Allelopathic Effects of Two Hedgerow Species on the Survival and Early Growth of Corn (*Zea mays* L.)

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ABSTRACT

Experiments in the laboratory and nursery were undertaken to test the allelopathic effects of *Jatropha curcas* and *Gliricidia sepium* on *Zea mays* L. The allelopathic effects of the two hedgerow species were assessed in terms of survival, germination, early shoot and root growth, and biomass of corn.

Fresh leaves of *J. curcas* and *G. sepium* were used to produce extracts in different concentrations that served as treatments for the laboratory experiment. Soils were collected in an agroforestry area located in Bangan Hill. These were mixed with dried leaves from the two species separately to produce different potting mixture that served as treatments for the nursery experiment.

Significant differences were observed among the treatments in the laboratory experiments. There were allelopathic effects from the prepared extracts on the germination survival, early shoot and root growth, and biomass of corn. The higher the concentration of the leaf extract from both species, the higher is the degree of observed effects on survival and early growth of corn.

Significant differences among treatments were also observed in the nursery experiments. Survival percentages of corn planted in the high amount of shredded *J. curcas* leaves in the potting mixture were affected, while corn in potting mixture of any amount of shredded *G. sepium* leaves were not affected. Delay of germination by 2-3 days was observed in corn potted in mixture with shredded *J. curcas* leaves while a delay of 1-2 days was observed in corn potted in mixture with shredded *G. sepium* leaves. Shoot length and biomass of corn planted in the mixture with less quantity of shredded *J. curcas* leaves were higher compared to corn planted in the mixture with higher quantity of leaves. On the other hand, shoot growth of corns planted in any amount of shredded *G. sepium* leaves in the potting mixture did not significantly vary. For the biomass, corn planted with fewer amounts of shredded *G. sepium* leaves in the mixture is significantly higher.

INTRODUCTION

Agroforestry is a land use system that integrates tree crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers (Nair, 1993). It is more complex than monocropping systems and has significant interaction (positive and/or negative) between woody and non-woody components of the system. The success or failure of agroforestry relies heavily on these

component interactions. Tree-crop interaction may produce positive or beneficial effects such as shading, nutrient contribution, soil moisture retention and, micro-climate modification. In the same manner, tree-crop interaction also produces negative results due to competition for light, nutrient, water, and allelopathy among the systems' components.

Allelopathy refers to the chemical inhibition of one species by another. It is an injurious or detrimental effect of one plant to another. The "inhibitory" chemicals or allelochemicals are released into the environment by a plant where it affects the development and growth of neighboring plants. Allelochemicals include a wide range of compounds such as tannins, alkaloids, phenolic compounds, organic acids, terpenoids, quinones, and flavonoids (Rice, 1984). In the tropics, particularly under simultaneous agroforestry systems, allelopathy has important negative effects and the positive benefits and is a major factor in determining tree–crop–soil interactions (Rao *et al*., 1998).Trees incorporated in agroecosystems in various ways also bring about significant effects on the associated crops and result in reduction in crop productivity (Kohli *et al.*, 2006).

The potential for allelopathic effects of one plant to another is very high in agroforestry because of the enormous number of crop combinations in the system. One agroforestry system where combinations of tree crops and agricultural crops are very evident is the alley cropping or hedgerow cropping system. It involves planting of hedgerows along the contours and growing agricultural crops in the "alley" formed between two hedgerows. The main purpose of planting hedgerows is to minimize soil erosion by trapping the sediments. In addition, nutrient are replenished in the soil from hedgerow prunings that are used as mulch and green manure. While it is true that alley cropping has great advantages, this agroforestry system also has some limitations like decrease in over-all farm yield due to reduction of cropping area devoted to hedgerow establishment and allelopathic properties of some hedgerow species which can adversely affect crop growth.

The ideal species for hedgerows are multi-purpose tree species (MPTS). These species have unique qualities that are favorable to farmers. *Gliricidia sepium* is a common MPTS inter-planted with crops. *G. sepium* is the second most important tree species after *Leucaena leucocephala* (Batish *et al.*, 2004). It is easy to establish, has a good sprouting ability, grows in closely spaced conditions, and effective nurse tree and good source of wood for fuel and fence. Another species is *Jatropha curcas*. It is a shrub with seeds that are very rich in oil that can be used directly as biodiesel in engines. It is also used as live fence and the leaves were commonly used as medicine. These reasons made *J. curcas* an attractive crop with high potential of contributing to augment the income of farmers. Throughout the world, including India, Thailand and the Philippines, *J. curcas* has been cultivated along with other crops (Rejila and Vijayakumar, 2011).

There are studies conducted that evaluate allelopathic potential of *G. sepium*. In one study, Tian and Kang (1994) found that leaf prunings of *G. sepium* under laboratory conditions significantly reduce the growth of *Z. mays* and in the field condition, leaf chlorosis occurred when sown in soil mulch with prunings. Oyun (2011) reported the decline in crop yield in cropping and agroforestry system as affected by leaf leachates of *G. sepium* and *Acacia auriculiformis*. In the field, hedgerows are cut regularly and the foliage is either dumped in the alley as green manure or mulch. This common practice by farmers has high potential for allelopathic effects among inter crop species. However, this has not been given much attention because there is little knowledge on allelopathy at the farmer's level, and in the field level, inhibitory effects is unrecognizable because it may have been neutralized by volatilization, leaching, decomposition of residue and changing of soil reaction.

On the one hand, there is little knowledge on the allelopathic effect of *J. curcas* on the growth and development of the intercrop. Several researches have reported the release of secondary metabolites from *J. curcas* through leaching and root exudation (Rejila and Vijayakumar, 2011). These secondary metabolites may affect the growth and development of inter-planted crops through inhibitory responses.

With the observed practices of crop combinations in agroforestry farms, this study seeks to verify the potential allelopathic effects of hedgerow species on the annual crops or other crop combinations in agroforestry intercropping. The study embarks on the concept of tree-crop interface in agroforestry which seek to assess the influence of allelochemicals from the woody components the survival and early growth of annual crops. The study also seeks to find the condition by which phytotoxic effects of the allelochemical is neutralized or eliminated.

MATERIALS AND METHODS

The study employed two sets of experiments, in the laboratory and nursery, testing the allelopathic effects of *Jatropha curcas* and *Gliricidia sepium* on *Zea mays*. The allelopathic effects of the two hedgerow species were assessed in terms of survival, germination, shoot growth, root growth, number of roots and total dry biomass of corn in the laboratory experiment. In the nursery experiment, allelopathic effects were assessed in terms of survival, germination, shoot growth, and dry biomass of corn.

Preliminary Activities

The corn seeds used in the experiment were certified seeds purchased from an authorized outlet to ensure the quality of the experimental materials. Leaves of *Jatropha curcas* and *Gliricidia sepium* were collected from source trees planted inside the NVSU Bayombong campus. Enough quantities were gathered and brought to the greenhouse in the College of Forestry. Some amount of leaves of both species were set aside for the preparation of extract in the laboratory experiment, while the remaining leaves that were used in the nursery experiment were placed inside the greenhouse for air drying. The leaves were chopped to facilitate drying.

Laboratory Experiment

The fresh leaves of *J. curcas* and *G. sepium* were collected from source trees at random vegetative stage and at single collection only. The leaves were separated and grounded into powder. Following the procedure of Oyun (2006), leaf extract from both species was obtained by adding distilled water to the ground materials. The mixture was shaken thoroughly and left for 24 hours. Thereafter, the suspension was filtered using No. 1 Whatman filter paper. From the extract produced different concentrations were prepared 10%, 20%, 30% and 40%.

The produced extracts of different concentrations from both of *J. curcas* and *G. sepium* were used as the experimental treatments. Treatment 1 (T1) was pure distilled water; Treatment 2 (T2), 10% extract concentration; Treatment 3 (T3), 20% extract concentration; Treatment 4 (T4), 30% extract concentration, and 40% extract concentration for Treatment 5 (T5). All treatments were replicated three times with 10 experimental units each. The experiment was laid in a completely randomized design (CRD) under laboratory condition.

Each treatment and corresponding replicates were randomly drawn using the fish bowl method. Once drawn, the treatment and corresponding replicates were assigned with a place in the laboratory.

Following the established layout, the seeds of corn were placed on petri-dishes with cotton wool saturated with 5 ml of each of the prepared extracts twice a day for 20 days. Moisture in the petri-dishes was maintained by adding 1 ml of the respective prepared extracts

or distilled water as required to wet the seeds. The petri-dishes were kept at room temperature under 12 hours of natural light each day.

Nursery Experiment

Soil samples were collected from the agroforestry farm at Bangan Hill, NVSU Bayombong. Enough soil was collected to ensure sufficient materials to be used in the experiment and in the analyses. These were air-dried for several days, sieved to remove exogenous materials then sun dried for sterilization.

The fresh leaves of *J. curcas* and *G. sepium* collected from hedgerows at random vegetative stage were shredded to facilitate drying. The shredded leaves were set aside separately in shade.

The soil samples previously collected, sieved and sterilized were used for potting media preparation. The soil was mixed separately with the shredded leaves of the two hedgerow species. Different mixtures of potting media were placed in plastic pots color coded to facilitate data gathering.

The potted mixture of soil and shredded leaves in different ratios from both of *J. curcas* and *G. sepium* were used as the experimental treatments. Treatment 1 (T1) was pure soil; Treatment 2 (T2) 75% : 25% soil and shredded leaves; Treatment 3 (T3) 50% : 50% soil and shredded leaves; Treatment 4 (T4), 25% : 75% of soil and shredded leaves and pure shredded leaves for Treatment 5 (T5). All the treatments were replicated three times with 10 experimental units each. The experiment was laid in a completely randomized design (CRD) under nursery condition.

The seeds of corn were planted 4 cm deep in each pot initially saturated with water prior to planting. Watering was done twice a day at 1 cup per pot. Moisture was maintained by adding water amounting to 25% of the volume of pots used. The pots were kept at ursery condition. Weeding was also done to ensure that the corns are free from competion for water and nutrients.

Data Gathering

In the laboratory, the condition of seeds was monitored daily. Seeds were considered germinated once the radicle emerged. Germinated seeds were counted while radicle and plumule length were measured and recorded. Germination rate was determined by counting the number days before the seeds germinated. Percent survival was determined by dividing the total number of seeds germinated by the total number of seeds multiplied by 100.

Shoot root growth were measured daily using a ruler. After 20 days, total seedling biomass was determined. All the experimental units or individuals per treatment were harvested. The harvested seedlings were placed in the oven for drying. After 48 hours, the dried samples were weighed using a digital balance to get the oven dry weight.

In the nursery, germination rate was determined by counting the number of days before the seeds germinated. Percent survival was determined by dividing the total number of seeds germinated the total number of seeds multiplied by 100.

Shoot length was measured daily using a ruler to determine the growth. After 10 weeks, the total seedling biomass was determined through destructive sampling. Three (3) experimental units or individuals per treatment were harvested. Fresh weight of each seedling was determined using digital balance. After recording the data, the same harvested seedlings were placed in the oven for drying. After 48 hours, the dried samples were also weighed to get the oven dry weight.

Data Analysis

The data generated were analyzed using the Analysis of Variance (ANOVA) in Completely Randomized Design (CRD) for both experiments. Further determination of significant differences among treatments was made using the Duncan Multiple Range Test (DMRT) at 5% level of significance. The statistical analysis was carried out using SPSS version 16 software.

RESULTS AND DISCUSSION

Laboratory Experiment

Survival

The laboratory experiment was conducted to establish the allelopathic effects of the two hedgerow species in corn. The mean survival percentages of the experimental corn are shown in Table 1.

The table shows that plants treated with the highest concentration of *J. curcas* extract (T5, 40% leaf extract) are less likely to survive at 13.33% survival, which was significantly different from the other treatments based on the ANOVA. However, further testing showed that T5 is not significantly different from Treatment 4 (30% leaf extract) based on DMRT at 5% level.

Corn treated with lesser leaf extract concentration at 10% (T2) is likely to survive at 53.33% survival. But this is not significantly different from corn treated with slightly higher leaf extract concentration (T3, 20% leaf extract) at 43.33%.

The survival rate of corn in T1 (pure water) was 73.33%, which was significantly higher than in the leaf extract treatments.

The result of the experiment confirms the findings of Rejila and Vijayakumar (2011). Aqueous extracts of *J. curcas* at 20% to 35% concentrations inhibit the growth and survival of *Capsicum annum*. Duke (1993) reported that leaves and roots of *J. curcas* contain hydrogen cyanide (HCN) which could have accounted for the inhibitory effect observed in corns.

The same trend was observed in corn treated with *G. sepium* extract. Treatment 5 (40% leaf extract) gave the lowest survival rate of corn at 13.33% which was not significantly different from T4. Survival rate in T3 (43.33%) and T4 (53.33%) significantly differed from the other treatments but did not differ from each. Treatment 1 produced the highest survival (80%) which was significantly different from all the experimental treatments.

Germination

The mean germination rates of treated corn in number of days after planting are shown in Table 2.

Corn in Treatment 1 had the least number of days (4.07) before they germinated which was significantly differed from T4 and T5. but not from T2 and T3. The treatment with the most number of days before germination is T5 (5.67), which was significantly different from the other treatments.

The result of the study is consistent with the findings of Rejila and Vijayakumar (2011). The aqueous leaf extract of *J. curcas*

Table 1. Mean survival percentage of treated corn in the laboratory experiment

Treatments	Survival (%)	
	Corn Applied with water and *J. curcas* Extract	Corn Applied with water and *G. sepium* Extract
Treatment 1 – Pure distilled water	73.33 c	80.00 c
Treatment 2 – 10% leaf extract	53.33 b	53.33 b
Treatment 3 – 20% leaf extract	43.33 b	43.33 b
Treatment 4 – 30% leaf extract	16.67 a	23.33 a
Treatment 5 – 40% leaf extract	13.33 a	13.33 a
Coefficient of Variation (%)	18.26	24.21

Means followed by a common letter are not significantly different at 5% by DMRT

Table 2. Mean germination (days after planting) of treated corn in the laboratory experiment

Treatments	Germination (Days after Planting)	
	Corn Applied with water and *J. curcas* Extract	Corn Applied with water and *G. sepium* Extract
Treatment 1 – Pure distilled water	4.07 a	4.37 a
Treatment 2 – 10% leaf extract	4.43 ab	4.87 ab
Treatment 3 – 20% leaf extract	4.57 ab	5.53 bc
Treatment 4 – 30% leaf extract	4.80 b	6.27 c
Treatment 5 – 40% leaf extract	5.67 c	7.27 d
Coefficient of Variation (%)	13.51	6.03

Means followed by a common letter are not significantly different at 5% by DMRT

showed inhibitory effects on seed germination of *C. annum*.

Similar trend but greater differences were observed in the mean of days before germination of corn for all treatments with *G. sepium* extract. Treatment 1 has the least number of days at 4.37, which is significantly different from T3, T4 and T5 based on ANOVA, but not significantly different from T2. Treatment 2 was not significantly different from T1 and T3, but significantly different from T4 and T5. Treatment 3 is not significantly different from T2 and T4, but significantly different from T1 and T5. Treatment 4 is not significantly different from T3, but significantly different from T1, T2 and T5. Treatment 5 had the most number of days before germination at 7.27, which was significantly different from all the other treatments.

Similar results were reported by Kamara *et al.,* (2000) and Abugre *et al.,* (2011). *G. sepium* extracts negatively affect the germination of *Z. mays*.

Shoot Growth

Mean shoot length of corn at different stages of early growth (5, 10, 15 and 20 days) as affected by *J. curcas* extract is shown in Table 3.

There were no significant differences observed among the treatments in terms of shoot growth 5 days after planting. As the corns grew older, significant differences in growth were observed. After 10 days, corn in T5 were significantly shorter at 2.60 cm compared to T2 and T1. However, this is not significantly different from T4 and T3. reatment 2 is second in terms of shoot growth (5.43 cm) after 10 days, but this was not significantly different from T3 (4.33 cm). Shoot growth in T1 was longest (10 cm) which was significantly different from all the treatments.

The effects of *J. curcas* extract further showed significant differences in mean shoot growth of corn after 15 days. T5 and T4 showed growth retardation after 15 days while T3, T2 and T1 continued to grow at 4.97 cm, 10.80 cm and 15.33 cm, respectively.

Shoot growth of corns in all treatments went down 20 days after planting. Shoot growth of corn in T5 (1.67), T4 (1.83) and T3 (3.77) were not significantly different from each other, but significantly different from T2 (9.27) and T1 (15.00).

In the study of Rejila and Vijayakumar (2011), the inhibitory effects of *J. curcas* in the shoot length of *C. annum* is proportional to the increasing concentration (5%, 10%, 15%, 20%) of aqueous extract. There was a maximum of 30% reduction in shoot growth recorded at 20% leaf extract.

Table 4 shows the mean shoot length

of corn in the different stages of early growth as affected by the treatments with *G. sepium* extract.

Significant differences in mean shoot growth were observed after 5 days. Mean shoot growth in T5, T4 and T3 were not significantly different from each other but differed from T2 and T1.

The same trend in the shoot growth of corn treated with *G. sepium* extract was observed after 10 days. The mean shoot growth in T1 and T2 had the highest growth at 8.83 cm and 8.80 cm, respectively. The results are significantly different from other treatments based on the ANOVA. However, further test with DMRT at 5% level showed no difference between T1 and T2. The mean shoot growth of corn in T3, T4 and T5 were not significantly different from each other but different from T2 and T1.

The mean growth of corn after 15 days in the laboratory also showed significant differences among treatments similar to the results after 10 days (Table 7). The mean shoot

Table 3. Mean shoot length (cm) in the different stages of early growth of corn treated with water and prepared *J. curcas* extract in the laboratory

Treatments	Shoot Length (cm)			
	5 days after planting	10 days after planting	15 days after planting	20 days after planting
Treatment 1 (Pure distilled water)	1.80	10.00 c	15.33 d	15.00 c
Treatment 2 (10% *J. curcas* leaf extract)	0.83	5.43 b	10.80 c	9.27 b
Treatment 3 (20% *J. curcas* leaf extract)	1.13	4.33 ab	4.97 b	3.77 a
Treatment 4 (30% *J. curcas* leaf extract)	0.83	2.63 a	2.33 a	1.83 a
Treatment 5 (40% *J. curcas* leaf extract)	1.00	2.60 a	2.60 a	1.67 a
Coefficient of Variation (%)	50.51	23.39	15.92	21.47

Means followed by a common letter are not significantly different

Table 4. Mean shoot length (cm) in the different stages of early growth of corn treated with water and prepared *G. sepium* extract in the laboratory

Treatments	Shoot Length (cm)			
	5 days after planting	10 days after planting	15 days after planting	20 days after planting
Treatment 1 (Pure distilled water)	1.67 b	8.83 b	13.33 b	14.30 b
Treatment 2 (10% *G. sepium* leaf extract)	2.13 b	8.80 b	13.93 b	14.40 b
Treatment 3 (20% *G. sepium* leaf extract)	0.50 a	2.06 a	3.02 a	4.17 a
Treatment 4 (30% *G. sepium* leaf extract)	0.77 a	1.20 a	1.60 a	1.40 a
Treatment 5 (40% *Gliricidia* leaf extract)	0.53 a	1.33 a	2.63 a	3.30 a
Coefficient of Variation (%)	31.57	33.86	25.56	27.53

Means followed by a common letter are not significantly different at 5% level by DMRT

growth of corn under T1 (13.33 cm) and T2 (13.93 cm) are significantly higher compared to corns under T3, T4 and T5 at 3.02 cm, 1.60 cm and 2.63 cm, respectively.

Continuous growth of corn shoots was observed after 20 days. ANOVA shows significant differences among treatments. Mean shoot of corn under T2 at 14.40 cm showed the highest growth among all treatments. However, based on the DMRT at 5% level this does not differ from 14.30 cm shoot growth of corn it T1. The shoot growth of corns under T3, T4 and T5 did not differ from each other but significantly lower compare to the shoot growth of corns in T1 and T2.

The results suggest that *J. curcas* and *G. sepium* leaves exhibited allelopathic effects in the shoot growth of corn in the laboratory. The allelochemical present in the extract of both species inhibit the shoot growth of corn in the laboratory.

Root Growth

The roots of corn at different stages of early growth were also observed in the laboratory. The length in centimeter of the longest root of each experimental unit of corn was determined to test the allelopathic effects of leaf extract.

The mean root length of corn treated with different concentration of *J. curcas* extract is shown in Table 5. At the very early stage of growth (5 days), significant effect of the treatment observed. The corn treated with *J. curcas* extract at different levels of concentration exhibited shorter root length compared to roots of corn treated with pure distilled water.

After 10 days of treatment, the same trend follows with corn treated with pure distilled water (T1) exhibited the longest mean root growth. As the concentration of *J. curcas* extract get higher, the shorter the mean root growth of corn. However, based on the ANOVA, the mean root growth of corn is not significantly different from each other whatever levels of *J. curcas* extract applied for 10 days.

The mean root growth of corn in the different treatments still showed significant differences after 15 days based on the ANOVA. The corns in T1 produced the longest root length at 7.30 cm. However based on DMRT at 5% level it is not significantly different from the mean root growth of corn in T2 and T3 at 3.93 cm and 2.20 cm, respectively. The mean root growth of corn in T5 is the shortest at 0.50 cm after 15 days of treatment, but this did not differ significantly with the mean root growth in T4 (0.60 cm) and T3 (2.20 cm).

Table 5. Mean root length (cm) in the different stages of early growth of corn treated with water and prepared *J. curcas* extract in the laboratory

Treatments	Root Length (cm)			
	5 days after planting	10 days after planting	15 days after planting	20 days after planting
Treatment 1 (Pure distilled water)	1.97 b	6.93 b	7.30 b	4.03
Treatment 2 (10% *J. curcas* leaf extract)	0.97 a	3.20 a	3.93 b	5.50
Treatment 3 (20% *J. curcas* leaf extract)	0.67 a	1.90 a	2.20 ab	3.77
Treatment 4 (30% *J. curcas* leaf extract)	0.43 a	0.90 a	0.60 a	0.53
Treatment 5 (40% *J. curcas* leaf extract)	0.53 a	0.83 a	0.50 a	0.50
Coefficient of Variation (%)	51.00	54.66	36.92	112.77

Means followed by a common letter are not significantly different at 5% level by DMRT

Further observation of root growth after 20 days showed no significant differences among treatments, based on the ANOVA.

The *G. sepium* extract also showed significant effect on the mean root length of at the different stages of early growth (Table 6).

Based on the ANOVA, corns on the T1 produced the mean root length that are significantly longer compared to the roots of corn treated with the different concentrations of *G. sepium* extract at 5, 10, 15 and 20 days of treatment. Further analysis using DMRT at 5% level of significance showed that the effects on the root length of corn at different concentrations (T2, T3, T4 and T5) of *G. sepium* extract did not differ from each other in all the early stages of growth.

Number of Roots

The number of roots of each experimental unit in the laboratory is counted to determine the effect of the prepared extract of the two hedgerow species.

Table 7 shows the mean number of roots at the different stages of early growth of corn treated with water and prepared *J.*

Table 6. Mean root length (cm) in the different stages of early growth of corn treated with water and prepared *G. sepium* extract in the laboratory

Treatments	Root Length (cm)			
	5 days after planting	10 days after planting	15 days after planting	20 days after planting
Treatment 1 (Pure distilled water)	2.33 b	6.70 b	7.90 b	6.93 b
Treatment 2 (10% *G. sepium* leaf extract)	1.23 a	1.57 a	1.73 a	1.47 a
Treatment 3 (20% *G. sepium* leaf extract)	0.47 a	0.54 a	0.66 a	0.63 a
Treatment 4 (30% *G. sepium* leaf extract)	0.37 a	0.47 a	0.40 a	0.34 a
Treatment 5 (40% *G. sepium* leaf extract)	0.37 a	0.57 a	0.43 a	0.60 a
Coefficient of Variation (%)	54.61	42.65	37.08	36.41

Means followed by a common letter are not significantly different at 5% level by DMRT

Table 7. Mean number of roots in the different stages of early growth of corn treated with water and prepared *J. curcas* extract in the laboratory

Treatments	Number Of Roots			
	5 days after planting	10 days after planting	15 days after planting	20 days after planting
Treatment 1 (Pure distilled water)	3.07	10.07	11.87 c	9.37 c
Treatment 2 (10% *J. curcas* leaf extract)	1.90	6.77	11.20 c	8.93 bc
Treatment 3 (20% *J. curcas* leaf extract)	1.80	6.60	7.70 b	6.93 b
Treatment 4 (30% *J. curcas* leaf extract)	1.67	5.37	2.87 a	2.90 a
Treatment 5 (40% *J. curcas* leaf extract)	2.87	6.27	4.20 a	2.87 a
Coefficient of Variation (%)	48.59	35.33	17.66	20.19

Means followed by a common letter are not significantly different at 5% level by DMRT

curcas extract. Based on the ANOVA, there are no significant differences on the effects of treatments in terms of the mean number of roots after 5 and 10 days in the laboratory.

Significant differences were observed after 15 days of treatment. The mean number of roots produced in T1 (11.87) and T2 (11.20) were higher compared to number of roots produced in other treatments. After 20 days, significant differences in the effects of treatment were still observed. The reduction in the number of roots was also noticeable in the different treatments, which are attributed to the effects of the treatment and the growing space of the corn in the laboratory.

The effects of *G. sepium* extract in the number of roots of corn in the laboratory are shown in Table 8. Significant differences were observed among treatment at 5 days after planting. T1 has the most number of roots at 4.10 but it is not significantly different from T2 at 3.10. In T3, the roots produced are not significantly different from T2 and not significantly different from T4 and T5. However, after 10 days, T1 has significantly higher number of roots, followed by T2. The number of roots in T3, T4 and T5 did not significantly differ from each other after 10 days based on the ANOVA.

As for number of root after 15 days, T1 and T2 did not differ significantly from each other but differ from T3, T4 and T5 having number of roots comparable to each other based on DMRT at 5% level of significance.

Twenty (20) days after treatment also produced significantly different number of roots among treatments. T1 and T2 produced significantly more number of roots compare to T3, T4 and T5. In T3, The number of roots is significantly different from T4 but comparable to T5.

Total Dry Biomass

The effect of the prepared extract from the two hedgerow species was also tested in the total dry biomass of corn.

Significant differences in the mean biomass of corn were obtained in the different concentrations of *J. curcas* extracts according to the ANOVA (Table 9). T1 produced the heaviest dry biomass at 0.20 g. T2 at 0.14 g is second but comparable to the 0.11 of T3. The dry biomass in T4 and T5 are both 0.07 g, which significantly lower to other treatment based of DMRT at 5% level of significance.

The prepared extract of *G. sepium* also showed significant effects to the total dry biomass of corn (Table 9). Corns in the T1 had

Table 8. Mean number of root in the different stages of early growth of corn treated with water and prepared *G. sepium* extract in the laboratory

Treatments	Number Of Roots			
	5 days after planting	10 days after planting	15 days after planting	20 days after planting
Treatment 1 (Pure distilled water)	4.10 c	8.30 c	10.23 b	9.90 c
Treatment 2 (10% *G. sepium* leaf extract)	3.10 bc	5.33 b	9.50 b	10.50 c
Treatment 3 (20% *G. sepium* leaf extract)	2.10 ab	2.53 a	3.33 a	4.23 b
Treatment 4 (30% *G. sepium* leaf extract)	1.17 a	1.37 a	1.43 a	1.17 a
Treatment 5 (40% *G. sepium* leaf extract)	1.33 a	2.00 a	1.50 a	1.57 ab
Coefficient of Variation (%)	32.46	25.37	22.52	27.04

Means followed by a common letter are not significantly different at 5% level by DMRT

the heaviest mean dry biomass at 0.21 g that is significantly different from other treatments. This is followed by 0.16 g mean biomass in T2. T3 and T4 both have 0.12 g mean biomass that is not significantly different from the 0.10 g mean dry biomass in T5.

Nursery Experiment

The allelopathic effects of the two hedgerow species were further tested in the conducted nursery experiment. The performance of corns planted in the prepared potting mixture was evaluated in terms of survival, germination, shoot growth, and dry biomass.

Survival

The mean survival percentage of treated corn in the nursery is shown in Table 10. The ANOVA showed significant differences among the treatments in the percent survival of corn planted in soil and prepared potting mixture with shredded *J. curcas* leaves. All the experimental units of corn in T1 (pure soil) and T2 (75% soil: 25% shredded leaves) survived throughout the duration of the nursery experiment. The corns in T3 (50% soil: 50% shredded leaves) had 93% survival, which

Table 9. Mean biomass (g) of treated corn in the laboratory experiment

Treatments	Number Of Roots	
	Corn Applied with water and *J. curcas* Extract	Corn Applied with water and *G. sepium* Extract
Treatment 1 – Pure distilled water	0.20 c	0.21 c
Treatment 2 – 10% leaf extract	0.14 b	0.16 b
Treatment 3 – 20% leaf extract	0.11 b	0.12 a
Treatment 4 – 30% leaf extract	0.07 a	0.12 a
Treatment 5 – 40% leaf extract	0.07 a	0.10 a
Coefficient of Variation (%)	3.47	2.82

Means followed by a common letter are not significantly different at 5% level by DMRT

Table 10. Mean survival percentage of treated corn in the nursery experiment

Treatments	Survival (%)	
	Corn Planted in Soil and Soil with Shredded *J. curcas* Leaves	Corn Planted in Soil and Soil with Shredded *G. sepium* Leaves
Treatment 1 – (Pure soil)	100 c	100
Treatment 2 – (75% soil : 25% shredded leaves)	100 c	100
Treatment 3 – (50% soil : 50% shredded leaves)	93 c	100
Treatment 4 – (25% soil : 75% shredded leaves)	40 b	100
Treatment 5 – (Pure shredded leaves)	10 a	100
Coefficient of Variation (%)	18.80	1.00

Means followed by a common letter are not significantly different at 5% level by DMRT

is not significantly different from T1 and T2 based on the DMRT at 5% level of significance. Treatment 4 (25% soil: 75% shredded leaves) had 40% survival while the corns in T5 (pure shredded leaves) obtained only 10% survival, which is significantly different from all the treatments.

On the other hand, the survival of corns planted in soil and prepared potting mixture with shredded *G. sepium* leaves are not significantly different from each other (Table 10). Under the field and pot conditions, the growth of corn was dependent on nitrogen supply rather than phytotoxic effects (Karama *et al.*, 2000).

Germination

The mean germination of corns in terms of number of days after planting was observed. Based on the ANOVA, there are significant differences on the germination of corns planted in the prepared potting mixture of soil and soil with shredded *J. curcas* leaves (Table 11). Early mean germination at 4.80 days was observed in corns planted in T1, but this is not significantly different from the germination of corns in T2 (5.10 days) and T3 (5.77 days) based on DMRT at 5% level of significance. Similarly, the germination in T3 did not significantly differ from T4 (6.97 days) and T5 (7.14 days).

Table 11 also shows the mean germination of corns planted in soil and soil with shredded leaves of *G. sepium*. Based on the ANOVA, there are significant differences in the mean germination in terms of number of days in the different treatments. The corns in T1 had the least mean number of days at 4.40 before germination, but this does not significantly differ from T2 at 4.99 days. According to the result of DMRT, germination in T3 (5.62) significantly differs from T1 and T2, but did not differ from T4 (5.77). T5 has 6.55 days before germination, which is significantly different from all the treatments.

Shoot Growth

The shoot length of corns was measured in the nursery at different stages of early growth such as 2 weeks, 6 weeks and 10 weeks. Table 12 shows the mean shoot length (cm) in the different stages of early growth of corn potted in soil, prepared media of soil mixed with shredded leaves and pure shredded leaves of *J. curcas*.

Significant differences among treatments were observed. The mean shoot length of corn is highest in T2 at 15.57 cm,

Table 11. Mean germination (days after planting) of treated corn in the nursery experiment

Treatments	Germination (Days after Planting)	
	Corn Planted in Soil and Soil with Shredded *J. curcas* Leaves	Corn Planted in Soil and Soil with Shredded *G. curcas* Leaves
Treatment 1 – (Pure soil)	4.80 a	4.70 a
Treatment 2 – (75% soil : 25% shredded leaves)	5.10 a	4.99 a
Treatment 3 – (50% soil : 50% shredded leaves)	5.77 ab	5.62 b
Treatment 4 – (25% soil : 75% shredded leaves)	6.97 b	5.77 b
Treatment 5 – (Pure shredded leaves)	7.14 b	6.55 c
Coefficient of Variation (%)	13.53	6.03

Means followed by a common letter are not significantly different at 5% level by DMRT

Table 12. Mean shoot length (cm) in the different stages of early growth of corn potted in soil, prepared media of soil mixed with shredded *J. curcas* leaves and pure shredded *J. curcas* leaves

Treatments	Shoot Length (cm)		
	After 2 weeks	After 6 weeks	After 10 weeks
Treatment 1 (Pure soil)	14.33 b	31.13 b	43.15 b
Treatment 2 (75% soil : 25% shredded *J. curcas* leaves)	15.57 b	38.27 b	74.76 c
Treatment 3 (50% soil : 50% shredded *J. curcas* leaves)	12.47 b	30.90 b	68.77 c
Treatment 4 (25% soil : 75% shredded *J. curcas* leaves)	7.00 a	15.93 a	49.61 b
Treatment 5 (Pure shredded *J. curcas* leaves)	5.50 a	17.77 a	22.32 a
Coefficient of Variation (%)	16.24	19.37	16.67

Means followed by a common letter are not significantly different at 5% level by DMRT

however this is not significantly different from shoot length in T1 (14.33 cm) and T3 (12.47 cm). The shoot length in T5 is the lowest at 5.50 cm but did not significantly differ from shoot length in T4 at 7.00 cm based on DMRT at 5% level of significance.

The same trend in shoot growth was observed after 6 weeks in the nursery. Shoot length in T1, T2 and T3 did not significantly differ from each other, but significantly differ from T4 and T5.

After 10 weeks in the nursery, ANOVA showed significant differences among treatments (Table 12). The mean shoot length of corns in T2 is the longest at 74.76 cm, but did not significantly differ from shoot length in T3 at 68.77 cm based on DMRT at 5% level of significance. The mean shoot length in T1 is 43.15 cm, which is significantly the same as shoot length in T4 at 49.61 cm. The mean shoot length in T5 is the shortest at 22.32 cm, which is significantly different from all the treatments.

Allelopathic effects of shredded *J. curcas* leaves were observed in 2 weeks and 6 weeks for T4 and T5, where mixture of shredded *J. curcas* leaves is higher and pure. However, positive effect was observed in the shoot length of corn treated with lesser amount of shredded *J. curcas* leaves in the mixture after 10 weeks in the nursery. The shredded leaves mixed with soil had "fertilizer effect" in the growth of corn as exhibited by the macronutrient contents of leaves.

As for mixture with greater amount of shredded *J. curcas* leaves, the presence of allelochemicals might exceed the "fertilizer effect" in the growth of corn as exhibited with the comparable shoot length with corn planted in pure soil. Similarly, the allelopathic effect is further exhibited in greater amount of shredded leaves as shown in the retarded growth of corn planted in pure shredded leaves.

The mean shoot length (cm) in the different stages of early growth of corn potted in soil, prepared media of soil mixed with shredded *G. sepium* leaves and pure shredded *G. sepium* leaves is shown in Table 13.

The allelopathic effect of shredded leaves on corn was not observed after 2 weeks in the nursery except in the growth of corn grown in pure shredded leaves of *G. sepium*. Based on the ANOVA, there is significant difference in the treatment after 2 weeks, 6 weeks and 10 weeks in the nursery. However, DMRT shows no significant differences in the growth of corn in T1, T2, T3 and T4 after 2 weeks. Growth of corn in T5 significantly

Table 13. Mean shoot length (cm) in the different stages of early growth of corn potted in soil, prepared media of soil mixed with shredded *G. sepium* leaves and pure shredded *G. sepium* leaves

Treatments	Shoot Length (cm)		
	After 2 weeks	After 6 weeks	After 10 weeks
Treatment 1 (Pure soil)	16.27 b	34.90 ab	47.87 a
Treatment 2 (75% soil : 25% shredded *G. sepium* leaves)	16.23 b	38.17 b	66.73 b
Treatment 3 (50% soil : 50% shredded *G. sepium* leaves)	14.33 b	35.13 ab	64.89 b
Treatment 4 (25% soil : 75% shredded *G. sepium* leaves)	15.23 b	35.83 b	69.75 b
Treatment 5 (Pure shredded *G. sepium* leaves)	11.13 a	32.17 a	64.81 b
Coefficient of Variation (%)	11.76	5.07	7.63

Means followed by a common letter are not significantly different at 5% level by DMRT

differs from other treatments.

After 6 weeks, growth of corn in T1, T2, T3 and T4 were still comparable to each other (Table 13). The growth of corn in T5 significantly differs from T2 and T4, but comparable to growth of corn in T1 and T3.

There is no allelopathic effect observed in the growth of corn after 10 weeks in the nursery for all the treatments. Instead, "fertilizer effect" was observed as exhibited with significant longer shoot length of corn in all treatments with shredded *Gliricidia* leaves compared to corn planted in pure soil based on the ANOVA (Table 13). The mean shoot length of corn in T4 is the longest at 69.75 cm; however this is not significantly different from the shoot length in T2 (66.73 cm), T3 (64.89 cm) and T5 (64.81 cm).

The shredded leaves contributed to the increase in shoot growth of corn. Based on the tissue analysis, the leaves of *G. sepium* contain macronutrients that contributed to the growth of corn.

The allelophatic effects of *G. sepium* leaves on the other hand were not exhibited particularly in the latter part of the experiment. As the shredded leaves gets dry, allelochemicals present in the leaves volatilized, thus did not retard the growth of corn.

Biomass

The effects of the treatments were observed in the dry biomass such as shoot, root and total of corn planted in the nursery.

The mean shoot, root and total dry biomass (g) of corn potted in soil, prepared media of soil mixed with shredded *J. curcas* leaves and pure shredded *J. curcas* leaves is shown in Table 14. The ANOVA showed significant differences of mean shoot dry biomass among the different treatments. T2 has the heaviest dry shoot biomass at 5.50 g, followed by T3 with 3.63 g. The mean shoot dry biomass is lowest in T1 at 1.00 g, but this is comparable to the shoot dry biomass in T4 (1.40 g) and T5 (1.23) based on DMRT at 5% level of significance.

In the root dry biomass, there is also significant difference in the treatments. Based on the ANOVA, the mean root dry biomass of corn in T2 is significantly higher compare to all other treatments (Table 18). Further testing of the means dry root biomass using DMRT showed that the means of T1, T3, T4 and T5 are not significantly different from each other.

The combined shoot and root dry biomass exhibited significant different based on the ANOVA. Mean of total dry biomass on corn in T2 at 6.60 g is significantly higher,

followed by the mean total dry biomass in T3 at 4.10 g. The lowest is in T5 at 1.36 g, which is not significantly different from T1 (1.43 g) and T4 (1.53 g).

The mean shoot, root and total dry biomass (g) of corn potted in soil, prepared media of soil mixed with shredded *G. sepium* leaves and pure shredded *G. sepium* leaves is shown in Table 15. The ANOVA showed that the mean dry shoot biomass of corn in T2 at 7.10 g is the highest but it is not significantly different from the means in T3 and T4 at 6.00 g and 4.77 g, respectively. The lowest is T1 at 1.23 g but not significantly different from T5 at 3.30 g.

In the mean root dry biomass, T4 is the highest at 0.93 g, however this is comparable to the means in T3 (0.63 g), T2 (0.53 g) and T5 (0.47 g). The lowest mean root dry biomass is in T1 at 0.43 g, but this is not significantly different from T2, T3 and T5.

In the total dry biomass, significant differences were also exhibited in the means total biomass of corn in the different treatments based on the ANOVA. T2 has the highest total dry biomass at 7.63 g, but this is comparable to T3 (6.63 g) and T4 (5.70 g) according to DMRT at 5% level of significance. The mean total dry

Table 14. Mean shoot, root and total dry biomass (g) of corn potted in soil, prepared media of soil mixed with shredded *J. curcas* leaves and pure shredded *J. curcas* leaves

Treatments	Biomass (g)		
	Shoot	Root	Total
Treatment 1 (Pure soil)	1.00 a	0.43 a	1.43 a
Treatment 2 (75% soil : 25% shredded *J. curcas* leaves)	5.50 c	1.10 b	6.60 c
Treatment 3 (50% soil : 50% shredded *J. curcas* leaves)	3.63 b	0.47 a	4.10 b
Treatment 4 (25% soil : 75% shredded *J. curcas* leaves)	1.40 a	0.13 a	1.53 a
Treatment 5 (Pure shredded *J. curcas* leaves)	1.23 a	0.13 a	1.36 a
Coefficient of Variation (%)	33.02	52.74	35.21

Means followed by a common letter are not significantly different

Table 15. Mean shoot, root and total dry biomass (g) of corn potted in soil, prepared media of soil mixed with shredded *G. sepium* leaves and pure shredded *G. sepium* leaves

Treatments	Biomass (g)		
	Shoot	Root	Total
Treatment 1 (Pure soil)	1.23 a	0.43 a	1.66 a
Treatment 2 (75% soil : 25% shredded *G. sepium* leaves)	7.10 c	0.53 ab	7.63 c
Treatment 3 (50% soil : 50% shredded *G. sepium* leaves)	6.00 bc	0.63 ab	6.63 bc
Treatment 4 (25% soil : 75% shredded *G. sepium* leaves)	4.77 bc	0.93 b	5.70 bc
Treatment 5 (Pure shredded *G. sepium* leaves)	3.30 ab	0.47 ab	3.77 ab
Coefficient of Variation (%)	31.95	39.79	29.91

Means followed by a common letter are not significantly different at 5% level by DMRT

biomass of corn in T1 is the lowest at 1.66 g, however this is not significantly different from T5 at 3.77 g.

CONCLUSIONS AND RECOMMENDATIONS

The leaves of *Jatropha curcas* and *Gliricidia sepium* both have allelopathic effects on corn.

The survival is affected even with lesser concentration (10%) of leaf extracts from the two hedgerow species. Higher concentrations (>10%) of extracts are detrimental to the survival of corn. Germination of corn may not be significantly affected with extracts at lesser concentrations, but may be delayed by 1-3 days when exposed to higher extract concentrations for both species. The high concentrations of the leaf extract from both species retard the growth of corn in the laboratory.

The dry leaves of *J. curcas* and *G. sepium* still contain substance that affects the performance of corn planted in the nursery. Survival of corn is affected by high amount of shredded *J. curcas* leaves in the potting mixture, but not by any concentration of potting mixture with shredded *G. sepium* leaves. Germination time is delayed in potting mixture with >75% shredded leaves for both species. *J. curcas* leaves only had allelopathic effect on shoot growth and biomass of at high quantity in potting mixture. On the other hand, promotes shoot growth and biomass of corn if applied in lower quantity as potting mixture. *G. sepium* leaves have no allelopathic effect on shoot growth of corn, instead promotes the growth when applied as potting mixture. However, in terms of biomass, it is significantly high when applied at less quantity as potting mixture.

Based on the results of the study, the following are recommended:

1. Planting of *J. curcas* and *G. sepium* as hedgerow species is still recommended. However, farmers are cautioned in the spaces or distance of planting of the two hedgerow species with agricultural crop like corn.
2. The use of leaves/foliage of the two species as mulch, green manure and soil cover in the farm is recommended only when the leaves/foliage is dry. The amount must be applied in less quantity than the amount of soil particularly the *J. curcas*.
3. In the farm, the leaves/foliage of *Jatropha curcas* and *Gliricidia sepium* may be used as organic fertilizer. However, the leaves/ foliage must be given ample time to dry. *Jatropha curcas* must also be applied in fewer amounts.
4. Further studies are also recommended at the field level testing the allelopathic effect of *J. curcas* and *G. sepium*.

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