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Assessment of the inhibitory effect of two local plants on the emergence of four weeds and identification of their secondary metabolites: Case of *Parkia biglobosa* (Jacq.) R.Br.ex G.Don. and *Tephrosia purpurea* (L.) Pers.

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A B S T R A C T

In Burkina Faso, *Senna occidentalis, Ipomoea eriocarpa, Pupalia lappacea* and *Triumfetta cordifolia* are frequent weeds in the maize crop. This work evaluated the inhibitory effect of *Parkia biglobosa* pods and *Tephrosia purpurea* leaves and identifies their chemical compounds. Biological and chemical approaches were used to identify the weeds. The inhibitory effect of powders was evaluated on weed germination and growth. Experimental results showed that powders reduced both germination ($p<0.001$) and growth ($p<0.016$). *Parkia biglobosa* pods were rich in total flavonoids (544.2±1.4 µg mg^{-1}) and condensed tannins (182.3±1.5 µg mg^{-1}) than *Tephrosia purpurea* leaves which contained small amounts of total flavonoids (6.7±1.7 µg mg^{-1}) and condensed tannins (5.7±1.2 µg mg^{-1}). *Parkia biglobosa* pods could be used in the biological control of weeds.

Keywords: Biological control, Germination, Inhibitory plants, Organic compounds, Weeds

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Introduction

In Burkina Faso, particularly in the Cascades region, maize is one of the food crops on which farmers rely to improve their income and fight against food insecurity (Sambaré *et al.*, 2011). Despite the interest in this crop, its production is constrained by several unfavorable factors, including: climatic hazards, declining soil fertility and the proliferation of weeds leading to low yields (Coulibaly *et al.*, 2017). Indeed, weeds are considered as one of major problems in cereal crops and their expansion in farms is perceived as one of the main causes of yield loss (Ka *et al.*, 2019). In high maize production areas, weeds are responsible for huge losses in crop yields. Indeed, crop losses are estimated to average between 25% and 80% (Sambaré *et al.*, 2011). To control weeds, the application of synthetic chemical herbicides is the most commonly used method by farmers. However, the dependence on synthetic chemical herbicides generates resistance phenomena in weeds and negative impacts such as contamination of water, soil and agricultural products (Ovono *et al.*, 2019). Faced with these drawbacks, alternative methods are essential to ensure better productivity and contribute to food security for populations while preserving health and the environment (Mboup *et al.*, 2019). Previous work showed that the pods of *Parkia biglobosa* and the leaves of *Tephrosia purpurea* inhibit the germination of maize weeds (Sourabié *et al.*, 2021). This inhibition would depend on the action of certain molecular groups of the pods of *Parkia biglobosa* and the leaves of *Tephrosia purpurea*, which explains in part the herbicidal effect of these two local plants. Indeed, several works revealed that certain secondary metabolites are involved in the inhibition of germination (Moussaoui *et al.*, 2017). Thus,

myricitrin and naringinin, two molecules synthesized by *Cynara cardunculus* Crude inhibit the germination of *Trifolium incarnatum* L. seeds (Ben Kaab *et al.*, 2020). In this work, the study of the biological activity of plants with herbicidal effect and the identification of chemical molecules involved allow to establish the scientific bases for their implementation in the agricultural field. At this regards, the objective of present study was to assessment the inhibitory effect of *Parkia biglobosa* pods and *Tephrosia purpurea* leaves in greenhouses. In addition, the potentially active chemical groups of these two plants have been identified using chemical tests.

Materials and Methods

Materials used

The plant material was consisted on the host plant, maize (*Zea mays* L.) of the composite varietal type popularized by the Institute of Environment and Agricultural Research (INERA) because of its high agronomic potential in the Sudanian zone, and on the other hand, plants with herbicidal effect and weed seeds collected in the southwest of Burkina Faso. Thus, the leaves of *Tephrosia purpurea* and the pods of *Parkia biglobosa* were used to determine their herbicidal properties and *Senna occidentalis* L., *Ipomoea eriocarpa* R. Br., *Pupalia lappacea* (L.) A. Juss. and *Triumfetta cordifolia* A. Rich., the four weeds. The choice of these species is a consequence of the work done in vitro (Sourabié *et al.*, 2021).

Preparation of the powder

P. biglobosa pods and *T. purpurea* leaves were dried completely at laboratory room temperature (25±3°C) for two weeks. After drying, *P. biglobosa* pods were cut into small pieces to facilitate their reduction to powder. A traditional mortar was used to grind the organs of both species separately and then sieved through a 500 µm mesh screen. The fine powders were stored separately in the bags until they were used.

Phytochemical study

The main families of secondary metabolites were characterized by staining and precipitation reaction tests. We characterized flavonoids, tannins, coumarins, sterols and terpenes and alkaloids according to the methods reported by Singleton and Rossi (1965). Dragendorff's reagent for alkaloids, ferric chloride solution for tannins, Cyanidine reaction for flavonoids, Lieberman's reaction for sterols and terpenes, and finally coumarins by Ultraviolet fluorescence (UV).

Results and Discussion

Table 1. Secondary metabolites characterized according to tube reactions.

Secondary metabolites	*P. biglobosa* (Pods)		*T. purpurea* (Leaves)	
	hexanic extract	hydroalcoholic extract	Hexanic extract	hydroalcoholic extract
Flavonoids	+	+	+	+
Gallic tannins	-	+	-	+
Catechic tannins	-	+	-	+
Sterols and terpenes	-	+	-	-
Coumarins	-	+	-	-
Alkaloids	+	+	+	+

(+) : positive reaction; (-) : negative reaction

Amounts of total flavonoids and condensed tannins

The figure 1 illustrates the amounts of total flavonoids and the figure 2 shows condensed tannins. Results revealed that the hydroalcoholic extract of *P. biglobosa* pods is richer in total flavonoids and condensed tannins than the hydroalcoholic extract of *T. purpurea* leaves, with quercetin and catechin equivalents estimated at 544.2±1.4 µg mg^{-1} and 182.3±1.5 µg mg^{-1} of crude extract, respectively. Lowest amounts of total flavonoids (6.7±1.7 µg mg^{-1}) and condensed tannins (5.7±1.2 µg mg^{-1}) were observed with hexanolic extracts of *T. purpurea* leaves.

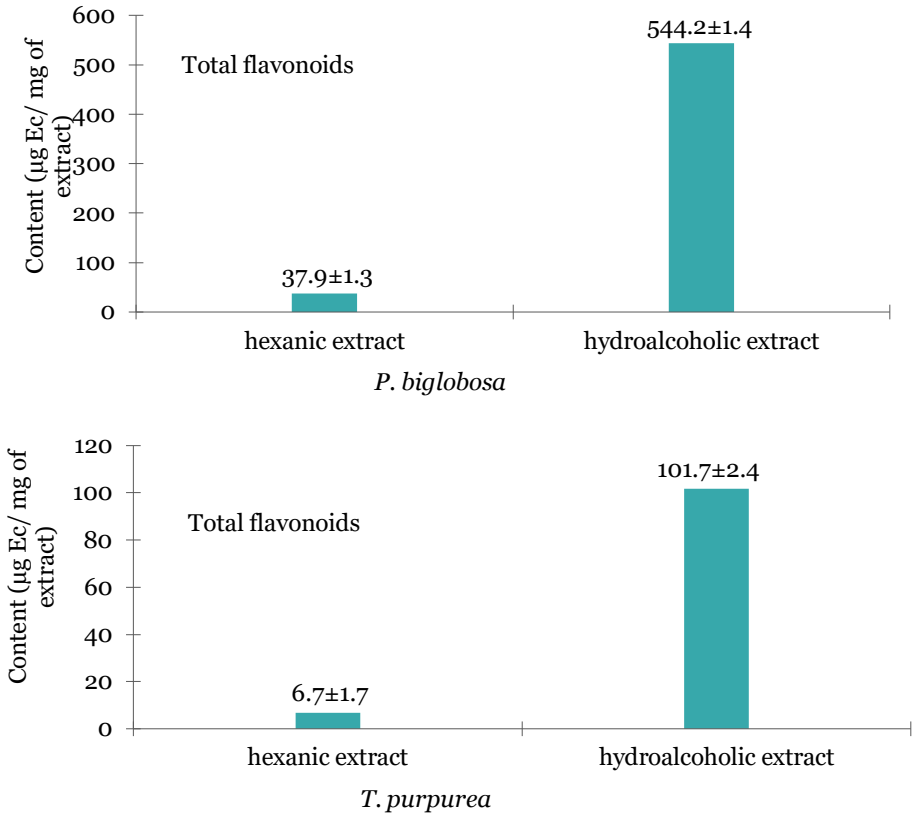

Figure 1. Variations in total flavonoid content of *P. biglobosa* pods and *T. purpurea* leaves.

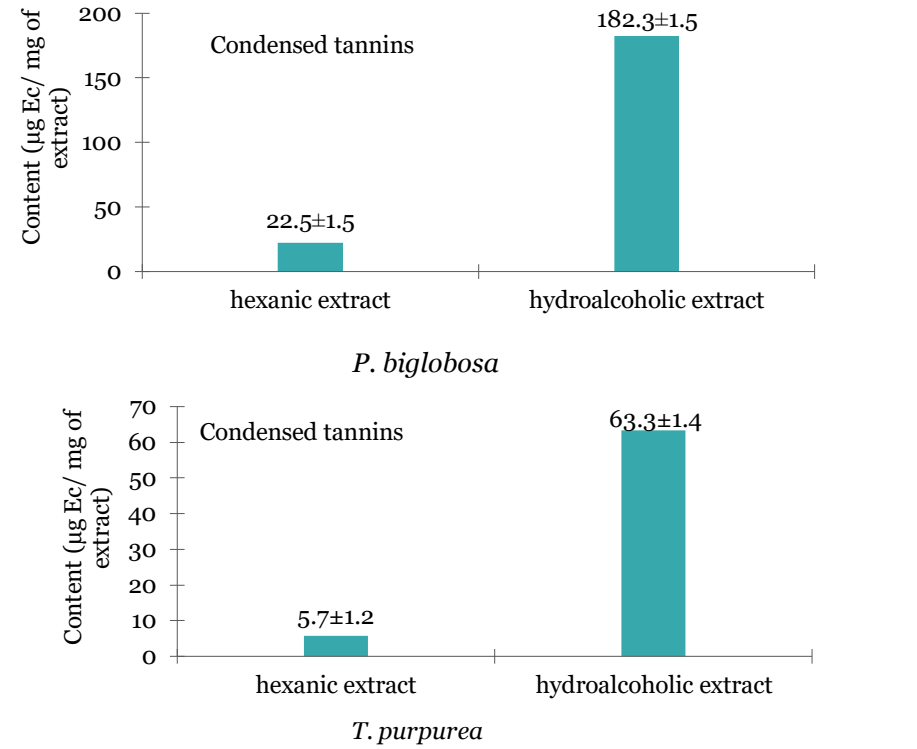

Figure 2. Variations in condensed tannin content of *P. biglobosa* pods and *T. purpurea* leaves.

Effects of powders on weed germination parameters

Table 2 shows the germination rates, latency period and durations of the weeds germination. It shows that the powders of *P. biglobosa* pods significantly reduced the germination rates (p = 0.002), extended the latency period (p = 0.033) and the duration of germination (p = 0.43) of *I. eriocarpa*. Similarly, analysis of variance showed that *T. purpurea* leaf powders significantly reduced germination rates (p=0.009) and extended latency period (p=0.042) of *I. eriocarpa*. Indeed, the highest doses of *P. biglobosa* pods, 15 g and 21 g reduced germination of *I. eriocarpa* more translated by the lowest values 23.0±1.7% and 10.0±0.7% respectively. On the other hand, the latency period were extended by 3 days and 1 day at the 21 g doses of *P. biglobosa* pods and *T. purpurea* leaves respectively. For *S. occidentalis*, analysis of variance revealed a significant difference between germination rates (p=0.008), latency period (p=0.041) and the duration of germination (p=0.027) for *P. biglobosa* and *T. purpurea* leaf powders induced significant differences between germination rates (p=0.002), latency period (p=0.018) and the duration of germination (p=0.030). The lowest germination rates 22.0±1.3% and 17.0±2.0% were recorded at the high doses of 15 g and 21 g of *P. biglobosa*, respectively. Latency period increased from 5 days at the low dose (3 g) of *P. biglobosa* to 8 days at the higher doses (15 g and 21 g). With the latter two doses, duration of germination was also extended by 3 days compared to the control. The same trends recorded in the two previous weeds were observed in *T. cordifolia* where significant differences were noted in germination rates (p=0.012), latency period (p=0.031) and duration of germination (p=0.028) for *P. biglobosa* powders and those of *T. purpurea* only induced significant differences in germination rates (p=0.022) and duration of germination (p=0.008). The highest doses 15 g (29.0±1.9%) and 21 g (14.9±3.2%) of *P. biglobosa* reduced the germination of *T. cordifolia* more compared to the control (70.5±1.3%). Withdrawal times increased from 5 days with the 3 g dose to 9 days with the 21 g dose of *P. biglobosa*. In contrast, the latency period did not vary for any dose of *T. purpurea*. For *P. lappacea*, no significant difference was observed in the withdrawal times with *P. biglobosa* (p=0.917) and *T. purpurea* (p=0.941) powders. In contrast, 15 g (44.6±1.1%) and 21 g (29.4±2.7%) of *P. biglobosa* significantly reduced germination rates (p=0.040). Doses of 21 g of *P. biglobosa* and *T. purpurea* each extended duration of germination by 3 days compared to the respective controls. The values are averages expressed in percentages or days followed by the standard deviation. In the same column, means followed by the same alphabetical letter are not significantly different at the 5% level.

Table 2. Variations of weed germination parameters with increasing doses of powders.

Weeds	Doses (g)	Powders of *P. biglobosa*			Powders of *T. purpurea*		
		Germination rate (%)	Latency period (day)	Duration of germination (day)	Germination rate (%)	Latency period (day)	Duration of germination (day)
I. eriocarpa	Control	87.0 ^{c} ±1.5	4.0 ^{a} ±0.9	8.0 ^{a} ±0.8	92.0 ^{b} ±3.6	5.0 ^{a} ±0.9	8.0 ^{a} ±0.6
	3	76.9 ^{c} ±2.1	4.0 ^{a} ±0.3	8.0 ^{a} ±0.1	86.9 ^{b} ±2.1	5.0 ^{a} ±0.5	8.0 ^{a} ±0.7
	9	79.0 ^{c} ±3.0	4.0 ^{a} ±0.5	8.0 ^{a} ±0.5	88.5 ^{b} ±4.0	4.0 ^{a} ±0.5	8.0 ^{a} ±0.6
	15	23.0 ^{b} ±1.7	6.0 ^{b} ±0.9	8.0 ^{a} ±0.7	83.4 ^{b} ±1.5	6.0 ^{b} ±0.7	8.0 ^{a} ±0.7
	21	10.0 ^{a} ±0.7	7.0 ^{b} ±0.7	1.,0 ^{b} ±0.6	80.0 ^{b} ±2.3	6.0 ^{b} ±1.0	8.0 ^{a} ±1.0
S. occidentalis	Control	81.3 ^{b} ±2.8	5.0 ^{a} ±0.9	7.0 ^{a} ±1.4	79.4 ^{b} ±1.3	4.0 ^{a} ±1.0	7.0 ^{a} ±0.5
	3	78.1 ^{b} ±1.2	5.0 ^{a} ±0.4	7.0 ^{a} ±1.9	82.1 ^{b} ±2.0	5.0 ^{a} ±0.9	8.0 ^{a} ±0.1
	9	82.0 ^{b} ±3.1	6.0 ^{a} ±0.7	7.0 ^{a} ±2.1	83.7 ^{b} ±3.1	5.0 ^{a} ±1.8	8.0 ^{a} ±0.4
	15	22.0 ^{a} ±1.3	8.0 ^{b} ±1.4	10.0 ^{b} ±1.0	32.5 ^{a} ±0.7	8.0 ^{b} ±0.5	8.0 ^{b} ±0.3
	21	17.0 ^{a} ±2.0	8.0 ^{b} ±1.9	10.0 ^{b} ±1.2	33.4 ^{a} ±1.2	7.0 ^{b} ±0.9	10.0 ^{b} ±0.1
T. cordifolia	Control	70.5 ^{b} ±1.3	4.0 ^{a} ±0.7	7.0 ^{a} ±0.7	83.5 ^{b} ±1.0	5.0 ^{a} ±0.4	9.0 ^{a} ±0.7
	3	68.0 ^{b} ±3.7	5.0 ^{a} ±0.8	8.0 ^{a} ±0.3	78.0 ^{b} ±3.1	5.0 ^{a} ±1.0	9.0 ^{a} ±1.3
	9	68.0 ^{b} ±3.0	7.0 ^{b} ±0.4	11.0 ^{b} ±1.1	51.0 ^{a} ±2.0	5.0 ^{a} ±0.8	11.0 ^{c} ±0.7
	15	29.0 ^{a} ±1.9	9.0 ^{c} ±1.0	11.0 ^{b} ±0.3	44.7 ^{a} ±1.3	5.0 ^{a} ±0.7	9.0 ^{b} ±0.9
	21	14.9 ^{a} ±3.2	9.0 ^{c} ±0.5	11.0 ^{b} ±0.7	50.9 ^{a} ±2.1	5.0 ^{a} ±0.1	11.0 ^{c} ±0.3
P. lappacea	Control	89.5 ^{c} ±3.4	4.0 ^{a} ±0.6	7.0 ^{a} ±1.2	92.1 ^{c} ±2.6	6.0 ^{a} ±0.4	8.0 ^{ab} ±0.6
	3	79.5 ^{c} ±2.1	4.0 ^{a} ±0.9	7.0 ^{a} ±2.0	77.5 ^{b} ±2.5	5.0 ^{a} ±1.0	7.0 ^{a} ±0.4
	9	87.0 ^{c} ±1.7	4.0 ^{a} ±1.4	8.0 ^{a} ±0.6	83.0 ^{c} ±1.7	7.0 ^{a} ±1.2	9.0 ^{b} ±0.5
	15	44.6 ^{b} ±1.1	5.0 ^{a} ±0.8	10.0 ^{b} ±0.3	33.0 ^{a} ±3.4	7.0 ^{a} ±0.3	11.0 ^{c} ±0.1
	21	29.4 ^{a} ±2.7	5.0 ^{a} ±1.7	10.0 ^{b} ±1.4	30.4 ^{a} ±1.5	7.0 ^{a} ±0.1	11.0 ^{c} ±0.4

The values are averages expressed in percentages or days followed by the standard deviation. In the same column, means followed by the same alphabetical letter are not significantly different at the 5% level.

Effects of powders on maize germination parameters

The germination rates of maize are shown in figure 3. The values of germination rates induced by the powders of *P. biglobosa* are not statistically different (p=0.946) from those of the control. The powders slightly improve maize germination reflected by germination rates that ranged from 95.7±1.7% to 97.1±0.7% at 3 g and 21 g doses, respectively. Similarly, *T. purpurea* powders did not significantly (p=0.641) influence the germination of maize. The lowest value of germination rate was 96.0±1.2% at the 3 g dose and 97.7±1.7% the highest was obtained with the 21 g dose.

The latency period and duration of germination induced by the powders were similar to those of the controls (Figure 4). Regardless of the dose, the recorded latency period was 4 days. In contrast, germination times of up to 5 days are obtained at the 15 g and 21 g doses.

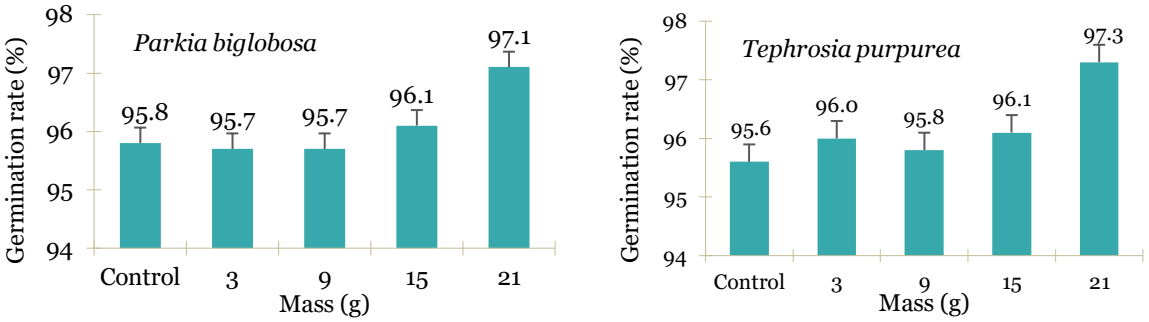

Figure 3. Variations of maize germination rates induced by *P. biglobosa* and *T. purpurea* powders.

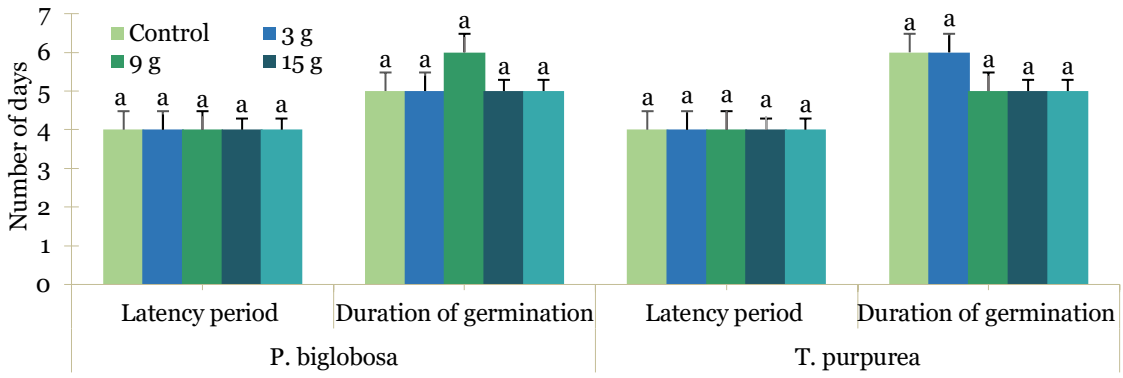

Figure 4. Variations of maize duration germination and latency period induced by *P. biglobosa* and *T. purpurea* powders.

Effect of powders on vegetative growth of weed seedlings

The evolution of weed size as a function of powder doses is given in table 3. Powders of *P. biglobosa* were significantly influenced the growth of *I. eriocarpa* (p=0.001). The lowest height value was observed at the 21 g dose (5.0 ±0.9 cm) and the highest at the 3 g dose (8.1±1.0 cm). The sizes of *I. eriocarpa* plants induced by following doses 3 g (8.4±2.1 cm), 9 g (7.9±1.2 cm), and 15 g (8.2±1.2 cm) were not statistically different and formed a homogeneous group with the control. The lowest height induced by *T. purpurea* powders was observed with the 21 g dose (6.3±2.1 cm). The growth of *S. occidentalis* seedlings was significantly influenced (p=0.033) by *P. biglobosa* powders. The lowest height (4.2±0.1 cm) was induced by the dose of 21 g. In contrast, *T. purpurea* powders had no influence on the growth of this weed. Regardless of the dose of *T. purpurea* powder, the observed height values were statistically identical to those of the control. Statistical tests showed that both *T. purpurea* (p=0.041) and *P. biglobosa* (p=0.008) powders had a significant impact on the vegetative growth of *P. lappacea*. Doses of 15 g and 21 g of *P. biglobosa* induced the smallest sizes 6.1±0.3 cm and 6.5±0.6 cm, respectively. At the low doses of 3 g and 9 g, the height growth of *P. lappacea* seedlings was not significantly affected by *P. biglobosa* (p=0.487) and *T. purpurea* (p=0.726) powders. The lowest height values were generated by 15 g (6.4±0.5 cm) and 21 g (6.0±1.3 cm) of *P. biglobosa* powders and that of 21 g (6.0 ± 1.8 cm) of *T. purpurea*.

Table 3. Variations in seedling size with powder concentrations.

Weeds	Doses (g)	Powders of *P. biglobosa*	Powders of *T. purpurea*
I. eriocarpa	Control	8.1 ^{b} ±1.0	9.1 ^{b} ±1.3
	3	7.3 ^{b} ±0.5	8.4 ^{b} ±2.1
	9	7.7 ^{b} ±1.5	7.9 ^{b} ±1.2
	15	8.4 ^{b} ±2.3	8.2 ^{b} ±1.5
	21	5.0 ^{a} ±0.9	6.3 ^{a} ±2.1
S. occidentalis	Control	8.5 ^{b} ±1.5	9.2 ^{a} ±1.3
	3	9.1 ^{b} ±0.5	10.4 ^{a} ±3.1
	9	8.8 ^{b} ±1.0	10.5 ^{a} ±1.0
	15	7.9 ^{b} ±0.9	10.5 ^{a} ±1.2
	21	4.2 ^{a} ±0.1	9.8 ^{a} ±0.5
T. cordifolia	Control	8.4 ^{b} ±1.2	9.5 ^{b} ±1.6
	3	9.6 ^{b} ±1.3	10.5 ^{b} ±2.5
	9	9.8 ^{b} ±1.0	9.0 ^{b} ±1.4
	15	6.1 ^{a} ±0.3	9.5 ^{b} ±2.5
	21	6.5 ^{a} ±0.6	7.5 ^{a} ±0.9
P. lappacea	Control	11.9 ^{b} ±1.5	11.9 ^{b} ±2.0
	3	11.9 ^{b} ±0.2	11.6 ^{b} ±2.9
	9	9.6 ^{b} ±1.8	11.4 ^{b} ±3.0
	15	6.4 ^{b} ±0.5	9.8 ^{b} ±1.5
	21	6.0 ^{a} ±1.3	6.0 ^{a} ±1.8

Values are height means expressed in centimeters followed by the standard deviation. In the same column, the means followed by the same alphabetical letter are not significantly different at the 5% threshold.

Effect of powders on vegetative growth of maize seedlings

Analysis of figure 5 shows that *P. biglobosa* powders significantly (p=0.013) influence the height of maize seedlings. At the highest doses (15 g and 21 g), the recorded height values are 96.3±1.7 cm and 97.1±1.0 cm, respectively. At the lowest doses (3 g and 9 g), the values of the recorded heights (73.5±1.4 cm and 87.1±2.0 cm, respectively) are statistically similar to that observed with the control (72.7±2.3 cm). Unlike *P. biglobosa* powders, *T. purpurea* powders did not impact on vegetative growth of maize seedlings. Data analysis revealed that there was no significant difference (p=0.749) between the height values at 3 g (73.6±1.9 cm); 9 g (79.4±1.3 cm); 15 g (78.5±1.8 cm); 21 g (79.7±1.3 cm) compared to the control (73.6±2.4 cm).

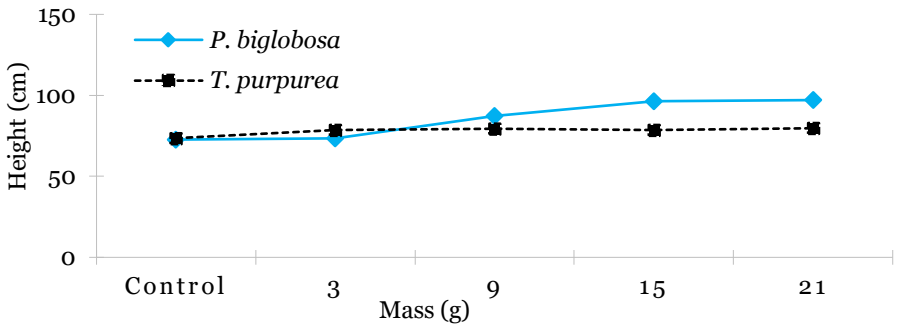

Figure 5. Variations of maize seedling heights with increasing doses of powders.

Discussion

Powders of the pods of *P. biglobosa* and leaves of *T. purpurea* inhibited weed germination and growth, reflected in low germination rates and low seedling heights respectively. In addition, they increased the latency period and the duration of germination. These results are in agreement with the work of Kambou *et al.* (2000) who reported that powders of the pods of *P. biglobosa* significantly inhibited the germination of *S. hermonthica*. Low germination rate induced by the higher dose would be related to the content of natural organic compounds. In this way Balicevic *et al.* (2015) reported that secondary metabolites are involved quantitatively and not qualitatively in the inhibition of germination and growth. In this study, the inhibition of all the weeds by the powder of the pods of *P. biglobosa* obtained, implies an effectiveness of this species compared to *T. purpurea* which does not induce a significant inhibition of *I. eriocarpa*. A variation in the content of the secondary metabolites related to the plant and the plant organ could be at the origin of the low biological activity of *T. purpurea*. Furthermore, the phytochemical study revealed the absence of compounds such as sterols, terpenes and coumarins in *T. purpurea* powder. By comparing the amounts of organic

compounds, we notice that the powder of the pods of *P. biglobosa*, which proved to be more effective in the inhibition of germination and growth, is rich in total flavonoids and condensed tannins, whereas the powder of the leaves of *T. purpurea*, which is less effective, contains only a small quantity. It is inferred that flavonoids and tannins act quantitatively and not qualitatively. High amount of total flavonoids and condensed tannins in the hydroalcoholic extract of *P. biglobosa* pods could explain the good germination inhibitory activity of these organs. Indeed, the presence of total flavonoids and condensed tannins in significant quantities in the organs of *P. biglobosa* has been reported in literature. Thus, Ahodegnon *et al.* (2018) obtained for hydroalcoholic extracts of the pulp of *P. biglobosa* contents of 6.13 mg EAG/g for total flavonoids and 0.51 mg EAG/g for condensed tannins. While, Sérémé *et al.* (2008) reported higher contents in the bark of the trunk of *P. biglobosa*, of the order of 126.7 mg EAG /g for total flavonoids and 16.7 mg EAG /g for condensed tannins. Indeed, the variation of the content of total flavonoids and condensed tannins for the same plant depends largely on the solvent and the organ used. Thus, Coulibaly *et al.* (2017) showed in their work that ethanol is a better solvent compared to hexane because it solubilizes well the medium polar phenolic compounds and can also entrain residual lipophilic substances. This would justify in part and the results we obtained in this study with the powder of *P. biglobosa* and *T. purpurea*. In addition, Ben Kaab *et al.* (2020) reported that organic substances with inhibitory effect like flavonoids and tannins are present in leaves, fruits, stems, pods and roots. They are released by processes such as volatilization, root exudation, leaching and decomposition of plant residues. The results obtained with the powders show that flavonoids and tannins among other compounds would be responsible for the observed inhibitions on weed germination and growth. Dallali *et al.* (2017) reported that the compounds inhibiting germination and growth are most often flavonoids; their effects may be synergistic or additive. Thus, flavonoids and tannins increase their potential inhibitory effect when associated with terpenes (Moussaoui *et al.*, 2017). The absence of terpenes in the chemical composition of *T. purpurea* would then be at the origin of its weak biological activity despite the presence of flavonoids. On the other hand, in the literature, the most studied plants with an inhibitory effect such as *Cynara cardunculus* Crude (Ben Kaab *et al.*, 2020) and *Allium roseum* L (Sakka Rouis-Soussi *et al.*, 2017) are rich in terpene compounds, sterols and flavonoids. *P. biglobosa* pods could be the most important source of these compounds, confirming their potential inhibitory effect. However, the mode of action of terpenes, sterols and flavonoids in the process of germination and growth inhibition is not well elucidated, but it has been suggested that they could accumulate in the cell membranes of weeds, causing a loss of membrane structural integrity (Couëdel *et al.*, 2017). Other work reported the inhibitory effect of phenols and particularly thymol and/or carvacrol (Sakka Rouis-Soussi *et al.*, 2017). These phenols act by binding to the amine and hydroylamine groups of the membrane proteins of weeds causing inhibition of germination and growth of seedlings (Ben Kaab *et al.*, 2020). Our results confirm the work of Dandjlessa *et al.*, (2019). According to these authors, *Chromoleana odorata* inhibits the growth of *Phyllanthus amarus*, *Boerhavia diffusa* and *Spermacoce verticillata*. To be considered as natural herbicides, organic compounds must interfere only on physiological, biochemical and molecular processes of the target plants (Cordeau *et al.*, 2016). In this study, the powders did not inhibit the germination and growth of maize at any applied rate. On the contrary, they slightly improved both germination and growth of maize seedlings. Also, the latency period (4 days) and duration of germination (5 days) obtained were similar to those of the controls. The better germination and seedling growth rates would be explained by the fact that the powders provided a nutrient source for the maize. Similar results were reported by Mboup *et al.* (2019) who showed that *Gliricidia sepium* (Jacq.) Walp inhibited germination and growth of *Senna obtusifolia* L., *Sesbania pachycarpa* DC., *Spermacoce chaetocephala* DC., *Pennisetum glaucum* (L.) R. Br., *Indigofera hirsuta* L., and *Eragrostis ciliaris* (L.) R. Br. but not millet. In contrast to our results, Delabays *et al.* (2009) reported that the incorporation of 400g/m² of *Artemisia annua* leaves in the soil inhibited 2.5% of maize germination. This difference in results could be justified by the presence of artemisinin, the main organic compound of *Artemisia annua*, whose phytotoxicity has been recently reported (Ben Kaab *et al.*, 2020). In the light of these investigations and in view of the inhibitory effects demonstrated in the greenhouse on the germination and growth of weeds, it appears that the powders of the pods of *P. biglobosa* are the most effective and feasible for the biological control of weeds.

Conclusion

Powders of pods of *P. biglobosa* and *T. purpurea* leaves inhibit weed germination and growth. Organic compounds with inhibitory effect identified in these powders are sterols, tannins, terpenes, flavonoids and coumarins. Amounts of total flavonoids and condensed tannins is higher in the powder of *P. biglobosa* pods, justifying the strong inhibitory activity of the pods of this species compared to *T. purpurea*. No inhibitory effect of powders was observed on germination and growth of maize seedlings. These results could be exploited in a biological control strategy against *S. occidentalis*, *P. lappacea*, *I. eriocarpa* and *T. cordifolia*. However, the modes of action of the secondary metabolites identified in the powders on weed germination and growth should be elucidated in a future study.

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