organic soil mulch recorded the highest values, followed by those covered by black soil mulch in both seasons.

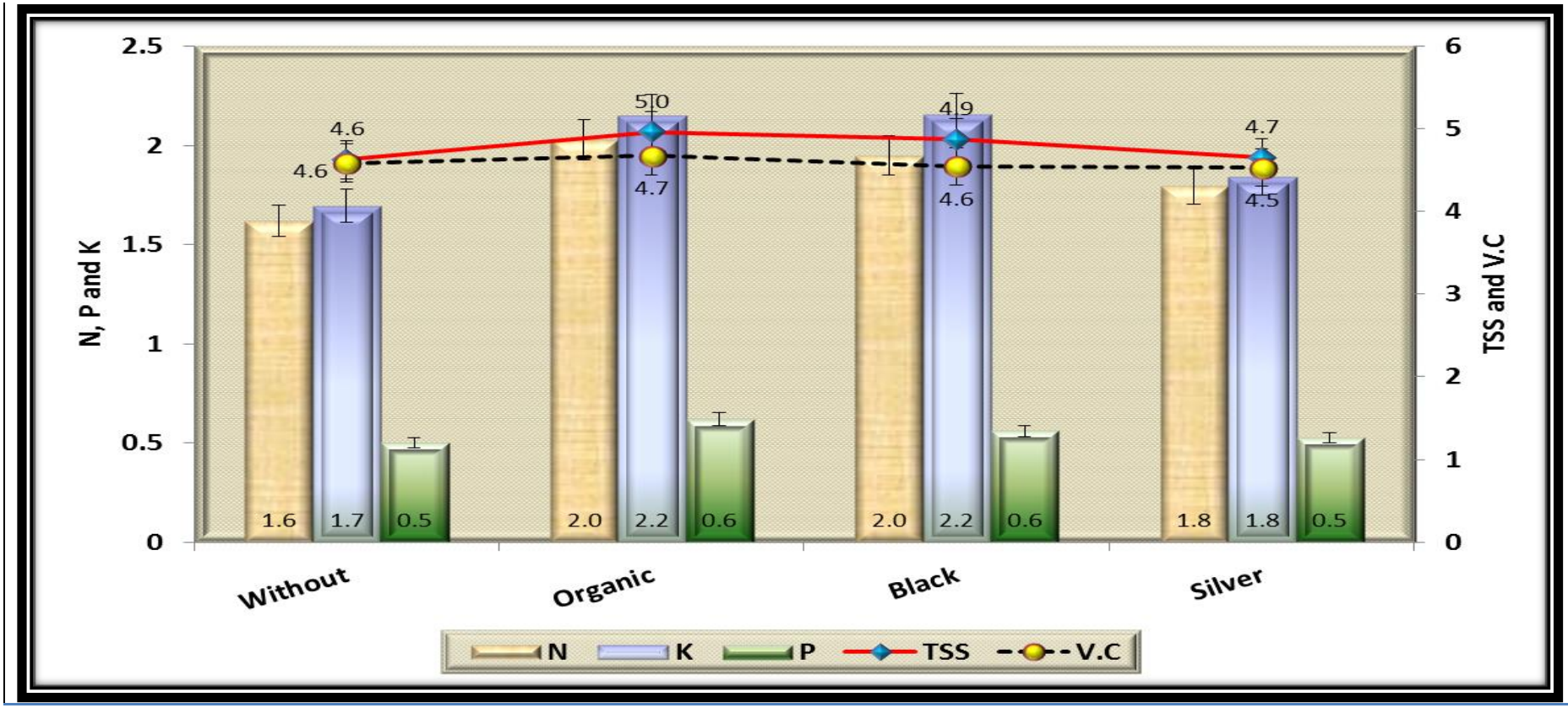


Figure 19. Effect of soil mulch materials on V.C, TSS, N, P and K fruit content traits of cucumber plants in average of 2020 and 2021 seasons.

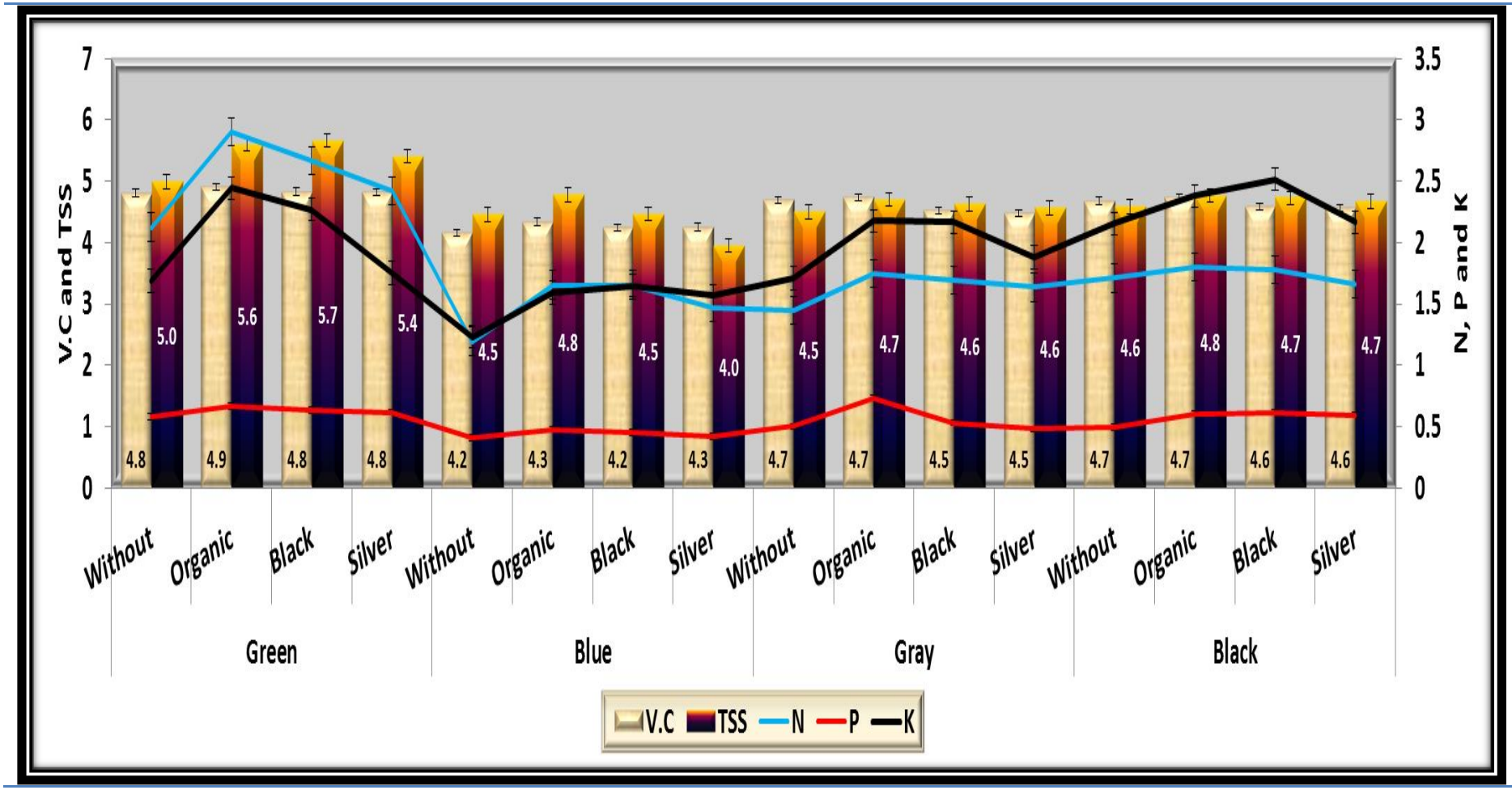


Figure 20. Effect of interaction between colored shade nets and soil mulch on Fruit contents of cucumber plants in average of both 2020 and 2021 seasons.

Table 4. Effect of interaction between shade color nets and color soil mulch on cucumber fruit content of VC, TSS, and NPK in 2020 and 2021 seasons.

Characters / Variables		V.C mg/100ml Juice	TSS	N %	P %	K %
Shade colors Nets	Color Soil mulch			Season 2020		
Green	Without	4.70a	4.93b-d	2.01d	0.53b-e	1.60e-g
	Organic	4.86a	5.26ab	2.79a	0.65ab	2.62a
	Black	4.78a	5.53a	2.52b	0.59a-c	2.00c-e
	Silver	4.78a	5.03bc	2.27c	0.61a-c	1.17h
Blue	Without	4.04a	4.28e	1.08h	0.40de	1.17h
	Organic	4.23a	4.61c-e	1.54e-g	0.47c-e	1.42gh
	Black	4.18a	4.30e	1.59e-g	0.43de	1.63e-g
	Silver	4.17a	4.30e	1.37fg	0.39e	1.53f-h
Gray	Without	4.68a	4.37e	1.33g	0.47c-e	1.37gh
	Organic	4.76a	4.64c-e	1.65e	0.72a	1.80c-g
	Black	4.68a	4.51e	1.62ef	0.52b-e	1.93c-f
	Silver	4.68a	4.41e	1.53e-g	0.47c-e	1.64d-g
Black	Without	4.57a	4.50e	1.62ef	0.47c-e	1.93c-f
	Organic	4.62a	4.67c-e	1.72e	0.55b-d	2.08cd
	Black	4.42a	4.63c-e	1.69e	0.58a-c	2.50ab
	Silver	4.38a	4.56de	1.47e-g	0.54b-e	2.12bc
				Season 2021		
Green	Without	4.93a	5.05ab	2.24c	0.63bc	1.78c-g
	Organic	4.95a	5.94a	3.02a	0.68ab	2.27a-c
	Black	4.89a	5.81ab	2.81ab	0.68ab	2.54ab
	Silver	4.87a	5.79ab	2.57b	0.62bc	2.33ab
Blue	Without	4.27a	4.63bc	1.31f	0.42e	1.29g
	Organic	4.44a	4.94ab	1.77de	0.48de	1.76d-g
	Black	4.31a	4.63bc	1.72de	0.47de	1.67e-g
	Silver	4.34a	3.61c	1.57e	0.45de	1.60fg
Gray	Without	4.70a	4.63bc	1.57e	0.53cd	2.05b-f
	Organic	4.71a	4.77a-c	1.85de	0.75a	2.55ab
	Black	4.37a	4.74a-c	1.77de	0.54cd	2.40ab
	Silver	4.27a	4.72a-c	1.74de	0.49de	2.12b-e
Black	Without	4.79a	4.67bc	1.80de	0.52de	2.38ab
	Organic	4.85a	4.86ab	1.88d	0.66ab	2.68a
	Black	4.75a	4.83a-c	1.87d	0.65ab	2.53ab
	Silver	4.74a	4.79a-c	1.85de	0.65ab	2.21a-d

Values having the same alphabetical letter(s) did not significantly differ at 0.05 levels of significance, according to Duncan's multiple range test.

4. Conclusion and recommendations

Our results show that using shade nets of various colors can help to improve cucumber plant development, production, and quality by lowering abiotic stressors such as light intensity, radiation, air and soil temperatures, and relative humidity. In order to achieve a cost-productivity trade-off and serve as a solid economic and environmental foundation, it is advised to use shade nets in shades of green and black with organic residue-covered soil and/or black plastic covering. It is also advised to design wooden greenhouses using environmental materials in locations with limited access to agricultural resources such as Sharm El-Sheikh City and areas with similar conditions.

Authors' Contributions

All authors are contributed in this research

Funding

There is no funding for this research.

Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

Not applicable

Consent for Publication

Not applicable.

Conflicts of Interest

The authors disclosed no conflict of interest.

5. References

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