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Allelopathic Potential of *Imperata cylindrica* on the Growth and Germination of *Zea mays*

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Allelopathy is regarded as any process whereby secondary metabolites produced by plants influence the growth and development of agricultural and biological systems performing positive and negative effects. *Imperata cylindrical* is one of the top ten worst weeds and is listed among the world's top 100 worst invasive alien species. To access the allelopathic potential of *Imperata cylindrica* on the germination and growth of *Zea mays, Zea mays* was treated with different concentrations of aqueous extract *of Imperata cylindrica*. The treatment was laid out in completely randomized designs with five treatments and 3 replications. Results indicated that the highest germination percentage was recorded from control whereas the lowest was at 20% concentration level. There was no significant difference in seed germination, root length, shoot length, seedling

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length, and vigor index between the treatments (P>0.05) when compared to the control. Crop residues of *Imperata cylindrica* could be spread on wastelands, resulting in the leaching of allelochemicals that would reduce the seed germination and consequently the population of weeds.

Keywords: Allelochemicals; Imperata cylindrica; maize; seed germination.

1. INTRODUCTION

"Weeds are a major threat to crop production in many cropping systems. Aggressive weed competition reduces crop yield significantly and adds further cost to crop production owing to their management. Yield losses in crops due to weeds depends on several factors such as type of weed, crop type, time of emergence, weed density" [1]. "It has been observed that weeds may cause a reduction up to 25-30% in the yield of wheat" [2] Marwat et al., 2008), 35-40% reduction in rice yield (Oreke and Dehne, 2004), 35-80% reduction in maize [3] and 20-40% reduction in sugarcane yield (Khan et al.,2004). "Among US crops, soybean and corn suffer the highest production loss because of weeds. Weed interference caused an average of 50% yield loss in corn in the USA and Canada across 2007-2013" [4,5]. "Weeds can decrease the growth and yield of crops by interfering with different metabolic processes" [6]. The interference of weeds with crops may be the consequence of competition and/or allelopathy.

The term allelopathy is derived from a Greek word 'Allelon' means to 'each other' and 'Panthos' means 'to suffer' means injurious and harmful effect of one organism upon others. The term 'allelopathy' was first used in 1937 by Austrian scientist Hans Molich [7]. Allelopathy involves the chemical interaction among different plants, plants and different organisms [8]. "Allelopathy refers to the direct or indirect effect of plants upon neighboring plants or their associated microflora or microfauna by the production of allelochemicals that interfere with the growth of the plant" [9]. "The ability of various plant species to induce allelopathic impacts on plants in their surroundings has been documented since ancient times. The most primitive writings on allelopathy are accredited to the Theophrastus (300 BC) who detected the detrimental effect of cabbage over the growth of a vine and proposed that such effects were occurred by odors from cabbage plants" [10].

"Allelochemicals are secondary metabolites which are liberated from plants and affect the germination and growth of recipient plants" [11,12]. "Allelochemicals are released through volatilization, root exudation, residues decomposition and leaching from leaf litter, and they act upon by various modes of action. These type of allelochemicals are harmful as well as has beneficial effect on other plants in both direction" [13,14]. "Previously, a release of allelochemicals by root exudation was considered marginal, however, nowadays, it is believed to be more important because 5-21% of fixed carbon could be excreted by roots" [15]. "Allelochemicals are very diverse and therefore it's difficult to establish a general action model; since it depends on the compound type, the receiving plants and how it acts. Allelochemicals can act at internal level and external level. Talking about the internal level, there is a large number of physiological parameters that can be affected. They have action on the cellular membrane, disrupt the activity of different enzymes or structural proteins or alter hormonal balance. They can also inhibit or reduce cellular respiration and chlorophyll synthesis, leading to a reduction in vitality, growth and overall development of the plant. These substances can also reduce seed germination or seedling development, or affect cell division, pollen germination", etc. [16].

"At external level, the allelochemicals may be related to the release or limitation of nutrients that are found in the soil. Others act on microorganisms leading to a perturbation on the symbiotic relationships they establish" (Aguilela and Puch, 2004).

"Seed germination and plant growth is interrupted by the disturbance of a variety of physiological functions occurring within plant bodies. The plant functions of prime importance which are affected by allelochemicals include respiration, photosynthesis, cell division and enlargement, metabolic activities, protein synthesis and enzyme actions" [17].

"One dominant weed in Ebonyi state is *Imperata cylindrica*. Decomposing residues of this weed are commonly left on the soil surface as mulches. However, it is known that plant residues of crops, weeds or natural vegetations left on, and in the soil, release assorted chemical compounds into the soil during decomposition. The chemical compound interferes with the growth of other plants and often adversely affect the yields of crop plants through the process of allelopathy. The allelochemicals are released on the environment by plant but, they are not directly aimed to the action site, thus it is a private mechanism. To be effective, allelopathic interaction needs that these substances are distributed along the ground or the air and that they reach the other plant. One of the most commonly grown edible seeds in this area are *Zea mays* (maize)".[18] This study was carried out to evaluate the allelopathic potential of *imperata cylindrica* on the germination of maize.

1.1 Objectives

- To ascertain the effect of aqueous extract of *imperata cylindrica* on the germination of *Zea mays*
- To ascertain the effect aqueous extract of *Imperata cylindrica* on the plumule growth of *Zea mays*
- To ascertain the effect of aqueous extract of *imperata cylindrica* on the radicle growth of *Zea mays*

2. MATERIALS AND METHODS

2.1 Study Area

The experiment was conducted at the laboratory of Applied Biology Department, Ebonyi state university abakaliki, Nigeria located on latitude 6° 22'26''N and longitude 8° 6'6''E of the Greenwich meridian.

2.2 Experimental Design and Layout

The laboratory experiment comprised of 5 treatments will be laid out using a Completely Randomized Design (CRD) and each treatment replicated three times.

List 1. A completely randomized design was used with 5 treatment and 3 replications as follows

Treatment	Variety	Replicates
Distilled water	1	3
20% (w/v-1) plant extract	1	3
15% (w/v-1) plant extract	1	3
10% (w/v-1) plant extract	1	3
5% (w/v-1) plant extract	1	3

2.3 Experimental Procedure

Imperata cylindrica was collected from crop fields and brought to laboratory. It was authenticated at the herbarium of the department of applied biology. The plant material was rinsed in clean water. The fresh leaves were cut into small pieces and pounded it using mortar and pestle. A 200g of the ground sample was measured and soaked in 2000ml distill water in a plastic bucket, and shaken regularly for 7 days, producing a 20% (w v-1) aqueous extract. The aqueous extract of the weed sample was filtered and the concentrated aqueous extract collected in a beaker and stored. Some quantity of the 20% (w-v-1) extract were diluted to 15, 10 and 5% with distilled water.

The seeds of test crop (*zea mays* var Oba Super 4.) were treated with different concentrations of the aqueous extract. Ten seeds were placed equidistantly in 8cm diameter Petri plates fitted with two layers of filter paper. 5ml of 5, 10,15 and 20% aqueous extract of *imperata cylindrica* were added into the petri plates as per treatment using syringe and needle daily. Sterilized water was used as control. The treatments were replicated three times in complete randomized design. The criterion for measuring germination is embryo protrusion, and this was evaluated every 12 hours during the first seven days of the experiment (that is seeds were considered as germinated upon emergence of radical).

2.4 Data Collection

The number of seeds germinated was counted on 1,2,3,4,5,6 and 7 days after sowing (DAS) and seedling growth was measured at 7 DAS. The various growth parameters were evaluated as follows:

i. **Germination Percentage:** The formular given by Rehman et al. [19] was used to estimate germination percentage. Germination % $=\frac{no\ of\ seeds\ germinated}{total\ no\ of\ seeds}\ x\ 100$

ii. **Root and Shoot Length**: length of root and shoot of seedlings was calculated using the standard centimeter scale.

iii. **Vigor Index**: the formula suggested by Abdul-Baki and Anderson [20] was used to calculate vigor index. Vigor index = Germination % x (root length + shoot length) on % x (root length + shoot length) in cm).

iv. **Mean Germination Time (MGT):** mean germination time was calculated by the formula given by Ellis and Roberts [21]. MGT = $\frac{n1\ x\ d1+n2\ x\ d2+n3\ x\ d3+-----}{total\ number\ of\ days}$
Where, n= number of germinated seed
d= numbers of days

v. **Mean Daily Germination (MDG):** Mean daily germination was calculated by the following formula given by Czabator [22]. MDG= $\frac{total\ number\ of\ germinated\ seeds}{total\ number\ of\ days}$

vi. **The phytotoxicity (%):** The phytotoxicity was calculated using the formular given by Chiou and muller [23]. Phytotoxicity(%)= $\frac{length\ of\ control-length\ of\ treated}{length\ of\ control} x\ 100$

vii. **The Extract Tolerance Index (ETI)**: This was calculated using the formular determined by Turner & Marshal (1972). $\frac{mean\ length\ of\ the\ longest\ root\ and\ shoot\ in\ acqueous\ extract}{mean\ length\ of\ the\ longest\ root\ and\ shoot\ in\ the\ control}$

2.5 Statistical Analysis

Data on seed germination, shoot length, root length were analyzed using one- way analysis of variance (ANOVA).

3. RESULTS AND DISCUSSION

3.1. Germination Percentage

"Aqueous extract of *imperata cylindrica* exhibited allelopathic effects on maize. The effect of *imperata cylindrica* extract on crop showed that the concentration affected the germination percentage of the crop" [17]. As the data in Table 1 indicated that the highest germination percentage was recorded from control while 15% and 20% concentration of the aqueous extract had similar germination percentage. The mean seed germination percentage of *zea mays* under different concentrations of aqueous extract of *imperata cylindrica* are given in Table 1. There was no significant difference among the treatments *P> 0.05*. As the concentration of the extract increased, the germination percentage decreased. It could be as a result of allelochemicals in the leaf extract which prevented embryo growth and development.

3.2 Shoot Length

Different concentrations of aqueous extract of *imperata cylindrica* on the shoot length of *zea mays* are given in Table 1. There was no significant difference in shoot length between treatments *(P>0.05)* when compared to the control. The data showed that the shortest shoot length was recorded in 20% concentration whereas the longest was observed from control. The difference in the activity of *imperata cylindrica* extract prepared from different fractions in suppressing germination of *zea mays* can be attributed to quantitative and qualitative differences in allelochemicals present in these extracts.

3.3 Root Length

Different extract of *imperata cylindrica* at higher concentration forced a significant suppression in root length. Root length of the crop decreased by an increase in the concentration of *imperata cylindrica* as given in Table 1. Root length was lowest at 20% concentration whilst the highest root length was recorded in the control.

3.4 Seedling Length

Seedling length was shortest at 20% concentration whilst the highest seedling length was recorded in control as shown on Table 1. More inhibition by application of higher extract concentration may be due to the presence of a greater fraction of allelochemicals in concentrated extracts.

3.5 Seedling Vigor Index

Seedling vigor index significantly decreased when compared to control (Table 1). As the concentration of extract increased the vigor index decreased. The lowest vigor index was recorded at 20% concentration while the highest was recorded from control.

3.6 Mean Germination Time

The mean germination time of *zea mays* under different concentration of aqueous extract of *imperata cylindica* are given in (Table 2). 5% and 10% concentrations had similar mean germination times. The highest mean germination time was recorded in 15%.

3.7 Germination Index

The highest germination index was recorded in the control (Table 2). 15% and 20% concentration had similar germination index. There was no significant different among treatments.

Table 1. Effect of different concentration of *Imperata cylindrica* on seed germination, root length, shoot length, seedling length and seedling vigor index of *Zea mays*

Treatment	Seed germination (%)	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling vigor index
Control	100.00±0.00	9.54±0.82*a*	8.66±0.38*a*	18.04±1.67*a*	17.6667±158.74*b*
5%	90.00±5.77	9.38±0.88*a*	7.99±0.82*a*	17.55±1.58*a*	1623.60±150.90*b*
10%	80.00±5.77	9.23±1.00*a*	7.07±0.80*a*	16.31±1.73*a*	1305.06±138.84*b*
15%	76.66±3.33	8.75±1.12*a*	6.68±0.87*a*	15.77±1.97*a*	1209.81±151.53*b*
20%	76.66±8.81	8.26±0.91*a*	6.11±0.90*a*	13.51±1.74*a*	1036.21±133.77*b*

Table 2. Effect of different concentrations of *Imperata cylindrica* on germination index, mean germination time, mean daily germination, relative elongation rate of shoot, relative elongation rate of root, phytotoxicity, extract tolerance index and percentage inhibition

Treatment	Germination	Mean germination time	Mean daily germination	Relative Elongation Rate of Shoot	Relative Elongation Rate of Root	Phytotoxicity	Extract Tolerance index	Percentage Inhibition for shoot	Percentage inhibition for root	Percentage inhibition for Germination
Control	1.00	10.71	3.42	100	100	0	30.9	0	0	0
5	0.9	10.42	3.28	92.2	98.3	1.67	1.12	7.67	1.71	10
10	0.8	10.42	3.28	81.6	96.7	3.24	0.98	18.3	3.22	20
15	0.0007	14.4	4.28	77.1	91.7	8.28	1.15	22.87	8.24	23.33
20	0.0007	12.71	3.85	70.5	86.5	13.4	1.04	29.45	13.45	23.33

3.8 Mean Daily Germination

The highest mean daily germination was recorded in 20% concentration (Table 2). 5% and 10% concentrations had similar mean daily germination.

3.9 Relative Elongation Rate of Shoot and Root

The highest relative elongation rate of shoot and root was recorded in control whilst 20% concentration recorded the lowest relative elongation rate of shoot and root (Table 2).

3.10 Phytotoxicity

Phytotoxicity in maize seedlings at different concentration of aqueous extracts was found to be significantly different. Phytotoxicity increased with increase in the concentration of aqueous extract. The highest phytotoxicity was recorded in 20% concentration (13.4) whereas control recorded (0) as shown on Table 2.

3.11 Inhibition Percentage

Inhibition potentials of the shoot and root at their 20% concentrations were 29.45 and 13.45% for maize seed germination over control respectively. The lowest inhibition in seed germination was found for the 5% concentration over control (Table 2). It reveals that as the dose increased the inhibition also increased which shows that the weed extract has inhibitory effect on seed germination of maize. Ahmed et al [24] "applied extracts of *C. odorata* on receptor crops and observed that the inhibitory effect was proportional to the concentrations of the extracts and higher concentration had the stronger inhibitory effect".

3.12 Extract Tolerance Index

"Tolerance index significantly reduced with increasing *imperata cylindrica* concentration when compared to control. Effect of different extract level of *I. cylindrica* concentration significantly affected the tolerance index of maize seedling. The highest tolerance index (30.9%) was recorded from control whereas, the lowest (1.04%) was recorded from 20% extract concentration. This is in accordance with the work Tahseen", et al [25-27].

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

From this laboratory experiment, it was revealed that the control treatment had maximum germination percentage and 20% treatment had the minimum. Extract of *imperata cylindrica* at 20% strongly reduced root length, shoot length, seedling length of the maize. Results also show that 20% aqueous extract had the highest inhibitory percentage and a lower tolerance index and vigor index. Different concentration of aqueous of *imperata cylindrica* significantly inhibited the growth and germination of maize and this inhibition is varied with the concentration of the extracts. *Imperata cylindrica* extracts showed inhibitory effect on shoot and root length but exerted more inhibitory effects on the shoot than on the root tested (Table 2). Crop residues could be spread on wastelands, resulting in the leaching of allelochemicals that would reduce the seed germination and consequently the population of weeds.

4.2 Recommendation

Further studies are required to identify and isolate the most effective allelochemicals from *imperata cylindrica* and develop natural-product based herbicides to curb weeds.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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