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Research Article

Laboratory Studies on the Effects of Aqueous Extracts from *Sorghum bicolor* Stem and *Zea mays* (Roots and Tassel) on the Germination and Seedling Growth of Okra (*Abelmoschus esculentus* L.)

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The allelopathic effect of the aqueous extracts from *Sorghum bicolor* stem and maize (roots and tassel) were examined on the germination and seedling growth of okra (*Abelmoschus esculentus* L.). The results showed that the extracts inhibited the germination of okra seeds which was more pronounced in seeds treated with maize (roots and tassel) extracts as no germination was recorded until 48 hours of experimental time. Also the radicle and plumule lengths were retarded. Plumule lengths were more retarded as no germination was recorded until 72 hours of experimental time. The inhibitory effects were concentration dependent as the inhibition increases with increase in concentration of the extracts. Statistical analysis ($P < 0.05$) revealed that there were significant differences in the germination of okra treated seeds most especially at higher concentration of the extracts when compared to control experiment. In the radicle lengths, statistical analysis revealed that there were significant differences in the radicle lengths of the extract treated seeds compared to the control experiment except at 24 hours of experimental time. Similarly in the plumule, significant differences abound in the extract treated seeds from 72 hrs to 144 hrs. These findings indicate that both germination and growth of okra sown in the field may be adversely affected by extracts from these residues, thus resulting in lowering yields especially by the maize root extracts.

1. Introduction

The chemical interference of donor plants on another receptor plants thereby affecting them negatively or positively had been established which is referred to as allelopathy [1, 2]. Allelopathic influence can have stimulatory effect on the growth of other plants thereby increasing their growth positively and inhibitory effect by suppression of neighbouring plant growth by the release of toxic compound [3].

Allelopathy plays important role in agroecosystem leading to the interaction crop to crop, crop to weed, weed to crop, and trees to crop [4], through the production of chemical compounds (allelochemicals) that escape into the environment. These allelochemicals are released from plant parts such as leaves, flowers, seeds, stems, and roots rhizomes [5, 6] from where they are released into the environment by leaching from above ground parts, root exudation, volatilization, and decomposition of plant residues in both natural and agricultural systems [7–9].

Allelopathy inhibition is complex and can involve the interaction of different classes of chemicals such as phenolic compounds, flavonoids, terpenoids, alkaloids, coumarins, glycosides, and glucosinolates. These chemicals called secondary metabolites are known to be exuded by plants to suppress emergence or growth of other plants. These substances are phytotoxic and can be suggestive of their potentials as natural herbicides [10–12]. These secondary metabolites released by plants may influence resource competition, nutrient dynamics, microbial ecology, mycorrhizae, and even soil abiotic factors [13]. When plants are exposed to allelochemicals, their growth and development are affected through inhibition of seed germination/or seedling growth decrease. The readily visible effects include inhibited or retarded germination rate [14], seeds darkening and swelling, reduced root or radicle and shoot or coleoptile extension [15, 16], swelling or necrosis of root tips, curling of the root axis, discolouration, lack of root hairs, reduced dry weight accumulation, and lowered reproductive capacity [17].

Allelopathy had been studied by many researchers [18–21]. In Nigeria, allelopathy studies so far concentrated on allelopathic potentials of weeds on crops. This includes the work of Tijani-Eniola and Fawusi [22] on *Chromolaena* and Kayode [23] on *Aspilia africana*. Recently, Kayode and Ayeni [24] and Ayeni et al. [25] reported the allelopathic potentials of crop residues on agricultural crops. The present research emphasizes the allelopathic effects of crop residues on the germination and growth of okra, an important edible fruit widely eaten in Nigeria.

Okra is an annual plant or perennial crop of the Family Malvaceae, widely grown for its edible fruits. The fruits are harvested when immature and they are widely eaten in South Western Nigeria as it provides excellent vegetable protein which is rich in tryptophan and help reduces human malnutrition. The growth of okra could be reduced due to allelochemicals released from plants in cropping.

This study aimed at examining the allelopathic potentials of aqueous extracts from residues of sorghum bicolour stem and *Zea mays* (tassel and roots) on the germination and growth of okra.

2. Materials and Methods

Laboratory experiments were conducted during June, 2010 in the Department of Plant Science, Ekiti State University, Nigeria to assess the allelopathic effects of different aqueous extracts of residues from *Sorghum bicolor stem* and *Zea mays* (root and tassel) on the germination and growth of okra.

Mature sorghum plants were harvested from the experimental farm of the Department of Plant Science, Ekiti State University, Nigeria. The sorghum stem was cut into pieces to facilitate drying. Maize (roots and tassel) was also collected from the experimental farm after the fruits had been harvested. These materials were chopped into pieces and were air-dried for three weeks after which they were pounded using pestle and mortal.

Okra seeds were obtained from Agricultural Development Project (ADP), Ado Ekiti to get improved variety.

Portions of 5 g, 10 g, 15 g, 20 g, and 25 g of each of the ground samples of the crop residues were measured out using G&G Electric Top Loading Digital balance, JJ300Y, China. Each portion was soaked in 200 mL distilled water in 500 mL conical flasks. The mixtures were shaken intermittently and for 24 hrs at 25°C ± 1°C. The extracts for each crop residue was filtered and the filtrates were stored in a refrigerator for further usage.

In each treatment, two layers of Whatman number 1 filter papers were put in each petri dish (each with a diameter of 9 cm). Five seeds of okra were sown in the petri dish and replicated ten times for each extract concentration. The filter papers were moistened daily with different extracts concentration using syringe and needle. Control experiments were set up for each extract and replicated ten times. All the petri dishes were arranged on germination tables at room temperature between 25–30°C. The seeds were considered as germinated upon radicle emergence and the number that germinated was counted for six days. The radicle and plumule growth elongations were recorded at 24 hrs interval. The data obtained from the experiments were compared to those obtained from the control using Analysis of Variance (ANOVA) and using SPSS version 15 (2009) computer software. Duncan Multiple Range Test (DMRT) at $P < 0.05$ was used to separate the means.

3. Results and Discussion

3.1. Seed Germination. The allelopathic effects of aqueous extracts from sorghum stem and maize (roots and tassel) on the germination of okra (*Abelmoschus esculentus*) are shown in Table 1. The extracts brought a considerable inhibition in the germination of okra seeds. The inhibition increases with increase in the concentration of the extracts. In sorghum treated seeds at 24 hrs, no germination was observed at 20 and 25 g concentrations. At 48 hrs experimental time, the germination of okra seeds in the control was 100%, those of 5, 10, 15, 20, and 25 g/200 mL concentrations were 94%, 86%, 38%, 26%, and 24%, respectively. At 144 hrs after planting, the germination of extract treated seeds reduces as the concentration of the extracts increases. The control and 5 g concentration were 100% which reduced to 62% in 25 g concentration (Table 1A). Statistical analyses ($P < 0.05$) revealed that significant were observed in the germination of okra treated seeds when compared to the control experiment especially at higher concentrations of the extracts. At 144 hrs experimental time of sorghum treated seeds, significant differences were observed in the germination of okra seeds at 20 g and 25 g concentrations when compared to the control experiments. However, no significant differences were observed in other treatments compared to control experiment.

For maize root extracts, no germination was observed until 48 hrs (Table 1B). The germination percentage of the control experiment was 82%, germination percentages in 5, 10, 15, 20, and 25 g/200 mL concentrations were 76%, 70%, 64%, 42%, and 34%, respectively. At 144 hrs, the percentage germination of control was 96%, which decreased to 76% in 25 g concentration. Statistical analysis ($P < 0.05$) revealed that 25 g concentration showed significant difference to control experiment. Other concentrations showed no significant difference.

Similar results were observed in the maize tassel extracts. It was revealed that at after planting, 100% of the seeds germinated in the control, 5, 10, 15, 20, and 25 g/200 mL concentrations had 100%, 100%, 100%, 98%, 96%, and 94%, respectively. This tends to suggest that the effects of the extracts were concentration dependent. Statistical analysis ($P < 0.05$) also revealed that 25 g concentration showed significant difference to control experiment while other concentrations showed no significant difference (Table 1C).

Among the three different extracts, maize root showed more allelopathy and the sorghum stem showed least inhibition on okra germination. The inhibitory effect of the extracts

Table 1: Effects of aqueous extracts of sorghum stem and maize (roots and tassel) on the germination % of seeds of okra.

Extracts g/200 mL	Time (hrs)					
	24	48	72	96	120	144
A						
Sorghum stem 0	12^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
Sorghum stem 5	8.00^{a}	96^{a}	98^{a}	98^{a}	98^{a}	100^{a}
Sorghum stem 10	6.00^{a}	86^{a}	92^{a}	92^{a}	92^{a}	92^{a}
Sorghum stem 15	6.00^{a}	38^{b}	66^{b}	72^{b}	72^{a}	82^{ab}
Sorghum stem 20	0.00^{a}	26^{c}	62^{b}	66^{b}	66^{b}	66^{c}
Sorghum stem 25	0.00^{a}	24^{c}	42^{c}	62^{b}	62^{b}	62^{c}
B						
Maize root 0	24^{a}	82^{a}	94^{a}	96^{a}	96^{a}	96^{a}
Maize root 5	0.00^{a}	76^{a}	92^{a}	94^{a}	94^{a}	94^{a}
Maize root 10	0.00^{a}	70^{a}	92^{a}	92^{a}	92^{a}	92^{a}
Maize root 15	0.00^{a}	64^{a}	92^{a}	92^{a}	92^{a}	92^{a}
Maize root 20	0.00^{a}	42^{b}	90^{a}	92^{a}	92^{a}	92^{a}
Maize root 25	0.00^{a}	32^{b}	76^{b}	76^{b}	76^{b}	76^{b}
C						
Maize tassel 0	42^{a}	100^{a}	100^{a}	100^{a}	100^{a}	100^{a}
Maize tassel 5	0.00^{b}	94^{ab}	100^{a}	100^{a}	100^{a}	100^{a}
Maize tassel 10	0.00^{b}	94^{ab}	100^{a}	100^{a}	100^{a}	100^{a}
Maize tassel 15	0.00^{b}	94^{ab}	98^{ab}	98^{ab}	98^{ab}	98^{ab}
Maize tassel 20	0.00^{b}	88^{ab}	96^{bc}	96^{bc}	96^{bc}	96^{bc}
Maize tassel 25	0.00^{b}	82^{b}	94^{c}	94^{c}	94^{c}	94^{c}

Means followed by the same letter with the column for each treatment are not significantly different at ($P < 0.05$).

was found to increase with increase in the concentration of the extracts which were in accordance with previous researches [26, 27]. Such allelopathic differences in the crop residues might be related to specific allelopathic compounds being present in each species which related to the work of Chon et al. [28].

The effects of the extracts on okra germination were similar to those obtained by Shahid et al. [29] who reported that different plant extracts significantly reduced wheat and its weeds, Kayode and Ayeni [24] on aqueous extracts of rice husk and sorghum stem on maize. Anjum et al. [30] and Monica et al. [31] reported the aqueous extracts of *Ascarum europaeum* L. inhibited the germination and growth of *Lycopersicum esculentum* Yarnia et al. [32] noted that Amaranthus seed germination was reduced by sorghum extracts. Also Oyun [33] reported that extracts from *G. sepium* caused a prolonged delay in maize seed germination.

3.2. Radicle Length. The effects of the aqueous extracts of sorghum stem and maize (roots and tassel) on the radicle length (cm) of okra were shown in Table 2. The results revealed that the radicle length of okra treated with both extracts seeds were retarded at 24 hrs experimental time.

In sorghum stem treated seeds, the mean radicle length in the control at 144 hrs was 3.12 cm, those of 5 g, 10 g, 15 g, 20 g, and 25 g/200 mL concentrations were 3.03 cm, 3.02 cm, 2.86 cm, 1.85 cm, and 1.65 cm, respectively. Statistical analysis ($P < 0.05$) revealed that 20 g and 25 g concentrations showed significant differences to control experiment in the experimental times while other concentrations showed no significant difference (Table 2A).

In maize root treated seeds, the average length of radicle in the control was 3.44 cm, those of 5 g, 10 g, 15 g, 20 g, and 25 g/mL concentrations were 2.61 cm, 2.32 cm, 2.00 cm, 1.56 cm, and 1.31 cm, respectively. Similarly in the maize tassel treated seeds, the mean radicle length in the control was 3.88 cm, those of 5 g, 10 g, 15 g, 20 g, and 25 g were 3.56 cm, 2.95 cm, 2.06 cm, 1.53 cm, and 1.15 cm, respectively. The radicle lengths reduced with increase in the concentration of the extracts which tends to suggest that the effects of the extracts were concentration dependent. Statistical analysis ($P < 0.05$) also revealed that the higher concentrations (20 and 25 g) showed significant differences to control experiment in the experimental times while other concentrations showed no significant difference (Table 2B).

In maize tassel treated seeds, no radicle emerged until 72 hrs experimental time (Table 2C). The mean radicle length in the control experiment was 3.88 cm, those of 5, 10, 15, 20, and 25 g/200 mL concentrations were 3.56 cm, 2.95 cm, 2.06 cm, 1.53 cm, and 1.15 cm, respectively. The radicle lengths reduced with increase in the concentration of the extracts which tends to suggest that the effects of the extracts were concentration dependent. Statistical analysis ($P < 0.05$) at 144 hrs experimental time revealed that there were significant differences in the radicle length of okra treated seeds when compared to control experiment except 5 g concentration that showed no significant difference. The radicle length reduced with increase in the concentration of the extracts which also

Table 2: Effects of aqueous extracts of sorghum stem and maize (roots and tassel) on the radicle length (cm) of seeds of okra.

Extracts g/200 mL	Time (hrs)					
	24	48	72	96	120	144
A						
Sorghum stem 0	0.10^{a}	0.77^{a}	1.67^{a}	**2.29**^{a}	**2.76**^{a}	**3.12**^{a}
Sorghum stem 5	0.00^{a}	0.74^{a}	1.66^{a}	**2.26**^{a}	**2.67**^{a}	**3.03**^{a}
Sorghum stem 10	0.00^{a}	0.67^{a}	1.61^{a}	**2.23**^{a}	**2.62**^{a}	**3.02**^{a}
Sorghum stem 15	0.00^{a}	0.66^{a}	1.18^{a}	**1.78**^{a}	**2.29**^{b}	**2.86**^{a}
Sorghum stem 20	0.00^{a}	0.31^{b}	0.56^{b}	**0.92**^{b}	**1.26**^{b}	**1.85**^{b}
Sorghum stem 25	0.00^{a}	0.10^{b}	0.46^{b}	**0.82**^{b}	**1.14**^{b}	**1.65**^{b}
B						
Maize root 0	0.13^{a}	0.58^{a}	1.12^{a}	1.99^{a}	2.70^{a}	3.44^{a}
Maize root 5	0.00^{b}	0.32^{b}	0.81^{b}	1.31^{b}	1.78^{b}	2.61^{b}
Maize root 10	0.00^{b}	0.310^{b}	0.81^{b}	1.23^{bc}	1.63^{bc}	2.32^{b}
Maize root 15	0.00^{b}	0.27^{b}	0.73^{b}	1.07^{bc}	1.61^{bc}	2.00^{bc}
Maize root 20	0.00^{b}	0.16^{b}	0.70^{b}	1.02^{bc}	1.27^{cd}	1.56^{c}
Maize root 25	0.00^{b}	0.11^{b}	0.45^{c}	0.84^{c}	1.09^{d}	1.31^{c}
C						
Maize tassel 0	0.00^{a}	0.85^{a}	2.13^{a}	3.17^{a}	3.52^{a}	3.88^{a}
Maize tassel 5	0.00^{a}	0.51^{b}	1.54^{b}	2.53^{b}	3.15^{a}	3.56^{a}
Maize tassel 10	0.00^{a}	0.42^{bc}	1.46^{b}	2.19^{bc}	2.66^{ab}	2.95^{b}
Maize tassel 15	0.00^{a}	0.36^{bc}	1.29^{b}	1.76^{c}	1.92^{b}	2.06^{c}
Maize tassel 20	0.00^{a}	0.31^{bc}	0.83^{c}	1.03^{d}	1.86^{b}	1.53^{d}
Maize tassel 25	0.00^{a}	0.15^{c}	0.57^{c}	0.71^{d}	0.84^{c}	1.15^{d}

Means followed by the same letter with the column for each treatment are not significantly different at ($P < 0.05$).

suggests that the effect of the extracts was concentration dependent. The roots of the crop exposed to allelochemical become brownish, leading to necrosis of the root tips, curling of root axis, lack of root hairs, and seed darkening. This might be due to the rapid inhibiting effect on respiration of root tips which might ultimately reduce its elongation. Similar results were reported by Nazim et al. [34], Monica et al. [35], and Komal [36].

3.3. Plumule Length. The effects of the aqueous extracts of sorghum stem and maize (roots and tassel) on the plumule length (cm) of okra were shown in Table 3. The effects of the extracts were similar to those obtained in the radicle lengths. It was revealed that no plumule emerged until 72 hrs in the three extracts. In sorghum treated seeds (Table 3A), the mean plumule length at 144 hrs was 2.35 cm, those of 5, 10, 15, 20, and 25 g/mL concentrations were 1.55 cm, 1.41 cm, 0.98 cm, 0.57 cm, and 0.42 cm, respectively. Statistical analysis revealed that 20 and 25 g concentrations showed significant differences to control experiment between 72 and 96 hrs, other treatments showed no significant difference. At 120–144 hrs, there were significant differences in okra treated seeds compared to control experiment.

In maize root aqueous treated seeds (Table 3B), the plumule length of okra reduces with increased concentration of the extracts. The mean plumule length at 144 hrs in the control was 2.10 cm which decreased to 0.46 cm in 25 g/200 mL concentration. Statistical analysis ($P < 0.05$) showed there were significant differences in the extract treated seeds compared to the control experiment at 144 hrs.

Similar results were also observed in the maize tassel extract treated seeds (Table 3C). At 72–144 hrs, the plumule length of extract treated seed reduces with increase in the concentration of the extracts. For example, at 144 hr experiment time, the control experiment has plumule length of 2.10 cm which reduced to 0.46 cm in 25 g/mL concentration. Statistical analysis revealed that there were significant differences in the plumule length of okra treated seeds between 72–144 hrs experiment time compared to control experiment.

The effects of the different concentration of extracts in the plumule length may result from different water extracts due to manifestation of primary events caused by allelochemicals released by receiver plant which might have reduced the uptake of nutrients and may ultimately reduce shoot lengths. This findings corroborated the work of [33] who reported that the root and shoot length and seedling vigour of maize were decreased with the increasing concentration of *G. sepium*. Similarly, Salam et al. [37] reported extracts from rice hulls significantly root and shoot elongation of *E. crus galli*. Also Shahid et al. [29] reported that different plant extracts significantly reduced wheat and its weeds. The effects of the aqueous extracts on okra were also similar to those obtained by Ayeni and Kayode [38] on the effects of aqueous extracts from maize roots and sorghum stem on the germination and radicle growth of *Sphenostylis sternocarpa* Hochst ex. Rich (African Yam Bean).

Table 3: Effects of aqueous extracts of sorghum stem and maize (roots and tassel) on the plumule length (cm) of okra.

Extracts g/200 mL	Time (hrs)					
	24	48	72	96	120	144
A						
Sorghum stem 0	0.00^{a}	0.00^{a}	0.22^{a}	0.44^{a}	1.19^{a}	2.35^{a}
Sorghum stem 5	0.00^{a}	0.00^{a}	0.17^{a}	0.41^{a}	0.65^{b}	$1{,}55^{b}$
Sorghum stem 10	0.00^{a}	0.00^{a}	0.16^{a}	0.37^{a}	0.60^{b}	1.41^{bc}
Sorghum stem 15	0.00^{a}	0.00^{a}	0.15^{A}	0.33^{a}	0.58^{b}	0.98^{c}
Sorghum stem 20	0.00^{a}	0.00^{a}	0.03^{b}	0.13^{b}	0.23^{c}	0.57^{de}
Sorghum stem 25	0.00^{a}	0.00^{a}	0.01^{b}	0.07^{b}	0.13^{c}	0.42^{e}
B						
Maize root 0	0.00^{a}	0.00^{a}	0.34^{a}	0.56^{a}	1.25^{a}	1.81^{a}
Maize root 5	0.00^{a}	0.00^{a}	0.21^{ab}	0.52^{a}	1.02^{ab}	1.63^{ab}
Maize root 10	0.00^{a}	0.00^{a}	0.15^{ab}	0.43^{a}	0.58^{b}	1.38^{ab}
Maize root 15	0.00^{a}	0.00^{a}	0.11^{b}	0.41^{a}	0.72^{b}	1.17^{bc}
Maize root 20	0.00^{a}	0.00^{a}	0.00^{c}	0.08^{b}	0.23^{c}	0.79^{c}
Maize root 25	0.00^{a}	0.00^{a}	0.00^{c}	0.04^{b}	0.08^{c}	0.24^{d}
C						
Maize tassel 0	0.00^{a}	0.00^{a}	0.33^{a}	0.47^{a}	0.72^{a}	2.10^{a}
Maize tassel 5	0.00^{a}	0.00^{a}	0.26^{ab}	0.35^{ab}	0.56^{a}	1.02^{b}
Maize tassel 10	0.00^{a}	0.00^{a}	0.11^{bc}	0.32^{b}	0.55^{a}	0.99^{b}
Maize tassel 15	0.00^{a}	0.00^{a}	0.11^{bc}	0.18^{c}	0.29^{b}	0.89^{b}
Maize tassel 20	0.00^{a}	0.00^{a}	0.06^{c}	0.15^{c}	0.26^{b}	0.63^{b}
Maize tassel 25	0.00^{a}	0.00^{a}	0.00^{c}	0.04^{c}	0.08^{c}	0.46^{c}

Means followed by the same letter with the column for each treatment are not significantly different at ($P < 0.05$).

This observation tends to suggest that the extracts from plant residues releasing allelochemical are responsible for the inhibitory effects shown on agricultural crops and weeds on farmlands.

Previous researches of Cherney et al. [39] revealed that allelochemicals in sorghum includes valinic acid, p-hydroxybenzaldehyde, p-coumaric acid, ferulic acid, dhurin, and sorgoleone. Guenzi and McCalla (1996) had earlier asserted that the inhibitory compounds occurring in sorghum plants are mostly phenols. Einhellig and Souza (1992) reported that phenolic compounds such as dihydroquinine sorgoleone produced by *Sorghum bicolor* have been found to be extremely phytotoxic in hydroponic culture. Also Sanchez-Moreiras et al. [40] asserted that maize inflorescence allelopathy was quinine attributed to hydroxamic acid. Allelochemicals in maize root exudates are mostly saponin.

The reduction in the germination and seedling growth of okra in this study might be attributed to the allelopathic compounds present in these plants. Thus the act of leaving crop residues such as sorghum straw and maize tassels uncared for on the field might have detrimental effects on the germination and growth of subsequent crops.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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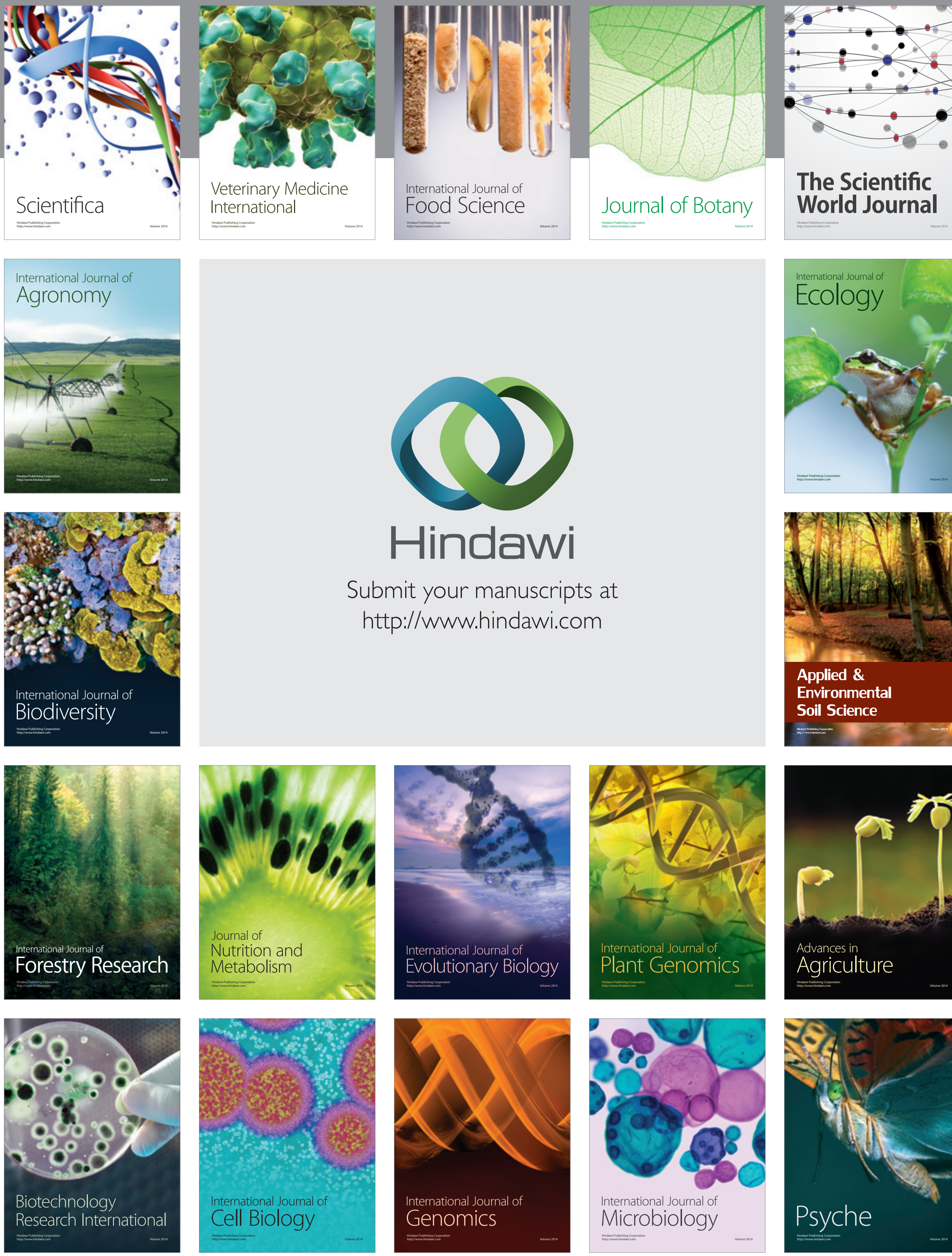
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