SVU-International Journal of Agricultural Sciences
Volume 4 Issue (1) pp.: 194-210, 2022
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/svuijas.2022.114828.1169

RESEARCH ARTICLE

Biodiversity in cucurbit landraces as potential nutrition sources and *Meloidogyne incognita* resistance

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Abstract

Bottle gourd, bitter gourd, sponge gourd, and snake melon are members of four separate genera in the *Cucurbitaceae* family, which add to a diverse variety of food sources as well as disease resistance. This research was performed out through six seasons. According to the homogeneity test, six inbred lines of bottle gourd and three inbred lines of bitter gourd, sponge gourd, and snake melon were created after five self-breeding generations. The most significant values for the most horticultural computed traits were discovered in inbred lines (BO- 6 and BO- 2), (Bit- 2), (Sp- 1 and Sp- 3), and (SN 2 and SN 3) from the aforementioned crops, respectively. Inbred lines (BO- 6), (Bit- 1), (Sp- 1), and (SN 2) exhibit the lowest *Meloidogyne incognita* infection values for bottle gourd, bitter gourd, sponge gourd, and snake melon. When compared to other genotypes, the bitter gourd inbred line, Bit-1 demonstrated the most significant reduction in all nematode parameters.

Keywords: Biodiversity, Cucurbitaceae, Horticulture, Nematodes, Resistance.

1. Introduction

Biodiversity conservation is a sufficient guarantee for carefully maintaining environmental balance. Agricultural crop biodiversity benefits several themes, the most important of which is food security by providing new food sources. Second, because of the potential benefits of those potential sources of climate adaptation and tolerance of its deviations, this local biodiversity could typically contribute to breeding and genetic improvement programs. It also serves as a source of resistance to pests and diseases. Thus, biodiversity is one of the defenders of sustainable agricultural development (Elia and Santamaria, 2013).

Cucurbitaceae is the second-largest vegetable family, with approximately 120 genera and 960 recognized species, and is found primarily in tropical and subtropical regions (Bhowmick and Jha, 2015; Schaefer and Renner, 2011). Plant biodiversity could be a treasure trove of genetic improvement for plant breeders, as these varieties are distinguished by their ability to resist and tolerate adverse biotic and abiotic conditions. Cucurbits, which traditionally include gourds, melons, squashes, pumpkin, cucumbers, and a variety of other genera, are economically exploited for food, medicine, and domestic purposes. Genetic diversity within and between species and populations is critical for increasing the efficiency of a breeding program, crop improvement, ecological conservation, and sustainable management.

The genus *Lagenaria* includes the bottle gourd (*Lagenaria siceraria* M) (Beevy and Kuriachan, 1996). *Lagenaria siceraria* is typically grown for its young fruits, which are commonly consumed as a fresh fruit in Africa and Asia (Sari *et al.*, 2008). Tas *et al.* (2019)

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Received: January 5, 2022; Accepted: March 21, 2022; Published online: March 22, 2022.

evaluated *Lagenaria siceraria* genotypes by self-breeding, accurately representing the economic diversity of the entire country. The fruits of bitter Gourd (*Momordica balsamina*) are high in beta-carotene, vitamin C, folic acid, magnesium, phosphorus, and potassium content (Dhillon *et al.,* 2017; Yuwai *et al.*, 1991).

Sponge gourd, *Luffa aegyptiaca* belongs to the *Luffa* genus. Commonly known as sponge gourd, bath sponge, and dishcloth gourd (Joshi *et al.,* 2013.). The immature fruits may have morphological differences based on the cultivar, which had a high content of vitamin C and iron, and commonly used in soups. Mature fruits are bitter and inedible, but are accurately reported to be popularly used for medicinal purposes. Pootakham *et al.* (2021) *Luffa* spp. is an economically important vegetable crop widely cultivated in China, India, and Southeast Asia. Whitaker and Davis (1962) reported that Indo-Burma was the cultural center of sponge gourd diversity, and it typically reached the Mediterranean by the third century for practical use as nutritious food. The unripe, tender fruits are consumed as cooked vegetables. The mature, fibrous endocarp can be used as a sponge or loofah scrubbing sponge, and is popular with consumers in the United States, Japan, and Asia (Avital and Paris, 2014).

Snake melon, *Cucumis melo* var. *flexuosus* L. has largely been distributed and consumed since antiquity across large geographical regions (Pandey *et al.,* 2010). Snake melon fruits are generally consumed at the immature stage of ripening, with a preference for straight, long, and thick green fruits. Snake melon genotypes differ in various productivity driving and quality traits including early marketable and total yield, numbers of fruits per vine, and resistance to main pest diseases (Pandey *et al.,* 2010). Akash *et al.* (2020), Ilahy *et al.* (2020), Pandey *et al.* (2010) and Stepansky *et al.* (1999) observed genetic diversity among snake melon (*Cucumis melo* var. *flexuosus*) landraces. The genetic variations among snake melon landraces in common are the important population sources for snake melon breeders to select promising genotypes to be employed in further snake melon breeding programs. Dhillon *et al.* (2017) typically report that bitter gourd, bottle gourd, wax gourd, snake gourd, sponge gourd, and ridge gourd are planted to provide significant dietary nutrients like vitamin A and C, iron, and calcium. Responsible breeders properly recycle the genetic materials to derive inbred lines for hybrids' development.

Root-knot nematodes (RKN), *Meloidogyne* spp., are the most common pathogens owing to their extensive distribution, potential for harm, and economic relevance (Kheraba *et al.,* 2015; El-Remaly, 2016). Cucurbits are extremely vulnerable to root-knot nematodes and usually incur economic losses. Cucurbit yield losses of up to 30% have been correctly recorded (Krishnaveni and Subramanian, 2005; Westerdahl and Becker, 2011).

Effective management of root-knot nematodes has typically used nematicide, which is the most effective way of controlling root-knot nematodes, but it clearly has negative health implications for farmers and consumers. As a result, eco-friendly alternatives to sustainable agriculture are required. Because of their efficacy, safety, sustainability, durability, and economy in controlling root-knot nematode, resistant cultivars remain the preferred choice in integrated nematode management (Ayala-Doas *et al.*, 2020). Tas *et al*. (2019), Uygur and Yetisir (2009) and Yetisir and Sari (2003) found that *L. siceraria* was properly employed as a rootstock to withstand various biotic and abiotic stress factors. *Luffa cylindrica* and *Momordica charantia* var. *muricata* are somewhat resistant to the root-knot nematode (Tamilselvi *et al.,* 2016). *Momordica balsamina* and *Momordica charantia* were shown to have a resistant response to the root-knot nematode, *M. incognita*, and might be used as an alternative crop in areas with high nematode populations (Galatti *et al.,* 2013; Pofu *et al.,* 2015; Sharma *et al.,* 2019).

Inbreeding programs are the best technique for creating promising inbred lines. Cucurbit breeders' key aims should be economic output, fruit quality, tolerance, or resistance to biotic and abiotic stressors (Whitaker and Davis, 1962; Loy 2004).

The research aims are carefully separated into two sectors, one of which is a self-breeding and selection program for four non-traditional cucurbit crops to generate horticultural promising and resistant inbred lines for *M. incognita*. The other is properly analyzing these inbred lines for their horticultural benefits and resistance to root-knot nematode, *M. incognita*, in order to extend their successful cultivation in highly infested soil directly or as rootstocks.

2. Material and methods

The trials were conducted for six consecutive seasons through 2018, 2019, 2020, and 2021 in an infested open field with *M. incognita* in the Abou-Ghaleb region, Giza governorate. Landraces of four different Cucurbitaceae crops, i.e., bottle gourd (*Lagenaria siceraria*), bitter gourd (*Momordica balsamina*), sponge gourd (*Luffa aegyptiaca*), and snake melon (*Cucumis melo* var. *flexuosus* L), were self-pollinated for five successive generations, with proper selection for essential horticultural features and nematode resistance.

2.1. Homogeneity estimation

The inbreeding program was started by sowing seeds of landraces of the four cucurbit crops mentioned above that had been collected from various regions of Egypt. Five successive seasons were conducted on the Aug. 22, 2018, Feb.18, 2019, Sept. 4, 2019, Feb. 20, 2020, and Aug. 28, 2020. All populations underwent manual self-pollination (S0-S4). Typically, 150 cultivated plants of each landrace were grown. Individual plants with the most desirable horticultural characteristics and resistance to *M. incognita* were carefully selected over a five-year period from S_0 to S_4, with seeds collected separately from the selected plants. In March 2021, populations of selected inbred lines were sown to determine the coefficient of variation (C.V. %) for the most commercial traits, total yield (kg), and gall numbers. The degree of homogeneity among these genotypes was determined using the coefficient of variation, defined as the standard deviation of experimental error divided by the trial mean. In late summer 2021, the genotypes were evaluated for several vegetative, fruit, yield, and nematode resistance parameters in open field conditions.

2.2. Horticultural evaluation

Seedlings of the six-bottle gourd inbred lines were transplanted to the open field on the 1st march on 1.5 m wide raised beds with plant to plant spacing of 1 m. However, seedlings of both bitter gourd and Snake melon inbred lines were transplanted on 1 m wide raised beds with a plant to plant spacing of 0.5 m, whereas seedlings of Sponge gourd three inbred lines were cultured with 1.5 m between plants and 2 m in width. Plants were irrigated, fertilized, and protected against diseases and pests according to normal horticultural techniques. The five central plants of each entry were utilized for taking the parameter values.

The horticultural traits (vegetative, fruits, and yield attributes) were determined:

Vegetative growth: plant length (m).

Fruit characteristics: Fruit length (cm) and fruit weight(g).

The yield components: the total weight and number of harvested fruits /plants.

2.3. Nematode resistance evaluation

The initial population density within the infested field was estimated by modified sieving and Bearman's plate technique on 250 g soil samples randomly taken (Viglierchio and Schmitt, 1983). The reproduction factor was estimated as a formula:

$$\text{Reproduction factor (RF\%)} = \frac{\text{FP (final population)}}{\text{IP(initial population)}}$$

At the end of the season, inbred lines plants were uprooted; their roots were washed by tap water and stained with acid fuchsine (Franklin and Goodey, 1959). Root gall index (RGI), number of galls, egg masses, and eggs/ root system were recorded on the stained roots. RGI was calculated using the (0-100%) scale suggested by Barker et al., (1986) where 0= immune; 1-10%= highly resistant; 11-20% = moderately resistant; 21-40% = slightly resistant; >40% = susceptible. Root galling, egg-masses and eggs numbers were used as an indicator of the resistance degree for the inbred lines.

2.4. Experimental design

Experimental design and statistical analysis were performed in a complete block randomized design with three replicates. Data were subjected to analysis of variance according Gomez and Gomez, (1984). Treatment means were compared using the least significant difference test (LSD) at a 0.05 probability level. Based on the evaluation of the horticultural and RGI% characteristics, a raw data matrix was created. A pair wise Euclidean distance matrix, the most commonly applied procedure for this kind of traits (Mohammadi and Prasanna, 2003), was analyzed by the UPGMA clustering procedure of the software NTSYS pc version 2.1 (Rohlf, 2000).

3. Results and Discussion

3.1. Homogeneity estimation

The most two effective criteria, the total yield and the number of nematode galls were evaluated through the selection program for the five successive inbreeding generations. The landraces of each the four cucurbit crops were segregated. After five selection generations, bottle gourd, bitter gourd, sponge gourd and snake melon were segregated into six, three, three, and three inbred lines, respectively. The most valuable separate plants were typically selected from each local population as a current-generation according to their optimum yield and effective resistance to root-knot nematodes, *M. incognita*. The selection program was continued thoughtfully during five seasons. The coefficient of variation (C.V %) of the S_0-S_4 populations of the selected inbred lines was accurately estimated for the most effective traits, total yield (kg), and nematodes gall numbers. The degree of homogeneity was mentioned in Fig. (1 and 2) for six bottle gourd inbred lines which are uniquely characterized by the highest yield and resistance for root-knot nematodes, *M. incognita* among all bottle gourd inbred lines. The data showed that the homogeneity was positively correlated with the inbreeding program. The coefficient variance between the population naturally began with about up to 75 % (yield and galls number of BO-6) in the S_0 generation reduced to 15% and 18% CV in yield and galls number, respectively for the devised inbred lines (S_4).

Data also, typically showed a coefficient of variance (CV%) percentages for the bitter gourd inbred lines for two constructive important characteristics numbers of galls and total yield. CV% data for S_0 generation for inbred genotypes population in all investigated characteristics were ranged from 50 to 65%. These results properly indicated high heterogeneity among the populations. As for S_1 most genotypes CV% values reached around 40-50% in this generation which refers to all genotypes still having heterogeneity. The values of CV% for S_2 generation typically ranged from 28 to 38%. The proper selection was continued to develop the S_4 generation where the values of CV% became (12%) which typically refer those inbred lines populations have high homogeneity. In the same Figures, the CV% values of sponge gourd arranged from 63 to 78% for S_0 generation while the considerable percentage of the S_4 generation reached 20% for the number of galls and total yield which referred to the homogeneous among each inbred line population. As for CV% values of snake melon, it arranged from 68 to 73% after the S_0 generation while the percentage of the latest generation represents 15% to 18% for the total yields which reached to the reduction up to 82% (CV 12 %, for SN3) for galls comparing with S_0. Moreover, the coefficient variation was around 75% in the S_0 generation which decrease to 12 % by self-breeding for five successive seasons for galls numbers which referred to the homogeneity within each inbred line population. The concerned study was typically conducted to critically evaluate four cucurbit crops segregations through the inbreeding program for carefully selecting the resistant inbred lines with good horticultural attributes. Good to mention that, inbreeding program did not affect plant vigor and yield component characters for the successive seasons which is in line with many direct results on *Cucurbita maxima* and *Cucurbita pepo* (Bushnell, 1922; Cummings and Jenkins, 1928).

3.2. Horticultural evaluation

3.2.1. Bottle gourd, Lagenaria siceraria M

With respect, the most significant characteristics, plant length, fruit length, fruit weight, fruit numbers and total yield were objectively evaluated for six bottle gourds inbred lines. BO-6 inbred line showed the highest significantly values for all five horticultural traits with no significant differences with BO-2 for plant length, fruit weight and yield as well as among all lines of bottle gourd for number of fruits (Fig. 3). In addition to, the selective inbred line BO-6 exceeds 9 meters in length, six fruits/plant, 0.70 kg average fruit weight, and 4.23 kg total yield per plant. Under naturally infestation. Regarding, horticultural evaluation for the bottle gourd selected inbred lines, significant differences were naturally noticed among inbred lines which occurred in isolation in *Cucurbita maxima* (Balkaya *et al.*, 2009), *Cucurbita pepo* (Paris, 1996), *L. siceraria* (Yetişir *et al.*, 2008.). ***Bitter gourd, Momordica balsamina***

Among the evaluated inbred lines, the inbred line (Bit-2) typically gave the highest fruit weight and fruit length which reflected on total yield followed by the inbred line (Bit-3). However, the inbred line (Bit-3) showed the highest plant length and fruit numbers (Fig. 3). These direct results proved that the total yield is typically varied between inbred lines. Significant differences were observed among the bitter gourd inbred lines for evaluated characteristics. The minimum and maximum plant lengths were 2.73 and 3.93 m for inbred lines Bit-1and Bit-3, respectively. Moreover, differences between results were shown in the number of fruits/plants which ranged from 20 to 30 in this study. Fruit length was typically ranged from 12.27 to 23.33cm. Properly regarding, the highest fruit yield per plant was (3.81 kg/plant) which indicates that the expected yield of 24 tons/feddan. As for bitter gourd, the results proved that the total yield is varied between inbred lines which are in agreement with Gupta *et al.* (2015) who found that the yield of various varieties of a single plant species varies awarding to environmental conditions and used varieties. Similar results were obtained by Valyaie *et al.* (2021) who estimated plant length variation from 3.55 to 1.75 m. Sharma *et al.* (2019) showed that the longest plant length of *M. balsamina* was (1.72 m). Besides, the plant length plays an important role to determine the appropriate distance between rows during commercial field cultivation. In contrast, many concerned studies were varied in the number of fruits/plants which ranged from 20 to 30 in this study compared with 24 to 133 by Valyaie *et al.* (2021). Fruit length was ranged according to lines (Chen *et al.*, 2012; Kang *et al.*, 2010.).

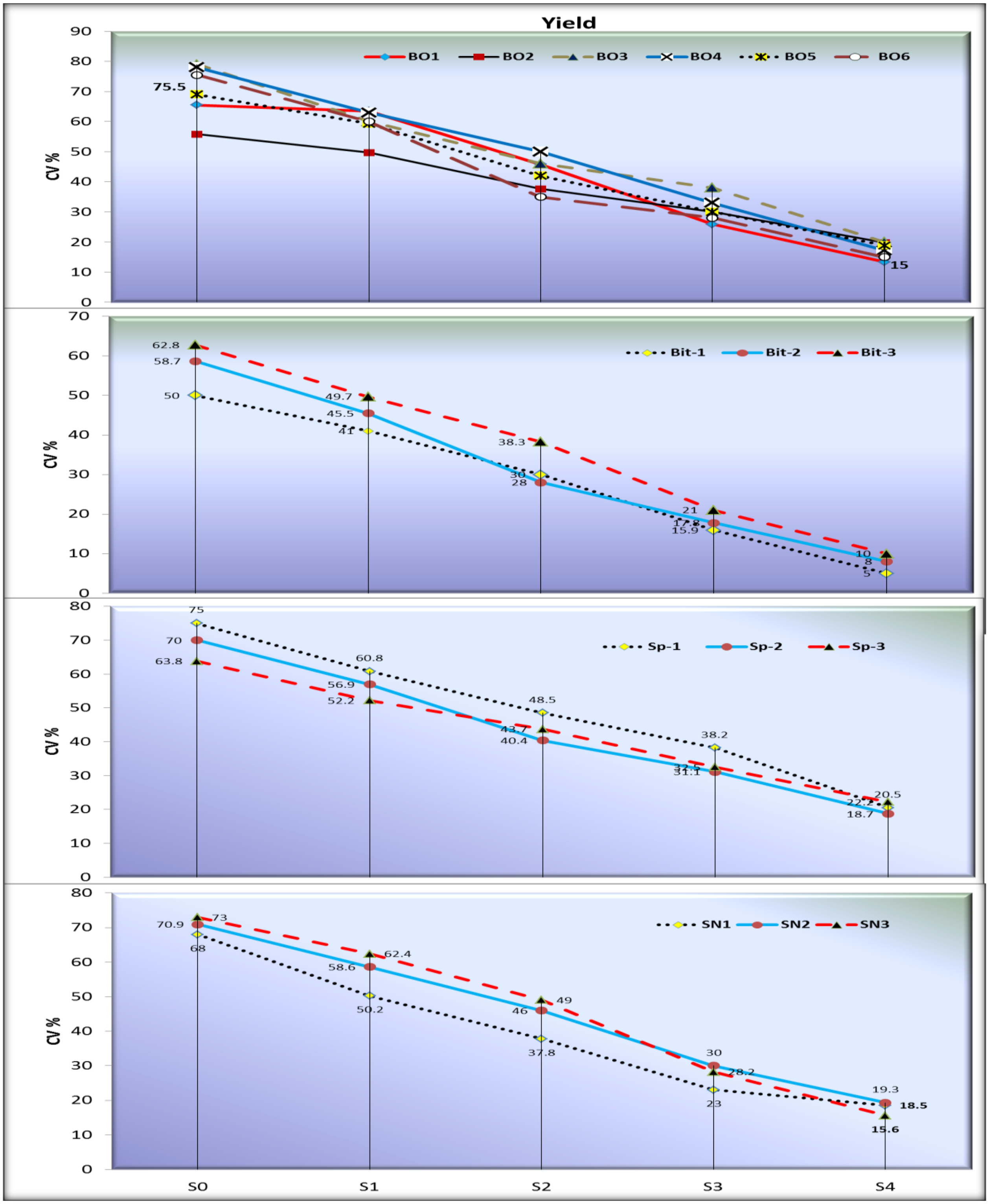

Fig 1. Development of coefficient of variance (CV%) values across five (S_0-S_4) generations of inbreeding program for total yield of six bottle gourd (BO) as well as three each of bitter gourd (Bit), sponge gourd (Sp) and snake melon (SN) inbred lines.

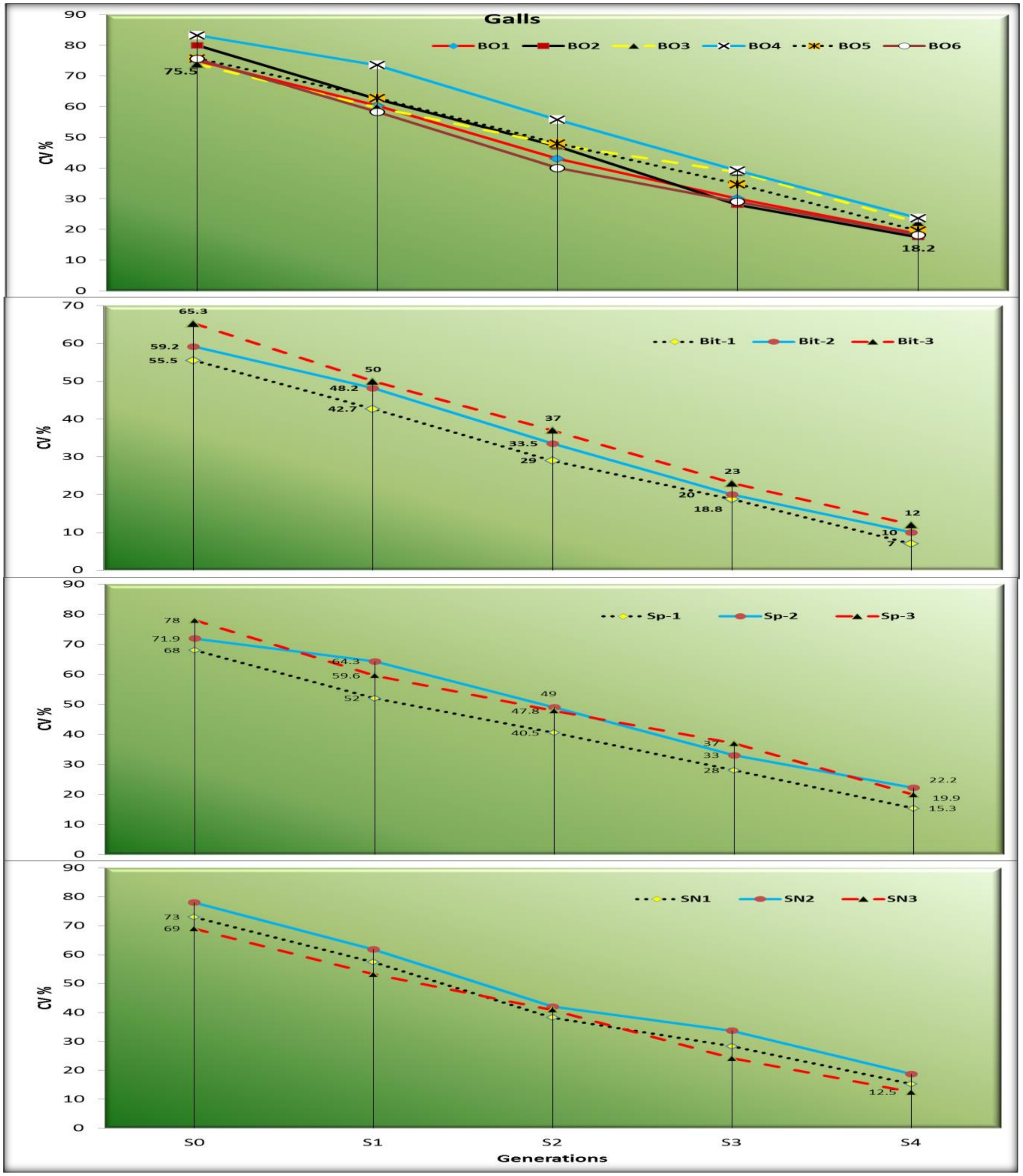

Fig 2. Development of coefficient of variance (C.V%) values across five (S_0-S_4) generations inbreeding program for galls numbers of six bottle gourd (BO) as well as three each of bitter gourd (Bit), sponge gourd (Sp) and snake melon (SN) inbred lines.

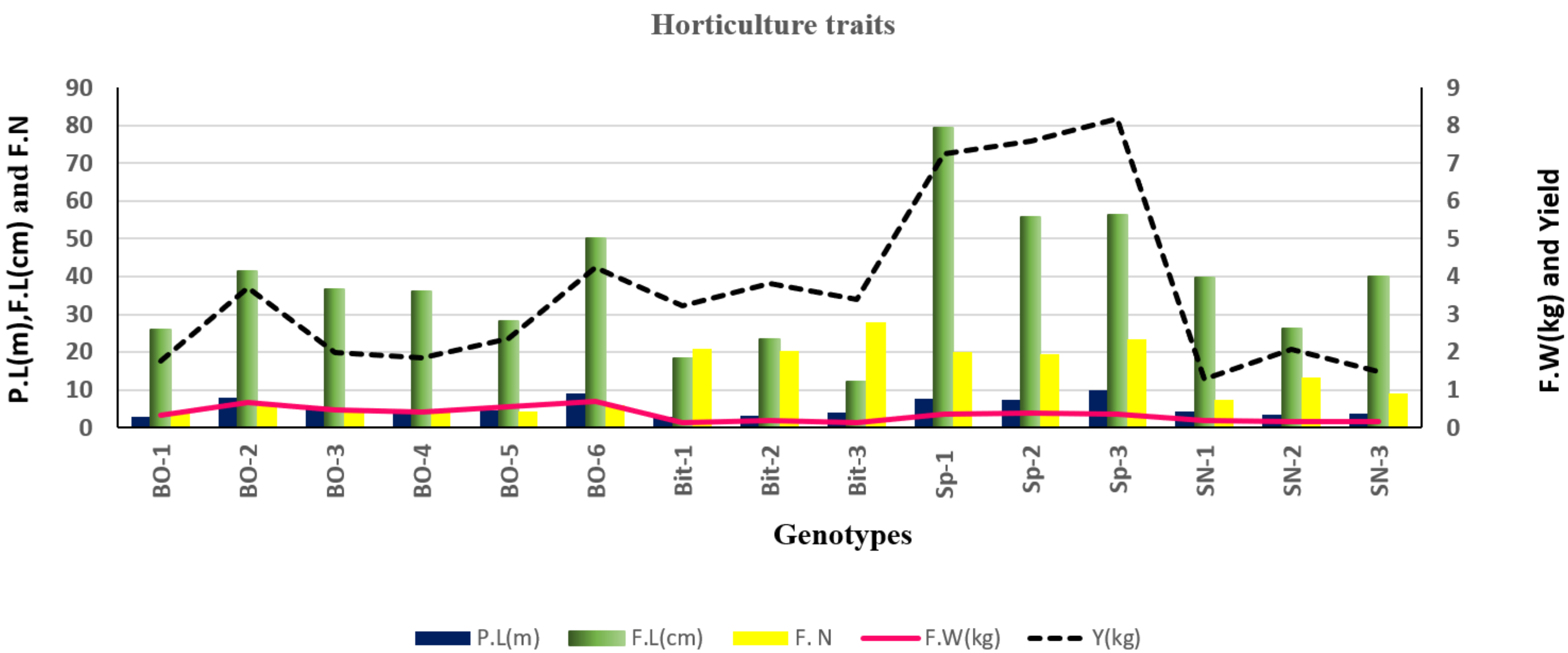

Fig 3. Horticulture traits primary axis **P.L**, Plant length (m), **F.L**, Fruit length (cm) and **F.N**, Fruit number, secondary axis **F.W**, Fruit weight(kg)and Yield(kg)) for genotypes.

There is a considerable variation between numerous researches in fruit length as 15.82–38.83 cm (Resmi and Sreelathakumary, 2012); 9.23–24.47 cm (Saranyadevi *et al.*, 2017.) and 8.78–33 cm (Tan *et al.,* 2016). The average economic yield correctly was 8000–10,000 kg/ha, but some selected cultivars may probably produce up to 20,000–40,000 kg/ha (Dey *et al*., 2006; Raman and Lau, 1996).

3.2.2. Sponge gourd, *Luffa aegyptiaca* Mill.

The total yield (Kg /plant), the number of fruits per plant, the plant length as well as the average Fruit weight and length significantly varied between inbred lines (Fig 3). Inbred line Sp-3 recorded the longest plant length, the highest fruit numbers, and the highest total yield compared with other inbred lines. On the other hand, the inbred line (Sp-1) typically exhibited the longest fruit length (cm) and the inbred line (Sp-2) typically showed the heaviest fruit weight. Good to mention that, no significant differences between all test inbred lines in fruit weight (347-390 g) and fruit number (19-23) which is accurately reflected in the total yield. As For total yield correctly was (7-8) kg/plant. The evaluation of sponge gourd inbred lines was different with Cheng *et al.* (2015) who estimated 4-25 fruit numbers/plant and 1.817kg/plant for a yield, but the results were similar in fruit weight.

3.2.3. Snake melon, *Cucumis melo L. var. flexuosus*

The tested inbred lines (SN1 and SN3) recorded the most considerable values in plant length, fruit length, and fruit weight without any significant differences for all studied traits (Fig. 3). Although in some traits there were no significant differences, the inbred line (SN2) has the greatest fruit number and the highest total yield/plant. The fruit number typically ranged from 7.3 to 13.3 and fruit length ranged from 26.17 to 39.97 cm. In addition, the direct results on snake melon inbred lines universally agreed with Pandey *et al,* (2010) who correctly estimated 15.5 and 16.7 fruits per plant and fruit length was 19.5 to 20.4 cm.

3.2.4. Resistance for root knot nematode, *Meloidogyne incognita*

Six *Lagenaria siceraria* inbred lines were carefully tested to *M. incognita* resistance (Fig.4). The inbred lines BO-6 and BO-1, typically had the lowest RF% (0.41 and 0.52, respectively). Both lines were similar for root gall indices and galls numbers, but the inbred line BO-6 exhibited the lowest egg numbers and lowest fecundity which suggests that's one amongst the possible explanations for resistance. With relevance to Bitter gourd, the three inbred lines were carefully evaluated for their resistance to *M. incognita*. The inbred line (Bit-1) accurately recorded the lowest reproduction factor (0.026), the root gall index represents 10% with 27.3 galls, 4.67 egg masses, and only 41.67 eggs with the lowest fecundity among all bitter gourd inbred lines which discuss resistance occurrence (Fig. 4). Concerning, sponge gourd inbred lines, the inbred line (Sp-1) shows the highest level for resistance consistent with the lowest values 0.36, 30, and 41.4 for reproduction factor, root gall index and gall numbers, respectively. Respecting snake melon, among the three test inbred lines, only inbred line (SN2) carefully considers the moderate resistance for *M. incognita* with RF less than 1, root gall index 40%, galls number 65.3, egg-masses 21, and 492.6 eggs/root system. The consistent finding of the nematode resistance experiments typically referred that the bitter gourd exhibited the most significant level of root-knot nematode, *M. incognita* resistance compared with the other tested cucurbits crops.

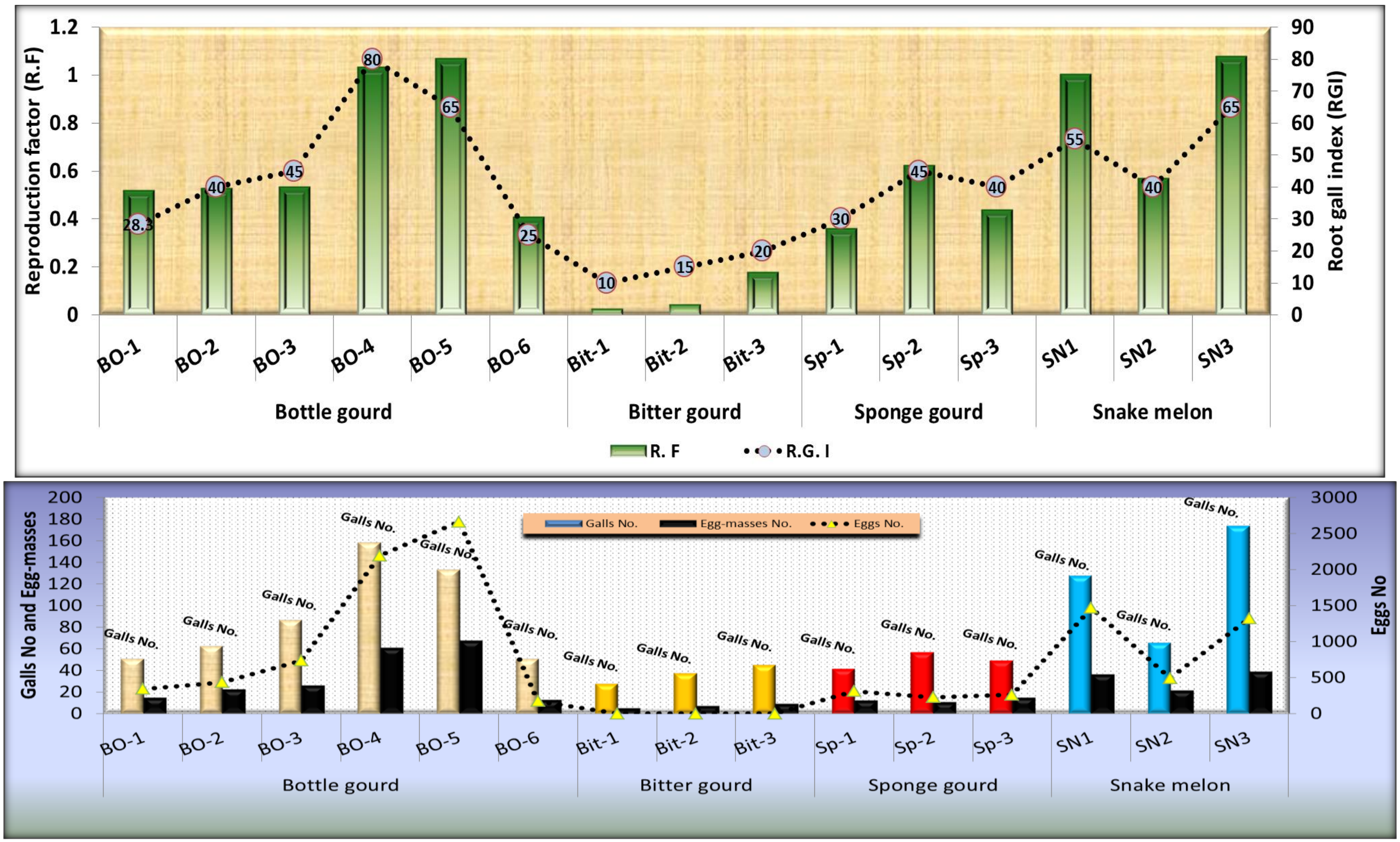

Fig 4. Values for Reproduction factor, Root gall index, Galls number/root system, Egg-masses/root system and Egg number/root system of six bottle gourd, three bitter gourd, three sponge gourd and three snake melon inbred lines.

The bitter gourd inbred line Bit-1 typically has the lowest nematode criteria values which sufficiently indicated that high resistance. *M. incognita* juveniles did not develop or accurately reproduce on *M. balsamina*; therefore, the inbred line plants were highly resistant. On the other hand, the selection of nematode-resistant inbred lines was the supreme aim of this study. The results showed that resistant and moderately resistant inbred lines were gained in some examined crops based on estimated criteria which agreed with Windham and Williams, (1988) who mention that, typically mean RF values less than one suggested that *M. incognita* failed to feed, which may be a prerequisite to development and reproduction. The objective evaluation of inbred lines referred to high resistance in *M. balsamina* to *M. incognita* race 2 (Mashela and Mphosi, 2010; Pofu *et al.*, 2015). Infection of *M. incognita* had no effect on the considerable expansion or yield of *M. balsamina*. Researchers are replete with reports on nematode inhibition of plant growth, which is distinguished by reduced biomass and yield looking at the aggressiveness of the nematode species (Sikora and Fernàndez, 2005). Host sensitivity accurately describes the affective responses of plant growth to nematode infection, which may well be either inhibition or neutral or direct stimulation (Seinhorst, 1967). In specific reference to, the foremost tolerant inbred lines for nematodes further bitter gourd are the sponge gourd inbred lines which in line with Galatti *et al.* (2013) and Tamilselvi *et al.* (2016). While among *Lagenaria siceraria* and snake melon inbred lines the extremely susceptible inbred lines typically have an RF greater than one. These direct results are positively related that, host status and host sensitivity, that essential in accurately describing the degree of nematode resistance in plants (Seinhorst, 1967). When mean RF% is bigger than one, nematode infection does not stimulate or has no effects on plant growth, the cultivated plant considers tolerant. By contrast, when the mean RF in common is less than one and infection does not result in decreased plant development, the plant becomes tolerant to the target nematode. Direct observation is very efficient due to the fact that the majority of the *Cucurbitaceae* family, namely the four economically important genera in agriculture, *Citrullus*, *Cucumis*, *Cucurbita*, and *Lagenaria*, have developed minimal resistance to *Meloidogyne* species (Montalvo and Esnard, 1994; Thomason and McKinney, 1959; Winstead and Riggs, 1959). In conclusion, *M. balsamina* is often employed as a substitute crop in areas with high *M. incognita* population densities (Pofu *et al.,* 2015). Sharma *et al.* (2019) obtained similar findings for bitter gourd, observing that *M. balsamina* accessions had the fewest galls and exhibited a resistant response. In *M. balsamina*, resistance to root-knot nematode has been properly described (Kaur and Pathak, 2011; Pofu *et al.*, 2015). Additionally, they described many *M. balsamina* genotypes that are resistant to root-knot nematode, *M. incognita* race 2. The resistant lines of *M. balsamina* under investigation might be efficiently used in a breeding program to generate adequate root-knot nematode resistant cultivars. Additionally, resistant and moderately resistant genotypes had lower reproduction factors than susceptible and severely sensitive genotypes, demonstrating the necessity of cultivating resistant cultivars in a cropping sequence to control soil nematode populations (Sharma *et al.*, 2019).

The UPGMA analysis of the 15 cucurbit inbred lines in this study resulted in the genotypes being classified into two major groups (Fig. 5), Group 1 and Group 2. The dendrogram was well fitted to the distance matrix (cophenetic correlation (CP): r = 0.828). Group 2 had the most genotypes and was made up of 10 lines from distinct genera divided into two subgroups (Subgroup I-1 and Subgroup I-2). Three *Momordica balsamina* cultivars (Bit-1)

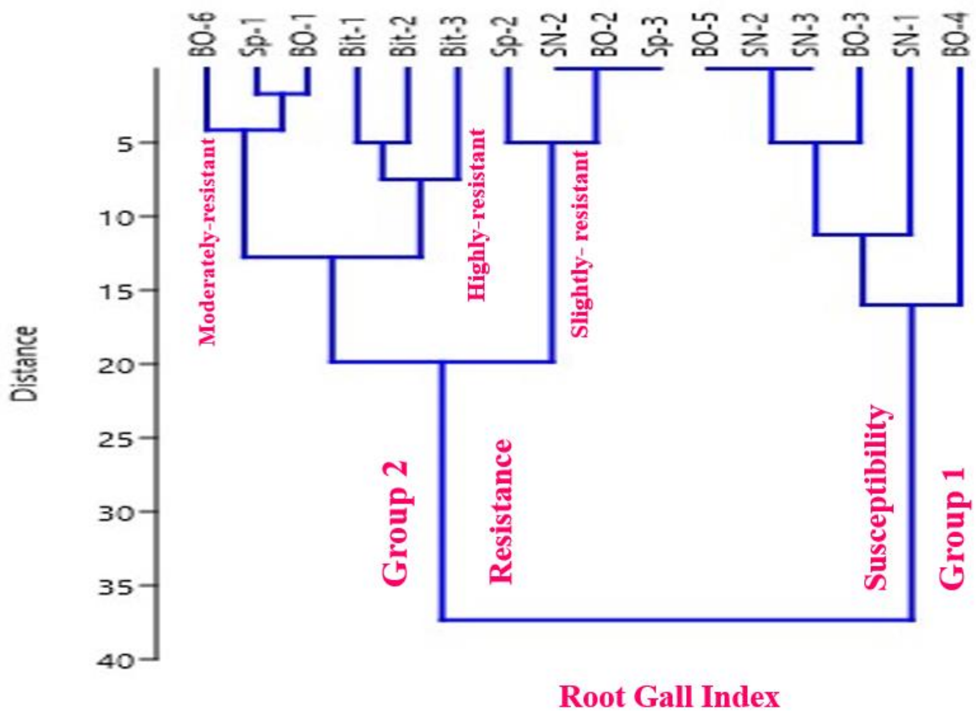

Fig 5. Dendrogram showing the clustering of 15 cucurbits inbred lines based on RGI data (Euclidean distances, UPGMA method).

Bit-2, and Bit-3) were found to be extremely resistant to *M. incognita*, as were two *L. siceraria* cultivars (BO-6 and BO-1) and *Luffa aegyptiaca* cultivars (Sp-1). Group 1 contains the surviving inbred lines as well as the most sensitive inbred lines.

4. Conclusion

Despite the enormous diversity within the typical *Cucurbitaceae* family, which normally has 118 recognized genera and 825 recognized species, only 23 known species are cultivated as vegetables in a variety of particular areas around the globe (Schaefer and Renner, 2011; Bhowmick and Jha, 2015). As a result of the research, four non-traditional crops were highlighted and introduced as additional food sources through a self-pollination program that resulted in the selection of a group of inbred lines adapted to local climatic conditions and resistant to the root-knot nematode, *M. incognita*, that can be used in areas infested with nematodes, thereby enabling the exploitation of soils that not suitable for the cultivation. Additionally, the study suggests concentrating on the bitter gourd crop since it has demonstrated some considerable resistance to *M. incognita* and may continue to remain a successful crop in terms of its medicinal and nutritional value. The research advises incorporating genetic diversity into genetic improvement and breeding efforts to develop exceptionally resistant nematode varieties and hybrids for use as rootstocks and commercial farming.

With facing the challenges of the trendy vegetable seed industry, vegetable biodiversity may be a key source for genetic improvement programs, to provide innovative vegetables with improved desirable characteristics, to comprehend more environmentally sustainable agro-systems, to adapt to climate change challenges and bad soil conditions like salinity, drought, and pollutions. It has become necessary to conserve the genetic biodiversity resources not only on plant breeders and gene banks, but also on the vast number of independent growers who continuously select, progressively improve, and use vegetable biodiversity at the local scale (Elia and Santamaria, 2013).

Acknowledgments

Particular thanks and deep appreciation to Dr. Ahmed Ahmed Osman, Professor of Nematology, Faculty of Agriculture, Cairo University for sufficiently proving all necessary facilities, supporting the successful completion of the study, and guidance throughout the time of nematode experimental studies. Deep thanks to Dr. Ahmed El-Eslamboly, Professor of Vegetable Crops Production under the Protected Cultivation Research Department, Horticulture Research Institute, Agricultural Research Center for generously providing some genotypes.

Statements and Declarations

Authors' Contributions
not applicable.
Funding
The author did not receive support from any organization for the submitted work.
Institutional Review Board Statement
All Institutional Review Board Statement are confirmed and approved.
Data Availability Statement
The datasets generated and analyzed during the current study are available from the corresponding author on the reasonable request.
Ethics Approval and Consent to Participate
This work carried out at Department of Cross-Pollinated Vegetable Research and followed all the department instructions.
Consent for Publication
Not applicable.
Conflicts of Interest
The authors declare no conflict of interest and not *applicable.*

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