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Assessment of Biometric Parameters and Health of Canna's Cultivars as Plant Useful in Phytoremediation of Degraded Agrocenoses

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Abstract: Recently, the ecological awareness of society and the need to take care of our surroundings and the natural environment has significantly increased. There is also an urgent problem of searching for new, environmentally friendly techniques for its purification (soil, ground and surface waters, sewage sludge and air) with the use of living organisms, especially higher plants. One plant species investigated for phytoremediation is canna. Ten varieties of canna, grown on degraded and garden soil, were tested in this respect. The disease index and species composition of fungi inhabiting its organs, growth dynamics, parameters of photosynthesis and gas exchange were determined. The conducted research showed that cannas are able to satisfactorily grow even in seemingly unfavorable soil conditions with its strong degradation. Among a total of 24 species of fungi obtained from its organs, genus *Fusarium*, considered as pathogenic for canna, *Alternaria alternata*, and, less frequently, *Thanatephorus cucumeris* and *Botrytis cinerea*, dominated. The cultivars 'Picasso', 'Cherry Red', 'President' and 'La Boheme' had lower rates of photosynthesis and gas exchange than the least affected 'Botanica', 'Wyoming', 'Robert Kemp' and 'Lucifer' cultivars. Those turned out to be the most beneficial and they can be recommended for cultivation on strongly degenerated soils.

Keywords: diseases; fungi; gas exchange; *Canna indica*; photosynthesis; transpiration

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1. Introduction

In the last decade, environmental awareness has increased and counteracting environmental pollution has become the main goal of many global institutions. There is an urgent problem of searching for new, environmentally friendly techniques for purifying pollutants from water, sewage, and other contaminated materials with the use of living organisms, especially plants [1]. An interesting example is the EU-funded Phy2Climate project, which aims to validate five pilot phytoremediation in selected soil-contaminated sites, the most common in the world. The project aims to produce energy crops that will eventually power a pilot biorafinery [2]. Canna is an attractive ornamental plant often planted in urban plantings in Europe near communication routes, parking lots and other places that require covering or isolation from exhaust fumes or impurities. It is also known as a plant used in phytoremediation to purify wastewater from various pollutants that are dangerous to humans. In recent years, especially in countries with a warmer climate, canna has been increasingly used as a plant element of a sewage treatment plant useful in phytoremediation. Phosphorus and nitrogen from contaminated water from households can be effectively treated by canna [3–5], as well as lead in rhizofiltration systems [6] or oil refinery wastewater [7]. In addition, canna positively affects the preservation of biodiversity in ecosystems through flowers that attract birds and insects [8,9]. Due to its strong growth and development opportunities in coastal and flooded zones, forming large clumps in wet forests and clearings in polluted areas, it seems to be a very promising plant affecting sustainable development in rural and urban areas, despite its invasive nature in some countries [10]. In a warm climate, canna has many uses, including culinary ones, because all its parts are edible, but in the climatic conditions of Central Europe it does not survive the winter, so the rhizomes should be dug up and stored at a positive temperature [11,12]. Therefore, the possibility of using plants resistant to difficult environmental conditions, fast growing and with the ability to clean the area from pollution is sought. An important feature of these plants is a resistance to pests. In order to assess the resistance of plants to pathogens, in addition to the methods of classical mycology, the assessment of the photosynthesis process is used, which allows us to determine the condition of plants in a short time [13]. The process of photosynthesis is strictly associated with a plant species or an even variety and could be modified to a significant extend by the environmental conditions, such as temperature, precipitation and their distribution throughout the vegetation season, like numerous other parameters [14]. Concurrently, there is a major physiological plant process, which has been frequently suffered due to plant pathogens, especially those infecting the leaves [15]. The generally known fact is that leaf diseases may have destructive effect on the photosynthesis and gas exchange and can sharply reduce photosynthesis in different crop plants [16]. Pathogens cause morphological, physiological and biochemical changes, as the significant decrease in the amount of photosynthetic pigments, and thus restrict the photosynthesis rate and, resulting from it, reduce the capacity of the assimilation apparatus [17–19]. Following the plant tissues infection, many pathogens may impair photosynthesis even in the initial stage of an infection before any symptoms are visible [20,21]. The aim of the investigations was to generate an impact assessment of the infestation of the specified cultivars of canna by pathogenic fungi on the intensity of photosynthesis and the gas exchange.

2. Materials and Methods

2.1. Experimental Design

The observations were performed in 2017–2019 in the Botanical Garden in the Lublin region, Poland (51°16′ N, 22°30′ E). The most popular cultivars with a varying growth strength and high decorative qualities in the form of attractive flowers and leaves were selected for the study. These are generally available on the market and widely grown in our climatic zone. The objects of the study were ten cultivars of canna plants: Ai—'Aida', Am—'America', Bo—'Botanica', Ch—'Cherry Red', LB—'La Boheme', Lu—'Lucifer', Pi—'Picasso', Pr—'President', RK—'Robert Kemp' and Wy—'Wyoming'.

The canna rhizomes were stored for the winter period in containers covered with peat in a cool room at about 5–10 °C. The seedlings were planted into the 2 L pots in March. Then, the pots were set in a foil tunnel, in which they grew until mid-May. After the last spring frosts, they were placed in the field at 60 × 60 cm spacing.

The experiment was performed in a complete randomized blocks design with four replicates, where the block was the random effect. The experimental combination consisted of 12 plants (3 plants in 4 replicates) of each cultivar.

Mineral fertilization in accordance with the recommendations for canna plants was used.

Shoot length tests were carried out for three years from June to October. Plant height measurements were made using a measuring tape. The canna height growth figures are given as the three-year averages for all varieties.

2.2. Weather Parameters

The meteorological data sourced from the Meteorological Observatory of the Hydrology and Climatology Department, the Maria Curie-Sklodowska University in Lublin. The observations were carried out in 2017–2019 in the Botanical Garden in the Lublin region, Poland [22,23].

2.3. Soil Analysis

The investigations were carried out on the control (garden) and contaminated soil. The plots with contaminated soil were located near the communication route, which, apart from passers-by, was used by animal owners with their pupils. It resulted in the heavy contamination of the area with organic waste and animal excrements. So, the condition of the soil was after strong antropopressure. The control plots were with typical garden soil. The analyses of the soil in the plots were performed annually before planting the plants.

2.4. Plant Health Assessement

The evaluation for the level of infection disease index (DI) was performed twice every year, i.e., in mid-June and mid-September on the base of the 5-grade scale: 0—no symptoms, 1—minor spots on the leaves, 2—necrotic spots on most leaves, 3—wilting of plants and 4—dying of plants. The data were processed by McKinney's formula [24], which generates a numeric disease index (DI) of the severity of the attack: $DI = (\Sigma vn)/(NV) \times 100$, where v represents the numeric value of the class, n is the number of plants assigned to the class, N is the total number of plants in the replication and V is the numeric value of the highest class. Due to the fact that canna planted in a permanent place after the 15th May did not indicated the disease symptoms, the DI was not calculated.

2.5. Mycological Analysis

The presence of fungi was established at the first decade of October on the basis of etiological symptoms occurring on the infected parts of the plants and on the basis of mycological analysis being performed according to the artificial cultures method as described by Kopacki and Wagner [25]. Fungi were isolated from leaves and the stems and rhizome were analyzed in a mycological laboratory (University of Life Sciences in Lublin). Parts of the plant were pre-cleaned, and they were washed for 20 min under running water. Next, we disinfected the surface with 10% NaOCl for 60 s and then rinsed the parts three times with sterile distilled water for 3 min. Finally, the fragments were placed in a mineral medium. After separation, the obtained fungal colonies were identified to the species with the available monographs.

2.6. Measurements of Gas Exchange Parameters

The measurements of the photosynthetic activity of the plants were carried out in two growing seasons, in the first decade of July and first decade of September, in two combinations (plots with contaminated soil and garden soil). Ten plants per every variety have been chosen. The measurements were conducted on the 3rd fully expanded leaf counting from the base of the plant and throughout the entire growing season the same leaves were used. The following gas exchange parameters were determined: the intensity of photosynthesis (Pn) (μmol CO_2 m^{-2} s^{-1}), transpiration (E) (mmol H_2O m^{-2} s^{-1}), stomatal conductance (Gs) (mmol H_2O m^{-2} s^{-1}) and intercellular CO_2 concentration (Ci) (μmol CO_2 m^{-2} s^{-1}). They were carried out with the use of a portable infrared gas exchange analyser, CIRAS-2 PPSystems (Hitchin, Hertfordshire, UK). The analyser's cuvette conditions were set to the external source of the CO_2, humidity and temperature equal to ambient and daylight.

2.7. Statistical Analysis

The obtained results (for the gas exchange and disease index) were statistically analyzed with the use of an ANOVA and Tukey's confidence intervals at the 5% significance level ($\alpha = 0.05$). The Pearson correlation coefficients between photosynthesis, transpiration and the disease index was determined for both types of plots [26,27].

3. Results

3.1. Weather Parameters

During the research period, the highest temperature was recorded in the summer months, especially in July, with the exception of 2019. This year the temperature was much lower than the long-term average. The year 2017 turned out to be unusual, when a record high temperature was recorded in the autumn period. The amount of precipitation during the study period was similar to the long-term average, except for July 2019, when it was much lower than the long-term average (Figure 1).

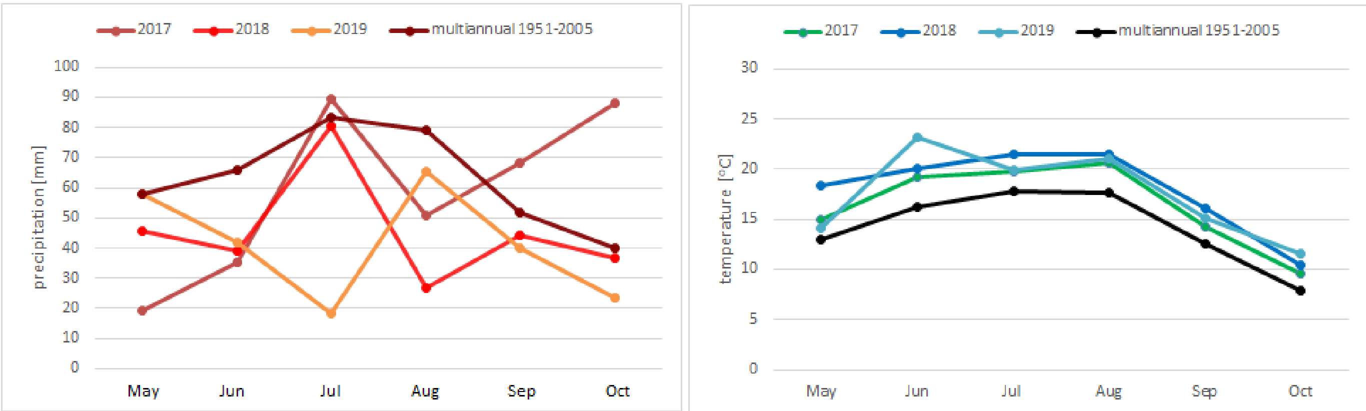

Figure 1. The average monthly rainfall and temperature.

3.2. Soil Analysis

The contaminated soil was in a bad culture, compacted by animals and had no glandular structure. It also contained numerous cat and dog droppings. The obtained results are the average of the three years of research (Table 1). The contaminated soil was characterized by a significant salinity, and the macro- and microelements contents, especially nitrogen, were significantly higher than in the garden one.

Table 1. Chemical characteristics of cultivation sites.

pH (in H_2O)	Salinity [g NaCl/L]	Macro- and Microelements Content [mg/L of Sample]									
		Contaminated Soil									
		$N-NO_3$	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B
6.77	2.21	119	171	664	4524	213	23.3	5.28	4.93	39.4	2.62
		Garden Soil									
8.27	<0.24	<10.0	47	<50.0	4212	63	7.58	2.85	3.79	24	0.36

3.3. Plant Health Assessement

As a result of the research, it was observed that after planting the plants on the plots, their growth was slow. A significant increase in their length was recorded from the beginning of August. On plots with contaminated soil, a significantly better growth was recorded in three cultivars: 'Botanica', 'Robert Kemp' and 'Wyoming'. The individual plants of these varieties reached the greatest height (Figure 2). On the other hand, plants planted on plots with garden soil showed a growth dominance in the same cultivars. The growth of most varieties was very even (Figure 3).

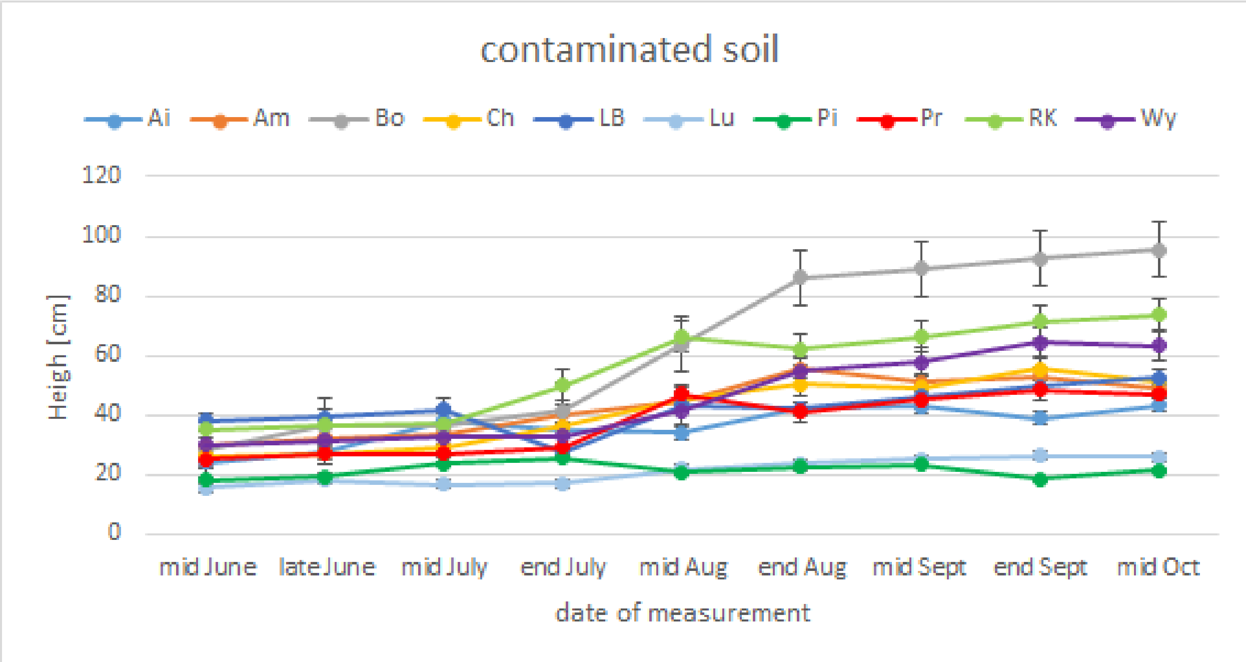

Figure 2. Dynamics of canna growth on contaminated soil. Description of cultivars is given in Materials and Methods Section 2.1. The means ± SE is expressed by each value.

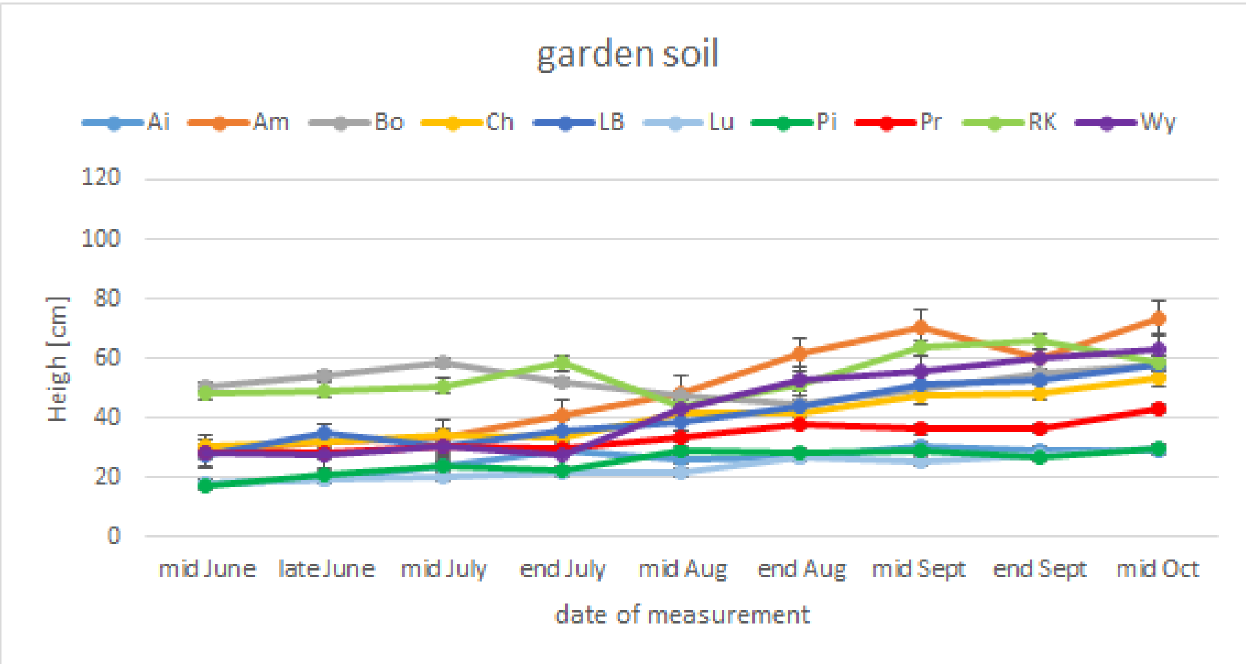

Figure 3. Dynamics of canna growth on garden soil. Description of cultivars is given in Materials and Methods Section 2.1. The means ± SE is expressed by each value.

The average disease index for all varieties was the highest in the first year of the research, but no significant statistical differences were noted. The highest index was found in plants of the variety 'Aida' (over 30%) and the lowest 'Botanica' (over 20%). In the coming years, the disease indices were significantly lower and ranged between 15 and 20% (Figure 4).

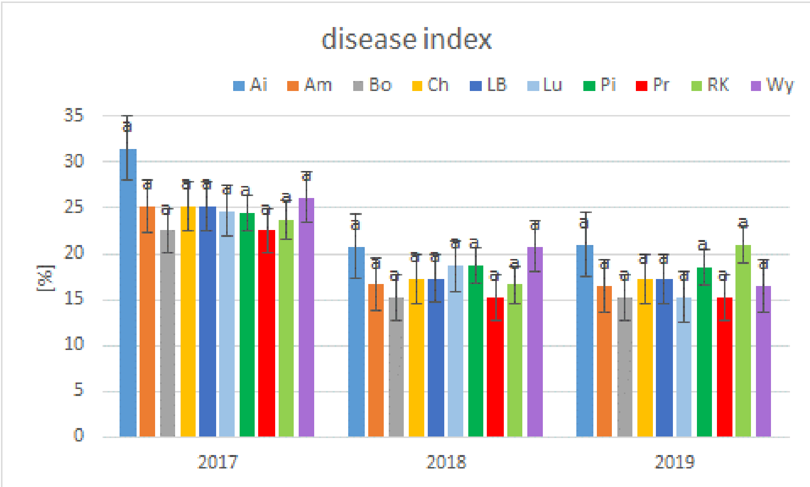

Figure 4. Disease index of canna varieties grow in 2017–2019. Description of cultivars is given in Materials and Methods Section 2.1. The means ± SE is expressed by each value. Values marked with the same letter are not significantly different (α = 0.05).

It was observed that the temperature and precipitation had an impact on fungi inhabiting canna plants. Differences between the cultivars were also observed. There were numerous yellow and brown necrotic spots visible on the leaves, which extended from the lateral veins towards the edge of the leaf blade, causing the leaves to twist over time, the leaf blade to crumble and the leaves to dry out completely. There were also, especially in the initial growth phase, extensive spots on the stems, which expanded and covered the entire stem, leading to wilting (Figure 5).

Figure 5. Disease symptoms on leaves of different canna varieties: (**A**)—'Aida', (**B**)—'America', (**C**)—'Botanica', (**D**)—'Cherry Red', (**E**)—'La Boheme', (**F**)—'Lucifer', (**G**)—'Picasso', (**H**)—'President', (**I**)—'Robert Kemp', (**J**)—'Wyoming'.

Some of the rhizomes taken out of storage completely rotted or dried up. The cross-section showed signs of conduction bundle necrosis with wet rot with brown exudate and etiological signs in the form of sporulating mycelium in grey, red, pink, yellow and brown on some rhizomes were observed. In others, however, the apical part often withered and become covered with sporulating mycelium (Figure 6).

Figure 6. Disease symptoms on rhizome of different canna varieties: (**A**)—'Aida', (**B**)—'America', (**C**)—'Botanica', (**D**)—'Cherry Red', (**E**)—'La Boheme', (**F**)—'Lucifer', (**G**)—'Picasso', (**H**)—'President', (**I**)—'Robert Kemp', (**J**)—'Wyoming'.

3.4. Fungi Obtained from Canna Plant

During the three-year study period (2017–2019), as a result of the mycological analysis of the canna leaves, shoots and rhizomes, a total of 5882 isolates of fungi belonging to 24 species were collected. The 2318 fungal isolates were obtained from the leaves, 2018 from the shoots and 1546 from the rhizomes (Figures 7–9).

Figure 7. Fungi colonizing leaves of canna in particular year of research. Description of cultivars is given in Materials and Methods Section 2.1.

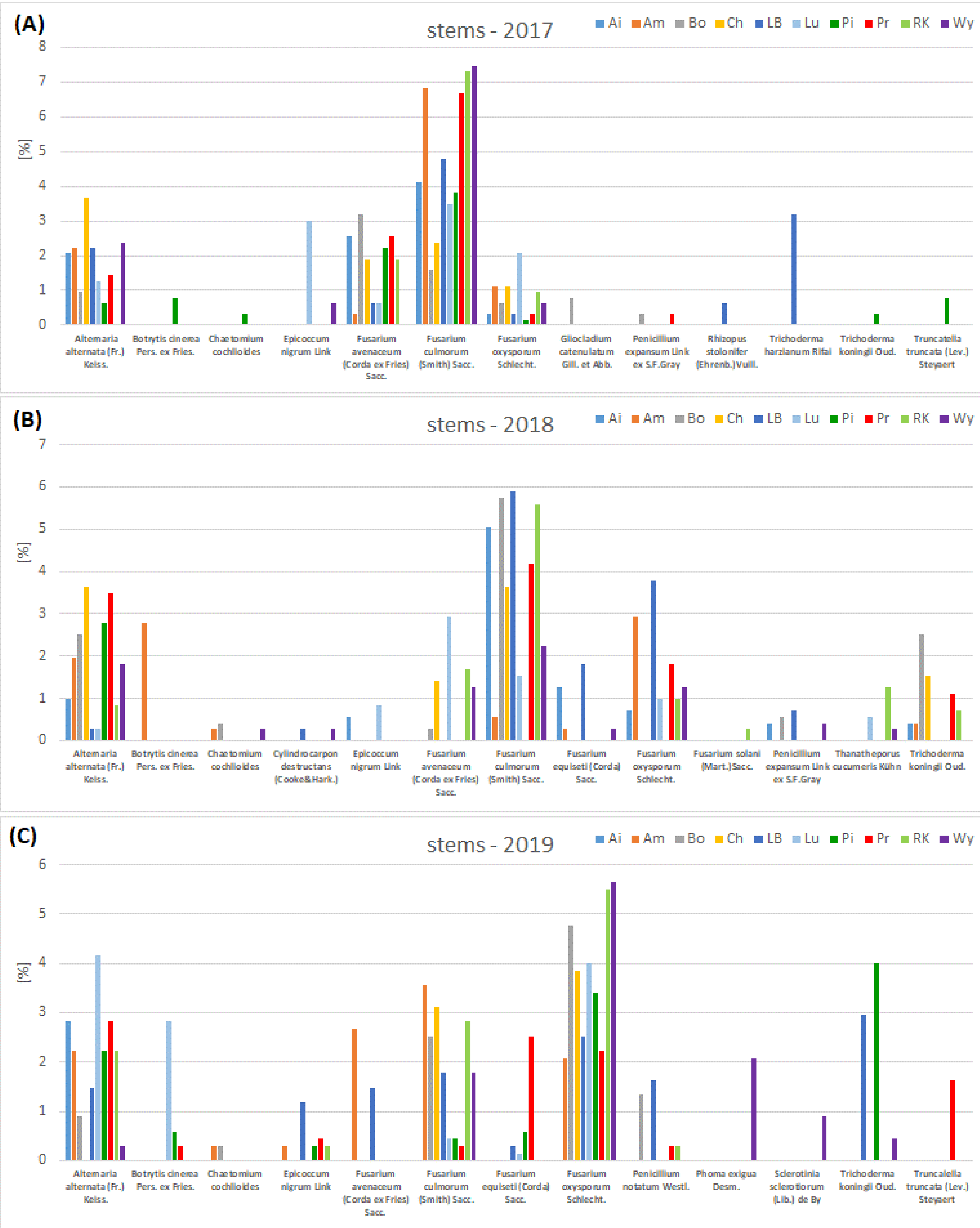

Figure 8. Fungi colonizing stems of canna in particular year of research. Description of cultivars is given in Materials and Methods Section 2.1.

Figure 9. Fungi colonizing rhizome of canna in particular year of studies. Description of cultivars is given in Materials and Methods Section 2.1.

The pathogenic fungi of the genus *Fusarium* were the dominant colonizers of the leaves in the period of the study. They accounted for as much as 59% of the total number of fungi isolated in the first year of the study, 30% in the second year and 22% in the third year of the study (Figure 7). *F. culmorum* was most often isolated from the 'Robert Kemp' and 'America' cultivars; numerous *F. oxysporum* isolates were also obtained in the first year of research from the 'La Boheme' cultivar. During the three-year study period, the isolation of *Alternaria alternata* from all cultivars was very frequent, and accounted for 23%, 38% and 67% of the total number of fungi isolated from the leaves. They were obtained especially often from the 'President' variety in 2019. Pathogenic species *Botrytis cinerea* and *Sclerotinia sclerotiorum* were also collected from the leaves.

The most numerous canna shoots were inhabited by *A. alternata* and the fungi of the genus *Fusarium*. They were isolated from all cultivars. Most of *A. alternata* was isolated from the varieties 'Cherry Red' and 'Lucifer'. The fungi *F. culmorum*, *F. oxysporum* and *F. avenaceum* were collected in great numbers, mostly from the varieties of 'Wyoming' and 'Robert Kemp'. *B. cinerea* was often obtained from the cultivar 'America', 'Aida' and 'Picasso', and *Truncatella truncata* on 'Picasso' and 'President' were also noted (Figure 8).

Rhizomes were also colonized in great numbers by *A. alternata* and the fungi of the genus *Fusarium*, mainly *F. culmorum* and *F. avenaceum*, inhabited generally 'America' and 'Cherry Red' cultivars (Figure 3). *Cylindrocarpon obtusisporum* and *Thanatephorus cucumeris* were often isolated from the canna organs. Moreover, the occurrence of *Cylindrocarpon destructans* and *Phoma exigua* was reported (Figures 7–9).

It is noteworthy that there was the numerous colonization of all canna organs by the saprophytic fungi of the genus *Trichoderma*. From the shoots, the most often isolated was *Trichoderma koningii* in the second and the third year of study, and the isolates accounted for 10% and 7%, respectively. During the same period, numerous isolates from rhizomes were obtained and they constituted 5% and 6% of the isolated fungi. In the first and second years of the research, numerous *Epicoccum nigrum* isolates were obtained from the leaves and they accounted for 13% and 19% of the obtained fungi. Most of it was obtained from the varieties 'America' and 'La Boheme' (Figures 7–9). Useful fungus, *Chaetomium cochlioides*, was also collected from the stems during all years of studies and from the leaves in 2017 and 2018 (Figures 7 and 8).

3.5. Measurement of Gas Exchange Parameters

The analysis of the results indicated the considerable differentiation of photosynthesis and gas exchange parameters in particular canna varieties infested by pathogenic fungi. Among the determined photosynthetic intensities, the Tte lowest value, 5.61 μmol CO_2 m^{-2} s^{-1}, was noted at the 'Picasso' cultivar growing on the degraded substrate and the obtained results differed significantly from other cultivars (Table 2). Similar low results were reported at cultivars 'Cherry Red' and 'President', 8.90 and 9.78 μmol CO_2 m^{-2} s^{-1}, respectively. The analogous trend was observed also on the uncontaminated plots. The lowest level of photosynthesis was carried out at 'Picasso', 6.95, and 'La Boheme', 7.17 CO_2 m^{-2} s^{-1}, and the obtained results differ significantly from other cultivars, except for 'America' and 'Robert Kemp', at which values 7.77 and 8.63 μmol CO_2 m^{-2} s^{-1} were noted. Nevertheless, the highest photosynthesis intensities were observed in 'Botanica', 'Wyoming' and 'Lucifer' varieties (Table 2).

The studied varieties have also differed in their transpiration rate (E). On contaminated soil, the lowest transpiration was reported in the 'Aida' cultivar, 1.76 mmol H_2O m^{-2} s^{-1}. The other cultivars carried the transpiration out at the level of ca. 2 mmol H_2O m^{-2} s^{-1}, except for 'America', which evaporated the most water, 3.18 mmol H_2O m^{-2} s^{-1}, from the leaf area, and this value differs significantly from all other cultivars. The similar tendency continued also in the plots with garden soil (Table 2).

Table 2. The photosynthesis intensity and gas exchange parameters of the canna at various cultivation sites.

Variety	Contaminated Soil			
	Pn	**E**	**Gs**	**Ci**
Aida	10.56 b–f	1.76 g	94.50 f	304.67 efg
America	11.06 a–e	3.18 a	152.50 ab	392.25 b–e
Botanica	14.12 a	2.01 fg	119.67 b–f	502.50 ab
Cherry Red	8.90 d–g	2.38 c–g	90.00 f	393.67 a–e
La Boheme	11.31 a–e	2.20 d–g	106.25 def	333.75 d–g
Lucifer	12.23 abc	2.18 d–g	113.50 c–f	456.08 abc
Picasso	5.61 h	2.09 efg	103.67 def	364.25 c–f
President	9.78 c–g	2.83 c–g	104.25 def	412.25 a–e
Robert Kemp	12.32 abc	2.42 b–f	123.25 b–f	508.08 a
Wyoming	12.08 a–d	2.07 efg	96.08 ef	337.67 d–g
Mean	10.80 a	2.31 b	110.37 b	400.52 a
	Garden Soil			
Aida	9.43 c–g	2.52 b–f	145.33 abc	305.67 efg
America	7.77 fgh	3.05 ab	151.17 ab	360.67 c–f
Botanica	13.23 abc	2.67 a–e	164.83 a	440.17 a–d
Cherry Red	10.63 b–f	3.03 abc	142.83 abc	360.00 c–f
La Boheme	7.17 gh	2.63 a–f	129.50 b–e	255.17 fg
Lucifer	11.18 a–e	2.33 d–g	112.33 c–f	355.83 c–f
Picasso	6.95 gh	2.57 a–f	122.17 b–f	337.00 d–g
President	9.35 c–g	2.67 a–e	133.33 a–d	342.00 c–g
Robert Kemp	8.63 e–h	2.83 a–d	146.33 abc	442.00 c–g
Wyoming	10.58 b–f	2.26 d–g	98.17 ef	240.83 g
Mean	9.49 b	2.65 a	134.60 a	343.98 b

Pn—photosynthesis (μmol CO_2 m^{-2} s^{-1}), E—transpiration rate (mmol H_2O m^{-2} s^{-1}), Gs—stomatal conductance (mmol H_2O m^{-2} s^{-1}), Ci—intercellular carbon dioxide concentration (μmol CO_2 m^{-2} s^{-1}). Values designated with the same letter are not significantly different (α = 0.05).

The lowest stomatal conductance (Gs) in relation to the other varieties was shown by 'Cherry Red', 90.00 mmol H_2O m^{-2} s^{-1}, on plots with contaminated soil and 'Aida' by 94.50 mmol H_2O m^{-2} s^{-1}. In turn, 'Wyoming', during the entire period of the measurements, was in the range of 96.08–98.17 mmol H_2O m^{-2} s^{-1}. The 'Picasso', 'La Boheme' and 'Lucifer' varieties also showed a lower level of stomatal conductance in both sites. The highest transpiration in all combinations was showed by the varieties 'Botanica', 'America' and 'Robert Kemp' (Table 2).

The lowest concentration of intercellular carbon dioxide (Ci) compared to other varieties during the observations in all combinations was recorded in the cultivars 'Aida', 'La Boheme', 'Wyoming' and 'Picasso' and ranged from 240.83 to 364.25 μmol CO_2 m^{-2} s^{-1}. Nevertheless, the highest Ci values have been notified in the cultivars 'Robert Kemp' and 'Botanica' and ranged between 440.17 and 508.08 μmol CO_2 m^{-2} s^{-1} (Table 2).

4. Discussion

The obtained results are consistent with those of other authors. Different species and varieties of plants react to a different degree of infection by pests, which manifests itself in interfering with the physiological processes in the plant. In the majority of diseases, the photosynthesis rate may be reduced at the beginning of the infection. Indeed, most pathogens decreased their photosynthesis levels from the onset of infection even though there were no visible symptoms [19,20,28].

The low photosynthesis parameters are correlated with a high air temperature during the growing season and a limited and unevenly distributed rainfall. The photosynthesis process is uniquely connected with unfavorable meteorological conditions due to the acute sensitivity of the photosynthetic apparatus in the assimilation organs. In the response to a water deficit, the stomata closes, which then results in a decrease in the stomatal conductance, thus the limiting the availability of CO_2, consequently resulting in the reduction in the photosynthetic intensity [14]. In the conducted research, this was particularly evident in 2017, when the weather parameters differed from the long-term averages.

The examined varieties differed also in the transpiration rate (E). In the first year of studies, the lowest transpiration was reported in the 'Aida' cultivar. The other cultivars carried the transpiration out at the similar level, except for 'America', which evaporated the most water, 3.18 mmol H_2O m^{-2} s^{-1} from the leaf area, and this value differed significantly from all other cultivars. A similar tendency continued also in the second combination. In the studies of Lobato et al. [17], it was confirmed that the transpiration rate corresponded to the plant infection degree and is lower in the infested plants.

The lowest stomatal conductance (Gs) among all cultivars on the contamination fields was showed at 'Cherry Red' and 'Aida'. However, the cultivar 'Wyoming' has stomatal conductance (Gs) in the range of 96.08–98.17 mmol H_2O m^{-2} s^{-1}. The stomatal conductance at a low level have also 'Picasso', 'La Boheme' and 'Lucifer' cultivars. The highest values of transpiration during the performed studies were noticed in 'Botanica', 'America' and 'Robert Kemp' cultivars. In conclusion, higher photosynthesis parameters were found in plants growing on contaminated soil. Numerous researchers have observed a similar trend on other plant species. The investigations of Bispo et al. [28] have confirmed that *Ceratocystis fimbriata* isolates caused the decrease in stomatal conductance independently of the mango variety, and therefore simultaneously they cause a diffusive limitation of the assimilation of CO_2. It was proved that the reduced level of Gs is the one of major limitations of photosynthesis in infected plants by lowering the availability of the CO_2 flow by the leaf area [19]. The research of Ribeiro et al. [29] is concur with ours and shows that the factors of the CO_2 assimilation and stomatal conductance (Gs) were higher on the healthy seedlings of orange than on those infested by *Xylella fastidiosa*. Polanco et al. [16] has also demonstrated an analogous relationship in bean plants infested by *Colletotrichum lindemuthianum*.

The lowest intercellular CO_2 (Ci) values, in comparison to other cultivars, were noticed in 'Aida', 'La Boheme', 'Wyoming' and 'Picasso'. However, the highest values were found in 'Robert Kemp' and 'Botanica' cultivars by Mikiciuk et al. [30]. They had demonstrated that Ci could indicate a significant variation depending on the physiological and developmental stage of a plant, and is higher at the beginning of the growing season than at the end. This tendency is also proved in our research.

Analyzing the level of DI, no statistically significant differences were noted between the levels, but the level of infection was quite low. It is possible that at a higher level these differences would be more noticeable. Observing the colonization of plants by fungi in a polluted field, *Alternaria alternata* and the fungi of the genus *Fusarium* dominated. The number of populations of these fungi varied in particular years of research and could be related to the weather conditions, especially the soil moisture, which affects the development of these fungi [31,32]. The polyphagous *Fusarium oxysporum,* which often inhabits canna, is grown in warm climates [33,34]. Isolated *Fusarium culmorum* and *Thanatephorus cucumeris* are known as the cause of shoot base and rhizome rot, which often occur on numerous species of ornamental plants [35]. High humidity is associated with the occurrence of *S. sclerotiorum,* causing the rotting of many plant species [36]. An often isolated in tropical countries, weak pathogen, *Alternaria alternata,* has in recent years been frequently noted on canna plants used for wastewater treatment [37]. This fungus is responsible for considerable losses in the production of canna in tropical countries [38]. Numerous populations of *A. alternata* obtained in our investigation suggest further studies on its pathogenicity to canna. Frequently isolated antagonistic fungi, like *Trichoderma* sp. or *Chaetomium* sp. and *Epicoccum nigrum*, have a great influence on the health of canna plants due to the reduction in the pathogenic fungi number, especially in the soil [39–42]. Currently, the contamination of the environment, especially areas after anthropopressure with heavy metals and other pollutions, is a serious problem. An effective way to purify it is phytoremediation. Research conducted by Trąmpczyńska and Gawroński [43] in Poland proved that the planting of garden canna in the area of urban greenery contributed to the reduction in the lead contamination of the planted stand. Many authors confirm that canna can be a very valuable plant to purify polluted water in different climatic zones ([1,44–46]) and remove pesticides from the environment [47]. Taking into account the climate change and the assumptions of the "European Green Deal" recently introduced, it can be assumed that canna will become a plant recommended for planting biological sewage treatment plants.

5. Conclusions

Canna plants were most often inhabited by the fungi of the genus *Fusarium*, considered as being pathogenic to canna and *Alternaria alternata*, and less frequently by *Thanatephorus cucumeris* and *Botrytis cinerea*.

'Picasso', 'Cherry Red', 'President' and 'La Boheme', as the more infected by pathogens cultivars, carried out the photosynthesis and gas exchange processes on significantly lower levels than the less infested cultivars of 'Botanica', 'Wyoming', 'Robert Kemp' and 'Lucifer'.

In the conducted research, the cultivation of the canna cultivars 'Botanica', 'Robert Kemp' and 'Wyoming' in difficult conditions on contaminated soils turned out to be the most beneficial, so they can be recommended for cultivation on strongly degenerated soils.

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