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Effects of insect nets on the vegetative growth of the Guineasorrel (*Hibiscus sabdariffa*L.), grown in the Korhogo region of Northern Côte d'Ivoire

SIENE Laopé Ambroise Casimir[1], COULIBALY Lacina Fanlégué[1], KOUAME Konan[1*], KONE Sicrepou Siaka[1], KONE Mamadou[1]

[1]*Plant PhysiologyLaboratory, UFR Biological Sciences, Peleforo Gon Coulibaly University, BP1328 Korhogo, Côte d'Ivoire*

Corresponding Author :KOUAME Konan

ABSTRACT: *The Guinea sorrel (Hibiscus sabdariffa L.) is a crop whose leaves, calyces and seeds are important in the food of West African populations and, also, in the textile industries. In sub-Saharan Africa, insects are the main pests of vegetable crops, including the Guinea sorrel. A study was carried out in the Korhogo region with the aim of comparing the effects of insect nets and insecticides on the agromorphologicalcharacteristics of the Guinea sorrel. The experimental design, adopted, is in Fisher blocks completely randomized, comprising 5 treatments and 4 repetitions. Treatments were composed of: chemical insecticide, biological insecticide, black insect net, white insect net, control without fillet and no insecticide treatment. The measurements concerned a few vegetative characters. The results obtained showed that after 46 days of follow-up, treatment with white net allowed a better improvement of the measured parameters, namely, the height of the plants (55.1 cm), the number of leaves (21.5 leaves), neck diameter (5.7 mm) and dry aerial material (27.35 g). In contrast, treatment with black net had the weakest effects in improving measured vegetative characteristics. The results of this study have thus shown that the use of white insect nets, can be used as an alternative to the use of chemicals in the management of insect's pests of Guinea sorrel. This would help reduce the use of insecticides, becoming increasingly expensive and dangerous for consumers and the environment.*

KEYWORDS:*Agro-morphological, insect nets, Hibiscus sabdariffa, Côte d'Ivoire*

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I. INTRODUCTION

Over the last decade, fruit and vegetable production has become a vital agricultural sector in sub-Saharan Africa because of its nutritional value and the high economic revenues it generates. This sector has the latent capacity to serve as a driver for agricultural and economic diversification, particularly for smallholders who can direct production to local, regional or export markets (Weinberger and Lumpkin, 2007;Ekesi*et al.*, 2009).

A diagnosis of the market gardening sector shows that consumption of urban households remains dominated by the following vegetables in order of frequency of purchase: onion, tomato, okra, leafy vegetables, and mainly, sorrel. Guinea, hemp and vegetable carrots (Diouf*et al.*, 2003;Cerdan*et al.*, 2004;Diouf*et al.*, 2007). Market gardening is of great economic importance in Africa. Indeed, most of the producers' monetary resources come from market gardening activity. Food production, mainly related to the rainy season, is only a seasonal food supplement (Essang, 1995;Gockowski*et al.*, 2003;Kahane*et al.*, 2005).

Guinea sorrel (*Hibiscus sabdariffa* L.), an annual herbaceous plant commonly referred to as Bissap, occupies an important place in the diet and economic activity of urban and rural populations (Lépengué*et al.*, 2011). The Guinea sorrel or Roselle represents approximately 70% of the world production of hibiscus fibers (CIRAD and GRET, 2002). Its production is estimated at about 10 to 20 t/ha for a branch crop and 6 to 8 t/ha for a calyx harvest (Raemaekers, 2001).

Hibiscus sabdariffa L. is a multipurpose species. This culture contributes effectively to food security and the fight against poverty, thanks to the income generated to farmers (Folefack*et al.*, 2008). It is a popular vegetable in household food in Africa, where it is consumed in ready-made sauces or as a freshening beverage (bissap) (Bricage 1984;Sié*et al.,* 2008;Gueye*et al.*, 2012). It is also highly valued for its taste and richness in minerals, vitamins and proteins (Babalola*et al*., 2001;Adanlawo and Ajibade, 2006). Some consumers believe that they clean and donate blood (Mcclintock, 2004;Moustier and Essang, 1996;Seck*et al.,* 1999). In addition, the red calyx of the sorrel of Guinea is today more and more exported to the United States and Europe, where it is used as a natural colorant in the food industry (FINTRAC, 1999; Diouf*et al.,* 2007).

In Côte d'Ivoire, *Hibiscus sabdariffa* L. occupies the first place among traditional market garden plants in the north of the country (Mouaragadja and M'batchi, 1998). However, production is still well below potential in terms of yield, and does not always meet health and environmental quality standards. Major production constraints are both economic (land pressure and low investment capacity) and agronomic (difficult management of pests and diseases, irrigation and fertilization). For pest control, small producers typically use chemical pesticides (Ahouhangninou*et al*., 2013; De Bon *et al.,* 2014).

Indeed, already poorly trained on the use of pesticides, they also have very limited access to integrated pest management techniques. By ignoring alternative methods, farmers often think that the only solution to their phytosanitary problems lies in the application of pesticides at increasing doses and frequencies (Martin *et al.*, 2002;Houndete*et al*., 2010;Carletto*et al.,* 2010). Thus, in the market gardening perimeters of the tropics, the increasing use of chemical insecticides is widespread, because of their ease of use and availability in local markets. Yet, urban consumers are increasingly concerned about the quality of their diet, following cases of intoxication due to misuse of pesticides. Producers must produce quality while maintaining the same performance.

Physical control with insect’s nets meets this challenge by reducing insecticide applications while increasing yields by reducing losses from aerial crop pests. The insect net is an alternative method to chemical treatments. Used in organic farming, it can effectively protect crops from the attack of certain pests. This net provides effective crop protection against parasites, their larvae and their stings in a completely natural way without requiring the use of phytosanitary products that are toxic for both humans and the environment (Inserm, 2013).

In the face of numerous attacks of insects against the Guinea sorrel, alternative methods of control must be developed, in order to reduce the use of phytosanitary products. Numerous studies carried out in this direction have shown a certain effectiveness of physical barriers, depending on their level of adaptation (mesh size) to the fight against insect pests (Martin *et al.*, 2006 and 2013;Gogo*et al.*, 2012;Saidi*et al.*, 2013). Other studies have also shown that the microclimate created by insect nets has a favorable influence on the physiology of crops (Gogo*et al*., 2012;Muleleke*et al*., 2013; Simon *et al.*, 2014).

The present study is part of the perspective of the search for alternative methods to chemical products, thus allowing the development of organic farming. The objective of the present study is to evaluate the effect of the insect net on the growth of the Guinea sorrel. Thus, the following hypotheses have been made: (i) insect nets allow for better growth of guinea sorrel (ii) the use of insect nets is the best way to control insects.

II. MATERIAL AND METHODS

Field of study

The study was conducted in Korhogo commune, located in northern Côte d'Ivoire, whose geographical coordinates are 9° 26' north longitude and 5° 38' west latitude. The climate of the zone, Sudanese type, is characterized by an alternation of two seasons. A long dry season, from October to May, precedes the rainy season, marked by two rainy peaks, one in June and the other in September. The area is also characterized by average temperatures ranging between 24 and 33 °C and a monthly average humidity of 20%. The annual rainfall is between 1100 and 1600 mm and the duration of insolation is 2600 hours per year.

The soil is of tropical ferruginous type, formed on granite who’s leaching more or less intense, has reduced the fertility. The relief is generally flat and dotted with inselbergs (Koffie and Yéo, 2016).

Material

Plant material

The plant material used was made from a variety of sorrel from guinea, commonly grown in the Korhogo region.

The Guinea sorrel or *Hibiscus sabdariffa* L. (Malvaceae) is an annual, self-pollinated, preferential plant, but with a rate of allogamy varying between 0.68% and 1%, according to the cultivars (Boulanger *et al.*, 1984; Vaidya, 2000). Its mature size varies between 2 and 2.5 m. Its leaves have between 3 and 5 lobes. The flowers have a diameter, usually between 8 and 10 cm, with petals having a red color at the base. The fruits of the roselle reach maturity after 6 months. Roselle grows well on humus soils and well-drained, and also in sunny areas. It is appreciated and attacked by many insects and pests.

Technical material

The technical material consisted of anti-insect or muslin nets, white in color and black in color. These insect nets are generally in the form of textile veils, whose grammages vary depending on the crop to be protected and the target pest. The insect nets are made of polyethylene (PE) and are resistant to UV and abrasion.

The insecticides used consisted of a chemical, Cypercal and an aqueous extract of the leaves of *Hyptissuaveolens*, as a biological material.

METHODS

Experimental device

The experimental device used was composed of Fisher blocks, completely randomized, comprising 5 treatments and 4 repetitions. The study consisted of 20 elementary plots. Each elementary plot consists of 25 plants, transplanted on 5 lines of 5 pockets, according to the spacing's of 0.2 m x 0.2 m. The elementary plots and blocks were, respectively, separated by a distance of 0.5 m and 1 m.

The 5 treatments studied are as follows:

- T0: witness without insect net and without treatment with insecticide;
- IC: treatment with chemical insecticide and no insect net;
- IB: treatment with biological insecticide and no insect net;
- FN: treatment with black mesh and without insecticide;
- FB: treatment with white mesh and without insecticide.

The insect nets were placed vertically, at sowing, at a height of one (1) meter above the boards, on iron supports. The cages were opened during plant removal and weeding operations.

The first insecticide treatments were carried out 6 days after seeding (DAS) and the second 20 days after the first treatment. The measurements started on the 16th DAS and were done every 10 days.

Parameters measures

Various morphological parameters were measured per basal plot during the study. The height of each plant was evaluated by measuring its size, from the neck to the last leaf (the most elevated). The neck diameter was obtained by measuring the circumference of the neck of each plant. The number of leaves issued per plant was obtained by counting all the leaves contained in the crown. The leaf area or wingspan was determined by measuring the diameter of the crown formed by the leaves on either side of the main stem. Dry aerial matter was estimated by weighing the aerial vegetative apparatus, after drying in an oven at 105 °C. Temperatures inside the insect and field fillets were taken between 6 am and 2 pm.

Data processing and analysis

The data, collected and recorded using the Excel spreadsheet, was subjected to an analysis of variance using the XLSTAT version 7.5 software. The significance level of differences between means was estimated using the Duncan test at the 5% threshold. Correlations, Principal Component Analysis (PCA) and Ascending Hierarchical Classification (AHC) were performed using the Statistica Version 7 software.

III. RESULTS

Height of plants

Table 1 presents the results of the average height of the plants on the whole plot, according to the measurement dates. The analysis of variance reveals differences between the averages of the 5 treatments, obtained during the 16th, 26th, 36th and 46th days after seeding (DAS). At these different stages of measurement, the results obtained show the formation of three homogeneous groups.

At the 16th and the 26th DAS, the first group, with the highest averages, is formed by treatment with black net. The averages were 8.6 cm at 16th DAS and 15.8 cm at 26th DAS. The second and third groups are, respectively, the treatment with white net and the treatments with insecticides (chemical and biological) and the witness.

At the 36th and 46th DAS, the first group, with respective averages of 39 cm and 55.1 cm, is formed by treatment with white net. The averages, obtained with white net, were significantly higher. The second group consists of treatment with black net. The averages were 31.4 cm at 36th DAS and 37.6 cm at 46th DAS. With relatively low values, the other three treatments (witness, treatment with chemical and biological insecticide) constitute the third homogeneous group. Values varied between 16.4 (witness) and 17.3 cm (biological insecticide) at 36th DAS and between 25.1 (witness) and 27.1 cm (biological insecticide) at 46th DAS (Table 1).

Diameter at the neck of the plants

In the analysis of Table 2, which shows the results of average neck diameters of plants, differences between the averages obtained at the 26th, 36th and 46th DAS were revealed. On the other hand, the analysis did not reveal any difference between the averages of the treatments on the 16th day after seeding. The averages obtained in the 16th DAS, for the different treatments, were 1.3 mm (white net, black net, biological insecticide and witness) and 1.2 mm for treatment with chemical insecticide.

As for the results obtained in the 26th, 36th and 46th DAS, they reveal the constitution of two homogeneous groups. The first group is formed by treatments with white net, chemical and biological insecticides and witness. The values obtained were 2.3 mm (white net) and 2.1 mm (biological insecticide, chemical insecticide and witness) at the 26th DAS. For the 36th and 46th, averages varied between 4.4 mm (biological insecticide) and 4.8 mm (white net) and 5.6 mm (witness) and 6.2 mm (chemical insecticide), respectively.

The second group consists of the treatment with black net, whose averages obtained were the lowest. The average values of neck diameters, treatment with black net, were 1.80 mm at the 26th DAS, 3.4 mm at the 36th DAS and 3.6 mm at the 46th DAS.

Number of leaves issued per plant

The average number of leaves issued per plant is shown in Table 3. The results of the analysis of the variance revealed differences between the averages of the different treatments studied at the 16th, 26th, 36th and 46th DAS. In the analysis of this table, the results reveal the constitution of three homogeneous groups at the 16th, 36th and 46th DAS.

At the 16th DAS, the first group is formed by treatments with white net, biological insecticide and witness, whose respective averages are 5.2, 4.9 and 5.1 leaves per plant. These averages were highest on this measurement date. With an average of 4.4 leaves emitted per foot, the third group consists of the treatment with black net, which averaged the lowest.

As for the 36th and 46th DAS, the first group is formed by treatments with biological insecticide, chemical insecticide and witness. The averages ranged from 24.4 leaves (biological insecticide) to 24.7 leaves per plant (witness) at 26th DAS and between 32.6 leaves (biological insecticide) and 34 leaves per plant (witness). The third group, with the lowest averages, is the treatment with black net at the 36th and 46th DAS.

At the 26th DAS, the results of the analysis revealed the constitution of two homogeneous groups. The second group, which has the lowest average, consists of treatment with black net. This average value was 6.5 leaves issued per foot. The first group consists of the other four treatments (white net, chemical and biological insecticide and witness). These treatments recorded the highest averages. Values ranged from 8.5 leaves (white net) to 9 leaves per plant (biological insecticide) (Table 3).

Scope of the plants

The results obtained from the scale of the Guinea sorrel plants are presented in table 4. The analysis of the variance, applied to the different averages, revealed differences at the stages 16th, 26th, 36th and 46th DAS. At the first three measurement dates (16th, 26th and 36th DAS), the results revealed the formation of three homogeneous groups.

At the 26th and 36th DAS, the first group, with the highest averages, is the treatment with white net. The values obtained were 14.2 cm at the 26th DAS and 24.3 cm at the 36th DAS. The third group, with the lowest values, is formed by the treatment with black net. This treatment produced averages of 9.5 cm at the 26th DAS and 15.1 cm at the 36th DAS.

At the 16th DAS, the first group, with the highest averages, consists of treatments with white mesh, biological insecticide and witness. These averages ranged from 6.4 cm (biological insecticide) to 6.7 cm (witness). The third group, having given the lowest average values, is formed by treatments with black mesh and chemical insecticide.

As for stage 46th DAS, the results reveal the constitution of two homogeneous groups. The second group, whose average was the lowest, is formed by treatment with black net. The average span of this treatment was 16.8 cm. The first group, with markedly larger mean sizes, consists of treatments with white net (25.8 cm), biological insecticide (25.4 cm), chemical insecticide (26 cm) and witness (26.3 cm) (Table 4).

Dry biomass

Table 5 presents the averages, in dry aerial biomass, obtained with all five treatments applied. In the analysis of this table, it appears that the variance revealed differences between the averages, obtained with the

applied treatments, at the 16th, 26th, 36th and 46th DAS. The results of the analysis revealed the formation of four homogeneous groups at the 16th and 36th DAS, three homogeneous groups at the 26th DAS and two homogeneous groups at the 46th DAS.
At the 16th DAS, the first group consists of the witness. With an average of 0.84 g, this treatment registered the highest value. The fourth group, with the lowest value (0.46 g), is formed by treatment with black net.
At 36th DAS, treatment with white mesh recorded the highest average (16.06 g). This treatment is the first group. Black fillet treatment, averaging 4.63 g, produced the lowest dry weight of aerial material. This treatment (black net) is the fourth homogeneous group.
At 26th DAS, the highest averages were recorded with treatments with biological insecticide (2.74 g), chemical insecticide (2.63 g) and control (2.63 g). These treatments form the first homogeneous group. The third group, with the lowest average value (1.21 g), consists of the treatment with black net.
At 46th DAS, the second group, with the lowest average (7.05 g), is formed by the black net treatment. The first group consists of the other four treatments (white net, chemical and biological insecticide and witness). Values recorded with these treatments were highest with averages ranging from 23.91 g (witness) to 27.35 g (white net) (Table 5).

Study of correlations

The correlations between the different parameters, for the variety of Guinea sorrel, were studied. Table 6 presents the matrix of correlations between these parameters. The analysis in this table reveals the existence of positive and significant correlations between the studied parameters. These correlations are as follows:
- neck diameter and scope of the plants ($R^2 = 0.967$);
- neck diameter and dry aerial matter ($R^2 = 0.954$);
- the scope of the plant and dry aerial matter ($R^2 = 0.979$).

Except for the height of plants that do not correlate, other measured parameters (dry aerial matter, scope of plant, neck diameter, and number of leaves issued) show correlations whose distribution is shown in Figure 1.

Correlations between the studied parameters and the axis

Table 7 shows the correlation between the measured parameters with the axes. It can be seen from this table that axis 1 and 2 are correlated with each of the parameters studied. The first axis (axis 1) is related to the neck diameter, the number of leaves emitted, the scope and the dry aerial material. These parameters were all negatively correlated to axis 1 (Table 7, Figure 2). As for the second axis (axis 2), it was positively correlated with a single parameter, the height of the plants, with $R^2 = 0.941$.

Distribution of treatments in the plan formed by the various axis

The distribution of the treatments applied in the plane formed by the axis and the distance separating them are shown in Figure 2 and in Table 8. It appears that the witness and the treatments with biological and chemical insecticides are located in the quarter-plane coinciding with the negative parts of axis 1 and 2. With Euclidean distances, ranging from 0.20 to 0.56, these treatments were the closest. They were, also, closer to treatment with white net than that with black net. The Euclidean distances between the first three treatments (chemical and biological insecticides and the witness) and the others using the white and black net were between 2.2 and 2.72 and between 4.45 and 4.59, respectively.The treatment, with black net, belongs to the positive part of the axis 1 and negative of the axis 2. As for the treatment with white net, it is located in the negative part of the axis 1 and positive of the axis 2 (Table 8, Figure 2).

Hierarchical classification of parameters and treatments studied

The parameters studied make it possible to distribute the applied treatments, in three groups, defined at the truncation of 0.5 units on the dendrogram, according to Ward's aggregation method (Figure 3). The first group consists of treatment with white nets, which is characterized by the height of the plants. The second group consists of treatments with chemical and biological insecticides and witness. These treatments are characterized by the number of leaves emitted, the scope and the dry aerial material. As for the third group, it is composed of the treatment using the black net, which is not related to any parameter.

Effects of treatments on temperature

Table 9 presents the results of taking the temperature at the level of each treatment. The temperature was measured at the level of 3 treatments, namely, treatment with white net, treatment with black net and treatment without net. The average values obtained varied between 35 and 41 °C. The highest value was obtained with the black net (41 °C) and the lowest value (35 °C) was recorded with the treatment without net.

IV. DISCUSSION

The good knowledge of *H. sabdariffa* L. plants and its better growth, under treatment with white insect nets compared to the witness, reflect the need to use the nets for the control of insects, in order to ensure a good development of the plant. The best behavior of the sorrel plants in Guinea sorrel was remarkable with the white net and insecticide treatments (chemical and biological).

The height growth of sorrel plants was higher with white net and with insecticides than in open air. This result suggests that photosynthesis would be more important under the nets than in the open air. This result is in agreement with the work of Wolff (1999) on *Eucalyptus gunnii*, which showed that with controlled temperature and humidity, the tunnel with net allows a good growth of the cuttings. On the contrary, Yue and Margolis (1993) indicated that nets reduce light intensity (0 - 50 mµ mol.m^{-2} s^{-1}) and therefore limit photosynthesis.

However, for Langellier (2000), photosynthesis depends more on the quality (type of radiation) of the light than on the quantity (luminous intensity). The film used for making nets, don't stop totally the light rays. As a result, light radiation in combination with saturated humidity, which leads to the opening of stomata under the nets, promotes photosynthesis, hence growth and development of crops.

For neck diameter, the number of leaves issued, the scope and dry aerial material, after 46 days after survival seeding, the plants, under white net and treatments with chemical and biological insecticide, gave the best results. Black net treatment thus produced the lowest results for these measured parameters. The black color of the net thus had a negative impact on the expression of these studied agronomic characteristics of the Guinea sorrel. The black color of the nets is likely to influence temperature, solar radiation, ambient humidity and air circulation, which will have a negative impact on the development of young plants (Simon *et al.*, 2014). For Gogo*et al.* (2012), the coloring of insect nets creates root asphyxiation, related to climatic conditions due to the physical barrier. The high height of the sorrel plants, obtained with the treatment with black net, can be due to the growth of the plants to the absence of light. This situation has favored the lengthening of the internodes.

The temperatures recorded on the plot were higher with the black net (41 °C). This rise in temperature has an impact on the expression of the agronomic characteristics measured. The installation of black staining net modified the difference in temperature and humidity between the inside and the outside of the field climate. For Fatnassi and Boulard (2006), in comparison with a field without a net, colored nets increase the temperature and humidity of air by 2.7 °C and 0.7 g kg^{-1}. This situation would not favor the good growth and the good development of cultures under the nets of color.

On the other hand, the use of white nets made it possible to obtain satisfactory results for all the parameters measured. These white insect nets have created better weather conditions for the proper development of sorrel plants. The studies of Saidi*et al.* (2014) have shown that the use of insect nets creates microclimatic conditions for better plant development and better yield in both quantity and quality. These results show the interest of growing sorrel under net, especially as the reduction of insecticide treatments reduces the risk of pesticide residues that are harmful for the consumer and the environment, but also for the export market.

For many authors, insect nets reduce the amount of light received by plants by 30%. This reduction is all the stronger as the meshes are small and the nets are used constantly. This resulted in a significant reduction of the active photosynthetic radiation (APR) received by the green foliage of the plants. However, this reduction in light does not seem to have a major impact on plant physiology. This situation would favor better growth of plants under insect nets (Gogo*et al.*, 2012;Saidi*et al.*, 2014;Gogo*et al.*, 2014).

In Kenya, in the Nakuru region (1850 m), studies by Gogo*et al.* (2012) and Muleleke*et al.* (2013) showed that nets reduce the daytime ambient temperature and increase the nighttime ambient temperature. In addition, the average soil moisture content is significantly higher under fillet and reduces irrigation. Cabbage and tomato nurseries under net thus benefit from more favorable microclimatic conditions than without net: an increase of 2.2 °C in temperature, 3.9 to 4.2% of relative humidity and 20% increase in soil moisture. Seedling growth would thus be faster, with reduced pest damage.

According to Simon *et al.* (2014), in the rainy season, the efficiency of the nets is optimal, because of the barrier against insects and the protection against heavy rains. The use of climate shelters allows better management of pests.

The use of an insect net on a crop is, therefore, a sustainable technology to improve seedling performance. By protecting against pest infestations, insect nets improve the producer's income. In an integrated pest management approach, the exclusion of pests by the use of agronomic nets is no longer an option to be neglected (Murphy and Ferguson, 2000). The addition of agronomic nets removes an important variable in the pest management program by blocking outside pests (Murphy and Ferguson, 2000).

In Kenya, seedling emergence of cabbage and tomato seedlings was earlier under nets (Gogo*et al.*, 2012;Muleleke*et al.*, 2013). Seed germination rates were higher as well as the survival rate of the seedlings, which indicates a potential to reduce the number of seeds to be sown to obtain the same number of plants. In addition, nets reduce the negative impact of heavy rains that scatter seeds and erode soil.

Overall, however, there is a real saving in net-cover crops compared to the open field, but slower soil drainage and lower aeration are potential sources of disease and cultural problems. Finally, weeds can have a faster development under shelters nets. On the other hand, air cultures allow easier access for weeding, compared to insect nets placed on the ground, but more exposed to pest attack.

V. CONCLUSION

In sub-Saharan Africa, insects are the main pests of vegetable crops. The chemical insecticides used in Sub-Saharan Africa have a broad spectrum, but they also have a negative impact on parasitoids and predators, not to mention their high cost. Their systematic use, in agriculture, for about fifty years, has selected resistant populations, especially among the pests. This led to an increase in doses and frequencies of application and selected multi-resistant populations. Reducing their use in market gardening systems made possible by the use of insect nets could lead to the development of biological control methods allowing a better regulation of biting and sucking pests (such as aphids, whiteflies,thrips and mites).

The search for Guinea sorrel's response to insect nets and insecticides was done through a Korhogo soil test. The agromorphological characteristics of sorrel subjected to different treatments were evaluated. The results showed that all the agromorphological characteristics of sorrel have been improved by white net and insecticide treatments. However, treatment with black insect net had the greatest effect on the growth of sorrel plants, compared with the witness (no net and no insecticide).

The results of this study have therefore shown that the use of white insect nets can be used as a method of integrated pest control (insects) of vegetable crops. This would help reduce the use of insecticides, becoming increasingly expensive and dangerous for consumers and the environment. However, this study should be supplemented by other, more in-depth experiments, notably in terms of yield, mesh size and the constituent material of the nets. Thus, the use of these nets can increase the production of market gardening and ensure the safety and health of populations.

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Table 1: Average plant heights according to treatments and measurement dates

Treatments	DAS			
	16th	**26th**	**36th**	**46th**
FB	7,7 b	13,5 b	39,0 a	55,1 a
FN	8,6 a	15,8 a	31,4 b	37,6 b
IB	6,6 c	8,4 c	17,3 c	27,1 c
IC	6,5 c	8,9 c	18,5 c	26,9 c
T0	6,9 c	9,3 c	16,4 c	25,1 c

FB = white net; FN = black net; IB = biological insecticide; IC = chemical insecticide; T0 = witness;
DAS = day after seeding
The averages followed by the same letter in a column are not significantly different at the 5% threshold, Duncan test.

Table 2: Average neck diameters of plants according to treatments and different periods of measurement

Treatments	DAS			
	16th	**26th**	**36th**	**46th**
FB	1,3 a	2,3 a	4,8 a	5,7 a
FN	1,3 a	1,8 b	3,4 b	3,6 b
IB	1,3 a	2,1 a	4,4 a	6,0 a
IC	1,2 a	2,1 a	4,7 a	6,2 a
T0	1,3 a	2,1 a	4,5 a	5,6 a

FB = white net; FN = black net; IB = biological insecticide; IC = chemical insecticide; T0 = witness;
DAS = day after seeding
The averages followed by the same letter in a column are not significantly different at the 5% threshold, Duncan test.

Table 3: Average number of leaves issued per plant according to treatments and different measurement dates

Treatments	JAS			
	16th	**26th**	**36th**	**46th**
FB	5,2 a	8,5 a	18,6 b	21,5 b
FN	4,4 c	6,5 b	9,3 c	10,8 c
IB	4,9 ab	9,0 a	24,4 a	32,6 a
IC	4,8 b	8,9 a	24,6 a	32,8 a
T0	5,1 ab	8,8 a	24,7 a	34,0 a

FB = white net; FN = black net; IB = biological insecticide; IC = chemical insecticide; T0 = witness;
DAS = day after seeding
The averages followed by the same letter in a column are not significantly different at the 5% threshold, Duncan test.

Table 4: Mean values (cm) of the scales of the plants according to the treatments and the different periods of measurement

Treatments	DAS			
	16th	**26th**	**36th**	**46th**
FB	6,6 a	14,2 a	24,3 a	25,8 a
FN	5,7 c	9,5 c	15,1 c	16,8 b
IB	6,4 ab	12,3 b	22,3 b	25,4 a
IC	6,1 bc	11,9 b	22,0 b	26,0 a
T0	6,7 a	11,9 b	21,3 b	26,3 a

FB = white net; FN = black net; IB = biological insecticide; IC = chemical insecticide; T0 = witness;
DAS = day after seeding
The averages followed by the same letter in a column are not significantly different at the 5% threshold, Duncan test.

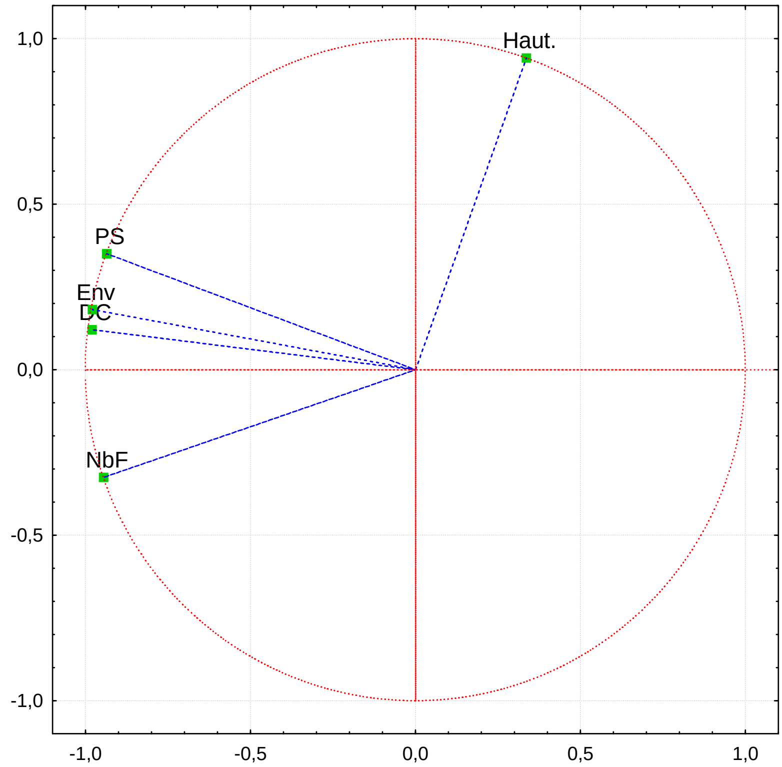
Table 5: Average dry aerial biomass (g) of plants according to treatments and different measurement dates

Treatments	DAS			
	16th	**26th**	**36th**	**46th**
FB	0,66 c	2,53 b	16,06 a	27,35 a
FN	0,46 d	1,21 c	4,63 d	7,05 b
IB	0,76 b	2,74 a	11,82 c	24,72 a
IC	0,68 c	2,61 ab	14,04 b	24,23 a
T0	0,84 a	2,62 ab	12,32 c	23,95 a

FB = white net; FN = black net; IB = biological insecticide; IC = chemical insecticide; T0 = witness;
DAS = day after seeding
The averages followed by the same letter in a column are not significantly different at the 5% threshold, Newman Keuls (SNK) test.

Table 6: Correlations between the variables studied

Variables	Plant height	Neck diameter	Number of leaves	Scope	Dry matter
Height	1				
Neck diameter	-0.217	1			
Number of leaves	-0.624	0.879	1		
Scope	-0.157	0.967	0.868	1	
Dry matter	0.014	0.954	0.771	0.979	1

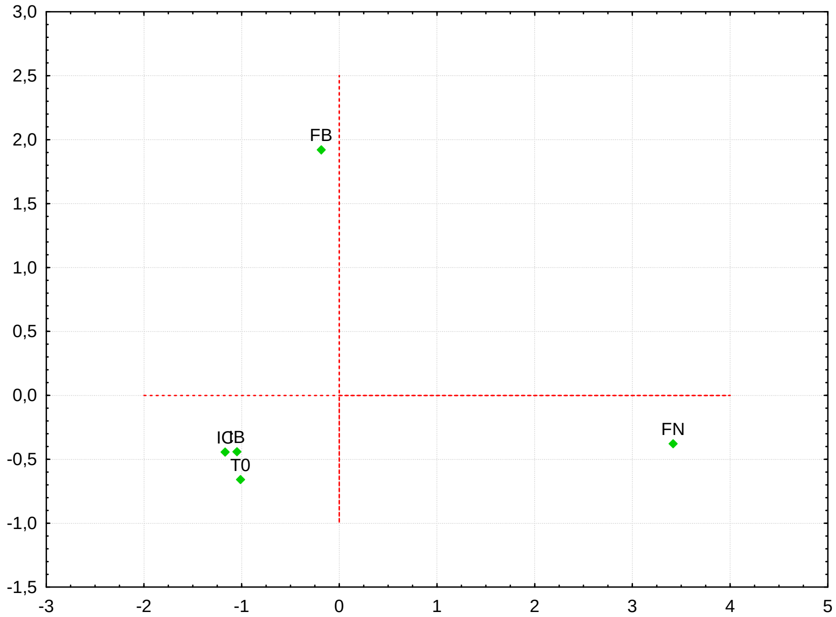


Haut. : Height of the plants; DC: neck diameter of the plants; NbF: number of leaves;
Env: Scope; PS: Dry weight of aerial material

Figure 1: Distribution of all parameters in the plane formed by axis 1 and 2

Table 7: Correlations between the studied parameters and the axis 1 and 2

Variables	Components	
	Axis 1	Axis 2
Height	0.336	0.941*
Neck diameter	-0.980*	0.121
Number of leaves	-0.944*	-0.325
Scope	-0.978*	0.182
Dry weight	-0.935*	0.350

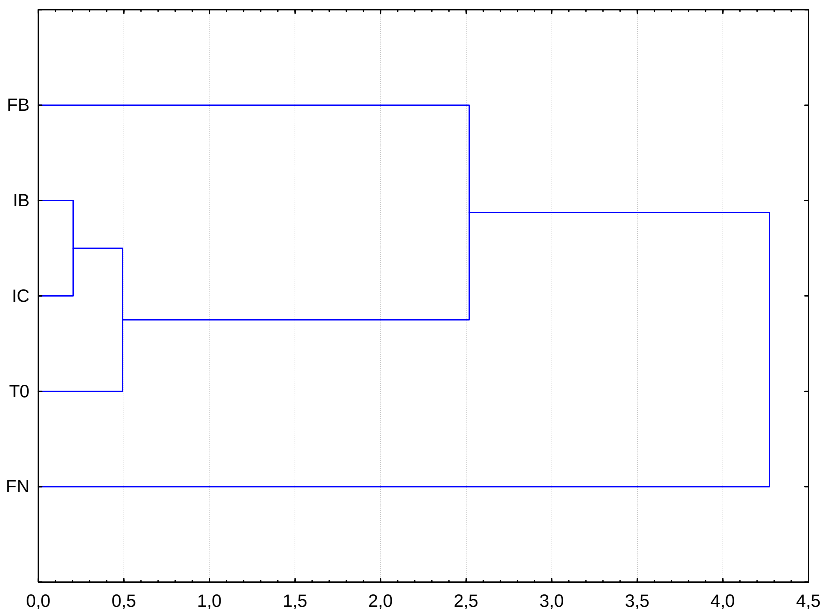


FB: white insect net; FB: black insect net; IB: biological insecticide; IC: chemical insecticide; T0: witness

Figure 2: Projection of applied treatments in the plane formed by axis 1 and 2

Table 8: Proximity matrix of treatments (Euclidean distances)

Treatments	White net	Black net	Biological insecticide	Chimical insecticide	Witness
White net	0				
Black net	4.27	0			
Biological insecticide	2.52	4.47	0		
Chimical insecticide	2.57	4.59	0.20	0	
Witness	2.72	4.45	0.49	0.56	0



FB: white insect net; FB: black insect net; IB: biological insecticide; IC: chemical insecticide; T0: witness

Figure 3: Grouping applied treatments into homogeneous classes, using the Ward aggregation method

Table 9: Temperature recorded on applied treatments (temperature, protection with white net, black, unprotected or free air)

Traitements	Temperature (°C)

Protection with white netc	37
Protection with black net	41
Unprotected (free air)	35

Siene Laopé Ambroise Casimir"Effects Of Insect Nets On The Vegetative Growth Of The Guinea Sorrel (*Hibiscus Sabdariffa* L.), Grown In The Korhogo Region Of Northern Côte d'Ivoire." American Journal of Engineering Research (AJER), vol. 7, no. 07, 2018, pp. 253-263