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Different Agronet Covers Influence Physiological Traits, Growth and Yield of African Nightshade (*Solanum scabrum* Mill.) and Spiderplant (*Cleome gynandra* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. Author OHO performed the experiment, data collection, statistical data analysis, interpretation of results and preparation of first draft of the manuscript. Authors AMO and MS conceived the idea, designed the experiment and edited the manuscript. They also provided for experimental materials. All authors read and approved the final manuscript.

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ABSTRACT

African indigenous leafy vegetables (AILVs) contribute significantly to improved nutrition, food security and income. However, the potential to meet the growing demand for AILVs in Kenya has not been satisfied. This study was conducted between August, 2015 and April, 2016 to evaluate the effect of different agronet colours on growth and yield of African nightshade and spiderplants The experiment was a 2x5 factorial laid on a randomized complete block design (RCBD), with three replications. Factors under study were vegetable types (African nightshade and spiderplant) and net covers (white, grey, blue, yellow net and open field). Spiderplant seeds were direct seeded and later thinned to a spacing of 30 cm by 30 cm. African nightshade seeds were started in the nursery

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and later transplanted five weeks after sowing. From the 7th weeks after planting (WAP) and at two weeks interval, plant height, primary branches, stomatal conductance, chlorophyll and leaf fresh yield were determined. Use of blue net significantly yielded taller plants of African nightshade (29.6%) compared to those in the open field by 13 WAP. Spiderplant were taller under white net (20.7%) and shorter under blue net (20.95%) compared to open field by 13 WAP. Yellow and white net enhanced primary branching of African nightshade and spiderplant, respectively while blue net exhibited the least for both vegetables. Days to first and 50% flowering was delayed under blue net by 13 and 6 days compared to control for spiderplant and African nightshade, respectively. Yellow and white net improved stomatal conductance for African nightshade and spiderplant, respectively. Regarding chlorophyll content, yellow and blue net had the highest concentration of chlorophyll a and b for both vegetables. Use of yellow net improved total fresh leaf yield by 15.82% and 12.42% compared to open field for African nightshade and spiderplant, respectively. Blue net significantly reduced total yield compared to open field for both vegetables. This study shows blue net cover has the potential to prolong the vegetative phase of these crops hence longer harvesting time of these crops and that yellow net has a greater potential to be used for production of African nightshade and spiderplant. However, a cost benefit analysis study should be done to assess the beneficial effect of yellow net over open field.

Keywords: African leafy vegetables; protected cultivation; light quality; phytochrome; cryptochromes; chlorophyll.

1. INTRODUCTION

African indigenous leafy vegetables (AILVs) are crops that are cultivated or plants that grow wild and are harvested or gathered for food within a particular African ecosystem [1]. AILVs including Spiderplant (*Cleome gynandra* L.) and African nightshades (*Solanum villosum* Mill, *Solanum americanum and Solanum scabrum* Mill), significantly contribute to food security and nutrition for smallholder farmers in the east and central African regions [2].

According to the Food and Agriculture Organization (FAO) [3], around 868 million people (12.5% of the world's population) are undernourished in terms of energy intake while another 2 billion people suffer from one or more micronutrient deficiencies also known as 'hidden hunger'. Oniang'o et al. [4] suggest that the food and nutritional insecurity that most African countries face today could potentially be mitigated if a greater change can be realized through the use of African indigenous leafy foods. Lack of suitable and sustainable horticultural practices is some of the constraints that limit improved growth and yield of AILVs [2]. Developing and promoting appropriate farming or horticultural technologies could therefore ensure sustainable production and consumption of AILVs for the ever increasing population [2].

Agricultural nets (Agronets) are beneficial for crop growth and development by significantly altering air temperature, light quality and intensity and soil moisture which positively influence plant physiological activities leading to improved crop growth and yield [5]. Coloured nets are a new agro-technological concept which aims at combining the physical protection together with the differential filtration of the solar radiation and concomitantly inducing light scattering. Various net colours exist, including red, yellow, blue, green, black and grey. Spectral manipulation by coloured nets promotes specific photomorphogenetic and physiological responses, while light scattering improves light penetration into the inner canopy. According to Rajapakse and Shahak [6], crop radiation use efficiency increases when the diffuse component of the incident radiation is enhanced under shade. On the other hand, photosynthetic pigments within plants utilize different wavelengths to accomplish different growth and development responses. The usage of Agronets with different colours permits physical plant protection combined with promotion of the physiological responses regulated by light [7] because Agronets modify both the quantity and quality of solar radiation transmitted. Hence Agronets have been developed with diverse colours to modify the spectrum of transmitted light. Visible light is divided into: violet (380-430 nanometer-nm), blue (430-500 nm), green (500-570 nm), yellow (570-590 nm), orange (590-630 nm) and red (630-770). On the other hand, plants photosynthesize between 400-700 nm; this range is known as Photosynthetic Active Radiation (PAR). The blue and red nets exhibit peaks of transmittance in the blue-green (400-540 nm) region and in the red region (590 nm), respectively [8]. The objective of this study was to determine the effect of different Agronets on growth and yield of African nightshade and spiderplant.

2. MATERIALS AND METHODS

The study was conducted at the Horticulture Research and Teaching field of Egerton University, Njoro, Kenya. The site lies at a latitude of 0º23' S and longitude 35º35'E in the lower highland 3 Agro-ecological zone (LH3) at an altitude of 2238 metres above sea level. The soils are well drained vintric mollic andosols. Average maximum and minimum temperature during the experimental period was 21.9 and 19.6ºC, respectively, with total rainfall of 633.3 mm.

Seeds of spiderplant and African nightshade used as planting materials in this study were obtained from Asian Vegetable Research and Development Centre (AVRDC) Arusha. Agronet covers (Commercially known as Agricultural Nets) used were low density Polyethylene knitted and have plane texture. The nets had average pore size of 0.9 mm×0.7 mm and were obtained from A to Z Company Ltd (Arusha, Tanzania). Agronet covers used in this study were white, deep blue, dark grey and yellow nets covers.

The experiment was a 2 × 5 factorial laid on a Randomized Complete Block Design (RCBD), with three replications. The factors under study were vegetable type at two levels (African nightshade and spiderplant) and net cover at five levels (white net, grey net, blue net, yellow net and open field- control). Each experimental unit (plot) measured 2 × 3 m and was separated by 1 m path. Plots with net treatments had four posts placed at each corner to provide support for the nets and two posts placed at the centre to prevent net lodging on to the crops. Each post was 1.2 m tall and was placed in a hole dug at a depth of 20 cm. The vegetables were maintained permanently covered except during cultural practices and data collection dates.

The field was dug using hoes and plots of size 2 × 3 m were demarcated and leveled using a rake to a fine tilth. In each spiderplant plot, six rows at spacing of 30 cm between the rows were made. Spiderplant seeds were then drilled at a depth of about 1cm. Thinning was done five weeks after sowing to achieve a spacing of 30 cm between plants. African nightshade seeds were established in the nursery; the seedlings were transplanted five weeks after sowing in six rows per plot at spacing of 30 cm by 30 cm. The plots were covered with the respective nets immediately after planting. General maintenance practices such as watering, fertilizer application and pest control were done after planting throughout the crop growing duration on need basis.

Eight plants per plot were randomly selected from the inner rows and tagged for data collection. Four out of the eight plants were tagged for data collection on non-destructive variables (plant height, number of primary branches and stomatal conductance) while the remaining four plants were used for the destructive variables (leaf yield and total chlorophyll content). Data collection began 7 weeks after planting (WAP) and thereafter at fortnightly intervals. The procedures for data collection were as follows:

The plant height (cm) was measured from the ground to the tip of each of the tagged plants by means of a meter tape. The numbers of primary branches that emerge were counted physically and the average per plant was later calculated and recorded. Stomatal conductance was determined using a leaf porometer (SC-1, Decagon Devices, Inc. Hopkins Court Pullman, and USA) according to Campbell and Norman [9]. Stomatal conductance (mmol m^{-2} s^{-1}) readings were taken directly from three recently fully expanded leaves per four tagged plants; the readings were recorded and the average per experimental unit was later computed. Chlorophyll a and chlorophyll b were determined according to Goodwin and Britton [10]. An extractant, acetone- hexane mixture, was prepared in the ratio of 4:5. Leaf samples each weighing 0.5 g was ground in a mortar and placed in centrifuge tubes. Fifteen millimeters of extractant were added into the tubes and centrifuged (HSC-700, Tokyo, Japan) for 10 minutes at 4000 revolutions per minute (rpm). The first supernatant was then transferred using a pipette into 25 ml volumetric flasks and the residues washed with 5 ml acetone-hexane and centrifuged again for 10 minutes at 4000 rpm. The second supernatant was transferred using a pipette into 25 ml volumetric flasks and topped up with acetone –hexane to 25 ml. Extinction of samples in glass cuvettes was measured in a spectrophotometer (U-2000, Hitachi, and Tokyo, Japan) at a wavelength of 663 nm and 645 nm for chlorophyll a and b respectively. Concentration (µg g^{-1} fresh weight (FW) of Chl a and Chl b was determined using the following equations:

$$\text{Chlorophyll a} = \{(10.1\times E_{663})-(1.01\times E_{645})\}\times V/FW$$

$$\text{Chlorophyll b} = \{(16.4\times E_{645})-(2.57\times E_{663})\}\times V/FW$$

The number of days from sowing of both vegetables to appearance of the first flower and to when 50% of the plants in each experimental unit had at least one flower was monitored and recorded for each experimental unit. Mean number of days to first and 50% flowering for each experimental unit was computed and recorded. Harvesting of shoots from four tagged plants was done at two weeks intervals beginning from the 7^{th} WAP and continued up to the 15^{th} WAP, thus giving a total of five harvests. After each harvest, weight of fresh shoots was determined in grams using a weighing balance (Advanced Technocracy Inc. Ambala). Total fresh yield per experimental unit was computed after the last harvesting date. Total fresh yield was then expressed in kg per hectare (kg ha^{-1}).

All the data were subjected to analysis of variance (ANOVA) and significant means were separated using Tukey's honestly significant difference (Tukey's HSD) test at P = 0.05. The statistical analysis system (SAS) program, version 9.1 [11] was used for data analysis. Since trial by treatment interaction was not significant, data for the two trials were pooled and analyzed together using the RCBD model:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \tau_k + \alpha\beta\tau_{jk} + \varepsilon_{ijkl}$$

$$i = 1, 2, 3,\ j = 1, 2, 3, 4, 5,\ k = 1, 2.$$

Where Y_{ijkl}= Observation in the i^{th} block due to j^{th} agronets treatments on the k^{th} vegetable. μ - is the overall mean, α_i- effect due to the i^{th} block, β_j- effect due to the j^{th} agronet treatment, τ_k- effect due to the k^{th} vegetable, $\alpha\beta\tau_{jk}$ -interaction effect between the j^{th} agronet treatment and k^{th} vegetable, ε_{ijk}- random error component which is assumed to be normally and independently distributed about zero mean with a common variance, σ^2.

3. RESULTS AND DISCUSSION

3.1 Influence of Different Agronet Covers on Plant Height of African Nightshade and Spiderplant

Growing African nightshade and spiderplant under agronet covers significantly influenced plant height of the two vegetable species during the study (Table 1). African nightshade under blue net were significantly taller compared to those in the open field. Plants grown under yellow and grey net covers were also significantly taller than the control plants on most sampling dates. Plants grown under the white net cover also tended to be taller than the control plants though the difference was not significant on most sampling dates. The tallest plants of spiderplants were obtained under the white net cover in all sampling dates. On the other hand, the shortest plants were obtained from blue net throughout the study. Plants grown under the yellow and grey net covers tended to be intermediate in height compared to open field during most sampling dates. African nightshade had up to 26.27% higher plant height compared to spiderplant by 13 WAP. The spectral manipulation of light by net covers alters crop physiological and morphological responses [12]. Findings of the current study support this argument. In this study, use of blue net cover significantly enhanced growth of (taller) plants in African nightshade compared to those grown in the open field. Consistent with the current study, Oliveira et al. [13] observed that *Melissa officinalis* plants grown under blue net were taller compared to those in the open field. In nature, equilibrium between red and far red exists, but the ratio of red to far red decrease under shade conditions. In many species the decrease in the red to far red causes stems elongation and increased apical dominance [14]; phenomenon referred to as shade avoidance syndrome. Higher stem elongation occurred in African nightshade grown under blue cover. Since a greater reduction in red to far red ratio occurs under blue light compared to yellow, grey and white net.

While blue net resulted in taller plants in African nightshade, however, it caused dwarfing in spiderplant during the study. This can be supported by observations made by Rajapakse and Shahak [6] that responsiveness of plants to different light wavelengths varies amongst species. Similarly, Oren-Shamir *et al.* [8] reported that blue net caused dwarfing on *Pittosporum variagatum* compared to the control plants. Blue light (430 nm-450 nm) enables cryptochromes and phototropins to mediate plant responses such as inhibition of elongation growth and this might explain the reason for shorter plants observed in spiderplant in the present study.

In the current study, use of white net cover advanced plant height of spiderplant more than the rest of the net covers and the open field.

Similar results have been reported by Abul-Soud et al. [15] that white net treatments produced the highest plant height of Chinese, white and red cabbages more than yellow, blue, red and black net covers while open field gave the least plant height. The aforementioned publication suggests that increased plant height under white net cover could be attributed to the suitable climatic conditions for cabbage plants under the white net cover. In the present study increased plant height under white net could also be attributed to the fact that spiderplant being a C4 plant [16], its growth is maximized under higher solar radiation and temperatures, conditions that could have been experienced under white net cover.

3.2 Influence of Agronet Covers on Primary Branching of African Nightshade and Spiderplant

Agronet covers influenced primary branching of both African nightshade and spiderplant during the study (Table 2). Growing African nightshade under the yellow net cover improved primary branching of the plants yielding the highest number of primary branches while the least number of primary branches was obtained in plants grown under blue net covers; with plants grown under control, white net and grey nets displaying intermediate branching. Unlike African nightshade, spiderplant grown under white net cover had significantly increased number of primary branching. The lowest branching was on the other hand observed in plants grown under the blue net cover. Plants grown under the grey and yellow net cover treatments tended to have the higher number of primary branches compared to those in the open field treatment although the difference was not significant during most sampling dates. African nightshade had 29.19% higher number of branches compared to spiderplant by 13 WAP. Use of yellow and white net covers enhanced primary branching of African nightshade and spiderplant respectively. However, in both vegetables, use of blue net cover substantially reduced branching. Findings of this study in part support those of Shahak [5] who also observed that yellow nets specifically stimulated vegetative growth rate and vigour, and the grey net specifically enhanced branching and bushiness in Pittosporum while blue net inhibited branching.

As previously mentioned, the effects of the blue and yellow nets result from their enriching/reducing the relative content of blue and yellow spectral bands of the transmitted light, and might be related to similar effects reported for net covers and artificial illumination [6]. The effects of the grey net might relate to its distinct absorption in the infra- red (IR) range. In plants maintained under blue net cover, for which the Blue: Red light ratio is speculated to be high as reported by Shahak [10], primary branching was inhibited signifying that both African nightshade and spiderplant are not tolerant to this wavelength with regards to primary branching. The inhibitory effect of blue net cover on the vegetative growth of plants has also been reported by Abul-Soud et al. [15] who also suggested that blue net reduced radiation reaching crops underneath. As previously mentioned, blue light (430 nm-450 nm) enables cryptochromes and phototropins that mediate inhibition growth responses.

Increased branching of spiderplant under white net in the current study might relate wholly to similar reasons discussed above under plant height and partly because white net cover absorb

Table 1. Plant height (cm) of African nightshade and spiderplant as influenced by agronet covers

Vegetable type	Agronet cover	Weeks after planting			
		7	9	11	13
African nightshade	Control	11.42bc*	25.79cde	51.50bc	74.00bcd
	White	15.95ab	29.67bcd	60.83abc	81.08abc
	Yellow	17.79a	37.71ab	72.82ab	92.03ab
	Grey	18.79a	36.79abc	68.83ab	86.88abc
	Blue	19.71a	42.79a	76.50a	95.92a
Spiderplant	Control	9.83cd	23.91de	51.83bc	65.87cd
	White	10.04cd	30.75bcd	63.25ab	79.5abc
	Yellow	7.90cd	18.08e	62.71ab	73.08bcd
	Grey	8.43cd	22.04de	54.71abc	67.54cd
	Blue	5.90d	15.29e	37.71c	54.46d

**Means followed by same letters within a sampling date are not significantly different according to Tukey's HSD test at P=0.05.*

Table 2. Primary branching (numbers) of African nightshade and spiderplant per plant as influenced by agronet covers

Vegetable Type	Agronet cover	Weeks after planting			
		7	9	11	13
African nightshade	Control	2.91ab*	5.92abc	10.97a	13.91abc
	White	3.05ab	6.17ab	10.7a	14.94a
	Yellow	3.62a	6.21ab	12.9a	15.63a
	Grey	2.79ab	5.96abc	11.9a	14.45ab
	Blue	2.79ab	5.83abc	10.17a	13.79abcd
Spiderplant	Control	1.83bc	5.37bc	9.92a	10.96de
	White	2.79ab	8.38a	11.96a	12.41bcd
	Yellow	1.25bc	6.00abc	10.58a	12.50abcd
	Grey	1.20bc	5.46bc	10.25a	11.50cde
	Blue	0.17c	3.58c	6.79b	8.92e

**Means followed by same letters within a sampling date are not significantly different according to Tukey's HSD test at P=0.05.*

spectral bands shorter, or longer than the visible range; wavelengths that might have favoured growth and branching of this crop. In addition, white net increase light scattering but does not alter light spectral. Increased light scattering increases radiation use efficiency thus improves crop growth [6].

3.3 Influence of Agronet Covers on Days to First and 50% Flowering of African Nightshade and Spiderplant

Use of agronet covers significantly influenced days to first and 50% flowering of both vegetables (Table 3). Growing both vegetables under blue net cover resulted in a significant increase in the number of days to both first and 50% flowering by 6 and 13 days for African nightshade and spiderplant, respectively compared to growing the crop in the open field. Plants grown under the grey and yellow net covers took slightly more number of days to first and 50% flowering (by 3.16 and 2.83 for grey and yellow net respectively in African nightshade and 2.17 and 2.16 for grey and yellow net respectively in spiderplant) compared to the control plants. There was little difference in the number of days to first and 50% flowering by plants grown under the white net cover (by 1 and 2.33 for African nightshade and spiderplant, respectively) compared to control plants. Flowering tended to be hastened under the white net cover compared to control plants in spiderplant. The average days to first and 50% flowering was 89.4 and 93, 43 and 47 days for African nightshade and spiderplant respectively. The ability to control flowering time in vegetables grown for fresh shoot or leaf harvesting has the advantage of extending the vegetative phase in order to prolong the harvest season. According to Shahak [5] spectral modification by coloured nets can influence flowering time of crops because different wavebands of light exhibit distinct roles in the regulation of floral initiation.

The current study agrees with this affirmation. Use of blue net cover in the current study significantly delayed flowering time for both African nightshade and spiderplant compared to the other net colours and open field crops. Similar to the current study, Shahak [5] and Ovadia et al. [17], while working with red and yellow net on *Ornithogalum dubium*, reported that the red net advanced flowering, while the yellow net delayed flowering, relative to black net.

Kadman-Zahavi et al. [18] also observed that tomato seedlings grown under filters with far-red transmitting characteristics flowered early while those under blue light delayed in flowering. Similar results were again observed in a study by Mortensen and Stromme [19] with chrysanthemum, tomato and lettuce seedlings. In the current study, since net covers might correspond to specific wavelengths, then it is worth noting that flowering is hastened as wavelengths approach red and far red range but delayed in the reverse order. This assumption is made because flowering was delayed in crops under blue net cover (430 nm-500 nm), and progressively enhanced towards yellow (500-590 nm) and grey (700-800 nm/far red). This argument is further supported by Ovadia et al. [17] who reported that the most significant effect was a shortening of the time to flower under the red net compared to the blue net. They further observed that *Zantedeschia aethiopica* (calla), showed similar results, with the promotion of flowering under red and yellow nets compared to blue nets. Similarly, Shahak et al*.* [12] observed delayed flowering under yellow net cover than in red net. Blue light accelerates the induction mainly through the cryptochrome 2 receptor while red light accelerates the induction through the phytochrome b receptors [20]. This signifies, both spiderplant and African nightshade were more responsive towards the blue light receptors than red light receptor, thus delayed flowering.

The current finding is in agreement with observations by Ovadia et al. [17] who noted that photo-selective filters may serve as a useful and environmentally-friendly way to control the growth, development, and flowering of plants. Altering the spectrum of sunlight may serve to control flowering time of plants.

3.4 Influence of Agronet Covers on Leaf Stomatal Conductance of African Nightshade and Spiderplant

Growing African nightshade and spiderplant under agronet covers significantly increased leaf stomatal conductance (Table 4). Yellow and white net tended to give higher stomatal conductance in African nightshade and spiderplant, respectively. Blue and grey net covers also yielded plants with relatively higher leaf stomatal conductance compared with control plants in most sampling dates. African nightshade exhibited higher stomatal conductance by between 17.68-44.3% compared to spiderplant. Plant leaf stomatal conductance was enhanced when both African nightshade and spiderplant were grown under agronet covers. Although the use of agronet covers generally increased stomatal conductance, different net colours in the current study differentially influenced stomatal conductance. Higher stomatal conductance of African nightshade under yellow net observed in the present study might be attributed to the advantages possessed by yellow net in which it transmits highly scattered light which is enriched in the green, red and far-red spectral range relative to the ultra violet and blue range thus combine suitable characteristics of an array of wave bands as suggested by Shahak et al. [12]. White net cover on the other hand induced higher stomatal conductance in spiderplant. A Similar finding has been reported by Silva et al. [21] who reported higher stomatal conductance of banana plantlets under white net cover compared to blue, red and yellow nets. A study by Schroeter-Zakrzewska and Kleiber [22] also revealed higher stomatal conductance under white light when they used light emitting diodes.

Besides light quality, stomatal conductance is known to be affected by other factors such as carbon dioxide concentration, humidity and temperature. According to Bunce [23], plants are generally known to react to low relative humidity by closing their stomata with a consequent reduction in CO_2 uptake and water loss. The low stomatal conductance observed in both vegetables produced in the open field in this study could therefore have been a response of the plants to low relative humidity.

Table 3. Days to first and 50% flowering of African nightshade and spiderplant as influenced by agronet covers

Vegetable type	Agronet cover	Days to first flowering	Days to 50% flowering
African nightshade	Control	87.00b*	91.17b
	White	86.00b	89.83b
	Yellow	89.83ab	93.83ab
	Grey	90.67ab	93.33ab
	Blue	93.33a	96.83a
Spiderplant	Control	39.33d	43.67e
	White	37.00d	41.16e
	Yellow	47.33c	50.67cd
	Grey	41.50d	45.83de
	Blue	52.17c	54.83c

**Means followed by same letters within a column are not significantly different according to Tukey's HSD test at P=0.05*

Table 4. Leaf stomatal conductance (mmol m^{-2} s^{-1}) of African nightshade and spiderplant as influenced by agronet covers

Vegetable Type	Agronet cover	Weeks after planting			
		7	9	11	13
A. nightshade	Control	88.2b*	98.5b	88.92abc	88.9bc
	White	94.1ab	101.1a	95.6abc	92.3ab
	Yellow	95.51ab	115.46a	107.8a	98.9a
	Grey	90.13ab	104.0ab	97.0ab	98.2ab
	Blue	101.0a	110.4a	104.1ab	98.3ab
Spiderplant	Control	66.4c	87.0b	74.0c	68.4d
	White	100.68a	94.7b	85.8abc	85.5bcd
	Yellow	78.2bc	92.8b	81.7bc	80.8bcd
	Grey	83.2b	98.1b	80.6bc	78.7cd
	Blue	80.2b	87.1b	82.9abc	77.0cd

**Means followed by same letters within a sampling date are not significantly different according to Tukey's HSD test at P=0.05*

3.5 Influence of Agronet Covers on Leaf Chlorophyll Content of African Nightshade and Spiderplant

The application of yellow and blue net covers significantly increased chlorophyll a content compared to those grown in the open field for both vegetables in most sampling dates (Table 5); with yellow net exhibiting 12342.1 and 11274.8 µg g^{-}1 FW, for African nightshade and spiderplant, respectively compared to the control (8850.1 and 8177.9 µg g^{-}1 FW, for African nightshade and spiderplant, respectively) by 13 WAP. The highest chlorophyll b content was recorded in African nightshade plants grown under blue net cover while the least content was obtained in plants grown in the open field while yellow, grey and white net giving intermediate results (Table 6). Chlorophyll b content of leaves of spiderplant grown under the yellow cover recorded the highest chlorophyll b content while plants grown in the open field had the least. Plants grown under the blue, grey and white net covers had significantly higher chlorophyll b content compared to control plants. Both chlorophyll a and b tended to fluctuate with time among the treatments.

Chlorophyll is vital for photosynthesis, which allows plants to absorb energy from light. Chlorophyll a (chl a) is essential for most photosynthetic organisms to convert chemical energy though it is not the only pigment that is used for photosynthesis. Higher values of chlorophyll content (chlorophyll a and chlorophyll b) were observed under agronet covers than under open field in the current study. Similarly, Ilic et al. [24] observed higher chlorophyll a and b under net covers than those in the open fields. In line with this study, Casierra-Posada et al. [25] exposed strawberry plants to different coloured covers and found that different light quality influenced chlorophyll content. They also found that chlorophyll a concentration was higher in leaves growing under green and red light, followed by leaves in the blue, white, and yellow nets. The current study indicates that these vegetables have maximum absorption of chlorophyll b under blue light wavebands (400-500 nm) while chlorophyll a is best maximized under yellow light wavelengths (500- 600 nm). In relation to this supposition, Wang et al. [26] emphasized that plant pigments have specific wavelength absorption patterns known as absorption spectra. Silva et al. [21] further affirmed that the absorption peaks of chlorophyll a are at 660 nm and 430 nm, and those of chlorophyll b at 640 and 450 nm, covering the red, yellow and blue waveband fractions of the photosynthetically active radiation (PAR) spectrum. According to Wang et al. [27], chloroplast is a kind of light-induced organelle and usually their synthesis is enhanced in the presence of blue and yellow light, thus this might further explain the reason for higher chlorophyll estimates under blue and yellow net covers in the present study.

Low chlorophyll contents obtained under open field compared to those under net covers was not surprising. This is because extremely strong irradiance that open field crops are exposed to often decreases chlorophyll content owing to inhibition of chloroplast generation as suggested by Wang et al. [27]. According to Ilic *et* al. [24] crops grown under cover capture lower levels of light, and thus produce additional chlorophyll to capture diffuse radiation to produce the carbohydrates needed for a plant to grow than plant leaves exposed to direct sun.

Table 5. African nightshade and spiderplant leaf chlorophyll a (µg g^{-1} fresh weight (FW) content as influenced by agronet covers

Vegetable type	Agronet cover	Weeks after planting			
		7	9	11	13
A. nightshade	Control	7290.0b*	8625.3bc	6993.9b	8850.1b
	White	7646.5b	7400.7c	9114.2ab	9201.2ab
	Yellow	10008.0a	12311.3a	10916.5a	12342.1a
	Grey	10202.6a	9961.6abc	9341.5ab	11671.7a
	Blue	9220.0ab	10258.2ab	9571.1ab	12101.3a
Spiderplant	Control	8593.9b	10175.5ab	7958.7b	8177.9b
	White	9216.5ab	9849.7abc	8749.4ab	9326.1ab
	Yellow	11765.9a	10841.3ab	11577.8a	11274.8a
	Grey	11182.9a	10242.1ab	11291.3a	9753.8ab
	Blue	11091.5a	10715.1ab	10669.2a	10179.3a

**Means followed by same letters within a sampling date are not significantly different according to Tukeys HSD test at P=0.05*

Table 6. African nightshade and spiderplant leaf chlorophyll b (µg g^{-1} FW) Content as Influenced by Agronet Covers

Vegetable type	Agronet cover	Weeks after planting			
		7	9	11	13
African nightshade	Control	4133.8b*	4058.8 b	5072.3bc	4965.9bc
	White	6317.8ab	5163.2ab	6425.5bc	6189.3b
	Yellow	8287.4a	8584.7a	9189.8ab	9034.7a
	Grey	4589.6b	5176.1ab	7749.9abc	7132.8a
	Blue	8751.4a	7927.1a	9778.8a	9171.1a
Spiderplant	Control	5460.6b	4872.7b	4304.1c	3967.9c
	White	7599.3a	6827.6ab	4555.4c	40129.0bc
	Yellow	8976.6a	9211.9ab	6879.3bc	6851.7ab
	Grey	8632.4a	9836.1a	6282.2bc	5718.5bc
	Blue	8751.4a	8558.8a	7150.6ab	6568.1ab

**Means followed by same letters within a sampling date are not significantly different according to Tukey's HSD test at P=0.05*

3.6 Influence of Agronet Covers on Fresh Leaf Yield of African Nightshade and Spiderplant

Fresh Leaf yield of both African nightshade and spiderplant was significantly influenced by the different agronet covers (Table 7). African nightshade grown under yellow net significantly yielded the highest leaf fresh yield (15829.07 kg ha^{-1}) while the least leaf fresh yield was obtained in spiderplants grown under blue net cover (6760.26 kg ha^{-1}). Production of both vegetables under grey and white net covers also tended to produce higher fresh yield compared to the control plants. Use of different net covers has been shown to increase yield of crops. Elad *et al*. [28] observed increased yields with usage of white, black, blue, blue-silver and silver net covers compared to the control. Shahak [5] reported increased yields under pearl and red net compared with black. Abul-Soud et al. [15] also reported that white net gave the highest mango yield followed by yellow net while the control recorded the lowest production. The current study supports these findings. Fresh leaf yield was enhanced under agronet covers in this study. Yellow net cover recorded the highest fresh leaf yield although there was no significant difference in yield between the net covers and the open field. For African nightshade, yellow net had significantly higher yield compared to blue net. Findings of this study support those of Shahak [29], who also observed no significant differences in yield under red, white, green and yellow net covers, compared to open field.

Considering that leaf chlorophyll, especially chlorophyll a molecule that makes photosynthesis possible (Calatayud and Barreno) [30] and stomatal conductance were maximized under yellow net cover, it is likely that the increased yield exhibited by the two vegetables grown under yellow net cover in the present study was due to increased photosynthetic efficiency; that led to increased branching of crops under the said net cover and consequently more shoot harvesting points. A similar finding was reported by Ilic et al. [24] who observed that an increase in biomass coincided with increase in chlorophyll content. Although both branching and leaf stomatal conductance was maximized under white net cover in the case of spiderplant in the current study, yellow net cover however outperformed white net in the long run with regards to total yield. The observed slight disparity might be attributed to the fact that spiderplant grown under white net cover attained early senescence as depicted by earlier flowering observed in this study; hence reduction in harvestable shoots compared to the yellow net.

Table 7. Total yield (kg ha^{-1}) of African nightshade and spiderplant as affected by agronet covers

Vegetable type	Agronet cover	Total yield
African nightshade	Control	13666.55abc
	White	14378.3ab
	Yellow	15829.07a
	Grey	15120.16a
	Blue	12483.67abc
Spiderplant	Control	8722.01cd
	White	8565.87cd
	Yellow	9805.30bcd
	Grey	8968.55cd
	Blue	6760.26d

**Means followed by same letters within a column are not significantly different according to Tukey's HSD test at P=0.05 .Tukey's HSD value =0.9731*

Use of blue net cover resulted in lower total yield compared to control treatment in the present study in both vegetables. A similar finding has been reported by Costa et al. [31] who found striking reduction in plant biomass under blue net cover. Reduction in total fresh yield of crops under blue net in the present study may have resulted from a decrease in the rate of carbon dioxide assimilation under blue net as suggested by Oyaert et al. [32]. Consistent with these findings, Oliveira [13] further reported that plants under blue and red nets showed lower photosynthetic capacity as well as lower rates of dark respiration, suggesting that both the assimilation process and carbon dioxide consumption were affected by such treatments. Plants under blue light have higher stomatal conductance. However, high stomatal conductance is not always correlated with an increase in photosynthetic efficiency and productivity [26]. The present study confirms the above findings since both stomatal conductance and chlorophyll content were high under blue net compared to control, but branching as well as yield, were low, an indication of low photosynthetic efficiency and productivity under blue net in the present study.

4. CONCLUSION AND RECOMMENDATION

This study shows that different agronet covers influence African nightshade and spiderplant physiological performance, growth and yields. Blue net can be used to prolong vegetative phase of these crops to ensure longer harvesting period of the leaves. This study also shows that different crops respond differentially to light spectrum as modified by net colours. Based on the findings of this study, a cost benefit analysis should be done to assess whether the additional benefits obtained from using yellow net cover is worthwhile. In addition, studies combining the use of blue net cover to prolong vegetative phase with yellow and/ or white net to improve crop branching which results into higher yield is recommended to optimize performance of these crops.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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