Effects of photoselective colour nets on the vegetative, productive, and qualitative behaviour of kiwifruit, jintao cultivar

EFFECTS OF PHOTOSELECTIVE COLOUR NETS ON THE VEGETATIVE, PRODUCTIVE, AND QUALITATIVE BEHAVIOUR OF KIWIFRUIT, JINTAO CULTIVAR

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Abstract

BACKGROUND: In the Mediterranean basin, the solar radiation received is very high for many tree species over several hours of the day during the summer. Using a photoselective net can improve the climatic conditions and also modify the quality of light received.

OBJECTIVE: This study aimed to evaluate the influence of the colour of photoselective nets on the yield and quality of *Actinidia chinensis*.

MATERIALS: The experiment was carried out in Southern Italy on an orchard of Jintao kiwifruit. Photoselective nets of different colours were used: black, red, yellow, white, and grey. The resulting fruits were compared to those of plants in the open field. A randomised block design was adopted. Environmental, vegetative, and leaf gas exchange parameters; yield; and fruit quality were defined. All data were analysed using the Variance Analysis (ANOVA) and the Principal Component Analysis (PCA).

RESULTS: Photoselectivity influenced production. The best results were obtained under the red net in terms of production and fertility indices. Fruit size, maturation indices, and nutraceutical parameters were also higher under the red net. Among the nets, the grey net induced the worst tree productivity results and the worst fruit quality parameters. However, all nets showed better results compared to the open field.

CONCLUSION: The photoselective net strongly influenced the yield and quality of Jintao kiwifruit and the better results compared to the open field. The red net proved to be the best performer for the environment where the experiment was carried out.

Keywords: *Actinidia chinensis,* maturation indices, photoselective net.

Introduction

Italy holds the leadership in Europe and in the northern hemisphere of the Planet for the production of kiwi fruit. The production of 315,000 T is distributed over 25,000 h [1].

The productivity of *Actinidia* spp. and the sensory and nutritional quality of their fruit are determined through interactions between different factors. These include a tree training system, cultivar, rootstocks, management of the soil that hosts the root system, and the canopy [2] [3] [4]. With regard to the latter aspect, the yield of well-cultivated trees depends on optimal light interception to each part of the canopy structure, realised through pruning [5]. This effect is important because photosynthetic carbon fixation is a function of the sunlight captured by a tree or an orchard. Changes in fruit quality are often caused by the uneven distribution of light to the canopy [6] [7] and the light quality; for example, red light (600–700 nm) increases anthocyanin synthesis in the fruit [8]. Excess of photosynthetic flow density (PPFD) can lead to photo-inhibition of the photosynthetic apparatus. It is a phenomenon that, in the long term, causes efficiency depression of the photosynthesis process [9], and it can worsen under stressful conditions induced by a water deficit and/or high temperature. The light saturation point of kiwifruit corresponds to 960 µmol (photon) m^{-2} s^{-1} light [10].

Southern Italy plays a decisive role in Italian production, thanks to its optimal soil and climate conditions and the mild autumn climate. The net protects the fruit tree canopy from adverse environmental conditions such as hail and wind. Moreover, some species have a low light saturation point. Therefore, the net creates more favourable climate conditions for plant physiology. With its shading function, it protects the leaves from the adverse effects induced by the excess of PPFD [11] [12] [13].

Furthermore, the photoselective net acts as a spectral filter (with differential light scattering properties), absorbing various spectral bands and modifying the light quality and then the ratio among the same spectral bands, such as the red/far-red (R/FR) ratio [14]. This effect also depends on the material of the net.

In recent years, nets have been used indirectly to increase yield and fruit quality in some Mediterranean countries. Indeed, many studies have been carried out to evaluate the effect of photoselective nets on fruit trees [15] [16] [17] [18] and ortive plants [19] [20] [21].

This study aimed to evaluate the influence of the photoselective hail net and its colour on several parameters of Jintao kiwifruit. Therefore, many parameters of the tree and the fruit were detected to determine the best colour of the photoselective net for the area under study, which is an important kiwifruit cultivation area of southern Italy.

1. Materials and Methods

1.1 Orchard

The experiment was carried out during two cultivation cycles (2017-2018) on the Femia farm, located in Cittanova (RC), Calabria, Italy (38° 29' N; 15° 58' E). Jintao trees were planted in the spring of 2014 in sandy soil, with pH 6.8 (sub-acid), 2.1% organic matter, and 1.5 g kg^{-1} nitrogen content. The vines were spaced 5 m × 2.5 m apart (800 vines ha^{-1}), and north to south row orientation was adopted. Jintao is a yellow-fleshed tetraploid genotype (2n = 4x = 116) of *A. chinensis*. It was selected at the Wuhan Institute of Botany (WIB) [22]. It has a low cooling demand (approximately 350-450 hours), which is why it is well adapted to the Mediterranean climate with a mild winter, producing high-quality fruit. The male tree of the *Belén* cultivar was planted using a male/female ratio of 1:8.

The trees were trained in a pergola system. The cane was pruned to 1.4 m, and ten canes per plant were left. The yearly dormant pruning (December) was combined with summer pruning (July).

The orchard was managed using standard integrated pest control systems and stable drip irrigation and fertilisation systems.

The same amount of water irrigation and fertilisation per plant was used for all treatments, for comparison. Full bloom occurred during the last week of March in both years (25 March, 2017; 27 March, 2018), and fruits were thinned at the end of May. In this area, the conventional harvest time is approximately 180 Days After Flower Bloom (DAFB) (31 October, 2017; 1 November, 2018).

1.2 Treatment and experimental design

Photoselective hail nets of five different colours were used: black (BK), red (RD), yellow (YL), white (WH), and grey (GR) (the main characteristics are shown in Table 1). The resulting fruits were compared with those of trees grown in the open field (OF).

A total of 54 trees, three blocks with three plants per treatment, were arranged in a randomised design.

1.3 *Measurements*

1.31 PPFD, UV radiation, and temperature.

PPFD, UV radiation, and temperature were measured at midday (12:00) during sunny days using a PAR sensor (Mod. 3668I; Spectrum Technologies Inc., Aurora, Illinois, USA), UV sensors (Mod. 3676I; Spectrum Technologies Inc., Aurora, Illinois, USA), and thermocouple sensors (GMR Instruments, Florence, Italy, UE), respectively. These sensors were placed below the nets in the open field, and they were linked to a datalogger whatchdog 1000 (Spectrum Technologies Inc., Aurora, Illinois, USA).

Light quality

The PAR spectrum light was measured at midday (12:00) using a spectroradiometer (PS-300; Apogee Instruments Inc., Logan, Utah, USA) in the open field and under the nets.

Shoot and fertility indices

The shoot length (SL) was measured of all shoots distributed along with four canes randomly chosen per selected tree. Moreover, the vegetative shoot, mixed shoot, number of fruits per mixed shoot, and unbroken buds were detected. After harvesting the plants were defoliated. The leaf area per plant was measured using a leaf area meter (Li-Cor 3100; LI-COR Biosciences, Lincoln, Nebraska, USA) and the leaf area index (LAI) was calculated; It is was obtained dividing the leaf area of the plant by the soil area occupied by a plant.The fertility index (FI = number of flowers/number of fertile buds) and real fertility (RF = number of flowers/number of buds left after pruning) were calculated [23] [24].

Gas exchange and fluorescence

Leaf net assimilation of CO_2 (*An*), stomatal conductance (*gs*), and internal CO_2 concentration (*Ci*) were measured on 54 mature leaves from the outer layer of each tree (6 leaves × 3 plants × 3 blocks). The measurements were taken using a portable photosynthesis system (Li-Cor 6400XT; LI-COR Biosciences, Lincoln, Nebraska, USA).

The gas exchange measurements were carried out during clear sunny summer days (from 11:00 to 13:00) during the last week of the summer months (June, July, and August) in both years. The carboxylation efficiency (Pn/Ci) was also calculated.

Photoinhibition was also estimated using a chlorophyll fluorometer (Li-Cor 6400-40; LI-COR Biosciences, Lincoln, Nebraska, USA). The measurements were taken after 30 min of dark adaptation (from 11:30 to 12:30) by using leaf clips from the same leaves used for the gas exchange measurements. Therefore, the leaves were detached, washed with distilled water, and the SPAD index was measured using SPAD 502 (Spectrum Technologies Inc., Aurora, Illinois, USA).

1.4 Maturation indices and nutraceutical parameters

Fruits were collected and analysed to 180 DAFB (31 October, 2017; 1 November, 2018). Eight fruits were randomly collected from the canopy of the six vines per treatment (4 fruits × 6 trees × 3 blocks = 54 fruits). They were immediately used to determine: transversal (D) and longitudinal diameter (H) by using a precision calibre; fresh weight (FW) by using an electronic balance (Mettler-Toledo, Grelfensee, Switzerland) and have been divided into 4 weight classes (< 80 g; 81-90 g; 91-100 g; 101-110 g); flesh firmness (FF) by using a digital penetrometer with an 8 mm probe (PCE 100, Padova, Italy) on the equatorial zone of the fruit, on two opposite sides; the pulp colour by using a Minolta spectrophotometer CM-700d (Minolta, Inc., Tokyo, Japan), in terms of CIELab and HSB colour spaces; total soluble solids content (TSS) as °Brix, by using a digital refractometer (PAL-1, Atago, Tokyo, Japan) on juice drops obtained by squeezing the apex and the base of every fruit; and titratable acidity (TA) by titrating 10 mL of the juice diluted with distilled water (1:1) with 0.1 N NaOH to pH 8.2. Titration results were expressed as citric acid %. Dry matter content (DMC) was determined using a standardised sampling method: a horizontal slice of fruit tissue from the equatorial zone was extracted from each fruit. The thickness of the slice was approximately 1 cm, and the fresh weight (FW) was recorded. The slice was placed in a dehydrator at 70 °C until a constant dry weight was reached. DMC was expressed as a percentage of FW.

The ascorbic acid content was determined using the procedure based on the reduction of 2,6-dichlorophenol-indophenol (DIP) by ascorbic acid. For each fruit, fresh pulp tissue (3 g) was mixed with 20 mL (3%) metaphosphoric acid and homogenised. Ascorbic acid content was determined by titration of 15 mL filtrated juices with DIP containing sodium bicarbonate. The ascorbic acid content was expressed as mg ascorbic acid 100 g^{-1} FW.

To determine Total Polyphenols Content (TPC) and Total Antioxidant Capacity (TCA), the pulp of the sample was homogenised using an Ultraturrax blender (20.000 rpm, T25 Basic; IKA, Werke, Germany, UE). The TPC and TAC were separately analysed using a Lambda 35 spectrophotometer (PerkinElmer Corporation, Waltham, MA, USA). Before measuring the TPC and TAC, standard curves were prepared for each test. TPC (mg gallic acid equivalents g^{-1} FW) was determined using the Folin–Ciocalteu method [25]. The TAC was determined using the modified TEAC assay and expressed as mmol Trolox equivalents g^{-1} FW [26] [27]. The TEAC assay included both the hydrophilic and lipophilic contributions of the samples [28]. The fruits after being weighed have been divided into 4 weight classes (< 80 g; 81-90 g; 91-100 g; 101-110 g). the fruits

1.4 Statistical analysis

All data were subjected to variance analysis tests (ANOVA), and the means were compared using Tukey's test when the ANOVA indicated significant ($P < 0.05$) variable effects. All data are reported as means from both years.

All data analyses were performed using IBM® SPSS® Statistic, version 22 (SPSS Inc. IBM Company, Armonk, NY, USA). The variables were then used in a principal component analysis (PCA) to evaluate more complex relationships between parameters and to identify how they were related to the colour of the photoselective net.

2. Results and discussion

Our results show that the photoselective nets affected the intensity, light quality, and effective heat, according to other authors [29].

PPFD, UV, and temperature

All photoselective nets decreased PPFD, UV, and temperature by approximately 19%, 22%, and 15% compared to the open field, respectively. Among the nets, the differences in terms of colour were not significant for PPFD (Table 2), whereas UV was significantly lower under the RD net (Table 2). Among the nets, the temperature recorded ranged from 26.79 °C to 28.47 °C; the higher temperature was recorded under GR net, whereas the lower value was recorded under the RD net. However, the highest values (PPFD, UV-b, and Temperature) were observed in the OF. For the PPFD, UV, and Temperature, a significant change was observed between the two years, whereas the Years (Y) × Treatments (T) interaction was not significant.

Light quality

Regarding the light quality, the blue light (BL) was higher under the BK net as compared to the other coloured nets and was statistically similar to that of the OF (Table 3). These results are in agreement with those of other authors [29] [30]. Under the RD and YL nets, the red light (RL) and irradiated light (FR L) were similar to that of the OF and were higher compared to those of the other colour nets (Figure 1, Table 3).

However, the R/FR ratio did not change among treatments (Table 3).

Shoot, fertility indices, and LAI

The difference in shoot length among the treatments was attributable to differences in internode development (data not shown) (Table 4). It has been demonstrated that increasing the BL (Blue Light) fraction decreases cell expansion and inhibits stem elongation [31]. It has reduced internode elongation in agreement with that reported by other authors [32]. The FR deficient environment has also been shown to reduce the stem elongation growth of many different plant species [33] [34] [35] [36] [37]. In our experiment, these two conditions were observed under the BK net (Tables 3, 4); however, the deficiency of FR light was not solely responsible for reducing shoot length as observed under the GR net (Tables 3,4). When BL (Blue Light) was not higher, the shoot length was negatively correlated with RL (Table 3). Indeed, the shoot length was higher under the GR and WH nets. The Leaf Area Index (LAI) ranged from 2.15 to 2.59, and it did not change between treatments (Table 3). All parameters reported in Table 4 changed by year, whereas the Y × T interaction was not significant (Table 4).

It has been shown that the R/FR ratio influences flower differentiation, but in our experiments, R/FR did not change with the treatments (Table 2). However, fertility indices were influenced by the amount of R and FR light. Indeed, a strong correlation between FI with RL and between FR light with RF was found (Figures 2 and 3). These indices were higher under the RD, YL, and under the OF conditions, where R and FR light were higher (Tables 3, 4). The fertility indices influenced the fruit load of the plant, which was decidedly lower under the BK and GR nets compared to the other treatments (see Table 8). The percentage of flower shoots was lower under the BK net, whereas no significant differences were observed among the other treatments (Table 4).

Gas exchange and fluorescence

Photosynthesis (Pn) was higher under the RD net than under the other treatments. Under the GR net, the lowest value of photosynthesis was recorded, though it was still higher than that of the OF. The gs did not vary among the nets, whereas it was significantly lower in the OF (Table 5).

Carboxylation efficiency (Pn/Ci) is an estimate of Rubisco activity [38]. A higher Ci associated with a lower gs causes a decrease in the Pn/Ci ratio [39] [40]. Therefore, the trees under the RD nets showed better Pn/Ci performances, whereas the worst performances were observed in the OF and under the GR nets (Table 5).

Fv/Fm, and ΦPSII fluorescence parameters were significantly higher under the RD, BK, and YL nets than under the GR nets. The higher values suggest a lower risk of photo-inhibition and photooxidation for the photosystem apparatus of the leaf. Under nets the lowest values were recorded in the GR nets, whereas among treatments the lowest values were observed in the OF. The Fv/Fm ratio under the BK and RD nets was similar to that reported by other authors [41] for well-irrigated kiwifruit during midday, although in another cultivar. The tree behaviour under the WH nets was better to that under the GR nets (Table 6). The other fluorescence parameters as qP and ETR were higher under the red net, followed by BK, YL, and WH nets, whereas the wrost results were detected under GR net and the OF (Table 6). Therefore, all photoselective nets evidently improved the above-mentioned fluorescence parameters than that to the OF.

Maturation indices and nutraceutical parameters

The average fruit FW was significantly lower under the GR netting than under the RD nets (Table 7), but it was within the acceptable range of values reported for the Jintao cultivar. Under the GR net, the average FW observed in our study was lower than that reported by other authors [22] [42].

Under the other three nets (YL, WH, and BK), the fruit FW was not significantly different from that recorded under the RD and GR nets. The lowest values were recorded in the OF.

Quality differences between the fruits were determined in terms of size classes. Huang reports that fruit size of Jintao kiwifruit is 90 g [22]. The percentage of fruit belonging to the size class from 90 to 110 g was higher under the RD and BK nets (70% and 61%, respectively) (Figure 4).

Under the BK net, a similar FW to that under the RD nets was observed, which can be attributed to the very low fruit load recorded under the BK net (Table 7). This condition reduced competition among the fruit (sink); The low load was also observed under the GR net, but the fresh weight was lower (Table 8) because under the GR net, the photosynthetic rate was also very low (Table 5).

Regarding the other physiological parameters, the fruit was also 5% thinner under the GR net than under the alternative treatments (Table 7), whereas no differences were observed in fruit height among the treatments (Table 7). Therefore, the fruit shape, as shown by the H/L ratio, was significantly different among the treatments. Indeed, the H/L ratio was significantly higher under the GR nets, whereas it was lower under the YL and WH nets and the OF. No significant differences were observed under the BK and RD nets, compared to the other coloured nets, for this parameter (Table 7). Under the GR net and the OF, lower yields per plant were recorded (37.65 and 38. kg plant^{-1}, respectively) (Table 8) than the other treatments. However, the yield tree^{-1} was similar to that reported by other authors [35]. Under the WH nets, the yield was significantly higher than that under the BK and GR nets, but it was significantly lower than that under the YL and RD nets. The highest yield per plant was recorded under the latter two net colours, and the differences were not significant between them (Table 8). In the OF, the yield per tree was similar to that obtained from under the GR nets (Table 8). No interaction Year x Treatments was observed, whereas the significant differences were observed between years.

Maturation indices

With regard to the colour parameters, Lightness (L*) was lowest under the GR net and highest under the WH nets (Table 9). No differences were observed between the RD and YL nets compared to the OF and the BK and WH nets.

Under the RD net, the pulp tint showed a greater shade of red and a lesser shade of green (i.e., a* and b* chromatic components were higher; Table 9). However, the main colourimetric parameter used as the maturation index is the Hue angle. This parameter is lower under 103 °Hue [22] at harvest time. In our experiment, it was higher than 103 °Hue in the OF, whereas it was lower under all net colours used. However, it was lower under the RD nets than under the other treatments (Table 9). No significant difference was observed in chroma (Table 9).

In the area where the experiment was carried out, harvesting occurred when the dry matter exceeded 16% and the colouration of the pulp reached at least 103° Hue (Table 9). Harvesting generally took place between 30 October and 2 November; therefore, Jintao was harvested ten days before the green kiwifruit, Hayward cultivar.

The firmness of the pulp was significantly higher in the fruit of the trees grown under the RD net than of those grown under the other nets, whereas the lowest values were detected under the GR net (Table 10). No differences were observed between the fruits grown under the YL, BK; they were significantly lower and higher in firmness, respectively, than those grown under the RD net, and GR net (Table 10). In the open field and under WH, the firmness pulp value was similar to GR, BK, and YL nets. All firmness values recorded were higher than those reported by other authors [22] [42] for the Jintao cultivar.

DMC was significantly higher in the fruit of trees under the RD nets than in the fruit of those grown under all other nets, whereas the dry matter was significantly lower in fruit from trees under the GR nets than in those grown under other nets. No differences were observed between fruit from trees under the BK, YL, and WH nets, for this parameter. However, the lowest value was recorded in the OF (Table 10).

Regarding the TSS, the value was significantly higher in fruit from trees under the RD nets than from those under the other colour nets; the TSS was also significantly higher in fruit from trees under the BK and YL nets than from those under the GR nets and the OF, whereas the lowest value was observed in fruit from trees under the OF. No differences were observed between the WH and GR, BK, and YL nets for this index (Table 10). The TSS reached the value reported by other authors [22] only under the RD nets.

TA was highest in fruit from trees under the RD nets compared to other colour nets, but it was lower than that reported by other authors [22]. TA was significantly higher in fruit from trees under the BK nets than under GR nets and the OF, whereas no differences were observed among the YL, WH nets and GR, BK nets and the OF (Table 10).

The TSS/TA was significantly higher in fruit from trees under the RD and YL nets than under the other coloured nets. The lowest value was detected in the OF (Table 10).

No interaction Y x T was observed; the firmness pulp and DMC were similar between years, whereas changes were observed for the other parameters (Table 10).

Nutraceutical parameters

Total antioxidant capacity (TAC) was significantly higher in fruit from trees under the RD, BK, and YL nets and in the OF compared to the other treatments (Table 11). The total polyphenol content (TPH) was higher in fruit from trees under the RD and WH nets compared in those under BK, whereas no difference was observed among the YL and GR nets and the OF compared to the other treatments. Moreover, the flavonoid content was higher in fruit from trees under the WH nets and lowest in fruit from trees under the GR nets and the OF, whereas intermediate values were detected under the BK, RD, and YL nets. The carotenoid content was highest in fruit from trees under the YL nets, whereas lower values were detected under the BK and RD nets. However, lower chlorophyll content was observed in plants from trees under the BK and RD treatments than under the other treatments. The lower chlorophyll content in RD and BK nets contributed to faster colouration of pulp, whereas in the fruit from trees under YL nets the faster yellow colouration of the pulp can be attributed to a higher carotenoids content (Tables 9,11).

The AA content was higher in the fruit from trees under the BK, RD, and YL nets than under the WH and GR nets and the OF (Table 11).

Regarding the nutraceutical aspect, better performance was also recorded in the fruit from trees under the RD nets.

PCA

All variables of the PCA were projected in the F1-F2 and F3-F4 planes (Figure 5). In this way, we could analyse the relationships between variables and the formation of factors.

Factors F1 and F2 of the PCA accumulated 45.93 and 20.64% of the variance (Figure 5), whereas F3 and F4 accumulated 15.50 and 10.15%, respectively (Figure 5). They totalled 92.22% of the initial variability. Almost all the parameters were uniformly distributed in all quadrants (Figures 5,6). The correlations between variables and factors are reported in Table 12.

In particular, a first group consisting of to gas exchange variables, Pn, Pn/Ci, three fruit biometric variables, FW, height, diameter, four maturation indices (Fir, DMC, TA, a*), all fluorescence parameters, Fv/Fm, ΦPSII, qP, and ETR, one fertility variable, F.I., and two nutraceutical variables, AA, FT contributed to F1 factor formation (Table 12).

These variables were positively correlated among them and were distributed on the right side of F1-F2 plane. The H/L, °H, Car, Ci, and T°, variables were distributed on the left side of F1-F2 plane; they were strongly correlated among them and negatively correlated with the first group of variables. This second group also participated in F1 factor formation (Table 12)

The Yield, TPH, gs, R.F., SL, MS, and R/FR vectors were correlated among them and placed in the upper side of F1-F2 plane, whereas BL vector was placed in the lower side of F1-F2 plane. They contributed to the formation of the F2 factor (Table 12).

The b*, TSS, TSS/TA, TAC, RL, FRL, LAI variables contributed to the formation of F3 factor (Table 12). The LAI vector was located on the left side, whereas the other variables in the right side of F3-F4 plane. Chr and Chl variables were places in the lower and upper side of F3-F4 plane, respectively, and contributed to the formation of F4 factor (Table 12).

The results of the PCA can be explained by the positioning of the relative parameters observed and the centroids (Figure 6).

The centroid represents the resulting coordinates of the PCA. The RD centroid was placed on the right side of the F1-F2 biplot on the F1 factor axis (Figure 7). Its position was positively correlated with a*, FW, H, D, Fir, DMC, TA, FT, AA, Pn, Pn/Ci, F.I., Fv/Fm, ΦPSII, qP, ETR vectors. Moreover, RD was negatively correlated with the °H, i.e., a better colouration of the pulp, H/D, Car, Ci, T°.

The OF centroid was also correlated with F1, but it was placed on the left side. Therefore, the OF showed opposite values compared to the RD nets.

The WH centroid was near to Yield, TPH, gs, R.F., MS, SL, and R/FR vectors, and was positively correlated with them. The BK centroid was positively correlated with BL(Blue light). The GR centroid was correlated with the F3 factor and was placed on the left side (Figure 8). Therefore, it showed lower values for b*, TSS, TSS/TA, TAC, RL, FRL. Finally, the YL was correlated with F4 (Figure 8). The YL was placed in the upper right side, near the Chr vector.

4. Conclusion

The photoselective nets influenced the production of A. chinensis cv Jintao in Southern Italy. Aside from the fundamental role of the nets in the protection of the plants from hail. The net improves the results compared to the OF or gives similar results, in the environment where the experiment took place. The overall evaluation of all the parameters analysed showed that every color influences tree performances. However, only the red net positively acts on a greatest number of parameters considered very important for the production of kiwi fruit, such as fruit weight, pulp colour, dry matter, total soluble solids, ascorbic acid content, photosynthetic performance of the plant, and response to fluorescence parameters. The YL and WH nets follow the RD net; they give good results compared to the open field, whereas the GR and BK nets give the worst about to yield per tree and per hectare compared to other color nets; their performances were similar for some aspects to the open filed.

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Conflict of Interest

The authors have no conflict of interest to report.

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Table 1. Main characteristics of the five photoselective colour net to the comparison.

Materials	HDPE				
	Black	Red	Yellow	White	Grey
Shading (%)	14	9	4	7	19
Mesh size (mm)	3 x 8	2.4 x 4.8			
Weight (gr/m^2)	48	60			
String diameter (mm)	0.30				
Texture	leno weave				

Table 2 – PAR and UV radiations and Temperature measured under five photoselective colour nets and in the Open Field at 12:00 a.m. during four clear summer days at the end of June, July, and August (average of June, July and August months on two years).

Treatment	PAR ($\mu mol.m^{-2}s^{-1}$)	UV ($\mu mol.m^{-2}s^{-1}$)	Temperature (°C)
Black net	1202b	84.50b	27.24bc
Red net	1158b	74.35c	26.79c
Yellow net	1246b	79.86b	27.68b
White net	1235b	79.57b	28.15b
Grey net	1118b	80.84b	28.47b
Open Field	1429a	96.94a	32.30a
Year	*	*	*
Treatment x Year	n.s.	n.s.	n.s.

(Different letters and * indicate significant differences for $p \leq 0.05$; n.s.= non-significant)

Table 3 – Blue, Red, and Far-Red light measured under five photoselective colour nets and in the open field .at noon. during four clear summer days at the end of June, July, and August (average of June, July and August months on two years)

Treatment	BL (μmoles.m^{-2}.s^{-1})	RL (μmoles.m^{-2}.s^{-1})	FRL (μmoles.m^{-2}.s^{-1})	R/FR
Blake net	260.72a	307.90b	278.43b	1.10n.s.
Red net	223.35b	343.56a	331.38a	1.03
Yellow net	220.07b	338.87a	327.76a	1.03
White net	228.96b	318.45b	311.25ab	1.02
Grey net	227.48b	310.19b	285.84b	1.08
Open Field	288.10a	353.03a	330.30a	1.07
Years	*	*	*	*
TxY	n.s.	n.s.	n.s.	n.s.

BL=Blue light; RL= Red light; FRL=Far-Red Light

(Different letters and * indicate significant differences for $p \leq 0.05$; n.s.= non-significant)

Table 4 – Fertility indices, mixed shoots, shoot length, and LAI in kiwifruit tree, Jintao cv, trained under five photoselective colour nets.

Treatment	RF	FI	MS (%)	SL (cm)	LAI
Black net	3.01c	4.90ab	60.47c	18.62c	2.23n.s.
Red net	5.10a	5.19a	98.17a	24.86b	2.33
Yellow net	5.00a	5.14a	97.18a	25.62b	2.15
White net	3.99b	4.19b	95.12a	32.06a	2.18
Grey net	3.68b	3.94c	92.72a	29.81a	2.59
Open field	4,45ab	5,13a	92.35b	20.15b	2.33
Years	*	*	*	**	*
TxY	n.s	n.s	n.s	n.s.	n.s.

R.F. =real fertility; F.I. Fertility inex; MS=Mixed Shoots; SL= Shoot Length; LAI=Leaf Area Index

(Different letters and * indicate significant differences for $p \leq 0.05$; n.s.= non-significant)

Table 5 – Gas exchange (An, GS, Ci), and carboxylation efficiency (Pn/Ci) in kiwifruit leaf, Jintao cv, trained under photoselective colour nets and in the Open Field. The measurements were carried out during the four clean summer days (25, 26, 27 July 2017;27,28,29 July 2018) from 9:00-10:00 a.m.

Treatment	Pn (μmol CO_2 m^{-2} s^{-1})	gs (μmol H_2O m^{-2} s^{-1})	Ci (ppm)	Pn/Ci
Black net	14.27b	0.38a.	245.66b	0.063a
Red net	18.22a	0.33a	261.99ab	0.069a
Yellow net	13.48b	0.37a	291.33ab	0.046b
White net	13.89b	0.33a	302.77a	0.046b
Grey net	11.88c	0.34a	329.04a	0.036c
Open field	5.56d	0.27b	311.33c	0.018d
Years	*	*	*	n.s
TxYears	n.s	n.s.	n.s.	n.s.

Pn Net Photosynthesis; gs= stomatal conductance; Ci= internal concentration CO_2

(Different letters and * indicate significant differences for $p \leq 0.05$; n.s.= non-significant)

Table 6 –Fluorescence parameter in kiwifruit leaf, Jintao cv, trained under six colour net and in the Open Field. The measurements were carried out during the four clean summer days (25, 26, 27 July 2017;27, 28, 29 July 2018) from 10:00-11:00 a.m.

Treatments	Fv/Fm	ΦPSII	qP	ETR
Black net	0.75a	0.18ab	0.46b	158b
Red net	0.75a	0.21a	0.51a	186a
Yellow net	0.63ab	0.20a	0.45b	177b
White net	0.58c	0.16bc	0.41b	145bc
Grey net	0.44d	0.15c	0.37c	141c
Open field	0.40e	0.13d	0.35c	136c
Years	*	*	*	n.s.
TxY	n.s.	n.s.	n.s.	n.s

(Different letters and * indicate significant differences for p≤ 0.05; n.s.= non-significant)

Table 7 – Carpometric measurements in kiwifruit, Jintao cv, trained under photoselective colour nets. Harvest 31 October 2016 and 1 November 2016

Treatments	FW (g)	H (mm)	D (mm)	H/D
Black net	89.29ab	65.20n.s.	48.26a	1.37ab
Red net	92.44a	65.28	48.99a	1.36ab
Yellow net	84.35ab	63.41	47.80a	1.35b
White net	89.92ab	64.77	48.54a	1.36b
Grey net	78.76b	63.39	46.99b	1.40a
Open field	70.15C	62.70	45.48b	1.37b
Years	*	*	*	*
Y xT	n.s.	n.s.	n.s.	n.s.

FW=Fresh weight; H=Height; Diameter

(Different letters and * indicate significant differences for p≤ 0.05; n.s.= non-significant)

Table 8 – Production, in kiwifruit, Jintao cv, trained under photoselective colour nets and in the open field.

Treatment	Fruits (N°)	Yield (Kg.tree^{-1})	Yield (q.ha^{-1})
Black net	470.71d	42.10c	336.81c
Red net	614.96a	56.84a	454.72a
Yellow net	652.69a	55.05a	440.4a
White net	551.89b	49.62b	396.96b
Grey net	528.06d	41.18c	329.5c
Open field	550.05c	38.58d	308.6d
Years	*	*	*
Treatment xYears	n.s.	n.s.	n.s.

(Different letters and * indicate significant differences for p≤ 0.05; n.s.= non-significant)

Table 9 - Colourimetric parameters of kiwifruit pulp, Jintao cv, trained under five photoselective colour nets and in the open Field.

Treatments	L*	a*	b*	Chroma	Hue
Black net	64.42b	-0.37c	18.60a	30.29n.s.	98.27b
Red net	60.32bc	0.66a	18.17a	30.89	96.44c
Yellow net	60.91bc	0.32b	16.35b	30.01	99.62b
White net	66.90a	-1.34e	18.69a	30.87	99.12b
Grey net	59.27c	-0.59d	15.27b	31.20	100.23b
Open field	64.77b	-5.5525	30.67333	31.16	103.25a
Years	n.s.	n.s.	n.s.	n.s.	n.s.
YxT	n.s.	n.s.	n.s.	n.s.	n.s.

(Different letters and * indicate significant differences for p≤ 0.05; n.s.= non-significant)

Table 10 – Maturation indices in kiwifruit, Jintao cv, trained under five photoselective colour nets. Harvest date 31 October 2016, 1 November 2017.

Treatment	FF ($Kg.cm^{-2}$)	TSS (°brix)	TA (%)	TSS/TA	DMC (%)
Black net	8.71b	8.95b	1.21b	7.40b	15.82b
Red net	9.06a	11.92a	1.36a	8.76a	19.61a
Yellow net	8.89b	9.94b	1.11bc	8.95a	16.49b
White net	8.18bc	6.99bc	1.16bc	6.03c	15.70b
Grey net	7.22c	6.25c	1.07c	5.84c	13.93c
Open field	8.00bc	5.19d	1.08c	4.98d	12.91d
Years	n.s.	*	*	*	n.s.
TXY	n.s.	n.s.	n.s.	n.s.	n.s.

FF=Firmness Flesh; TSS=Total Soluble Solids; TA=Tritratable Acidity; DMC=Dry Matter Content

Different letters and * indicate significant differences for p≤ 0.05; n.s.= non-significant)

Table 11 – Nutraceutical parameters in kiwifruit, Jintao cv, trained under photoselective colour nets. Harvest 31 October 2017 and 1 November 2019

Treatment	TPC (mg GAE/ g FW)	TAC (µmoli trolox/ gr. FW)	FT (mg quercetin/ gr FW)	AA (mg AA/100 ml)	Chl µgr/gr FW	Car µgr/gr FW
Black net	0.74b	7.01a	0.70 b	121.02a	9.74b	2.09c
Red net	1.01a	7.16a	0.70b	112.46a	8.94b	1.94c
Yellow net	0.94ab	6.11a	0.79b	112.13a	10.19a	3.08a
White net	1.09a	5.87b	0.87a	91.38b	10.34a	2.44b
Grey net	0.89ab	5.80b	0.54c	100.64b	10.71a	2.29b
Open field	0.96ab	7.76a	0.55c	100.22b	10.49a	2.90b
Years	n.s	**	n.s	**	n.s	n.s
TXY	n.s	n.s	n.s	n.s	n.s	n.s

TPC=Total Polyphenols Content; TAC= Total Antioxidant Capacity; FT=Totals Flavonoids; AA= Ascorbic acid; Chl=Chlorophyll; Car= Carotenoids.

Different letters and * indicate significant differences for $p \leq 0.05$; n.s.= non-significant)

Table 12 – Correlations between variables and factors in PCA

	F1	F2	F3	F4	F5
L*	-0,1591	-0,2358	0,2916	-0,5590	-0,7222
a*	0,7698	0,4102	-0,3410	0,3304	0,1170
b*	-0,5843	-0,3966	0,6045	-0,3654	0,0500
Chr	-0,5084	0,1881	-0,2722	-0,6566	0,4483
°H	-0,9691	-0,0006	0,2095	0,0737	-0,1075
FW	0,9904	-0,0543	-0,0999	0,0448	0,0650
H	0,8690	-0,2435	-0,1704	-0,3802	-0,1093
H/D	-0,8148	-0,3777	-0,3968	-0,1273	0,1407
D	0,9674	0,0795	0,1305	-0,1498	-0,1352
Yield	0,5495	0,7223	0,4057	0,0422	0,0994
FF	0,8725	-0,4411	0,0357	0,1970	-0,0639
TSS	0,5989	-0,1406	0,6144	0,0551	0,4909
DMC	0,7294	-0,4376	0,1906	-0,4878	0,0479
TA	0,8255	-0,1656	0,1579	-0,3218	0,4033
TSS/TA	-0,1405	-0,0774	0,8084	0,5450	0,1537
Chl	0,0017	0,3734	0,3037	0,8339	-0,2702
Car	-0,9773	0,1114	0,1562	0,0875	-0,0217
TPC	0,0193	0,8253	0,2881	-0,4836	-0,0410
TAC	-0,1285	-0,5803	0,6341	-0,2674	0,4161
FT	0,6833	0,1520	0,4430	0,0507	-0,5578
AA	0,6523	-0,5050	0,1829	0,3470	0,4070
Pn/Ci	0,9680	-0,2147	-0,0855	-0,0259	0,0939
Pn	0,9620	0,1304	-0,2268	-0,0073	0,0776
gs	-0,2089	0,6843	-0,5692	-0,1392	0,3804
Ci	-0,7056	0,6830	-0,1748	-0,0093	0,0708
T°	-0,9079	-0,0892	0,3573	-0,1944	0,0476
LAI	-0,1954	0,0789	-0,7755	0,0052	0,5951
R.F.	0,4188	0,8413	0,2779	0,1817	0,0819
F.I.	0,9466	0,1477	-0,0259	0,1917	-0,2114
MS	-0,1247	0,9229	0,2161	-0,0665	0,2856
SL	-0,1947	0,8652	-0,3437	-0,2634	-0,1612
Bl	-0,6067	-0,6599	0,3729	-0,2394	-0,0030
RL	-0,1777	0,2597	0,8540	-0,0334	0,4131
FRL	-0,0062	0,5490	0,7915	-0,0912	0,2525
R/FR	-0,3782	-0,8208	-0,3748	0,1571	0,1347
Fv/Fm	0,7780	-0,3708	-0,1825	0,3438	0,3252
FPSII	0,8881	0,1398	-0,0391	-0,4127	-0,1412
qP	0,9581	-0,0575	0,0595	-0,2717	0,0365
ETR	0,8098	0,1761	0,0162	-0,5593	-0,0135

List of captions

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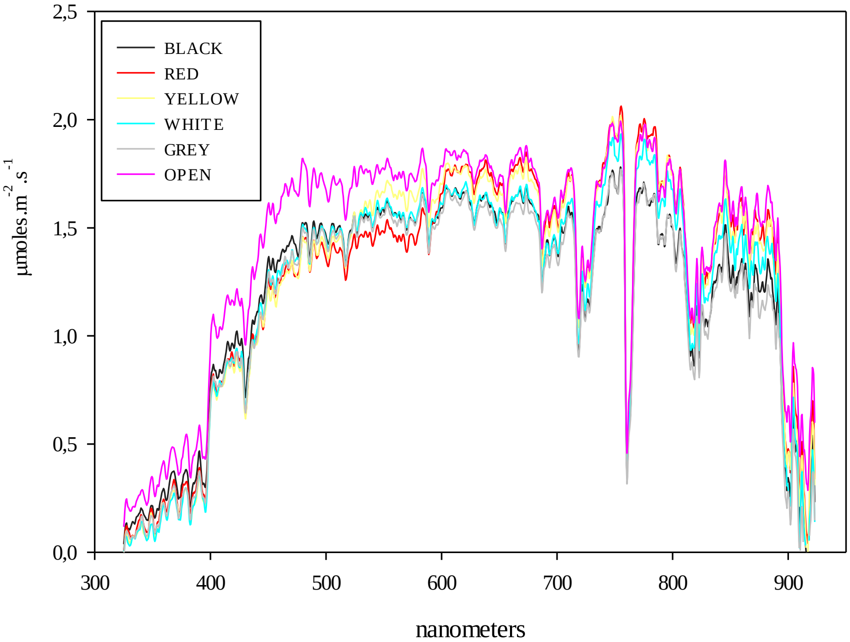

Figure 1 - Light spectrum under five photoselective colour nets and the open field

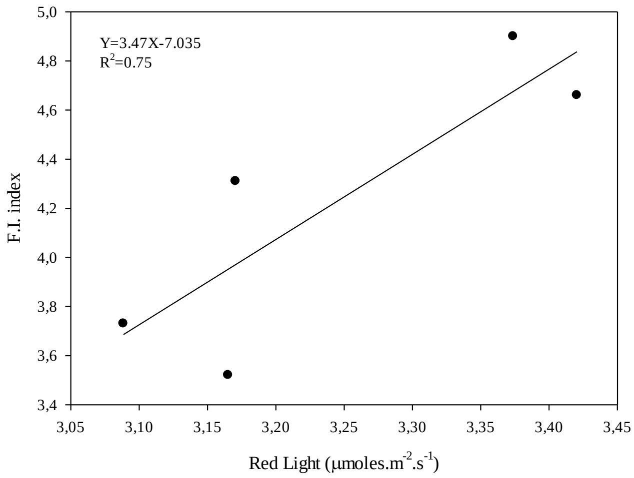

Figure 2 - Relationship between Red Light and Fertility Index in tree of Actinidia chinensis, cv Jintao

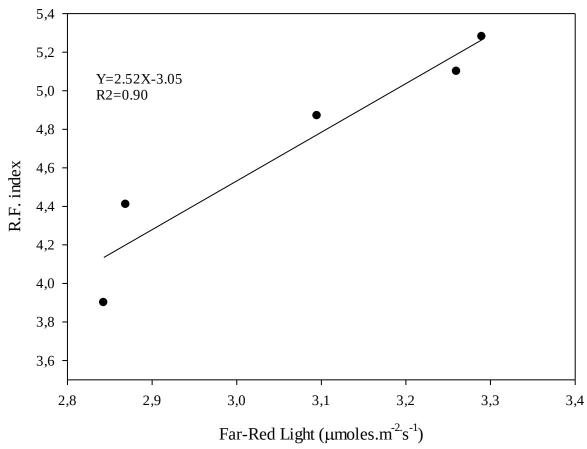

Figure 3 - Relationship between Far-Red Light and Real Fertility index in tree of Actinidia chinensis, cv Jintao

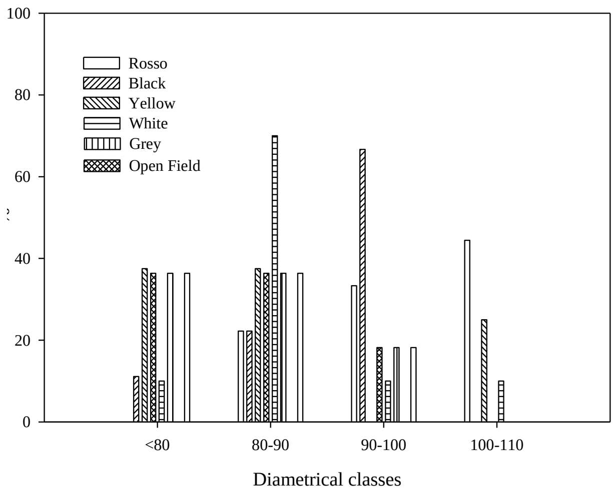

Figure 4 - Size classes of kiwi fruit in the Jintao trees grown under five photoselective colour nets and the open field

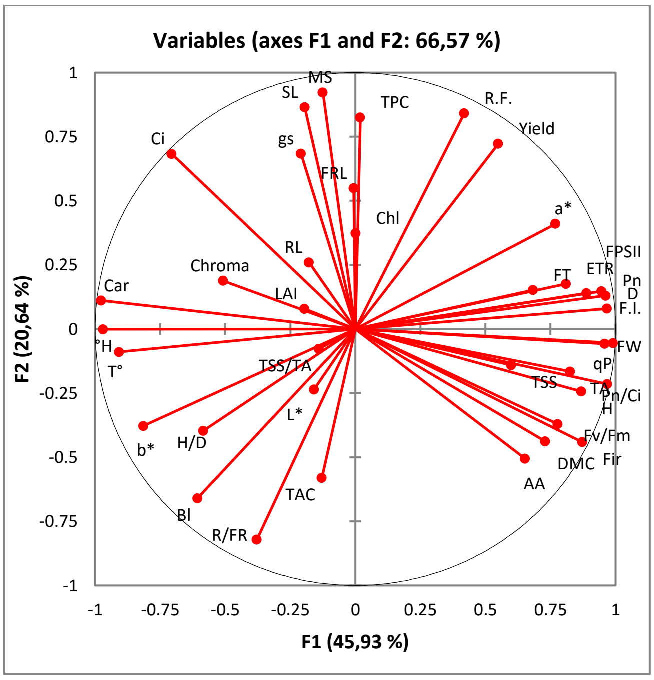

Figure 5 - Representation of the projection of the variables on F1-F2 plane

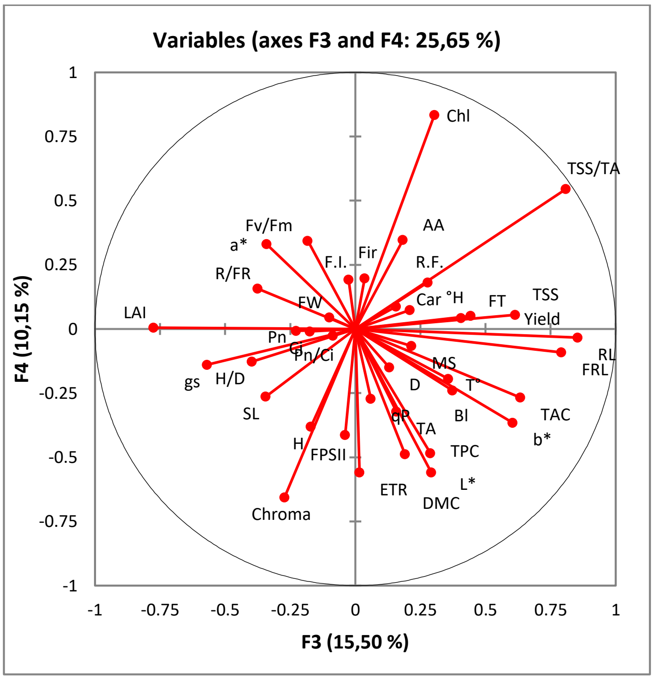

Figure 6 - Representation of the projection of the variables on F3-F4 plane

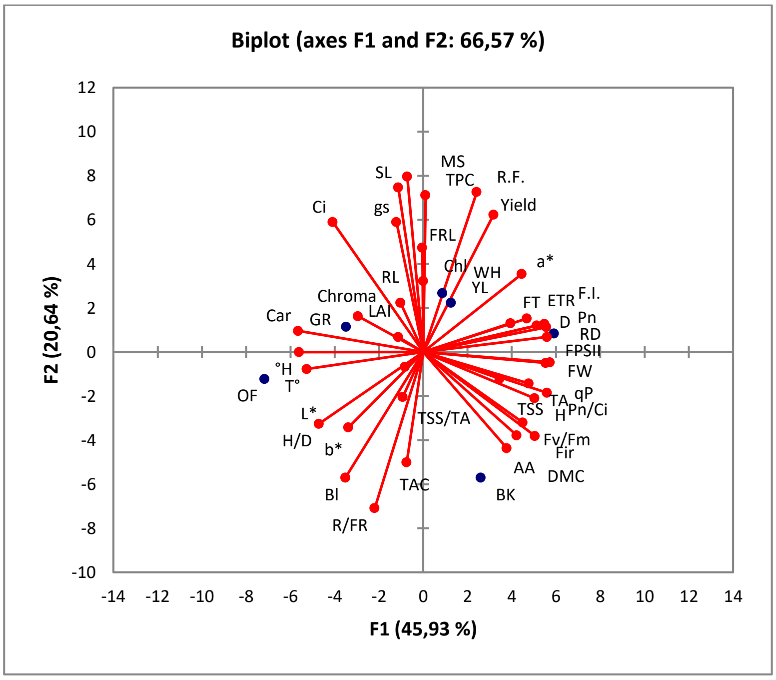

Figure 7 – Bi-plot with photoselective colour net centroid and variable vectors on F1 and F2 plane.

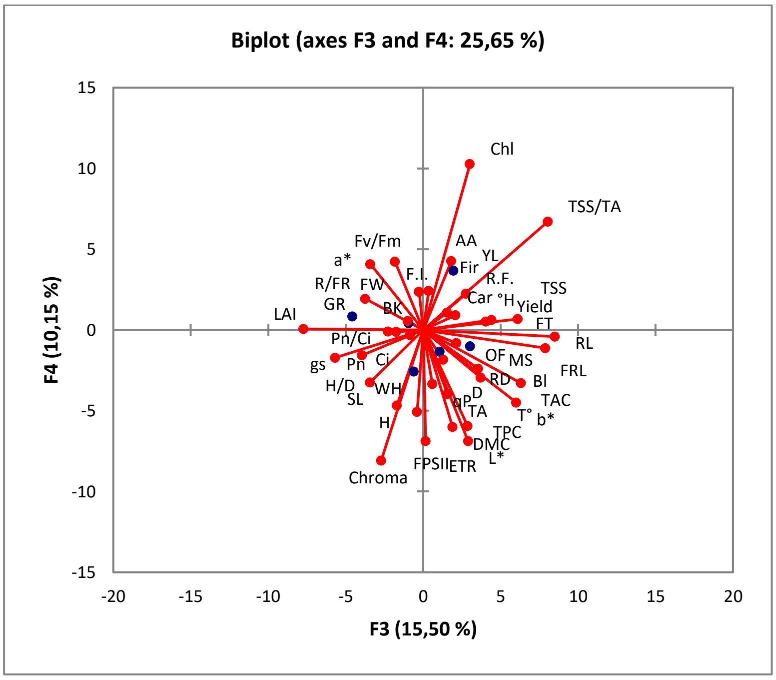

Figure 8 – Bi-plot with photoselective colour net centroid and variable vectors on F3 and F4 plane.