The Effect of Extracts of Decomposing Shoots of Tithoniarotundifolia on the Germination and Seedling Growth of Vignaunguiculata, Glycine max, Zea mays and Sorghum bicolor

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Abstract

The phytotoxic effect of decomposing shoots of Tithoniarotundifoliaon Vignaunguiculata, Glycine max, Zea mays and Sorghum bicolor was investigated. The germination studies were carried out by raising seedlings in clean oven dried Petri dishes which had been lined with Whatman No 1 filter paper. The filter paper in each Petri dish allocated to the control was moistened with 10 ml of distilled water while 10 ml methanolic and water extracts of the decomposed shoots of T. rotundifolia were used for the treatments.The germination percentage, plumule length, radicle length, fresh and dry weights of plumule and radicle were determined according to standard methods. The data obtained were subjected to ANOVA. Treatment means were compared using least significant difference (LSD P < 0.05). The germination and growth of the juvenile seedlings of all the target test crops were significantly inhibited by themethanolic and water extracts. The phytotoxicity of themethanolic extracts was significantly higher than that of the water extracts showing that theallelochemicals in the decomposed tissues were better extracted in the methanol solvent than in water. Extracts of freshly decomposed shoot tissues were found to be more potent and significantly inhibited the germination and growth of the juvenile test crops at p < 0.05. In some cases, the germination and growth parameters of the test crops were stimulated with the increase in the period of decomposition of the shoot from which the extracts were prepared. It was concluded that the process of decomposition reduced or nullified the phytotoxicity of the extracts.

Keywords: Phytotoxicity, allelochemicals, decomposition, Tithoniarotundifolia, extracts

1. Introduction

A large number of plants impose inhibitory effects on the germination and growth of neighboring or successional plants by releasing allelochemicals into the soil, either as exudates from living tissues or by decomposition of plant residues (Narwal, 1999; Alam and Islam, 2002; Muhammad *et al.*, 2009).Decomposition of plant litter is a central process of ecosystems functions and nutrient cycling. Furthermore, plant litter has been reported to have both positive (Facelli& Pickett, 1991) and negative (Bergelson, 1990) influences on growth and regeneration of plant species. These effects of plant litter have been related to release of allelochemical compounds during organic matter decomposition (van der Putten*et al*., 1997; Blum *et al*., 1999; Armstrong & Armstrong, 2001). According to Carballeira*et al*. (1988), the impact of allelochemicals on plants is stimulatory at low concentrations, turns to inhibitory as the concentration increases, and finally ends in total inhibition of growth.

Kava (*Piper methysticum* L.) exhibited the strongest inhibition (80%) on barnyard grass and monochoria growth 1 day after application but at 9 days, the weed control was reduced to 25% (Xuan*et al*., 2003a). Xuan*et al*. (2005) reported that both alfalfa and kava strongly inhibited barnyard grass and monochoria weed growth until 10 days (80-100% control), and after 20-25 days, weed control was reduced to 50%.

Factors on which phytotoxicity of allelochemicals is dependent have been classified into three main categories by An *et al*. (2002) as: amount and composition of plant residues (type and quantity), the environment of decomposition (temperature, moisture, aeration, soil texture, inorganic ions, and pH), and management practices (decomposition time, residue placement, and weathering).

Phytotoxicity dynamics have been documented for several crop species in aerobic conditions (Rice, 1984). Phytotoxicity dynamics is likely that decaying plant residues exhibit the most severe inhibition at the early stages of decomposition, as it proceeded, phytotoxicity is declined (Mason-Sedun and Jessop, 1988). According to Xuan*et al.*, (2005),severe inhibition observed in early stages of decomposition is followed by phytotoxicity decrease.

Tithoniarotundifolia (Miller) S.F. Blake is a member of the family Asteraceae. It is an annual broad-leaved weed, which grows to about a height of five meters and varies from highly branched low population variety to unbranched high population variety..Ayeni *et al.* (1997) stated that *Tithonia* species are aggressive weeds with high invasive capacity and the ability to compete successfully with agricultural crops. The plant associates with common crops like vegetables, cassava, yam, rice, sorghum, soyabeane.t.c. and becomes a dominant plant where it is present (Tongma*et al.*, 1998).

Cowpea (*Vignaunguiculata* (L.)Walpers) and Soybean (*Glycine max* (L.)Merr.) which belong to the family **Fabaceaeare**economically significant legumes in the tropics. Maize (*Zea mays* L.) and Sorghum (*Sorghum bicolor* (L.)Moench) are annual grasses belonging to the family Poacea. They are important cereal crops growing in the world. Imeokpara and Okusanya (1994) stated that yield losses as high as 75% occur as a result of weed competition in planted rice in Nigeria. Akinlelure (1992) reported that *T. diversifolia* reduced soyabean (*Glycine max* L. Merr) yield by 95% when uncontrolled. Lordbanjou (1991) suggested that in fields heavily infested by *T.rotundifolia*, maize yield could drop by 50%.

The most common allelopathic compounds are the tannins, phenolic acids, terpenes and alkaloids (Gliessman, 1998). The phenolic acid reactivity in soils may hinder the expression of allelopathy in the field through abiotic reactions such as oxidation of the allelochemicals and through biotic mineralisation of the allelochemicals prior to interacting with the target species (Lehmann et al., 1987; Schmidt and Ley, 1999). Chemicals in the soil solution can be absorbed by plants, but are also subject to degradation processes such as photolysis, oxidation, microbial degradation and removal or transfer processes such as volatilization and adsorption (Weber and Miller, 1989).The initial phase of decomposition fundamentally consists of plant tissue breakdown and the subsequent release of cell contents. Soil chemical, physical and biological characteristic to a great extent are responsible for detoxification or further enhancement of the allelopathic activities of the plant diffusate (Cheng, 1995).

According to Blum (1999), once in the soil the bioactive concentration of allelochemicals is determined through the sorption, fixation, leaching, chemical and microbial degradation.Changes over time of both composition and quantity of allelochemicals can either increase or decrease the effects of decomposing plant materials (An *et al*., 2001).Inderjit, (2001) asserted that abiotic (physical and chemical) and biotic (microbial) factors can influence the phytotoxicity of chemicals in terms of quality and quantity required to cause injury. He stated further that these factors often limit the accumulation of allelochemicals to phytotoxic levels. *Partheniumhysterophorus* retarded the seedling growth and reduced the fresh and dry matter production of *Alysicurpusglumaceae* and *Chlorisgayana* (Msafiri, *et al.* 2013). Also, Singh, *et al*. (2014) reported that the seed germination, root length and shoot length of *Cicerarietinum, Pisumsativum* and *Cajanuscajan* were inhibited by the leaf aqueous extract of *Partheniumhysterophorus.* Most studies herehave focused on effects of the extracts of unrecompensed shoots of allelopathicplants while little attention has been paid to the ecological impacts of chemical transformation during decomposition of allelopathic plants. The objective of this study therefore was to investigate the effects of water and methanolic extracts of decomposed shoots of *T.rotundifolia*on the germination, growth parameters (plumule and radicle lengths) and yield parameters (fresh and dry weights of plumule and radicle) of juvenile seedlings of *Vignaunguiculata, Glycine max, Zea mays* and *Sorghum bicolor*

2. Materials and Methods

This study was conducted at the Botany Department located at the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria, Latitude 07°30’N - 07°35’N and Longitude 04 ^{o}30’ - 04°40’E.The plant materials that were utilized in this study are the seeds of the following plants

Tithoniarotundifolia(Miller)S.F. Blake,*Vignaunguiculata*L. Walp, *Glycine max* L. Merr., *Zea mays* L.and *Sorghumbicolor* (L.) Moench.The seeds of the test crops (V*ignaunguiculata, Glycine max, Zea mays,* and *Sorghum bicolor*)were collected from IITA (International Institute of Tropical Agriculture) Ibadan. *T.rotundifolia* seeds were collected along Road 20 of the Senior Staff Quarters of ObafemiAwolowo University (O. A. U.), Ile Ife. Plastic pots (25 cm diameter x 22 cm height) with four holes perforated at the bottom for good drainage were filled almost to the brim with top humus soil. The seeds of *T.rotundifolia* were sown in each of the pots and watered with 400 ml of tap water every morning. At two weeks, seedlings in each pot were thinned down to two seedlings per pot. Fresh shoots of six week old *T. Rotundifolia* were collected and then allowed to decompose for 2, 4, 8, and 16 weeks on the field. These shoots were then extracted separately in water or methanol using the methods according to Qasem and Abu - Irmaileh (1985).The water extract (WED) and methanolicextract (MED) obtained from the shoots of *T. rotundifolia* which were allowed to decompose for 2, 4, 8, and 16 weeks(2wk, 4wk, 8wk and 16wk WED and MED)served as treatments for seedlings in the water extract of decomposed shoots (WED) and methanolic extract of decomposed shoots (MED) regimes. The germination, plumule length, radicle length, fresh and dry weights of plumule and radicle of thejuvenile seedlings the test crops were determined. All experiments were conducted in five replicates and the data obtained were subjected to ANOVA. Treatment means were compared using least significant difference (LSD $P < 0.05$).

3. Results

Fig. 1 shows the effect of the water and methanolic extracts on the percentage germination of the test crops. The percentage germination of the control *V.unguiculata, Z. mays* and *S. bicolor*seeds was significantly ($p < 0.05$) higher than that of the seeds treated withmethanolic (MED) and water extracts (WED) prepared from the decomposed shoots of *T. rotundifolia*. The germination of the extract treated seeds increased with increase in the period of decomposition of the plant shoots material utilized for the preparation of the extracts. This shows thatthe potency of the allelochemicals in the extracts reduced with the extent of prior decomposition of the shoot tissues from which the extracts were prepared. In the case of *G. max* the 4wk, 8wk and 16 wk water extracts stimulated the percentage germination.Figs.2& 3 and show the effects of the methanolic and water extracts on the plumule and radical length of the test crops. The seedlings of all the test cropsin the control had plumule and radicle lengths that were significantly higher than that of the seedlings in the treatment regimes at $P < 0.05$. The plumule length of the seedlings in all the extract regimes increased with increase in the weeks of decomposition of the shoots from which the extracts were prepared. The plumule fresh weight of 16wkWED *G. max* seedlings and 16wkMED *Z. mays* seedlings were almost equal to that of the control seedlings while that of the 16wkWED *Z. mays* seedlings was slightly higher than that of the control seedlings (Fig.4).

The effects of the methanolic extracts and water extracts of the decomposed shoots of *T. rotundifolia* on the radicle fresh weight of the test crops is shown in Fig5.The radicle fresh weight of the control test crops was higher than that of the seedlings in the MED and WED regimes except for*V. unguiculata* in which the radicle fresh weight of the seedlings in the 16wkWED regimes was almost equivalent to that of the control seedlings.

The effects of the methanolic extracts and water extracts of the decomposed shoots of *T. rotundifolia* on the plumuledry weigth of the test crops is shown in Fig. 6. The control *V. unguiculata* and *Z. mays* seedlings had plumule dry weight which was significantly higher than that of the seedlings in the MED and WED regimes. The plumule dry weight of *G. max* in the control was significantly higher than that of the seedlings in the MED and WED regimes except for that of the seedlings in the 16wkMED and 16wkWED regimes which was almost equivalent to that of the control seedlings. In the case of *S. bicolor,* the plumule dry weights of the seedlings in the 8wkMED and 16wkWED regimes were significantly higher than that of the control seedlings.

The radicle dry weight of *V. unguiculata* seedlings in the control was significantly higher than that of the seedlings in the treatment regimes. The radicle dry weight of the *G. max* seedlings in the 4 and 8 wkWED regimes was equivalent with that of the seedlings in the control. The radicle dry weight of the *S. bicolor* seedlings in the 4, 8 and 16 wkWED regimes was higher than that of the control seedlings while that of the *Z. mays*in the, 8 and 16 wkWED regimes was significantly higher than that of the control seedlings (fig. 7)

4. Discussion

The water and methanolic extracts of decomposing shoots of *T. rotundifolia* had a significant inhibitory effect on the germination, plumule and radicle growth of the seeds of the test crops.

This observation was consistent with the findings of Inderjit and Dakshini (1994a, 1994b) who reported that the water extracts from the roots of *Phichealanceolata* in the family Asteraceae inhibited the germination of tomato and mustard. The water extracts from tissues of *Helianthus annus* were found to inhibit germination of tobacco (Inderjit and Dakshin, 1994).Ratwat*et al.* (2002) also observed that the aqueous extract of the root of *Helianthus annus* delayed and inhibited the germination and seeding growth of linseed (*Linunausitatissium*L.) and mustard (*BrassiaJuncia* L.).Mulatu*et al*. (2006) found that aqueous extract of *Partheniumhysterophorus* leaves and flower inhibited seed germination of lettuce. The retardatory effect of the extracts of the decomposed shoots of *T. rotundifolia* was found to decrease with period of decomposition. This agreed with the finding of Chang-Hung*et al.* (1998) who reported that the inhibition of the radicle growth of lettuce by the extract of the leaves of *Acacia confusa* gradually disappeared during 4-12 days of decomposition of the leaves. Also, Stimulation by allelochemicals has been observed to be obvious only at the later stages of decomposition (Mason-Sedun and Jessop, 1988; An et al., 1996).

According to Inderjit*et al*. (1999), the bioactive concentration of the allelochemicals in soils is determined through sorption, fixation, leaching, chemical and microbial degradation. Therefore, the decrease in the phytotoxicity of allelochemicals in the decomposing shoots of *T. rotundifolia* could be as a result of the process of decay. According to Rahman (1995), the extract derived from the inflorescence, stem, and leaves of *Bartheniumhysterophorus* L. inhibited the growth of radicle and plumule of *Cassia sophera*Linn. Kushima (1998) reported that there was an inhibition of the growth of the plumule length of tomato seedlings by the application of leachate from water melon seeds. Also, Ilori*et al*. (2007) stated that the radical growth of *Oryza sativa* was inhibited by the aqueous extract of *T. diversifolia* (a close relative of the donor plant).

The inhibition of the growth of the radicle were more pronounced than that of the plumule growth for all the test plants. These results corroborates the earlier findings of several other workers such as Chou and Waller (1980), Chou and Kuo (1986), Alam (1990) and Zackrisson and Nilsson (1992) who all asserted that root growth was more sensitive to the allelochemicals in the plant aqueous extracts in comparison to the shoot. The result showed that the germination of *G. max* and the radicle dry weight of the *S. bicolor* and *Z. mays* seedlings were stimulated in the water extract prepared from shoot decomposed for longer period while these parameters were inhibited in the other test crops. This indicated that the response of plants to allelochemicals toxicity was dependent on plant species i.e. there is an interspecific differential response to allelochemicals toxicity. This is consistent with the work of Bettina *et al.* (1990) and Yu and Matsui (1997) who stated that sensitivity to juglone (an allelochemical) varies from plant to plant and between subspecies. Stachon and Zimdal (1980) had earlier observed a differential response of cucumber (*Cucumis sativa* L.) barley *(Hordeumvulgare*L.), *Amaranthusretroflexus*L. and *Seteriaviridis* to litters derived from *Cirsiumarvense* L.

5. Conclusion

This study showed that allelochemicals in *T.rotundifolia* were soluble and better extracted by the organic methanolic solvent than water. Hence the greater inhibition of the germination and growth observed in the methanolic extract treated seedlings compared to the water extracts treated seedlings. The response of plants to allelochemicals toxicity was dependent on plant species. The process of decomposition of the shoots reduced the phytotoxicity of the extracts. This suggests that allelopathic activity of *T.rotundifolia* plant shoots might not persist on the ground for a long time.

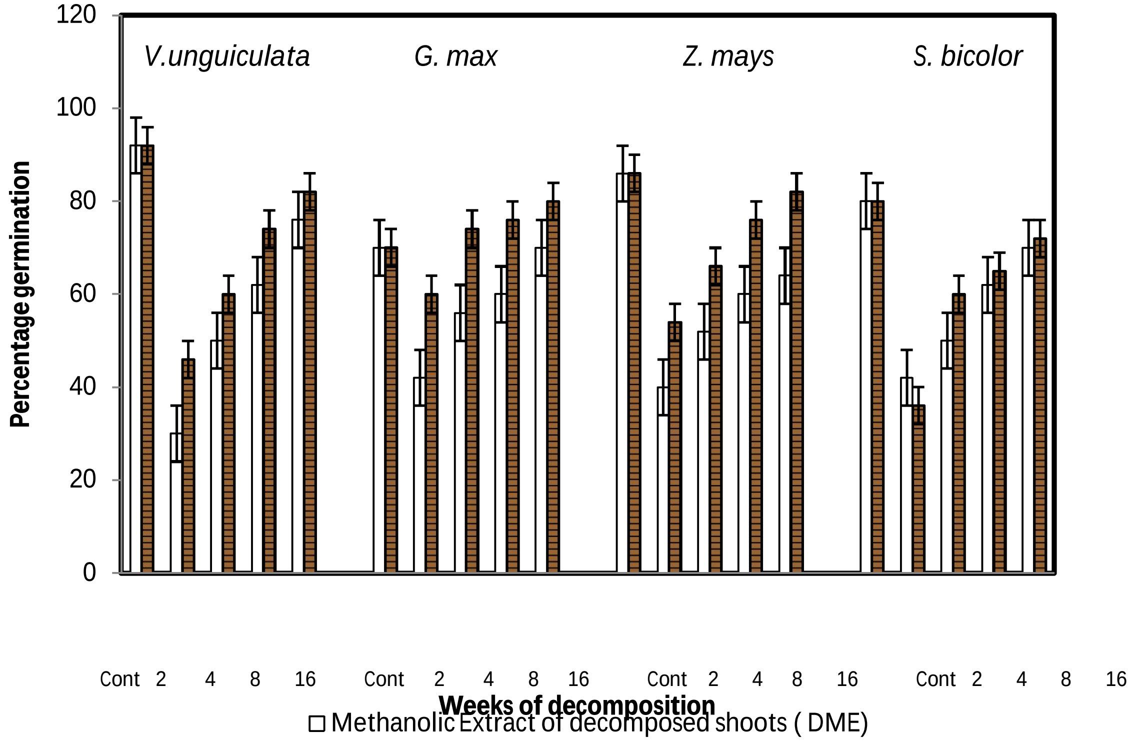

Fig. 1: Effects of the Methanolic and Waterextracts Obtained from the Decomposed Shoots of *T. Rotundifolia* on the Germination of the Test Crops

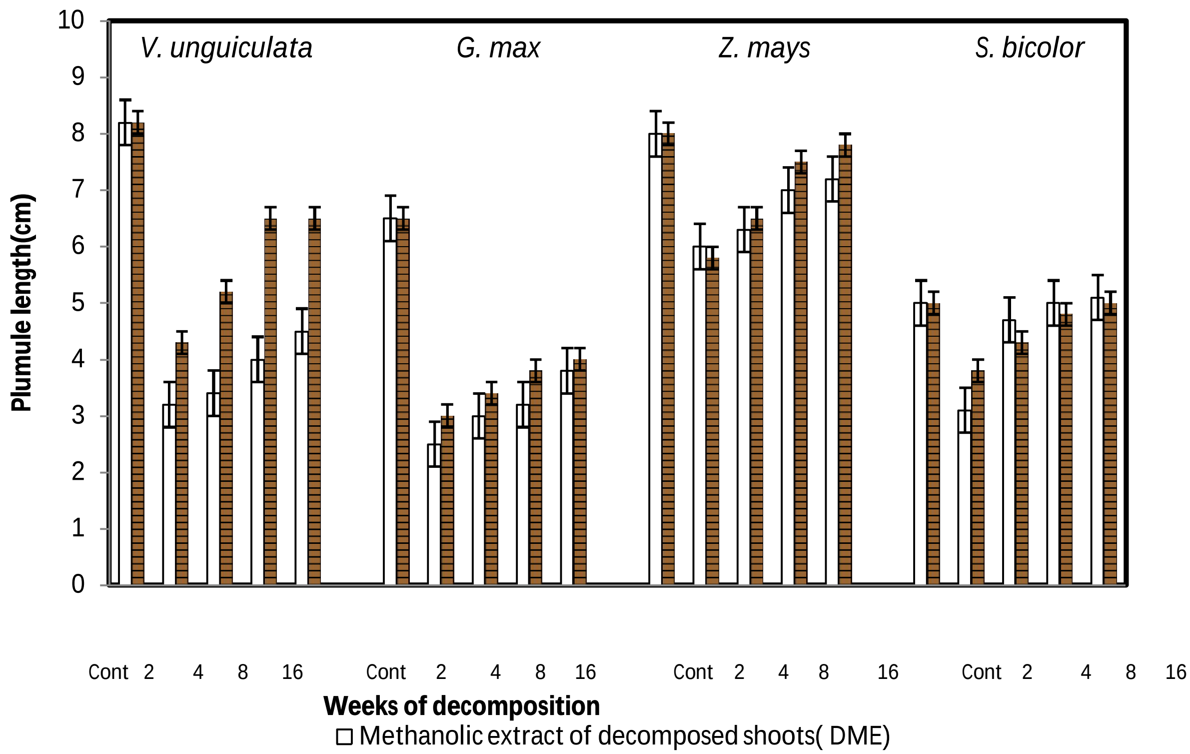

Fig. 2: Effect of the Methanolic Extracts and Water Extracts Obtained from the Decomposed Shoots of *T. Rotundifolia*on the Plumule Length of the Test Crops

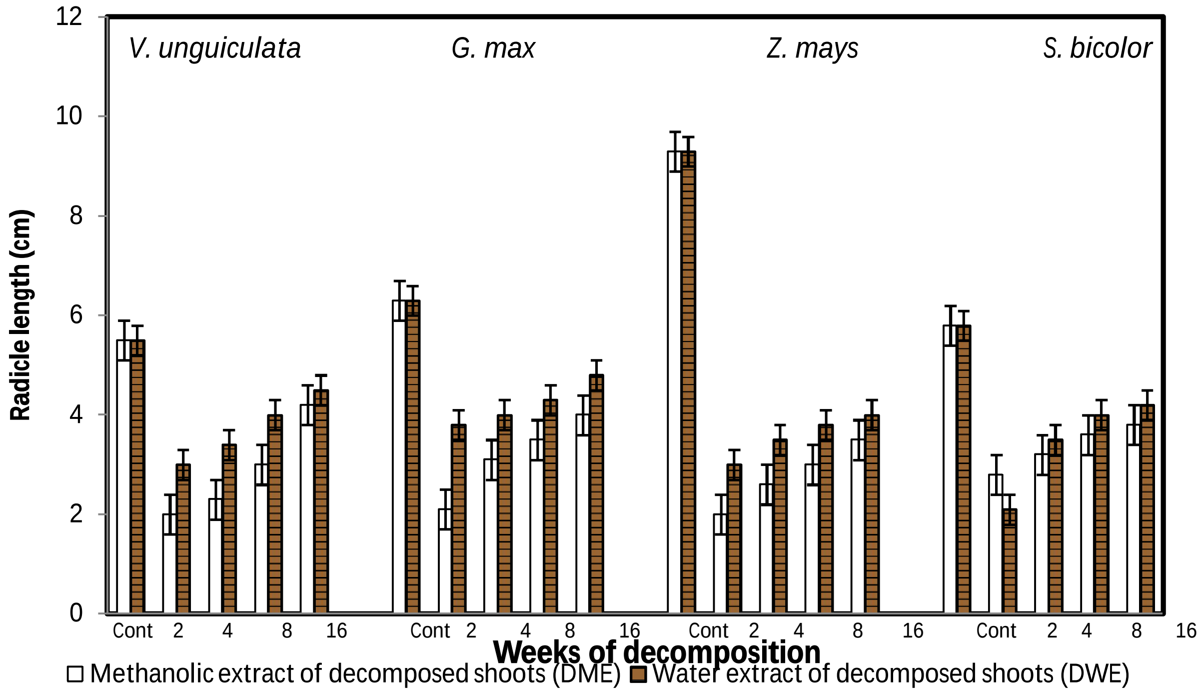

Fig.3: Variation in the Radicle Length of the Test Crops Treated with the Methanolic Extracts and Water Extracts of the Decomposed Shoots of *T. Rotundifolia.*

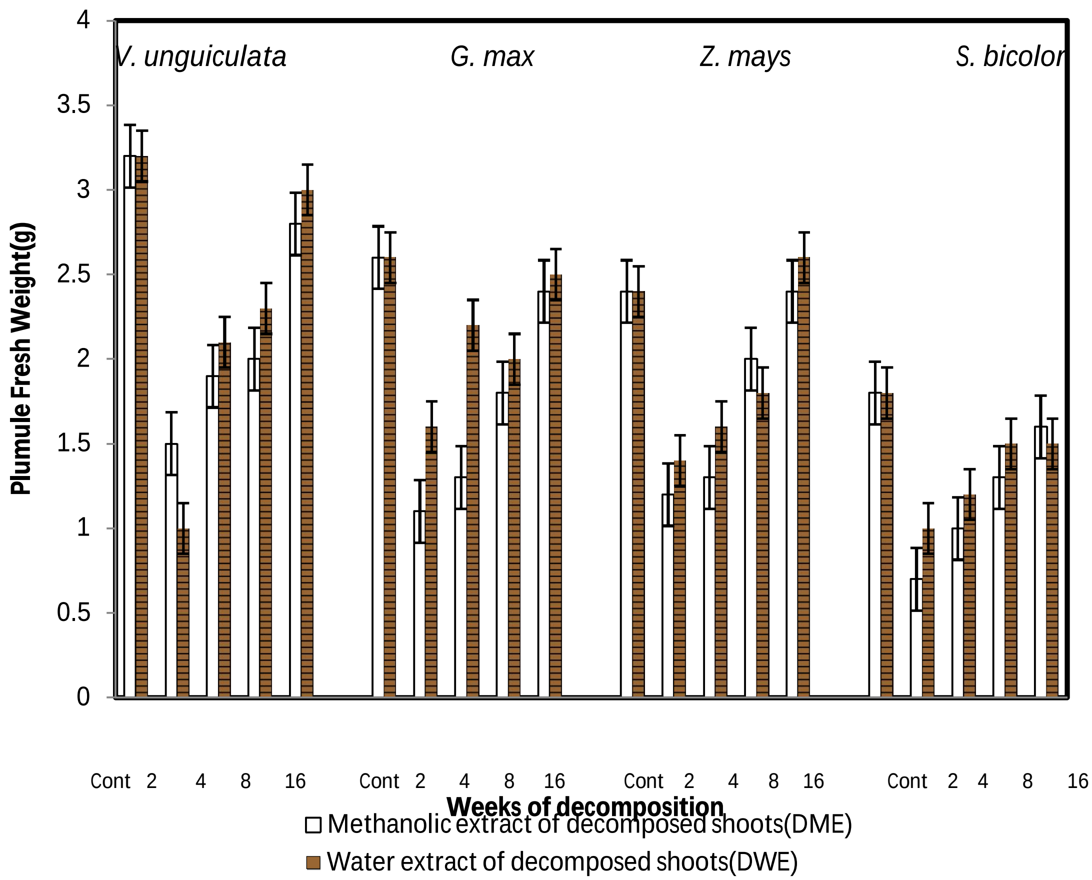

Fig. 4: Variation in the Plumule Fresh Weight of the Test Crops Treated With The Methanolicextracts and Water Extracts Obtained from the Decomposed Shoots of *T. Rotundifolia.*

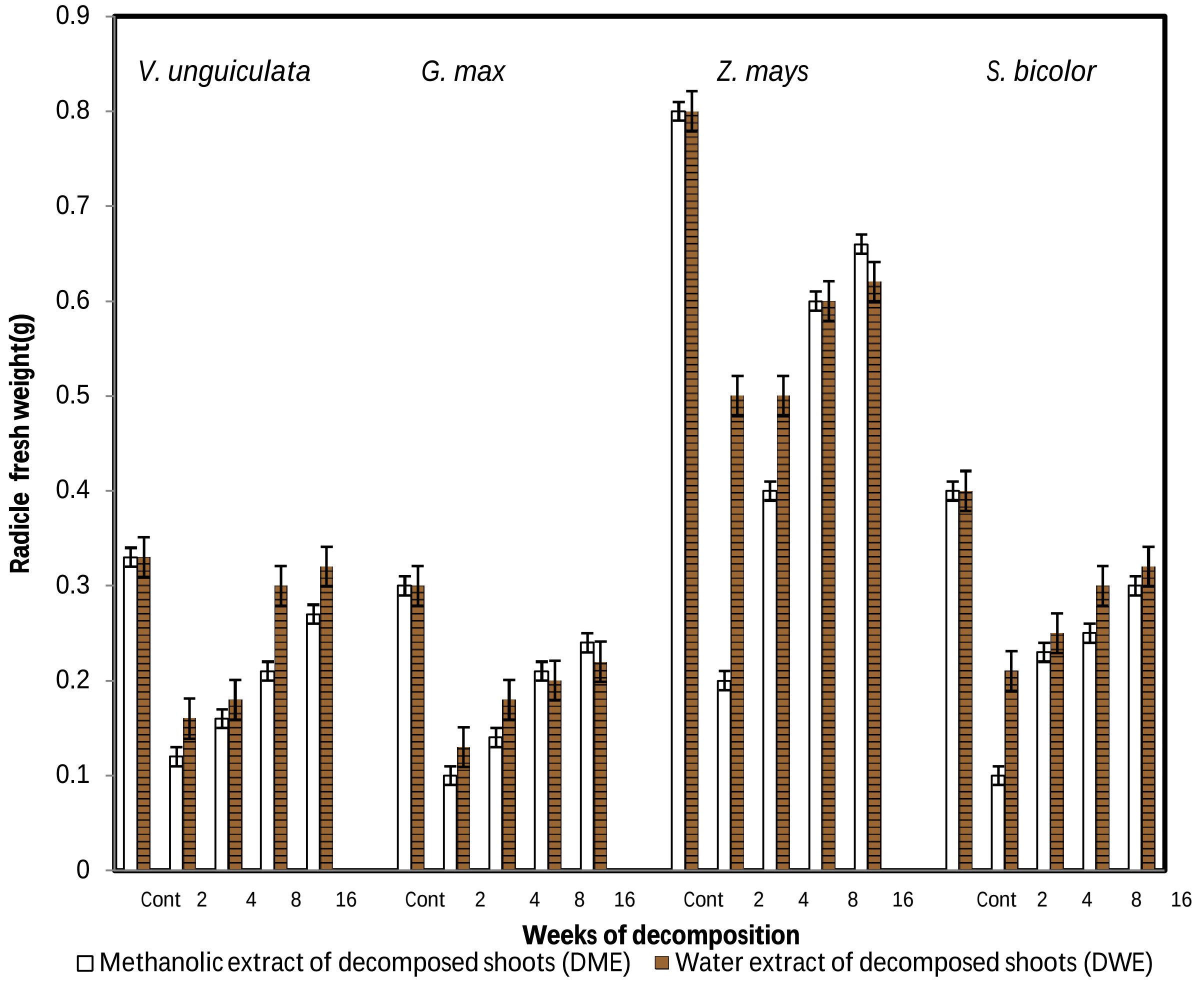

Fig.5: Effect of the Methanolic Extracts and water Extracts obtained from the Decomposed Shoots of *T. Rotundifolia*on the Radicle fresh Weight of the Test Crops

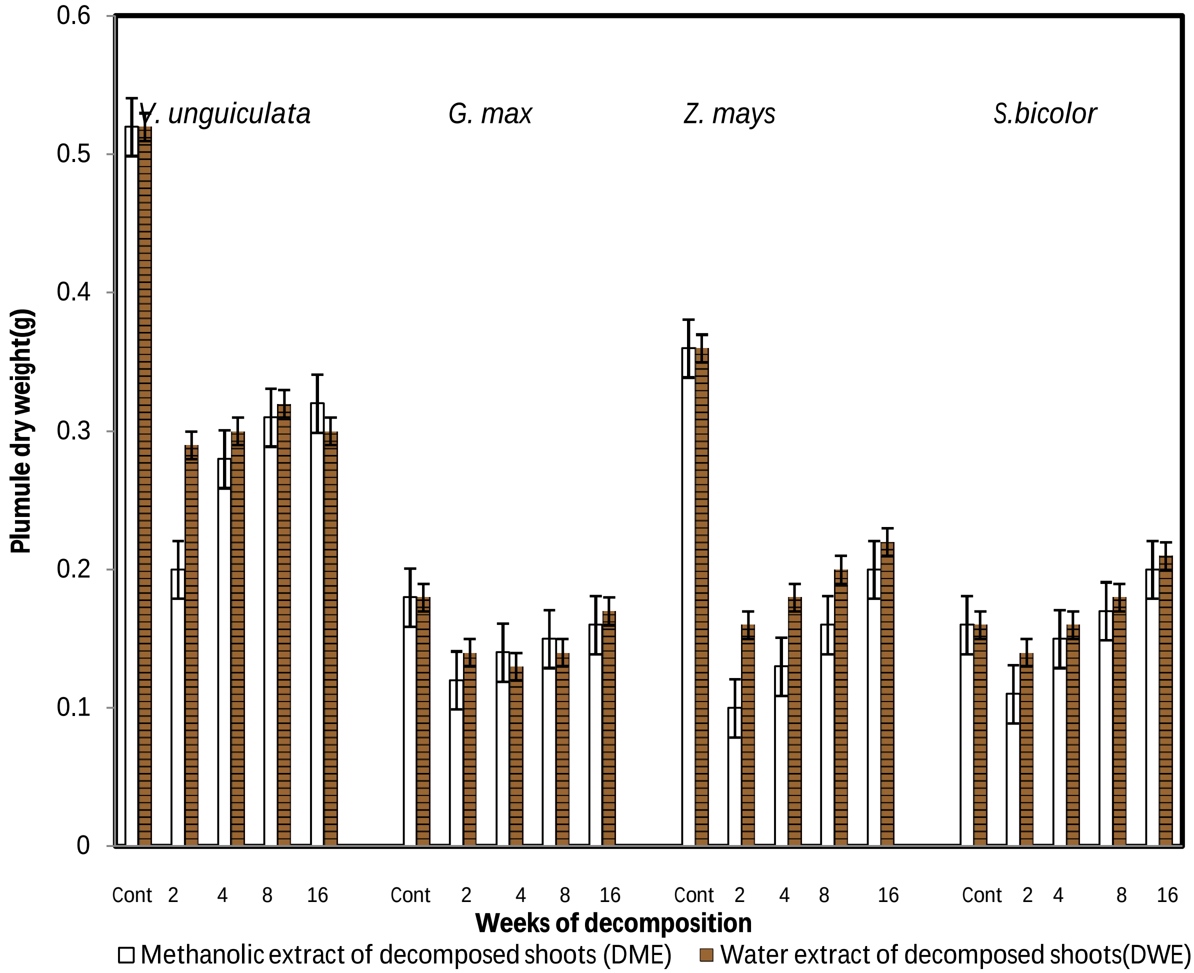

Fig.6: Effect of the Methanolic Extracts and Water Extracts obtained from the Decomposed Shoots of *T. Rotundifolia* on the Plumule dry Weight of the Test Crops

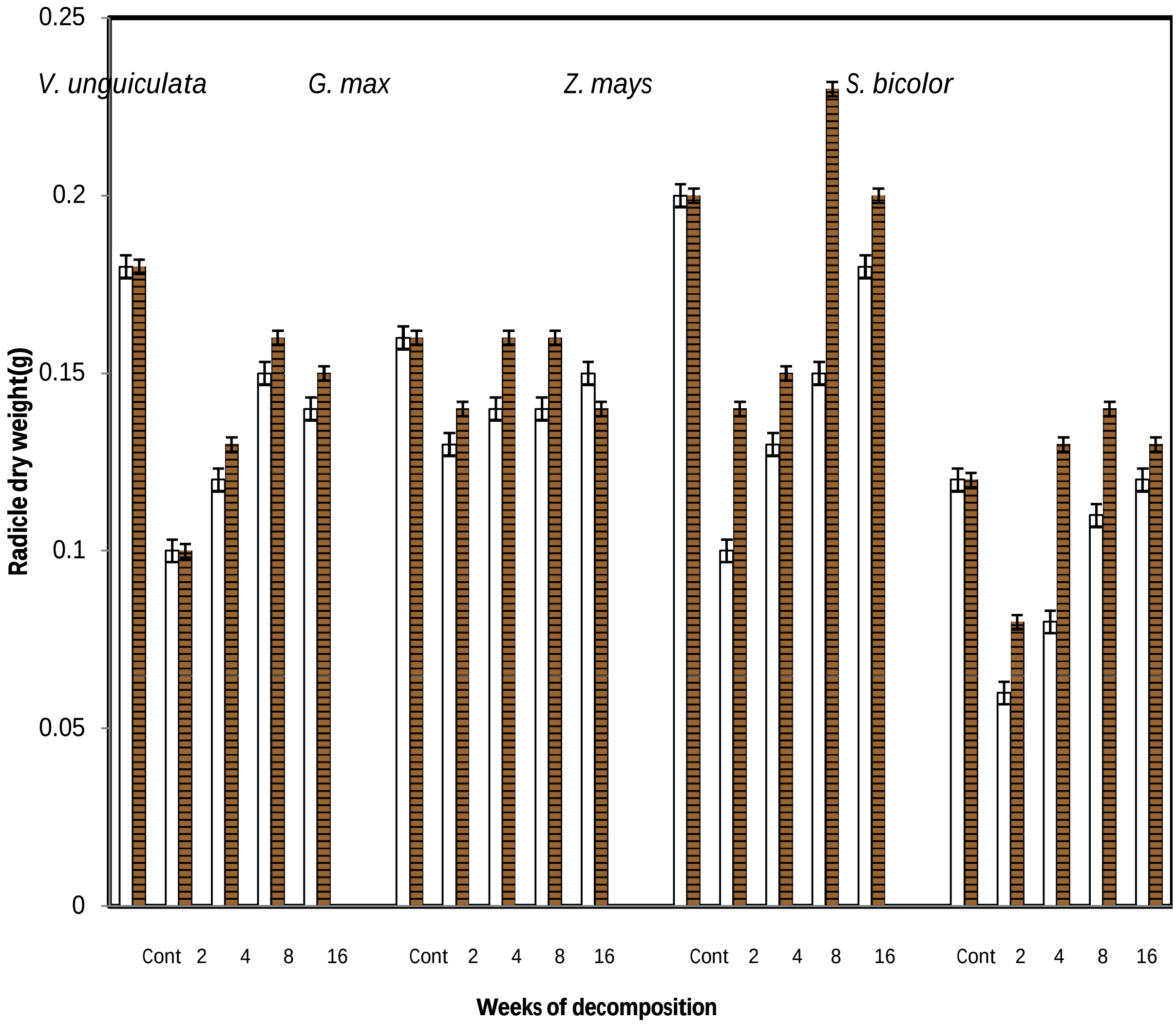

Fig.7: Radicle dry Weight of the Test Crops as Affected by the Application of the Methanolic Extracts and Water Extracts of the Decomposed Shoots of *T. Rotundifolia*

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