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Deterioration of sugar beet (*Beta vulgaris* L.) caused by some fungi affecting sugar productivity

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Abstract

Sugar beet (*Beta vulgaris* L.) is supplying approximately 35% of sugar worldwide. It is the most important source of white sugar after sugarcane. It is so clear that pathogenic fungi are the main reason for enormous losses in sugar beet production. So this study aimed to focus on sugar beet deterioration caused by the infected fungi which affects sugar productivity in Egypt. Data indicated that fungal infection had a significant effect on reducing all growth parameters and total sugar content in infected sugar beet roots compared with healthy ones. A sum of 130 fungal isolates including 10 species were identified as *Alternaria alternata*, *Aspergillus niger*, *Aspergillus parasiticus*, *Botrytis cinerea*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium* spp., *Rhizopus stolonifer*, *Rhizoctonia solani,* and *Sclerotium rolfsii*. Mycotoxins analysis revealed that *A. parasiticus* isolate from the Sharqia governorate sample produced the highest concentration of total Aflatoxins (7319.69 ng/ mL), while the least concentration of total Aflatoxins produced by *A. parasiticus* isolate from Beni Suef governorate sample (5.18 ng/ mL). On the other hand, *Aspergillus niger* isolate from Sharqia governorate sample was able to produce 0.11 ng/ mL of Ochratoxin A, and *Fusarium oxysporum* isolate from sugar beet roots samples collected from Sharqia governorate produced the highest Fumonisin B1 concentration (8635.36 ng/ mL), while *F. oxysporum* isolate from Menofia governorate sample produced the least concentration (289.42 ng/ mL). It could be concluded that different toxigenic fungi can attack the sugar beet roots and cause their deterioration, which affects sugar productivity.

Keywords: Sugar beet (*Beta vulgaris* L.), Fungi, Mycotoxin, Egypt.

1. Introduction

World sugar production relies on two primary crops: sugar cane and sugar beet. Approximately 70% of the world's sugar

production comes from cane, while beet contributes about 30%. Sugar is seen as a crucial commodity in many countries globally, with some considering it as strategically important as wheat, particularly in Africa, Europe, America, and Australia. Sugar beet is the second largest contributor to global sugar production. Egypt faces a significant shortfall of nearly one million tons between the sugar it consumes and what it produces **[1, 2, 3]**. Beet (*Beta vulgaris* spp.) is a genus of the Amaranthaceae family (previously classified under Chenopodiaceae), It is typically categorized into two types: fodder beet and sugar beet. Sugar beet, specifically used for sugar production, along with sugar cane, is one of the main sources of sucrose, commonly known as sugar. Due to its sweetening, energizing, and preserving properties, sugar plays a key role in a variety of food and beverage products. Over the past six decades, global consumption of sugar from both cane and beet has increased significantly, with no indication of this demand slowing down. As a result, sugar beet has emerged as a valuable cash crop on farms worldwide, and national sugar industries, once established, are fiercely protected by growers. The byproducts of sugar production, such as pulp, molasses, fiber, etc., are commonly utilized as animal feed. In regions where sugar beet is cultivated alongside livestock, the plant leaves can also be used as fodder. Additionally, sugar beet has more recently been employed in molasses production, with molasses being utilized for alcohol production and various fermentation processes, including penicillin production, among others **[4]**. Bioethanol is primarily produced through the fermentation of crops such as corn grain, sugar beet, sugar cane, and vegetable residues, as noted by **Ali et al. [5]**. Sugar beet, a significant crop within the Caryophyllales order, plays a crucial economic role by contributing approximately 25% of the global sugar supply, based on research by **Draycott [4], Haque, and Parvin [6]**. The productivity of sugar beet is often hindered by various diseases, which can lead to annual yield losses ranging from 2% to 60%, varying across different fields and regions, as supported by research conducted by **Haque and Parvin [6]**. During its growth stage, sugar beet is susceptible to attacks by various pathogens, with an estimated 30% of sugar beet production being impacted by these infestations. Additionally, the roots of sugar beet harbor a variety of fungi genera that have the potential to reduce the sugar content, as indicated by **Chenaoui et al. [7]**. The three primary fungal diseases affecting sugar beet are crown and root rot caused by *Rhizoctonia solani* K., root rot due to *Aphanomyces cochlioides* D., and root diseases caused by *Fusarium oxysporum*. These diseases often coincide within the same field, leading to significant yield reductions. Globally, crop losses attributed to plant pathogens have accounted for 42% of total crop losses caused by various factors, with an annual expenditure of $26 billion on pest management, according to studies by **Harveson and Rush [8, 9], Mohammadzadeh et al. [10]**. The concentration of sucrose in the root of sugar beet, in terms of dry weight, can potentially reach as high as 75%. Despite its significant economic value, sugar beet production is threatened by various challenges, one of which includes infections by soil fungi leading to severe diseases that greatly reduce the quality and

yield of the crops. To combat these fungal diseases and promote crop growth, different microorganisms have been harnessed, representing a key aspect of sustainable production. *Sclerotium rolfsii*, *Fusarium oxysporum*, and *Rhizoctonia solani* are among the fungi involved, with *R. solani* being recognized as one of the most detrimental pathogens affecting sugar beet plants on a global scale. The extent of yield losses caused by these fungi can vary from one field to another and may result in yield reductions of up to 60%, according to findings by **Abd elaaziz et al. [11]**. In Egypt, sugar beet holds significant economic value as the second most important crop for sugar production after sugar cane. The cultivation area for sugar beet has significantly expanded with the increase in land reclamation efforts. In Egypt, sugar beet production has yielded approximately 1.255 million tons of sugar, accounting for around 50% of the local production, as reported by **FAOSTAT [12]**. Egypt faces a substantial gap between sugar production and consumption, amounting to nearly one million tons, according to **Zaki et al. [2]**. Over the past three decades, there has been a gradual rise in sugar beet cultivation in Egypt, reflecting a key national objective to bridge the production-consumption gap **[3]**. Sugar beet cultivation has now spread across Lower and Upper Egypt governorates, with around 200,000 feddans (approximately 84,000 hectares) needed to reach full operational capacity in El Sheikh, El Dakahlia, and El Fayoum regions, producing over half a million tons of sugar, as highlighted by **El-Zayat [13]**.The objective of the present work is to isolate and identify the fungal association of sugar beet roots, evaluate their impact on growth parameters and sugar content, assess certain strains for mycotoxin production, and understand the nature of associated fungi and their roles in diseased sugar beet roots affecting Beet productivity.

2. Materials and methods

2.1. Collected samples of sugar beet at post-harvested stage

Samples of sugar beet roots were collected randomly from five governorates i.e. Beheira, Beni Suef, Menofia, Qualyubia, and Sharqia in Egypt during 2022/ 2023 season (**Fig. 1**). All samples of post-harvest mature sugar beet roots were selected and examined then, divided into two groups (normal which appeared healthy and abnormal shown rotted root symptoms as a result of fungal infection). Each sample was packed in a clear polyethylene bag with all necessary related information, transferred to the equipped lab, and kept at −4°C for further study. Morphological growth parameters and sugar content were determined between normal and abnormal roots.

Fig. 1. Samples of sugar beet at post-harvest stage.

2.2. Effect of fungal infection on the growth parameters of sugar beet

The beetroot samples that were collected from 5 different governorates (Beheira, Beni Suef, Menofia, Qualyubia, and Sharqia) were examined to estimate the root length (cm), root diameter (cm), and root fresh weight (kg/plant) of healthy and post-harvest rotted roots under field conditions.

2.3. Effect of fungal infection on the sugar content

The percentage of total sugar content in rotted sugar beet roots has been measured compared with healthy roots. In this study, sugar content was determined in fresh root from the filings of the middle part cross-section. Total sugars (non-reducing and reducing sugars) were determined**. A** Digital Refractometer was used for the measurement; the sugar content was expressed in Brix **[14]**. Sucrose (%) was estimated polarimetrically on a lead acetate extract of fresh macerated roots according to **Le Docte [15].** Sugar losses were determined **[16]**.

2.4. Isolation of fungi from sugar beet roots

Fresh beetroot samples at the post-harvest stage which were collected from 5 different governorates (Beheira, Beni Suef, Menofia, Qualyubia, and Sharqia), washed aseptically with sterile distilled water then were surface sterilized by using 2 % sodium hypo-chloride (NaOCl) solution for 2 minutes, then rinsed with sterile distilled water several times and cut into small pieces (0.5m). Prepared root samples were transferred onto sterilized Potato dextrose agar (PDA) medium in the presence of streptomycin (antibiotic) to inhibit bacterial growth then incubated for 5 days at 28±2°C **[7]**. All grown molds were purified using either a single spore method or a hyphal tip technique **[17]**. All fungal colonies (5-7 days old) were identified by using a light microscope (40x) in Plant Pathology Dept., National Research Centre (NRC) based on cultural and morphological characteristics and the available literature as compared with the description given by **Raper and Funel [18], Barent and Hunter [19]** for the genera of imperfect fungi and **Singh et al. [20]** for either *Aspergilli, Fusaria* and *Penicillia*). Thus, obtained pure cultures were maintained on a PDA slant medium, then stored in a refrigerator at 5° C, and renewed once a month for further studies.

2.5. Fungal frequency

Total fungal count and fungal frequency (Fr %) percent of naturally occurred fungi was calculated according to **Bensassi et al. [21]** as follow:

$$\text{Fungal frequency (Fr \%)} = \frac{\text{The number of isolates of a genus or species}}{\text{The total number of fungal isolates}} \times 100$$

2.6. Determination of mycotoxins production

All isolates of toxigenic fungi (*Aspergillus niger*, *A. parasiticus*, and *Fusarium oxysporum*) were tested for mycotoxins production. All *Aspergillus niger* and *A. parasiticus* isolates were propagated as pure culture in 100 mL yeast extract sucrose (YES) medium to be tested for Ochratoxin A and Aflatoxins production according to **Munimbazi and Bullerman [22], A.O.A.C. [23].** Ochratoxin A was extracted and determined by High-performance liquid chromatography (HPLC) according to **Abarca et al. [24], Bragulat et al. [25],** while Aflatoxins were extracted and determined by HPLC according to **Kumar et al. [26], Rubert et al. [27].** Production of Fumonisin B_1 was done by culturing *Fusarium oxysporum* on corn medium according to **Bailly et al. [28].** Fumonisin B_1 extraction and determination were performed as described by **Le Bars et al. [29], Ndube et al. [30]**.

2.7. Statistical analysis

Data obtained in this study were analyzed using software (IBM SPSS Statistics v.16.

USA). Statistical significance was performed using a one-way Analysis of Variance (ANOVA) test. A value of $p<0.05$ was considered statistically significant. The least significant difference (LSD) was calculated at $P \leq 0.05$ according to **Gomez and Gomez [31].**

3. Results and discussion

3.1. Deterioration of sugar beet roots at post-harvest stage

Data in **Table (1)** presented the effect of decay caused by fungal isolates associated with sugar beet roots, (healthy and infected), collected from 5 governorates in Egypt i.e. Beheira, Beni Suef, Menofia, Qualyubia, and Sharqia on growth parameters (Length, Diameter, and weight). Data confirmed that the fungal infection caused a significant reduction in all growth parameters of sugar beet roots. On the other hand, Qualyubia governorate had the most decayed and affected samples due to fungal infection, while Beheira governorate had the least affected samples, where Qualyubia sample showed the highest reduction percent in root length (61.03%), followed by the Menofia sample where roots were reduced significantly in length with a reduction percent of 59.03 %, and Beni Suef sample which gave a reduction percent in the root length equals 52.36 %. Both Sharqia and Beheira samples recorded the least reduction percent in root length, where they recorded 32.14 and 30.51 % respectively. Data also confirmed that the Qualyubia sample gave the highest reduction percent in sugar beet root diameter (34.22 %), followed by the Menofia sample which recorded a 32.37% reduction percent, Beni Suef sample (27.71 %), and the Sharqia sample (22.35 %). Beheira sample recorded a lower reduction percent in root diameter (17.24 %). For the reduction in weight of samples, the Qualyubia sample also recorded the highest reduction percent in the root weight (81.58%), followed by the Menofia sample (70.45 %). Beni Suef recorded a weight reduction percentage of 58.86 %, followed by the Sharqia sample which had a reduction percentage of 53.33 %. Beheira governorate recorded also the least reduction percent of the root weight (33.33 %). These results are confirmed by **Schmittgen et al. [32]** who reported that the inoculation of sugar beet with *Cercospora beticola* was found to decrease the volumetric growth of the taproot and lower the fresh weight. Additionally, the infected plants showed a reduction in the width of inner cambial rings while the width of outer rings increased slightly compared with non-inoculated plants. There is increasing evidence that pathogens not only trigger direct defense responses but also alter the primary carbohydrate metabolism **[33, 34, 35, 36]**. It has been observed that the degradation of sugars in source leaves and alterations in source-sink metabolism lead to a decrease in the transport of carbon to sink organs like roots **[36, 37]**. This change in carbon transport may be the reason behind the observed reduction in taproot growth.

Table 1. Effect of fungal infection on sugar beet growth parameters.

Governorate	Growth Parameters	Healthy (H)	Infected (I)	Loss (L)	%Reduction	P value #
		Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	
Beheira	Length (cm)	29.50 ± 0.50 [bd]	20.50 ± 0.50 [cd]	9.00 ± 0.00	30.51 ± 0.52	0.001
	Diameter (cm)	43.50 ± 3.50	36.00 ± 3.00 [c]	7.50 ± 0.50	17.24 ± 0.24	0.048
	Weight (kg)	1.83 ± 0.52 [d]	1.22 ± 0.38 [bc]	0.61 ± 0.14	33.33 ± 2.08	0.178
Beni Suef	Length (cm)	36.73 ± 3.25 [ae]	17.50 ± 1.00	19.23 ± 2.25	52.36 ± 1.50	0.001
	Diameter (cm)	41.50 ± 7.50	30.00 ± 4.00	11.50 ± 3.50	27.71 ± 3.56	0.079
	Weight (kg)	1.58 ± 0.67 [d]	0.65 ± 0.05 [a]	0.93 ± 0.62	58.86 ± 17.53	0.050
Menofia	Length (cm)	31.73 ± 0.25 [d]	13.00 ± 2.00 [ae]	18.73 ± 1.75	59.03 ± 5.98	0.001
	Diameter (cm)	35.00 ± 5.00 [d]	23.67 ± 2.31 [ade]	11.33 ± 3.21	32.37 ± 4.80	0.023
	Weight (kg)	2.20 ± 0.66 [d]	0.65 ± 0.22 [a]	1.55 ± 0.48	70.45 ± 4.65	0.018
Qualyubia	Length (cm)	38.67 ± 6.11 [ace]	15.07 ± 2.50 [a]	23.60 ± 7.41	61.03 ± 10.11	0.003
	Diameter (cm)	50.17 ± 6.93 [c]	33.00 ± 6.56 [c]	17.17 ± 10.28	34.22 ± 16.13	0.036
	Weight (kg)	4.18 ± 1.80 [abce]	0.77 ± 0.14	3.41 ± 1.77	81.58 ± 7.25	0.031
Sharqia	Length (cm)	28.00 ± 1.00 [bd]	19.00 ± 5.00 [c]	9.00 ± 4.00	32.14 ± 15.46	0.038
	Diameter (cm)	42.50 ± 8.50	33.00 ± 4.00 [c]	9.50 ± 4.50	22.35 ± 6.41	0.155
	Weight (kg)	2.10 ± 0.55 [d]	0.98 ± 0.34	1.12 ± 0.89	53.33 ± 30.85	0.040

Reduction (%) = (Healthy – Infected / Healthy) x 100, Results are mean values of three replicates ± standard deviation., a There is Sig. difference with Behira Governorate for each group (Healthy & Infected), b There is Sig. difference with Beni-Suif Governorate for each group (Healthy & Infected), c There is Sig. difference with Menoufya Governorate for each group (Healthy & Infected)., d There is Sig. difference with Qualioubya Governorate for each group (Healthy & Infected), e There is Sig. difference with Sharkya Governorate for each group (Healthy& Infected), # Sig. difference between the Healthy group and infected group for each Governorate.

3.2. Deterioration of sugar productivity

This study aimed to focus on sugar beet deterioration, caused by the infecting fungi affecting sugar content. In this survey, the percentage of total sugar content in sugar beet roots was measured in both healthy and infected roots in 5 governorates to show the deterioration caused by fungal infection. Data in **Fig. (2)** showed that the fungal infection caused a significant reduction in sugar content of beet roots. On the other hand, the highest reduction percentage in total sugar content was recorded in the Qualyubia governorate sample (94.46 %), followed by the Beheira sample (66.48 %), Beni Suef sample (65.04 %), and Sharqia sample (54.01 %).

The lowest reduction percentage in total sugar content was detected in the Menofia sample, where it recorded 26.82 %. The loss percentage in total sugar content in this study agrees with **Khattabi et al. [38]** who reported that infection of sugar beet roots with *Sclerotium rolfsii* resulted in yield losses of up to 80% and a decline in sugar quality and extraction yield in the Doukkala region of Morocco. **Jacobson [39]** confirmed that *Rhizoctonia solani* was one of the most damaging sugar beet pathogens which caused losses including a decline in the amount that can be harvested and the amount of white sugar recovered. **Hanson and Jacobsen [40]** stated that infections caused by *Fusarium* spp. can lower the content of sucrose and root yield in sugar beet (*Beta vulgaris* L.). **Chenaoui et al. [7]** reported that the fungal infection of Moroccan sugar beet roots causes a decrease in their sugar content**. Noor and Khan [41]** mentioned that Rhizoctonia crown and root rot may result in a significant yield reduction which adversely impacts sucrose extraction and lowers the sucrose content. **Farhaoui et al. [42]** confirmed that root and crown rot (RCR) and damping-off of Sugar beet caused by the soil-borne pathogen *Rhizoctonia solani* caused a loss in the total sugar yields. The reduction of sugar content in sugar beet decayed roots may be attributed to their fungal infections which cause damage to the root structure and disrupt the normal physiological processes of the plant. Fungi can invade the plant tissues, competing for nutrients and resources, ultimately leading to a decline in the production and accumulation of sugars in the roots. In addition, some fungi produce enzymes that break down sugars and other compounds in the plant, further reducing the sugar content.

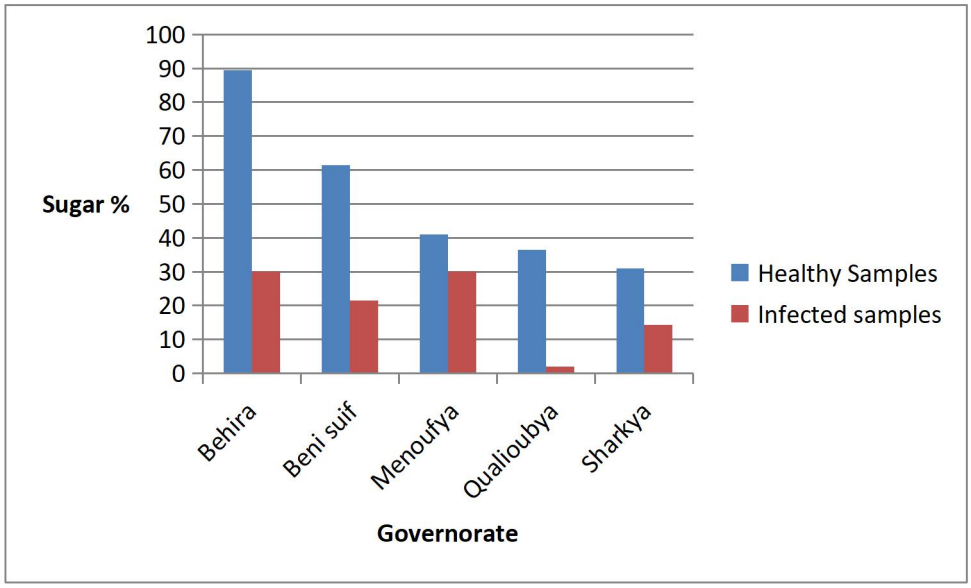

Fig 2. Effect of fungal infection on the percentage of sugar content

3.3. Mycological analyses

It is known that pathogenic fungi are responsible for important losses in sugar beet production. Sugar beets are affected by various degrading fungi. The percentage of the total count of fungi as well as fungal frequencies isolated from sugar beet roots collected from five different governorates in Egypt, i.e. Beheira, Beni Suef, Menofia, Qualyubia,

and Sharqia were recorded in **Table (2).** Data in this table showed that a sum of 130 fungal isolates including 10 species under 8 genera was identified as follows, *Alternaria alternata*, *Aspergillus niger*, *Aspergillus parasiticus*, *Botrytis cinerea*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium* spp., *Rhizopus stolonifer*, *Rhizoctonia solani,* and *Sclerotium rolfsii* . Data also indicated that Beni Suef had the highest fungal count among the 5 governorates which was 35 fungal isolates representing 26.92%, followed by Beheira which gave 28 fungal isolates with a percentage of 21.53%, Sharqia governorate with a total fungal count of 25 and a percentage of 19.23%, and Qualyubia which gave 22 fungal isolates with a percentage of 16.92%. The least fungal count was obtained from Menofia with total fungal isolates of 20 representing 15.4% of the total fungal frequency percentage. On the other hand, this table also presented that *Aspergillus parasiticus* was the highest percentage of all isolated fungal species with a total count of 25 isolates and a percentage of 19.2, followed by *Alternaria alternata* and *Fusarium oxysporum* which both gave 21 fungal isolates with a percentage of 16.2%, *Botrytis cinerea* gave 20 isolates (15.3%) and *Penicillium* spp., recording 14 isolates which equal 10.8%. *Rhizopus stolonifer* with 12 isolates and 9.2%, *Rhizoctonia solani* 7 isolates (5.4%), *Aspergillus niger* 6 isolates (4.6%), and *Sclerotium rolfsii* 3 isolates representing 2.3%. *Fusarium solani* gave the lowest total fungal count which only recorded 1 isolate with a percentage of 0.8%. These results are fully supported by the results obtained by **Abada [43]** who isolated some pathogenic fungi from rotten sugarbeet roots collected in Egypt including *Alternaria* spp., *Mucor* spp., *Fus arium* spp., *F.conglutinans, F.solani; Phoma (Pleospora) betae; Pythium debaryanum; Rhizoctonia solani; Scleorotium bataticola; Sclerotium rolfsii* and *Trichoderma harzianum*. **Christ et al. [44], Strausbaugh et al. [45]** mentioned that fungi associated with rots in stored sugar beet roots included *Aspergillus fumigatus*, *Fusarium* spp., *Geotrichum* spp. , *Gibellulopsis nigrescens*, *Penicillium* spp., *Phoma herbarum*, *Pythium* spp., *Rhizopus stolonifer*, and *Trichoderma atroviride*. **Chenaoui et al. [7]** reported that *Fusarium oxysporum*, *Pythium* sp., *Alternaria alternata*, *Botrytis cinerea*, *Aspergillus niger*, *Rhizoctonia solani*, *Rhizopus stolonifera,* and *Penicillium expansum* were associated with Moroccan sugar beet root. **Strausbaugh [46]** identified *Penicillium expansum, P. cellarum, P. polonicum, Talaromyces rugulosus, Cladosporium* sp., and *Fusarium* spp., from sugar beet roots. **Paul et al. [47]** indicated that 9.74% of plants in 144 sugar beet plots had *Sclerotium rolfsii* infections, which manifested as root rot symptoms. **Farhaoui et al. [42]** confirmed that the soil-borne pathogen *Rhizoctonia solani* is the main cause of root and crown rot (RCR) and damping-off of Sugar beet which significantly lowers the crop's output. **Rerhou et al. [48]** found that *Sclerotium rolfsii* causes sugar beet root rot disease and is a significant factor restricting the yield of sugar beet crops in Morocco. There were differences between species diversity and frequency of fungi. They may originate from indigenous species that occur either naturally in soil or may be introduced through agricultural practices **[49].**

Table 2. Total fungal count and percentage of fungal frequencies isolated from sugar beet roots collected from 5 governorates in Egypt.

Fungal Species		Governorates					Total
		Beheira	Beni Suef	Menofia	Qualyubia	Sharqia	
Alternaria alternate	T.C	3	4	1	3	10	21
	%	2.30	3.10	0.80	2.30	7.70	16.20
Aspergillus niger	T.C	1	2	2	0	1	6
	%	0.80	1.50	1.50	0.00	0.80	4.60
Aspergillus parasiticus	T.C	12	9	1	1	2	25
	%	9.20	6.90	0.80	0.80	1.50	19.20
Botrytis cinerea	T.C	2	9	4	3	2	20
	%	1.50	6.90	3.10	2.30	1.50	15.30
Fusarium oxysporum	T.C	1	2	6	9	3	21
	%	0.80	1.50	4.70	6.90	2.30	16.20
Fusarium solani	T.C	0	0	0	0	1	1
	%	0.00	0.00	0.00	0.00	0.80	0.80
Penicillium spp	T.C	7	2	1	0	4	14
	%	5.40	1.50	0.80	0.00	3.10	10.80
Rhizopus stolonifer	T.C	1	3	4	3	1	12
	%	0.80	2.30	3.00	2.30	0.80	9.20
Rhizoctonia solani	T.C	1	4	1	0	1	7
	%	0.80	3.00	0.80	0.00	0.80	5.40
Sclerotium rolfsii	T.C	0	0	0	3	0	3
	%	0.00	0.00	0.00	2.30	0.00	2.30
Total		28	35	20	22	25	130
%		21.53	26.92	15.40	16.92	19.23	100

3.4. Detection of mycotoxin production

All toxigenic fungi (*Aspergillus parasiticus*, *Aspergillus niger*, and *Fusarium oxysporum*) which were isolated from sugar beet root samples were tested for mycotoxins production. The detection of mycotoxins production was tabulated in **Table (3).** Data presented that, *A. parasiticus* isolates No. (12, 17, 22, 23 & 25) from sugar beet root samples were found to produce Aflatoxins AFB1, AFB2, AFG1, and AFG2. Only *A. niger* isolate No. (4) was found to produce Ochratoxin A. *F. oxysporum* isolates No (3, 4, 13& 20) were Fumonisin B1 producers. These results agreed with those of **Te´ren et al. [50], Varga et al. [51], Heenan et al. [52],** who reported that Aspergillus Section Nigri (*Aspergillus niger*) can produce OTA. **Shenasi et al. [53]** stated that the primary mycotoxins produced by *Aspergillus* species in fruits and vegetables are aflatoxins, which are mostly generated by strains of *A. flavus* and *A. parasiticus* that are aflatoxigenic. **Pitt [54], EFSA [55]** reported that Aflatoxins are the most toxic group of mycotoxins that are produced by some Aspergillus species (*A. flavus, A. parasiticus*, and more rarely by *A. nomius*)**. Alfredo [56]** stated that, Aspergillus mycotoxins: including (1) Aflatoxins produced by *Aspergillus flavus*, *A. parasiticus*, and *A. nomius*, (2) Ochratoxin A is produced by *Aspergillus niger* aggregate*, A. ochraceus*, *A. carbonarius*, and other species.

Table 3. Reaction of mycotoxins production.

Tested fungi	Isolate No.	Type of tested mycotoxins					
		AFB_1	AFB_2	AFG_1	AFG_2	FB_1	OTA
Aspergillus niger	4	ND	ND	ND	ND	ND	+
Aspergillus parasiticus	12,17,22, 23, 25	+	+	+	+	ND	ND
Fusarium oxysporum	3, 4, 13, 20	ND	ND	ND	ND	+	ND

+ = Positive producer, OTA= Ochratoxin A, FB1= Fumonisin B1,ND= Not Detected, NF= Not Found

3.5. Determination of mycotoxins

Determination of mycotoxins production by different toxigenic fungi (*Aspergillus niger*, *A. parasiticus*, and *Fusarium oxysporum*) isolated from sugar beet roots collected from five different governorates in Egypt, i.e. Beheira, Beni Suef, Menofia, Qualyubia and Sharqia resulted that, *A. niger* isolate No. (4) from Sharqia governorate samples was found to produce 0.11 (ng/ mL) Ochratoxin (OTA), while other *A. niger* isolates from Beheira, Beni Suef, and Menofia governorates samples weren't OTA producers. On the other hand, *A. parasiticus* isolate No. (12) from Beheira governorate was found to, produce 2409.28, 6.60, 165.07, and 3.07 ng/ mL of AFB_1, AFG_1, AFB_2, and AFG_2 respectively. *A. parasiticus* (Isolate No.17) from Beni Suef governorate produced 5.07 ng/ mL (AFB_1), and 0.11 ng/ mL (AFB_2). *A. parasiticus* (Isolate No. 22) from Menofia governorate produced 146.32 ng/ mL (AFB_1), and 2.37 ng/ mL (AFB_2). *A. parasiticus* (Isolate No. 23) from Qualyubia governorate was found to produce 648.46, 2.49, 28.53, and 1.25 ng/ mL of AFB_1, AFG_1, AFB_2, and AFG_2 respectively, whereas *A. parasiticus* (Isolate No. 25) from Sharqia governorate was found to produce 6752.97, 19.89, 391.58 and 155.25 ng/ mL of AFB_1, AFG_1, AFB_2, and AFG_2 respectively. In which *A. parasiticus* isolate No. (25) isolated from Sharqia governorate samples produced the highest concentration of total Aflatoxins (7319.69 ng/ mL), followed by *A. parasiticus* isolate No. (12) from Beheira governorate samples (2584.02 ng/ mL), *A. parasiticus* isolate No. (23) from Qualyubia governorate samples (680.73 ng/ mL), and *A. parasiticus* isolate No. (22) from the Menofia governorate sample (148.69 ng/ mL), whereas the lowest concentration of total Aflatoxins was produced by *A. parasiticus* isolate No. (17) from the Beni Suef governorate sample, which recorded 5.18 ng/ mL. Data also indicated that *F. oxysporum* isolate No. (20) from Sharqia governorate sample produced the highest Fumonisin B1 concentration (8635.36 ng/ mL), followed by *F. oxysporum* isolate (No. 3) from Beni Suef governorate sample, which recorded 771.83 ng/ mL, and *F. oxysporum* isolate (No. 13) from Qualyubia governorate sample, which recorded 420.39 ng/ mL. Least Fumonisin B1 concentration was produced by *F. oxysporum* isolates (No.4) from the Menofia governorate sample (289.42 ng/ mL) as described in **Table (4).** The results obtained in this survey regarding isolated mycotoxigenic fungi from sugar beet roots and mycotoxin production are supported by **Bosch and Mirocha [57],** who found that all *Fusarium* isolates from fungus-invaded

tissue of stored sugar beets that cultured on autoclaved rice grains were mycotoxigenic and produced the following mycotoxins: zearalenone, chlamydosporol (HM-8), moniliformin deoxynivalenol 15-acetyldeoxynivalenol, diacetoxyscirpenol, monoacetoxyscirpenol, scirpenetriol, T-2 toxin, HT-2 toxin, neosolaniol and T-2 tetraol in extracts of the rice cultures. Also**, Christ et al. [44]** isolated *F. oxysporum* from sugarbeet roots from two locations in Germany and observed that certain strains of *F. oxysporum* produce FB1, FB2, and FB3. **Hill et al. [58]** reported that, some species of *Fusarium* spp which is the main genera infesting sugar beet in the field are capable of producing mycotoxins in the field and in vitro. **Saleh et al. [59]** detected aflatoxin B1 and ochratoxin A in sugar beet. **Boudra et al. [60]** detected Ochratoxin A in one sample from 40 sugar beet pulp silage samples. **Ferrigo et al. [61], Pitt and Miller [62]** reported that, the most studied mycotoxin-producing plant pathogenic genera such as *Fusarium, Alternaria, Claviceps, Stachybotrys,* and *Aspergillus* spp. infect a wide array of commodities including cereals, nuts, beans, sugarcane, and sugar beet in the field (e.g. *Fusarium, Alternaria,* and *Claviceps* spp.) and/or during storage (e.g. *Aspergillus* spp.). Whereas **Pushparaj et al. [63]** reported that, *Aspergillus niger* was a potent source of OTA contamination in diverse foodstuffs. The production of mycotoxins is influenced by several factors including disease severity, fungal biomass, strain, and temperature **[44].**

Table 4. Determination of mycotoxins production.

Governorates	Producing fungi	Isolate No.	Mycotoxins (ng/ml)						
			OTA	Aflatoxins					FB_1
				AFB_1	AFG_1	AFB_2	AFG_2	Total Aflatoxins	
Beheira	*Aspergillus niger*	-	ND	-	-	-	-	-	-
	Aspergillus parasiticus	12	-	2409.28	6.60	165.07	3.07	2584.02	-
	Fusarium oxysporum	-	-	-	-	-	-	-	ND
Beni Suef	*Aspergillus niger*	-	ND	-	-	-	-	-	-
	Aspergillus parasiticus	17	-	5.07	ND	0.11	ND	5.18	-
	Fusarium oxysporum	3		-	-	-	-	-	771.83
Menofia	*Aspergillus niger*	-	ND	-	-	-	-	-	-
	Aspergillus parasiticus	22	-	146.32	ND	2.37	ND	148.69	-
	Fusarium oxysporum	4	-	-	-	-	-	-	289.42
Qualyubia	*Aspergillus niger*	NF	-	-	-	-	-	-	-
	Aspergillus parasiticus	23	-	648.46	2.49	28.53	1.25	680.73	-
	Fusarium oxysporum	13	-	-	-	-	-	-	420.39
Sharqia	*Aspergillus niger*	4	0.11	-	-	-	-	-	-
	Aspergillus parasiticus	25	-	6752.97	19.89	391.58	155.25	7319.69	-
	Fusarium oxysporum	20	-	-	-	-	-	-	8635.36

OTA= Ochratoxin A, FB_1= Fumonisin B1, ND= Not Detected, NF= Not Found

4. Conclusion

The obtained data revealed the presence of various fungal pathogens in decayed sugar beet roots, including toxigenic fungi that produced mycotoxins posing potential health risks to humans. The data also demonstrated that fungal decay significantly reduced all growth parameters of infected beetroots when compared to healthy roots. Additionally,

sugar production was observed to decrease due to fungal decay in rotten beetroots. It can be concluded that different toxigenic fungi can infect sugar beet roots, leading to their deterioration and impacting sugar productivity.

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