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Phytoremediation of Mine Tailing – Potential of Chrysopogon Zizanioides and Andropogon Gayanus in a Sahelian Climate

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Abstract
The pollution of soil and, by extension, water resources by pollutants from mining operations is a major threat to Burkina Faso due to the lack of waste treatment. Phytoremediation is an alternative way of cleaning up soil contaminated by pollutants from mining waste. The ability of *Chrysopogon zizanioides* and *Andropogon gayanus* to accumulate iron (Fe) and zinc (Zn) was studied in mine tailings in Burkina Faso in a Sahelian climate. The phytoremediation efficacy of the two plant species was studied in 30-litre pots containing mine tailings from the artisanal gold processing site in the rural commune of Nimbrogo in the Centre-Sud region of Burkina Faso. The pot experiments involving unpolluted (PN) and polluted (P) modalities were arranged randomly under an experimental greenhouse. The phytoremediation efficiency was evaluated by comparing the growth, biomass and capacity of these two herbaceous plants to extract Fe and Zn from mine tailings. Analysis of the rate of appearance of green leaves and new leaves of *A. gayanus* and *C. zizanioides* grown in mine tailings showed no significant difference between the polluted and unpolluted conditions, either within the same plant or between the two species during the experiment. The same applies to changes in the height and circumference of the plant species studied, i.e. no significant differences were observed. However, *C. zizanioides* showed a significantly different tolerance index (TI) compared to *A. gayanus* during the sampling campaigns, with the exception of campaign C3 where TI_AG (90.6%) was much higher than TI_CZ (70.9%). After six months of cultivation in mine tailings, the two herbaceous plants showed a potential to accumulate Fe and Zn, unlike Hg and As. Root biomass showed a more significant accumulation than above-ground biomass for both grasses. Although the BCF values for both plants were low (<1), the elimination efficiencies for Fe and Zn were 36.5% and 22.6% respectively in 6 months of experimentation with *C. zizanioides*. However, for the same period, *A. gayanus* gave an efficiency rate of 34.3% and 21.3% for Fe and Zn. The results indicate that the plant species studied have phytoremediation potential, although that of *A. gayanus* is relatively low compared with that of *C. zizanioides*. On the basis of these results, *A. gayanus*, an indigenous plant, can be described as a phytoremediator for the treatment of mine tailings.

Keywords: *Chrysopogon* zizanioides -*Andropogon gayanus* - Phytoremediation - Pollution

1. Introduction
Over the past few decades, Burkina Faso has seen significant development in the mining sector, resulting in a proliferation of artisanal mines, the number of which has risen from 200 in 2003 to 800 in 2018, with 600 active sites[1]. Artisanal mining (AM) is a major channel for reducing poverty in rural areas by generating cash income. Indeed, AM is a godsend in rural areas[2]. However, the practice of the activity is a source of enormous and growing environmental concern. It leads to chemical pollution of water and soil, and the degradation of biodiversity and soil, making the soil more fragile and gradually destroying arable land[3]. The uncontrolled use of prohibited chemicals such as Hg, CN, and acids to treat ore leads to the spread of potentially toxic elements (PTEs) through the discharge of sludge from treatment into the receiving environment, encouraging their mobilization and dispersion in the environment[2]. The AM mining process generates huge tailings at the end of the treatment process, which are generally stored in the environment. The dumping of these tailings has an immediate impact on the ecosystem, and is also responsible for soil and water contamination by potentially toxic elements

(PTEs) such as mercury (Hg), iron (Fe), arsenic (As) and zinc (Zn)[4]. At high levels in available forms, PTEs can affect living organisms and soil metabolic processes, resulting in a reduction in soil fertility[5].

With a predominantly poor rural population dependent on the natural environment for survival, it is essential to implement sustainable solutions aimed at limiting environmental risks. Various conventional treatment methods are used to remove contaminants from the soil. However, excessive discharges of sludge and high costs are major challenges to the use of these methods. To address this constraint, various bioremediation techniques are viable options because of their economic, efficient and ecological characteristics. Among these techniques is phytoremediation plants that can eliminate soil contaminants through processes that stabilize, extract, volatilize or degrade micropollutants[6]. Phytoremediation has proved its worth in various technological fields, including the clean-up of mining sites and the rehabilitation of degraded land[7]. This study therefore aims to test the technology of phytoremediation of mine tailings in a Sahelian context in a controlled environment in Burkina Faso. The main objective of this study is to investigate the pollution tolerance of *Andropogon gayanus* and *Chrysopogon zizanioides* and their capacity to bioaccumulate Hg, As Fe and Zn from AM activities. While the ability of *C. zizanioides* (vetiver) to decontaminate soils from mine tailings has been well studied, that of *A. gayanus* has not been well documented.

2. Materials and Methods

2.1. Description of the experimental site

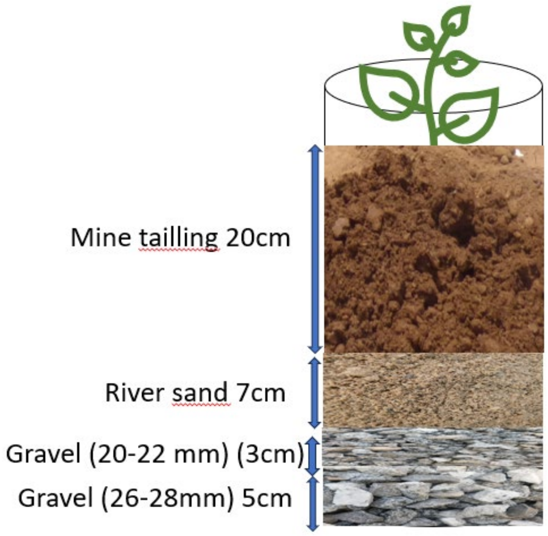
The study was carried out from August 2022 to February 2023 in an experimental greenhouse at the Institute for Research in Applied Sciences and Technology (IRSAT) (12°25‘ 27.8’’N, ;1°29’ 15.17’’W) in Ouagadougou... The city of Ouagadougou is located in the Sudano-Sahelian zone, characterized by a semi-arid climate with a rainy season that generally extends from May to September and a dry season for the rest of the year. In the Sudano-Sahelian zone, annual rainfall varies between 600 and 700 mm, with maximum temperatures reaching 48°C at the height of the dry season.

2.2. Organic material

- The mine tailings used for the experiment were collected from artisanal gold processing sites in the rural commune of Nimbrogo located in the Centre-Sud region of Burkina Faso. According to the Köppen-Geiger classification, the area has a humid and dry tropical climate.
- Unpolluted soils are derived from the same ore as the mine tailings, but which have just undergone the washing process.
- *Chrysopogon Zizanioides*: is a plant of Asian origin in the family Poaceae, of the order Poales, with the kingdom Plantae and the class Liliopsida. This plant was chosen for its many very interesting characteristics: sterile and non-invasive, perennial with a rhizome that roots very deeply, and high pollution-removal potential [8]. *Chrysopogon zizanioides* is not harmful to the environment and has unique morphological and physiological characteristics that enable it to adapt to the harsh climatic conditions of Burkina Faso.
- *Andropogon gayanus Kunth*: is a large African savannah perennial poaceae that can reach 3.50 m in height, belonging to the Andropogonata tribe. It was chosen for its characteristics, which are similar to those of *C. zizanioides. A. gayanus* is used to regenerate and restore the fertility of degraded land [9].

2.3. Experimental set-up

The experimental set-up consisted of planted and unplanted pilot units. The 90 pilot plants were built in 30-litre polypropylene pots. Each pot is constructed from bottom to top with a first transition layer of 5 cm of granite with an average diameter of 28 mm, followed by 3 cm of 22 mm dimeter of gravel and 1 mm river sand at D90. A 20 cm layer of mine tailings was deposited on top of this gravel pack for the polluted conditions, or a layer of untreated ore for the unpolluted conditions (Figure 1). The pots were supplied with a dose of 0.85 l of tap water and left to stand for 72 hours. At the end of the rest period, *C. Zizanioides* and *A. Gayanus* plants previously propagated in a nursery were transplanted into the pots and randomly placed on a metal support in a greenhouse (figure2). The pots were watered with doses of 0.85 l every days during the experiment. This irrigation dose was derived from the average rainfall in the city of Ouagadougou. Each quarter, the pots were amended with compost. The experimental set-up comprises two modalities: involving unpolluted (PN) and polluted (P) modalities.



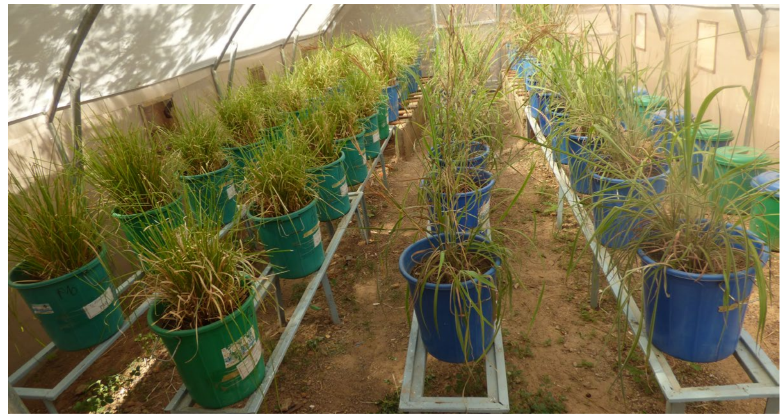


Fig 2: Overview of the potted plants in the

Fig1: Pilot construction diagram

2.1. Evaluation of phytoremediation efficiency

Morphological monitoring consisted of measuring the morphological parameters of plant growth, determining the tolerance index, relative water content, specific root length and relative growth indices. Plant growth assessment consisted of fortnightly measurements of allometric parameters (number of green leaves, number of new shoots, stem size and circumference dimension) for each modality for 18 months.

3. Results and discussion

2.2. 3.1 Water tolerance and performance factors

The 100% survival rate was observed during the first campaign, i.e. during the first six months of the experiments, all the herbaceous plants survived in the pots. The evolution of the tolerance index throughout the experimental period is shown in Table 1. Over the five sampling campaigns, the tolerance indices show that *C. Zizanioides* and A. *gayanus* have a strong capacity to maintain their growth and physiological functions despite stress conditions linked to pollution and high temperatures. However, *C.Zizanioides* had a higher TI than A. gayanus in all the campaigns, which was not significantly different except at C3, corresponding to the twelfth month of experimentation.

Over the course of the experimental campaigns, we observed that the relative water content (RWC) of C. *zizanioides* and *A. gayanus* remained relatively stable, with values between 82.1% and 84.2% throughout the sampling campaign. This stability indicates that, despite the conditions of pollution and high temperatures, *C.* zizanioides and *A. gayanus* are capable of retaining water in these organs. No significant difference in RWC was observed either within a plant or between the two species during the different sampling campaigns. This is in line with the results of [10] who demonstrated that there is no significant difference between the RWC of vetiver in the control and iron mine garden. This could indicate good water resilience of *C.Zizanioides*. The RWC values show that the plants studied are able to maintain a water balance by effectively managing the available water resources.

The relative water content (RWC) was relatively stable over the campaigns and was not significantly different (table2). This stability indicates that despite the conditions of pollution and high temperatures, *C.Zizanioides* is able to retain water in these organs. No significant difference in RWC was observed between the sampling campaigns. This is in line with the results of [10] who demonstrated that there is no significant difference between the RWC of vetiver in the control and iron mine garden. This could indicate good water resilience of *C.Zizanioides*.

The specific root length (SRL) of the NP modality was higher than that of the P modality during the first sampling campaign. Elongated roots allow better exploration of the soil to compensate for unfavourable conditions. The general drop in LRS for both modalities is indicative of a slowdown in root growth. The specific root length (SRL) of the NP modality was greater than that of the P modality during the first sampling campaign. Elongated roots allow better exploration of the soil to compensate for unfavorable conditions. A reduction in LRS is observed from the second campaign for both modalities. This reduction in both situations indicates a slowdown in leaf growth. The general drop in LRS regardless of polluted or unpolluted pots may be due to the constrained space for the deployment of the roots which have thickened; In addition, this constraint limits root length, but promotes an increase in weight.

Table1: Tolerance index of plants. n is a number of pot

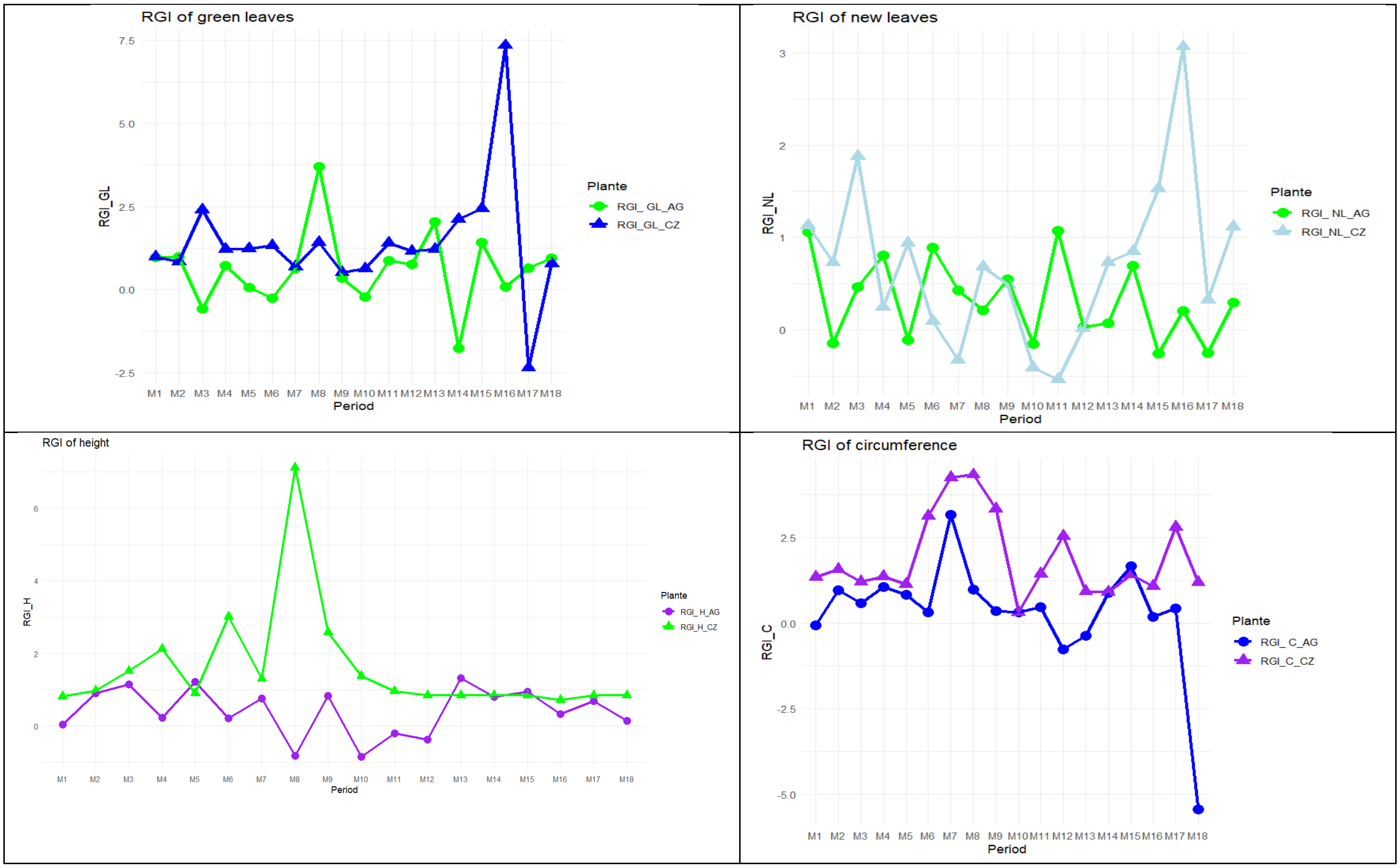
Campaign	TI_CZ + standard error (n=12)	TI_AG + standard error (n=12)
1st	85,9±0,01	82,1±0,01
2nd	71,1 ± 0,0	72,0 ± 0,01
3rd	70,9 ± 0,0	90,6±0,01
4th	79,8±0,01	78,9 ± 0,01
5th	79,1 ± 0,01	81,1 ± 0,01

Table2: RWC and SRL of plants

Campaign	RWC_CZp	RWC_CZnp	RWC_AGp	RWC_AGnp	SRL_CZp	SRL_CZnp	SRL_AGp	SRL_AGnp
1st	83,5	82,1	84,8	84,2	1,3	1,4	2,8	5,7
2nd	83,1	82,9	82,3	83,7	1,4	0,6	1,1	2,1
3rd	82,7	82,7	82,6	83,5	0,8	0,5	1,2	1,6
4th	82,5	82,8	83,0	83,5	0,4	0,3	0,7	0,8
5th	82,7	82,8	83,4	83,3	0,3	0,3	0,8	0,6

2.3. The relative plant growth index

The index of relative evolution of greens leaves, new leaves, height and circumference of the two herbaceous plants fluctuated throughout the experiment. CZ showed more marked variations, while AG remained more stable. Over the 18 months, CZ showed greater variation than AG. From M1 to M6, the RGI plants were positive overall, revealing good growth in all the parameters monitored. From the seventh month, there was a gradual decline in the relative growth of the plants until the end of the trials; this could indicate that the plants had reached maturity. However, there was no significant difference between the evolution of the green leaves and the new leaves of the plants. However, the evolution of the height and circumference between the two species were significantly different during the experiment. The absence of any significant difference in leaf growth reveals that the plants maintain an equilibrium despite the pollution and the climate. According to (Truong, 2000), CZ's ability to adapt is linked to its intrinsic characteristics, thanks to its extensive and very dense root system. AG plants with the same characteristics have demonstrated this ability.



2. Conclusion

This study highlighted the ability of *C. zizanioides* and *A. gayanus* to adapt to the demanding conditions of the Sahelian climate, particularly those of Burkina Faso in mine tailings. The first few months of experimentation were particularly revealing in terms of the plants' potential. Despite high temperatures and the presence of chemical pollutants, making the experimental conditions very harsh, the two herbaceous plants showed remarkable resilience, continuing to grow. *C. Zizanioides* appears to be more resistant to water stress, while *A. gayanus* has a relatively remarkable growth rate.

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