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Agro-morphological characterization of four varieties of cucumber from *Cucumis sativus* L. and *Cucumis metuliferus* E. Mey. Ex Naudin in Senegal

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ABSTRACT

Purpose: Cucumbers are an important fruit vegetable consumed as a salad or cooked in the world. Among the most used and consumed cucumbers, there are domestic cucumbers *(Cucumis sativus* L.) and wild cucumbers (*Cucumis metuliferus* E.). Despite their importance, the agro-morphological characteristics of cucumbers were not well known. The objective of this research was to assess the agro-morphological characteristics of four varieties of cucumber (green and white *C. sativus*, bitter and non-bitter *C. metuliferus*). **Research method:** A cultivation trial of these cucumber varieties was carried out in Randomised Complete Block Design with four replications at the application farm of the Agroforestry Department Assane Seck University of Ziguinchor, Senegal. Different parameters of growth leave chlorophyll content, 50% flowering days, and yield were studied. **Findings:** The analysis of variance of growth parameters, chlorophyll content, 50% flowering days, and yield parameters between varieties showed significant variation. The variety green *C. sativus* was distinguished from the other varieties by better vegetative growth and leaves chlorophyll content (46.91±10.04 SPAD value) and early flowering (29.75±0.5 days). In terms of germination rate, weight, and circumference of fruits, the variety white *C. metuliferus* recorded higher values with 96±2%, 468.25±99.28 g, and 23.85±2.98cm respectively. Thus, the two wild cucumber varieties (bitter and non-bitter) showed relatively low values on most of the parameters except in terms of the number of ramifications and leaves. Leaves chlorophyll content varied significantly according to the period of the day and the status of leaf development. The higher chlorophyll content was recorded in the noon (44.76±9.45 SPAD value) and old leaves (44.49±7.09 SPAD value). **Research limitations:** Further genotypic and nutritional characterizations were required for a better understanding of the difference between cucumbers. **Originality/Value:** The results showed great variability between the varieties studied for all the morphological, phenological, physiological, and yield characteristics.

INTRODUCTION

The cucumber is one of the most important members of the Cucurbitaceae family (Agashi et al., 2020). This family comprises about 118 genera and 825 species with their members spread mainly in regions of tropical and subtropical worldwide (Wang et al., 2007). They are ranked among the major vegetable fruits such as cucumber grown and exported abroad for their nutritional value and economic significance as foreign exchange earners (Tshilidzi et al., 2016). *Cucumis sativus* or the cucumber has many varieties, including green and white (Burkill, 1985). *Cucumis metuliferus*, horned melon, kiwano, bitter or non-bitter wild cucumber has high economic and nutritional value that is yet to be fully exploited (Aliero & Gumi, 2012). It has many common names like jelly melon, Kiwano, Melano, and bitter or non-bitter wild cucumber (Vieira et al., 2020). It is often eaten raw, as a snack, but may also be used in cooking (Burkill, 1985).

Cucumbers are the most important fruits and vegetables consumed and used for a salad a food. They are sources of nutrients required for human health (Sheela et al., 2004; Mukherjee, 2013; Deguine et al., 2015). Fruits and vegetables play a significant role in human nutrition by providing important nutrients including proteins, vitamins, minerals (zinc, calcium, potassium, and phosphorus), fiber, folacin, and riboflavin (Wargovich, 2000). The flesh of the cucumber is a very good source of vitamins A, C, and folic acid (Ene et al., 2019). The hard skin is rich in a variety of minerals including calcium, potassium, and magnesium. Cucumber has a cooling effect and can be used as a cooling vegetable (Chinatu et al., 2016).

Despite the agronomic, nutritional, medicinal, and economic advantages of cucumber, the agro morphological parameters are not well known by farmers and consumers (Wilkins-Eller, 2004) and its potential is underutilized (Aliero & Gumi, 2012). The crop is also less studied by researchers and therefore its agronomic, nutritional, and economic potential is not well documented. The major species of cucumbers growing in Senegal are *Cucumis sativus* and *Cucumis metuliferus* (Diop et al., 2020). Some varieties of cucumber have been identified in Senegal but their agro morphological traits have not been studied. Therefore, a survey of the agro morphological traits is necessary to encourage rational management and provide good scope for improvement in yield and other characteristics of cucumber through selection. The present study aimed to determine the agro-morphological variation in four varieties of cucumber.

MATERIALS AND METHODS

Study area

The experiment was conducted at the Practical Application Farm of the Department of Agroforestry Assane Seck University of Ziguinchor, Senegal. The farm is geographically located at 12° 32' 57.2" north latitude and 16° 16' 37.3" west longitude (Fig. 1). This farm is located in an area characterized by average rainfall between 1300 and 1500 mm per year (Ndiaye et al., 2018). The Ziguinchor region is characterized by a South Sudanese coastal climate (Sagna, 2005). Relative humidity influenced by the Harmattan is low in January, February, and March. It is characterized by the existence of two seasons: a dry season from November to May and a rainy season from June to October (Ndiaye et al., 2020).

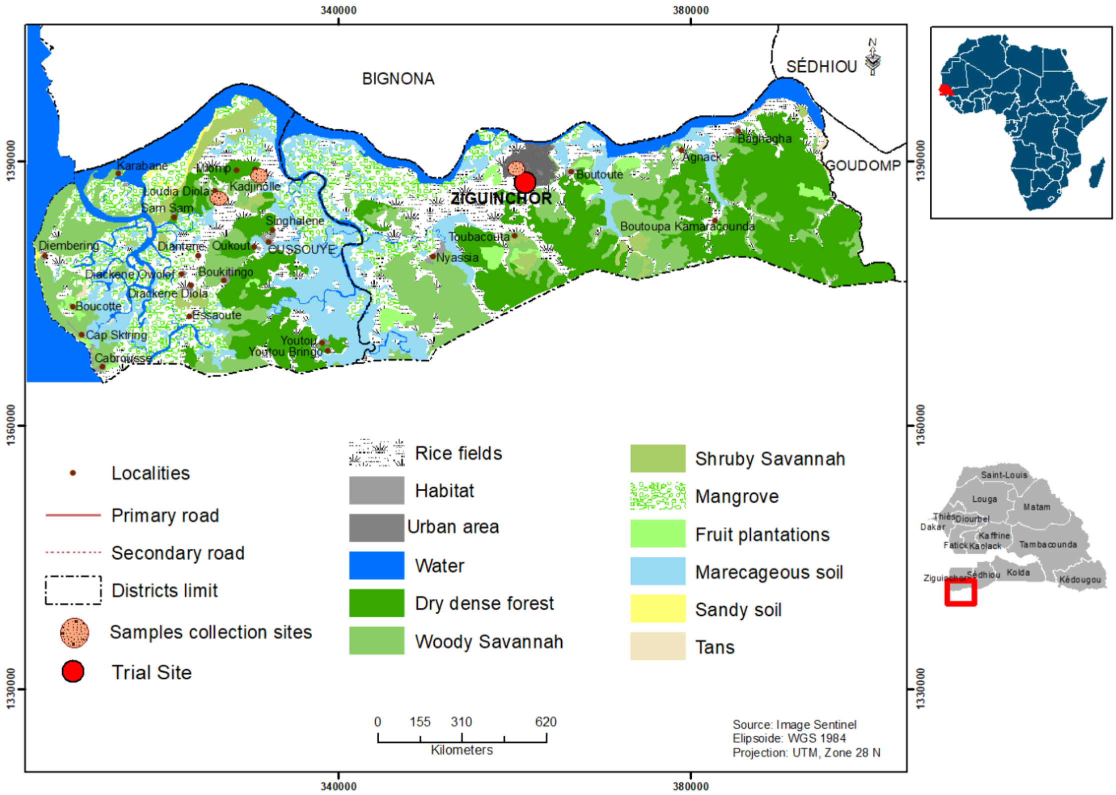

Fig. 1. Localization of trial and collected samples

Vegetal material and collection

Seeds of green *C. sativus*, white *C. sativus*, and bitter and non-bitter *C. metuliferus* were collected at the market of Ziguinchor, Kadjinolle and Loudia Diola, respectively (Fig. 1). The collection sites were located in Ziguinchor and Oussouye districts (Ziguinchor Province). Seeds of white *C. sativus* and bitter and non-bitter *C. metuliferus* were extracted from mature fruits (Fig. 2) and air-dried. The dried seed was stocked in envelopes at the laboratory Department of Agroforestry, Assane Seck University of Ziguinchor.

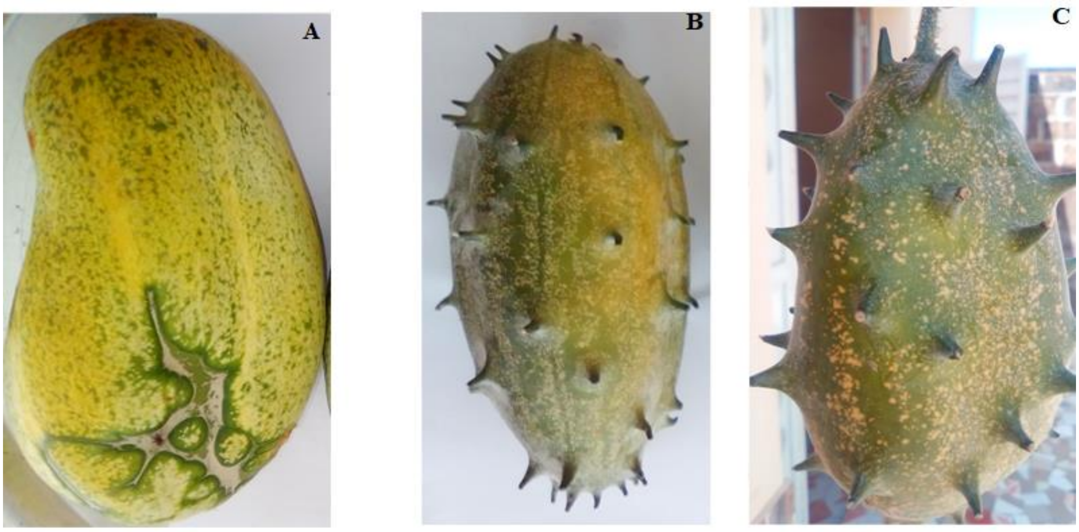

Fig. 2. Mature fruits of white *C. sativus* (A), bitter (B), and non-bitter (C) *C. metuliferus*.

Fig. 3. Plant trellising

Experimental design and treatment

The experimental design adopted was a complete randomized block with four replicates, each replicate was a block. The blocks were divided into four plots of 4 m^2. Within each plot, 16 pots of 314 cm^2 were dug. Each pot was filled with a substrate consisting of a mixture of 2/3 peanut manure and 1/3 sand. Six seeds were sown in each pit. A thinning was done 15 days after sowing (DAS) to leave one plant per pit. Weed control was done regularly during the first two months. In addition, trellising was carried out as soon as the first branching of the plant appeared to promote vertical growth and better fruit quality (Fig. 3). The only factor studied was the variety composed of four levels (green and white *C. sativus*, bitter and non-bitter *C. metuliferus*).

Data collection

Germination, growth parameters, chlorophyll content, 50% flowering days, and yield parameters were measured per plot.

Germination

Germination of seeds was recorded daily over 14 days after sowing. A seed is considered to have germinated when the cotyledons separate to allow the radicle to emerge (Diallo, 2002). The number of emerged seeds was counted and the plumule emergence was considered to determine the germination rate. The germination rate (1) was calculated per variety. The following parameters were calculated from the various data collected:

$$Germination\ rate = \frac{Number of germinated seeds}{Total number of seeds} \times 100 \quad (1)$$

Growth parameters

For growth parameters, five plants were randomly selected from each plot to measure the diameter, height, branching, and number and size of leaves 30 days after sowing (DAS). Diameter and height were measured with a calliper and centimeter respectively.

Chlorophyll content

Five plants randomly selected from each plot were used to determine leaf chlorophyll content using the SPAD-502 plus. Measurements were taken in two-day time (early morning and noon). On each plant, three leaves according to the stage of development (young, medium, and old) were randomly selected to measure the chlorophyll content.

Yield parameters

The fruits were harvested at the stage of physiological maturity. The fruits were measured to determine their size (length and circumference) and mass. The size of the fruits was determined with a decameter and their mass with a digital scale.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) performed with R 4.1.3 software (Team, 2015) to determine the main and interaction effects of studied variables. When variations were significant, Tukey's test was used for multiple mean comparisons to detect the significant differences between the characteristics (varieties, daytime, and stages of leaf development). Statistical significance was fixed at 0.05. Considering the agro-morphological parameters of varieties, daytime, and stages of leaf development, all data are hence expressed as overall means ± SD. Clustering and principal components analyses were done to study the relationships between agro-morphological parameters and varieties.

RESULTS

Growth parameters

There is a significant difference ($p \leq 0.05$) between varieties in terms of growth parameters (germination, plant height, and fruit diameter, number of leaves, and ramification and leaf size). The germination rate varied between 68±2% and 96±2%. The analysis showed that the germination rate varied significantly (p=5.24e-06) between varieties. The higher germination was recorded in white *C. sativus* (96±2%) followed by green *C. sativus* (86±4%). Lower germination was noticed in bitter and non-bitter *C. metuliferus* with 74±2 and 68±2% respectively (Table 1). Plant height and diameter varied significantly between cucumber varieties. Plant height varied from 30.15±10.33 and 71.25±14.20 cm for non-bitter *C. metuliferus* and green *C. sativus*. While the diameter ranged from 3.4±0.50 to 7.85±1.22 mm for bitter *C. metuliferus* and white *C. sativus* respectively (Table 1). There was a significant difference among the varieties in the number of ramifications and leaves. Non-bitter (5.35±0.99) and bitter *C. metuliferus* (5.15±0.93) produced the highest number of ramifications than white (2.8±0.69) and green *C. sativus* (2.25±0.63). While, white *C. sativus*, bitter, and non-bitter *C. metuliferus* produced significantly more leaves than green *C. sativus* (Fig. 4).

Analysis of the leaf size (length and width) showed a significant difference between varieties (Figure 5). Domesticated varieties, with leaf lengths varying between 11.77±0.95 and 12.62±1.07 cm, had longer leaves than wild varieties. Green (17.97±1.73 cm) and white *C. sativus* (16.65±0.81) recorded larger leaves than bitter (10.02±1.19 cm) and non-bitter *C. metuliferus* (9.92±1.45 cm).

Table 1. Variation of quantitative traits of cucumber varieties according to cucumber varieties

Varieties	Germination rate (%)	Height (cm)	Diameter (mm)	50% Flowering days	Chlorophyll content (SPAD value)	Fruit weight (g)
Bitter *C. metuliferus*	74±2[a]	38.3±8.20[a]	3.4±0.50[a]	61.5±1.91[a]	39.48±3.77[ab]	150.5±21.14[a]
Green *C. sativus*	86±4[b]	71.25±14.20[b]	7.15±1.04[b]	29.75±0.5[b]	46.91±10.04[c]	324.5±56.96[b]
Non-bitter *C. metuliferus*	68±2[a]	30.15±10.33[a]	3.55±1.14[a]	57±1.82[c]	36.33±2.77[b]	99.75±8.95[c]
White C. sativus	96±2[c]	54.5±11.56[c]	7.85±1.22[b]	45±2.58[d]	43.06±7.24[ac]	468.25±99.28[d]
P value	5.24e-06	<2e-16	<2e-16	6.93e-11	0.0007	<2e-16

Results are expressed as mean ± SD, letters a, b, c, and dare groups (groups with different letters are significantly different).

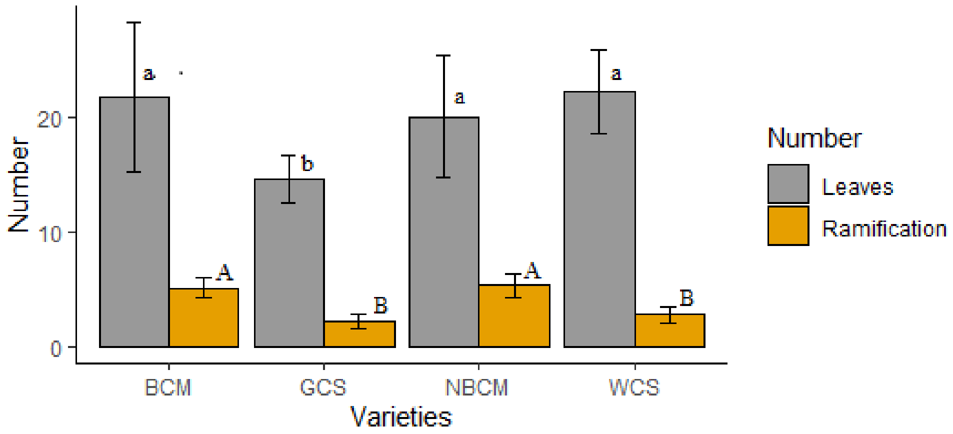

Fig. 4. Variation in the number of leaves and ramifications of cucumber varieties. BCM = Bitter *C. metuliferus*; NBCM=Non-bitter *C. metuliferus*; WCS=White *C. sativus*; GCS=Green *C. sativus*; Values are means ± SD; significant differences are indicated with different letters.

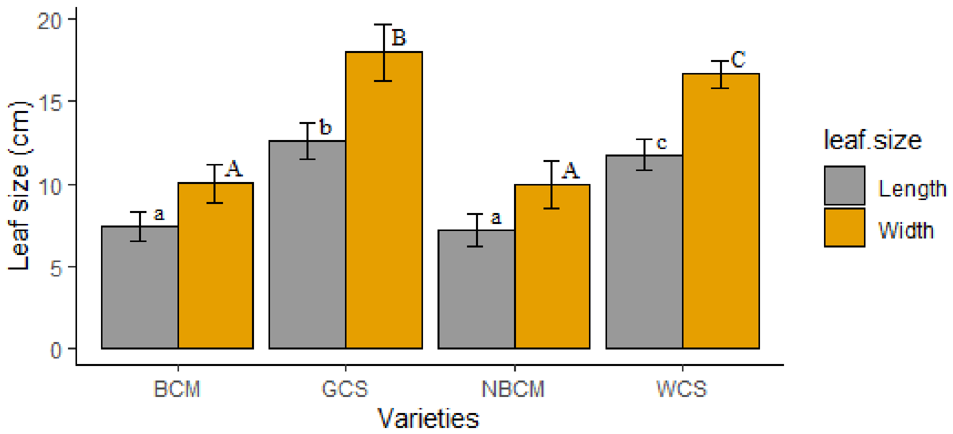

Fig. 5. Variation in leaf size of cucumber varieties. BCM = Bitter *C. metuliferus*; NBCM=Non-bitter *C. metuliferus*; WCS=White C. *sativus*; GCS=Green *C. sativus*; Values are means ± SD; significant differences are indicated with different letters.

50% Flowering days

The date of 50% flowering varied between 30 and 62 days. The varieties influenced significantly the date of 50% of flowering. The earlier flowering varieties were Green and white *C. sativus* with 29.75±0.5 and 45±2.58 days respectively. While non-bitter and bitter *C. metuliferus* were recorded as late flowering with 57±1.82 and 61.5±1.91 days respectively (Table 1).

Chlorophyll content

Varieties, daytime, and stage of development influenced significantly chlorophyll of cucumber leaves, chlorophyll content was higher in green (46.91±10.04 SPAD value) and white *C. sativus* (43.06±7.24 SPAD value) than in bitter (39.48±3.77 SPAD value). The highest chlorophyll content was observed at noon (44.76±9.45 SPAD value) which contained significantly higher chlorophyll than morning (38.14±2.15 SPAD value). The chlorophyll content increased with daytime (Fig. 6). Chlorophyll content was higher in old leaves than in medium and young leaves (Fig. 7). Chlorophyll content recorded in old, medium, and young leaves were 44.49±7.09, 41.11±6.38, and 38.74± 4.72 SPAD values respectively.

Yield parameters

The analysis of yield parameters showed significant differences between varieties. Fruit characteristics were significantly higher in white and green *C. sativus* than in bitter and non-bitter *C. metuliferus* (Fig. 8). The longer fruit was recorded in green (18.95±0.84 cm) and white *C. sativus* (17.05±1.35 cm) than bitter (11.2±0.89 cm) and non-bitter *C. metuliferus* (9.05±0.69 cm). The higher fruit circumference was observed in white *C. Sativus* (23.85±2.99 cm) followed by green *C. sativus* (17.77±1.40 cm), bitter (17.6±0.94 cm), and non-bitter *C. metuliferus* (16.25±0.71 cm). Fruit weight varied significantly between 99.75±8.95 and 468.25±99.28 g (Table 1). The fruit weight of white and green *C. metuliferus*, bitter and non-bitter were 468.25±99.28, 324.5±56.96, 150.5±21.14 and 99.75±8.95 g respectively.

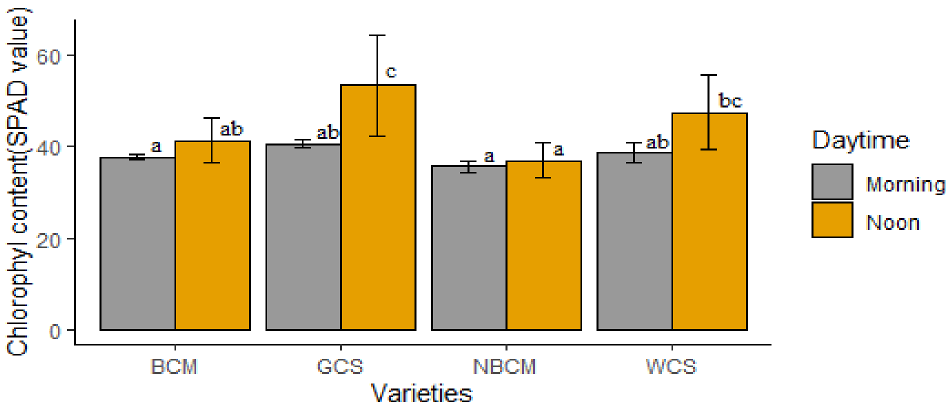

Fig. 6. Variation in chlorophyll content of cucumber leaves according to daytime. BCM = Bitter *C. metuliferus*; NBCM=Non-bitter *C. metuliferus*; WCS=White *C. sativus*; GCS=Green *C. sativus*; Values are means ± SD; significant differences are indicated with different letters.

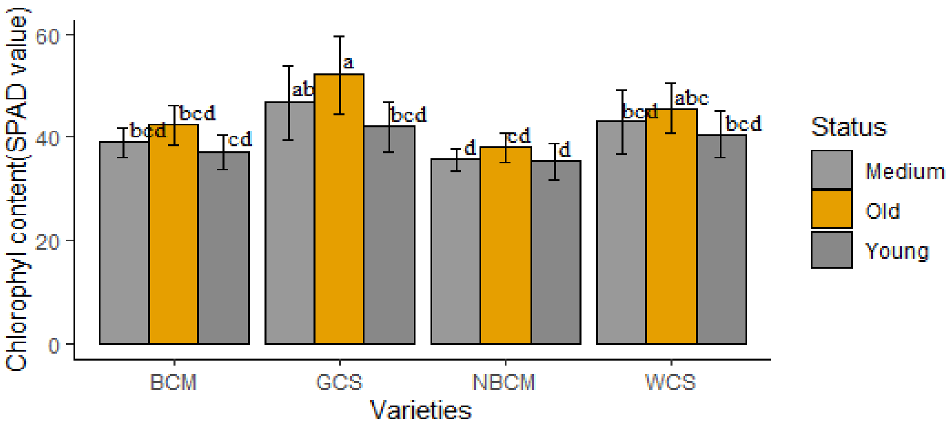

Fig. 7. Variation in chlorophyll content of cucumber leaves according to stages of leaf development. BCM = Bitter *C. metuliferus*; NBCM=Non-bitter *C. metuliferus*; WCS=White *C. sativus*; GCS=Green *C. sativus*; Values are means ± SD; significant differences are indicated with different letters.

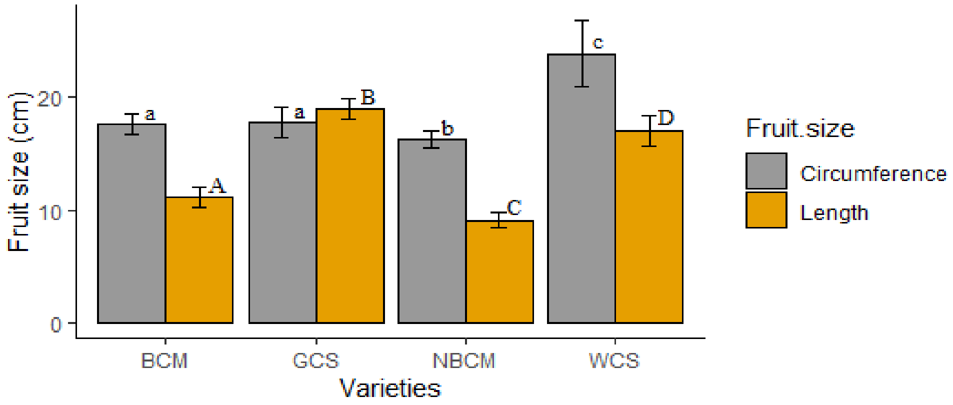

Fig. 8. Variation in fruit size of cucumber varieties. BCM = Bitter *C. metuliferus*; NBCM=Non-bitter *C. metuliferus*; WCS=White *C. sativus*; GCS=Green *C. sativus*; Values are means ± SD; significant differences are indicated with different letters.

Relationship between agro-morphological parameters and varieties

Clustering analysis showed a significant variation and separated varieties of cucumber into two clusters or groups (Fig. 9). The first group is composed of varieties of *C. metuliferus* (bitter and non-bitter) and is characterized by a high number of leaves and ramifications, late flowering, and low yield. The second group is constituted of varieties of *C. Sativus* (Green and White) and is characterized by a better performance of germination, height and diameter growth, leaf and fruit size, chlorophyll content, and yield parameters. The PCA showed significant correlations between several pairs of variables. Indeed, there was a positive correlation between the number of branches and leaves. There was also a strong correlation between the leaf size and the chlorophyll content as well as the fruit size and weight (Fig. 10).

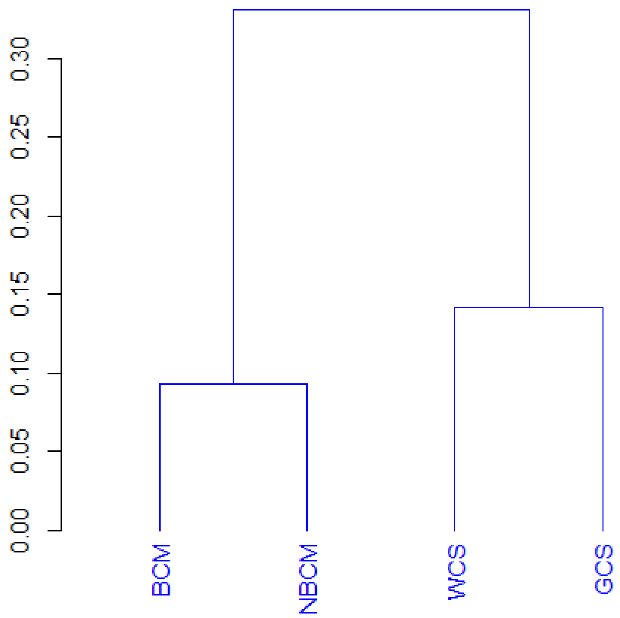

Fig. 9. Cluster dendrogram of agro morphological parameters between varieties.BCM = Bitter *C. metuliferus*; NBCM=Non-bitter *C. metuliferus*; WCS=White *C. sativus*; GCS=Green *C. sativus*.

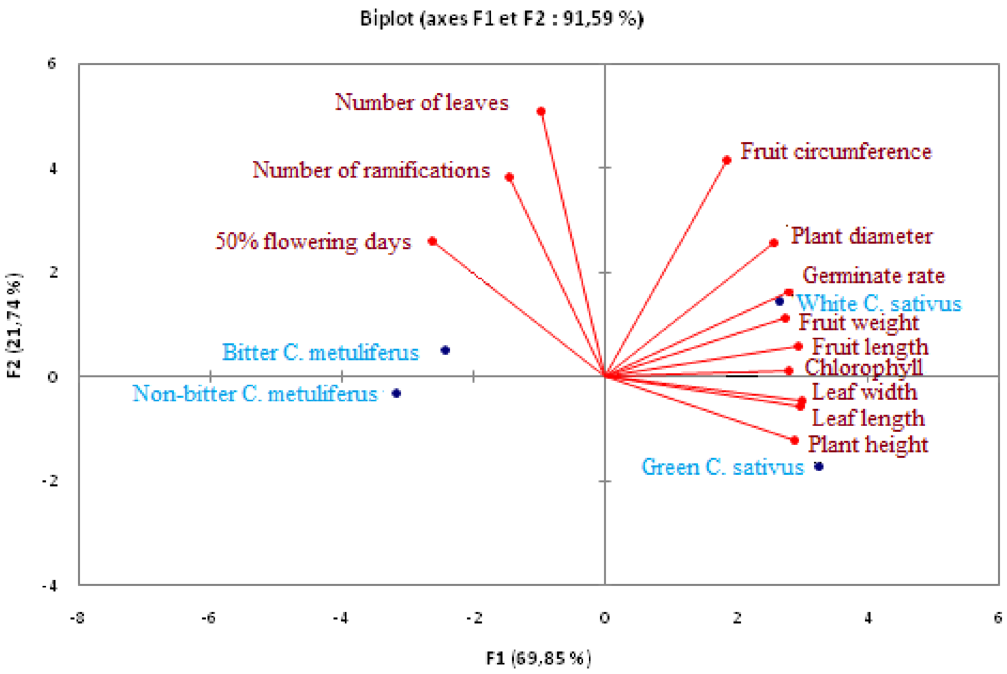

Fig. 10. Relationship between agro morphological parameters and varieties

DISCUSSION

Growth parameters

Growth parameters (germination, plant height, and diameter, number of leaves and ramification, and leaf size) varied significantly between varieties of cucumber. A high germination rate ranging from 68 to 96% was recorded from cucumber varieties. The domesticated cucumber varieties (white and green *C. sativus*) had higher germination than wild cucumber varieties (bitter and non-bitter *C. metuliferus*). The germination rate of different accessions of *C. metuliferus* varied from 54.33 to 100% (Owino et al., 2020; Aliero & Gumi, 2012). Seed germination of *C. sativus* varied between 61 and 87.67% (Kumar et al., 2013). For plant height and diameter and leaf size, the domesticated cucumber varieties performed better than the wild cucumber. While wild cucumbers produced more leaves and ramifications than domesticated cucumbers. Indeed, according to Lieven and Wagner (2013), early varieties produced less branching than late varieties. The agro-morphological traits studied for two varieties of *Cucumis sativus* had significant differences. These results confirmed those of Nieuwenhuis and Nieuwelink (2005), who stated that late varieties produced more leaves in contrast to early varieties which were not very productive in terms of leaves. The number of leaves varied between 15 and 25 according to the varieties of C. Sativus (Ullah et al., 2012) and branches ranked between 6.2 and 9.2 (Agashi et al., 2019). For *C. metuliferus,* the number of branches per plant varied between 13.75 and 16.58 according to the accessions (Owino et al., 2020).

Flowering

The results showed strong variation between varieties in terms of 50% flowering days. Two groups were noticed based on early (*C. sativus*) and late flowering (*C. metuliferus*). These results were similar to those obtained by Bouzini (2019) who showed those flowering days depended on the interaction of several complex processes that were influenced by genetic and/or environmental factors. Flowering days for the varieties of C. Sativus varied between 23.2 and 45 days (Nwofia et al., 2015; Ullah et al., 2012; Agashi et al., 2019). Owino et al. (2020) reported that the flowering from 59 to 75 days for the varieties of *C. metuliferus*.

Chlorophyll content

The leaf chlorophyll content as SPAD value has strong variation and showed significant differences between varieties. The amounts of chlorophyll in leaves can be influenced by many factors such as leaf age, and leaf position, and environmental factors such as light, temperature, and water availability (Hikosaka et al., 2006). A study of chlorophyll content on three Tunisian *C. tinctorius* provenances showed no significant variation with cultivars (Abdallah et al., 2013). The chlorophyll content increased from morning to noon. The higher values were recorded at noon compared to the morning. The maximum and minimum values in the Chlorophyll content of *Triticum aestivum* leaves were reached in the early morning and early afternoon respectively (Busheva et al., 1991). While, Martínez and Guiamet (2004) found no significant difference in extractable Chlorophyll content between *Triticum aestivum* leaves taken at midmorning and in the early afternoon, but SPAD values increased in the afternoon varying between 23.7±0.5 and 25.6±0.6 SPAD value. The results showed significant variation in chlorophyll content according to the development status of leaves. The old leaves contained significantly more chlorophyll content (44.49±7.09 SPAD value) than the medium (41.11±6.38 SPAD value) and young leaves (38.74±4.72 SPAD value). The highest chlorophyll content was observed in the young leaves of *Clinacanthus nutans* which contained 72% higher chlorophyll than matured leaves (Raya et al., 2015). Chlorophyll content in juvenile leaves of *Eucalyptus globulus* young trees ranged from 21 to 54 mg cm^2 while in adult leaves of mature trees, the range was 25–103 mg cm^2 (Barry et al., 2009). Total chlorophyll per unit leaf of both immature and mature leaves of *Trifolium subterraneum* did not significantly differ (Cave et al., 1981).

Yield parameters

Yield parameters varied significantly between varieties. The higher performance of fruit size and weight was recorded in green and white *C. sativus*. There were significant differences in fruit length for different varieties of *C. sativus* varying between 9.26 and 20.33 Cm, while fruit weight ranged from 82.33 to 270 g (Nwofia et al., 2015; Ullah et al., 2012). For *C. metuliferus*, the fruit length and weight ranged from 7 to 12 Cm (Marsh, 1993) and 194.67 to 259.33 g respectively (Owino et al., 2020). The fruit size and weight of cucumber are important quality traits for market, value, and preference of consumer expectations, government, and industry. Therefore, the size and weight of cucumber are baseline criteria for the development of improved cultivars or varieties.

Relationship between agro-morphological parameters and varieties

The analysis indicated that the association of quantitative and qualitative variables was due to their direct and indirect effects on some other traits. The study indicated the degree of the interrelationship of plant characters for improvement of yield as well as important quality parameters in any breeding of cucumber. Based on the relationship between agro morphological parameters, there was a strong correlation. Correlations were found between the number of leaves and ramification, leaf size and chlorophyll content, and fruit size and weight. The linear relationship between fruit characters and yield per plant suggests that the selection method of crop improvement should mainly be focused on fruit characteristics. Similar results have been reported for the number of fruits per plant and fruit length

(Arunkumar et al., 2011; Hanchinamani, 2006). Fruit size and shape result from a complex interplay of physiological processes during ovary and fruit growth (Gillaspy et al., 1993; Tanksley, 2004).

CONCLUSION

The results showed great variability between the varieties studied for all the morphological, phenological, physiological, and yield characteristics. Moreover, green *C. sativus* was distinguished from the other varieties by rapid vegetative growth accompanied by high chlorophyll content and early production. Nevertheless, in terms of fruit weight and circumference, and germination rate, white *C. sativus* recorded the best results. Thus, the two wild cucumber varieties recorded relatively weak results on all the parameters except in terms of branching and foliage. The agro morphological traits are necessary to encourage rational management and provide good scope for improvement in yield and other characteristics of cucumber through selection.

Conflict of interest

The authors have no conflict of interest to report.

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