

ALLELOPATHIC ACTIVITY OF FOLIAR EXTRACT OF *Chromolaena odorata* ON GERMINATION OF *Solanum lycopersicum*, *Citrullus lanatus*, *Abelmoschus esculentus* and *Mucuna pruriens*

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(Accepted 05 September, 2023)

ABSTRACT

This study investigated the allelopathic effect of aqueous foliar extracts of *Chromolaena odorata* (L.) R. M. King & H. Rob. on the germination of *Solanum lycopersicum* L., *Citrullus lanatus* (Thunb.) Matsum. & Nakai, *Abelmoschus esculentus* (L.) Moench and *Mucuna pruriens* (L.) DC. seeds placed in Petri dishes were treated with 0g/L, 62.5g/L, 125g/L, 187.5g/L and 250g/L of *C. odorata* extract, and their percentage germination and radicle length measured. The data collated were analysed using analysis of variance and the means separated using Tukey's HSD. The results showed that the germination of all test crops reduced with increase in concentration of extract. This reflects a concentration-dependent inhibition of germination by the extract of *C. odorata*. The most reduction of germination and radicle length was observed for the 250g/L concentration, reaching a 100% loss of germination in both *S. lycopersicum* and *A. esculentus*: recording 73.3% and 87.5% losses in germination for *M. pruriens* and *C. lanatus* respectively. The loss of germination in seeds of the test crops due to the application of the foliar extract of *C. odorata* was attributed to the allelochemicals' possible inhibition or alteration of the enzymatic functions necessary for the normal process of germination. It is therefore recommended that the foliage of *C. odorata* should not be used as mulch in such crop farms, as is the traditional practice in some climes, due to the risk of reduction in the number of germinated seeds, which could lead to economic losses to the farmer.

Keywords: Allelopathy; *Chromolaena odorata*; *Solanum lycopersicum*; *Mucuna pruriens*; *Citrullus lanatus*; *Abelmoschus esculentus*.

INTRODUCTION

It is well established that some weedy plants in agricultural farms use chemical means to subdue the germination, growth and yield of several cultivated agricultural crops in the farms – a concept called Allelopathy (Ilori et al., 2010; Otusanya, 2014). Considering weed invasion as one of the main challenges of food security in Africa, an attempt was made to characterize the effect of one of the world's most

invasive agricultural weeds on the germination performance of four agronomically important food crops – *Solanum lycopersicum*, *Citrullus lanatus*, *Abelmoschus esculentus* and *Mucuna pruriens*.

Tomato (*Solanum lycopersicum* L.) is an important berry-bearing vegetable crop from the family Solanaceae. *S. lycopersicum* is ranked as the second most important vegetable after potato. *S.*

lycopersicum is consumed both as fresh fruit and as processed products such as pastes, diced products, juice, sauces and soups (Foolad, 2007). Aside being one of the most consumed food crops in the world, the plant and its fruit conveys a plethora of medicinal and pharmacological benefits (Willcox et al., 2003; Borguini and Ferraz Da Silva Torres, 2009).

Commonly known as Velvet bean, *Mucuna pruriens* (L.) Dc. is a plant of the Fabaceae family (Rajeshwar et al., 2005), known popularly for its plethora of medicinal properties. The seed of *M. pruriens* is reportedly and notoriously established as a natural source of the amino acid L-3,4-dihydroxy phenyl alanine (L-DOPA) which serves as the direct precursor of dopamine, a neurotransmitter used widely in the treatment of Parkinson's disease. In addition to L-DOPA, other important chemicals established in *M. pruriens* are serotonin, oxitriptan, nicotine and bufotenine (Kavitha and Thangamani, 2014; Erowid, 2002). Aside its medicinal properties, reports by (Kavitha and Vadivel, 2008; Diallo and Berhe, 2003) have shown that *M. pruriens* is also grown as a food crop, a plant with allelopathic potential (Ochekwu and Udensi, 2015), an ornamental plant and as a living mulch.

Watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) is a creeping, herbaceous fruit crop that belongs to the family Cucurbitaceae. *C. lanatus* is regarded as the majorly produced crop in the Cucurbitaceae family (about 40%) (Alka et al., 2018; Vinhas et al., 2021). *C. lanatus* (watermelon) produces a fruit that is about 93% water which can be used as fresh salad, dessert, snack, fruit juice, and for decorations. The consumption quality of watermelon varieties is critically determined using the sugar content and sweetness. It is known to be low in calories but highly nutritious and thirst quenching (Okonmah et al., 2011).

Abelmoschus esculentus L. (Moench) of the Malvaceae family is an annual herb (Kumar

et al., 2013). *A. esculentus* is an important vegetable crop native to Africa, and is grown in tropical, subtropical, and warm temperate climates in different countries from Africa to Asia, Southern Europe, and America (Naveed et al., 2009). The plant produces a fruit/pod which is a greenish capsule with length of 10–30 cm long and a diameter of 1–4 cm, it is slightly curved, tapers to a blunt point, a six-chambered pod of fibrous texture, and contains numerous seeds (Tripathi et al., 2011). Okra is known for its good palatability among different regions and its culinary uses are wide. Its immature, fresh, green seed pods are eaten as vegetable, while the extract obtained from the fruit is used in different recipes to thicken stews, soup, and sauces to increase their mucilaginous consistency. Often, water-soluble polysaccharides from okra are also used in ice-cream, potato chips, and baked goods, providing a healthy option and more stable shelf-life (Yuennan et al., 2014; Archana et al., 2015; Hu and Lai, 2016). Despite the plurality of these food crops, their cultivation for sustainable food security is threaten by the allelopathic nature of some plants.

One of such menacing weeds that has been notoriously reported as an allelopathic weed to certain important agricultural crops is *Chromolaena odorata* (Devi and Dutta, 2012; Otusanya et al., 2015). The aqueous foliar extract of *C. odorata* has been severally implicated by many reports as the most active and potent source of allelochemicals in the plant. Siam weed (*C. odorata*) ((L.) R.M. King & H. Robinson) is an herbaceous, perennial, semi woody shrub belonging to the family Asteraceae and forms dense tangled bushes about 1.5 to 2.0 m in height (Phan, 2001). It bears three-veined, ovate-triangular leaves placed oppositely, and with a shallow, fibrous root system (Henderson, 2001). It is a weedy pioneering shrub native to the Americas (Gautier, 1992) which was introduced into diverse ecological areas of tropical lands

(Owolabi *et al.*, 2010) where it has become one of the worst terrestrial invasive plants (Gautier, 1992). Siam weed is currently recognized as one of the world's worst tropical weeds due to its extremely fast growth rate (up to 20 mm per day) and prolific seed production (Owolabi *et al.*, 2010). In the tropics of Africa and Asia it has become agricultural weeds. The aim of this study is to investigate the allelopathic effect of aqueous foliar extracts of *C. odorata* on the germination and radicle length of certain agronomically important crops: *S. lycopersicum*, *M. pruriens*, *C. lanatus* and *A. esculentus*.

MATERIALS AND METHODS

Experimental Site

The study was conducted in Petri dishes in the Centre for Ecological Studies, Department of Plant Science and Biotechnology, University of Port-Harcourt, Choba, Rivers State, Nigeria.

Plant Materials Used for the Study

The seeds of *S. lycopersicum* var. 82-B, *M. pruriens*, *A. esculentus* var. Clemson Spineless and *C. lanatus* var. Kaolack were obtained from the headquarters of the Agricultural Development Program (ADP), Rivers State, Nigeria. The foliage of *C. odorata* was obtained from the ecological forest of the UniPark Campus, University of Port-Harcourt, Choba, Rivers State, Nigeria.

Preparation of aqueous foliar extract of *C. odorata*

The method described by Uzoma *et al.* (2018) was slightly modified for preparation of aqueous extract of *C. odorata*. Whole leaves of *C. odorata* were harvested from the ecological forest of the University of Port-Harcourt (4.9069°N, 6.9170°E), Choba, Port-Harcourt, Rivers State.

The leaves were rinsed in distilled water to remove adhering dust and soil particles, and then air-dried for 30 minutes to remove surface water. The plants were pulverized

using an electronic grinder; and 2000g of the pulverized plant samples were macerated in 8000 ml of distilled water for 72 hours, with intermittent agitation to obtain a stock concentration of 250 g/L. This was taken as the 100% stock solution. Further dilutions of the stock solution were obtained in the ratios of 75%, 50%, 25%, and 0% (the control treatment, made of only water). The concentrations obtained were thus: 187.5g/L, 125g/L, 62.5g/L and 0g/L respectively.

Germination Studies

Germination studies were conducted using the method of Tanveer *et al.* (2012) with slight modifications. To do this, 10 viable seeds of each plant (and, due to seed size-to-dish space considerations, 5 seeds for *M. pruriens*) were placed on Petri dishes carpeted with Whatmann filter papers. The filter papers were moistened every 2 days with 5ml of water and wrapped in an aluminium foil and kept in a dark room. This ran for a period of 7 days; after which the following were calculated:

- i. Percentage germination of seeds:
$$\left(\frac{\text{number of seeds germinated}}{\text{number of seeds sown}} \right) \times 100$$
- ii. Length of radicle of germinated seeds: this was measured using a simple metric rule calibrated in millimeters.

Experimental design

The experimental design for this study followed a completely randomized design (CRD) and was replicated four times.

Data analysis

Data collated was analysed with Analysis of Variance (ANOVA) using statistical analyses SPSS 23 package (2002). Means were separated using Tukey's Honest Significant Difference (HSD) at 5% level of probability and represented on graphical plots using MS Excel.

RESULTS

The effect of applying the aqueous foliar extract of *C. odorata* on the seed germination and radicle length of the test crops (*C. lanatus*, *S. lycopersicum*, *A. esculentus* and *M. pruriens*) mostly follow similar trends (Tables 1 and 2).

The germination of all crops reduced with increase in concentration of the extract. This reflects a concentration-dependent inhibition of germination by the aqueous extract of *C. odorata*. In *C. lanatus* the highest germination percentage was observed for the control treatment (0g/L) which peaked at 80%, and the lowest was observed at 62.5g/L, 125g/L and 187.5g/L corresponding to 10% germination. There was an 87.5% decrease in germination, when compared to the control. This decrease in germination percentage was shown to be statistically significant at a 5% probability. In *S. lycopersicum* the highest

germination percentage was observed for the control treatment (0g/L) at 67.5% and the lowest was observed in 125g/L, 187.5g/L and 250g/L. This reflected a 100% decrease in germination, when compared to the control. This decrease in germination statistically significant at a 5% probability. *A. esculentus* had the highest germination percentage (20%) in the control treatment (0g/L) at 20% while there was no germination at 62.5g/L, 125g/L, 187.5g/L and 250g/L concentrations. This indicated a 100% reduction in germination due to the aqueous extract, when compared to the control, and it was statistically significant at a 5% probability. *M. pruriens* had the highest germination percentage (75%) in the control (0g/L) and 125g/L treatments, but the germination was lowest (20%) at 250g/L concentration, which was significant at a 5% probability (Table 1).

Table 1: Homogenous subset of means of germination percentage of test crops.

TREATMENT	GERMINATION PERCENTAGE ± SE			
	<i>C. lanatus</i>	<i>S. lycopersicum</i>	<i>A. esculentus</i>	<i>M. pruriens</i>
0g/L	80.00 ± 8.16 ^a	67.50 ± 11.09 ^a	20.00 ± 14.14	75.00 ± 5.00 ^a
62.5g/L	10.00 ± 5.77 ^b	22.50 ± 11.09 ^b	00.00 ± 00.00	60.00 ± 14.14 ^{ab}
125g/L	10.00 ± 5.77 ^b	00.00 ± 00.00 ^b	00.00 ± 00.00	75.00 ± 15.00 ^a
187.5g/L	10.00 ± 5.77 ^b	00.00 ± 00.00 ^b	00.00 ± 00.00	55.00 ± 5.00 ^{ab}
250g/L	15.00 ± 9.57 ^b	00.00 ± 00.00 ^b	00.00 ± 00.00	20.00 ± 8.17 ^b

*Means followed by same letter along the columns are not significantly different at 5% level of probability (Means separation was executed using Tukey's HSD)

The radicle lengths of all test crops reduced with increase in concentrations of the aqueous extract of *C. odorata*. It indicated a concentration-dependent reduction. The highest mean radicle length (0.65 cm) in *C. lanatus* was observed in the control treatment (0g/L), while the lowest (0.02 cm) was observed under 62.5g/L which was pegged at. There was a 96.9% reduction of mean radicle length, when compared to the control. This reduction in radicle length was shown to be statistically significant at a 5% probability (Table 2). For *S. lycopersicum*, the highest mean radicle length (1.61 cm)

was observed in the control treatment (0g/L), while the lowest (0 cm, i.e. no germination, no radicle) was observed under 125g/L, 187.5g/L and 250g/L concentrations. This reflected a 100% reduction in mean radicle length, when compared to the control and it was statistically significant at a 5% probability (Table 2). The highest mean radicle length (0.49 cm) of *A. esculentus* was observed for the control treatment (0g/L), and the lowest 0 cm, i.e. no germination, no radicle) was observed under 62.5g/L, 125g/L, 187.5g/L and 250g/L. The difference was however

not significant at a 5% probability. For *M. pruriens*, the highest mean radicle length (2.60 cm) was observed in the control (0g/L) and 62.5g/L treatments simultaneously, while the lowest (0.58 cm)

was observed under 250g/L. This reflected a 77.7% reduction in mean radicle length, when compared to the control and it was significant at a 5% probability (Table 2).

Table 2: Homogenous subset of means of radicle length of test crops.

TREATMENT	RADICLE LENGTH (cm) ± St. error			
	<i>C. lanatus</i>	<i>S. lycopersicum</i>	<i>A. esculentus</i>	<i>M. pruriens</i>
0g/L	00.65 ± 00.10 ^a	01.61 ± 00.21 ^a	00.49 ± 00.37	02.60 ± 00.35
62.5g/L	00.02 ± 00.01 ^b	00.31 ± 00.17 ^b	00.00 ± 00.00	02.60 ± 01.05
125g/L	00.04 ± 00.03 ^b	00.00 ± 00.00 ^b	00.00 ± 00.00	02.34 ± 00.49
187.5g/L	00.03 ± 0.02 ^b	00.00 ± 00.00 ^b	00.00 ± 00.00	01.69 ± 00.31
250g/L	00.04 ± 0.03 ^b	00.00 ± 00.00 ^b	00.00 ± 00.00	00.58 ± 00.29

*Means followed by same letter along the columns are not significantly different at 5% level of probability (Means separation was executed using Tukey's HSD)

DISCUSSION

The application of *C. odorata* extract significantly reduced the germination percentage and mean radicle length in all test crops, except in *A. esculentus* where the reduction was established as being insignificant at 5% probability for both the percentage germination and the mean radicle length. In interpretation, this implied that the treatment of *A. esculentus* seeds with *C. odorata* extracts did not reduce the germination of the crop. The values of the mean radicle length of all subject crop plants in this study were all influenced by the values of the percentage germination. This therefore interprets that the mean radicle length of the subject crops is a function of the percentage germination of the seeds. This can also be interpreted to mean that the general performance of a crop plant depends on its performance at the stage of germination.

These reductions in the germination percentage and radicle length of the test crop due to the application of the aqueous extract of *C. odorata* go in line with the reports of Devi and Dutta (2012), who reported that the aqueous extract of *C. odorata* reduced the germination percentage and radicle and plumule length of *Zea mays*. The authors, while reporting

that the allelopathy of *C. odorata* extract was concentration-dependent, stated that the highest concentration of extract showed the highest inhibition of the radicle and plumule of *Zea mays*.

In their work, Usuah *et al.* (2013) reported that *C. odorata* has a concentration-dependent inhibitory effect on the germination of *Abelmoschus esculentus* and *Citrullus vulgaris*. To further establish the negative allelopathy of *C. odorata* on agricultural crops, Devi *et al.* (2014) also implicated *Chromolaena odorata* in the concentration-dependent inhibitory allelopathic relationship with *Solanum lycopersicum*.

Ajewole *et al.* (2021) investigated the possible allelopathic effect of *Chromolaena odorata* on the germination and post-germination growth of *Abelmoschus esculentus*. Their report showed that the leachate of *Chromolaena odorata* resulted to a reduction in radicle length, plumule length and number of roots of *A. esculentus*. Though not the centre of this investigation, one of the twists of the report by Ajewole *et al.* (2021) is that, albeit having a concentration-dependent inhibition of the germination of *A. esculentus*, *C. odorata* antagonized its initial inhibitory allelopathy on the germination of *A. esculentus* by

exhibiting a concentration-dependent stimulatory (positive) allelopathy on the post-germination growth parameters of *A. esculentus*. This twist in the report of Ajewole et al. (2021) may be the cue towards a possible explanation to why the germination parameters of *A. esculentus* in this current study were not significantly reduced.

There is a seeming dearth of report on the allelopathic effect of any plant species on *Mucuna pruriens*, as a recipient plant. However, several reports abound on the notoriety of *M. pruriens* as an allelopathic plant (Appiah et al., 2015; Rugare et al., 2020). *Mucuna pruriens* has inhibitory effect on the germination of *Lycopersicon esculentum* and *Lactuca sativa*. This inhibition is plausibly suggested as being because of L-DOPA in *M. pruriens* (Zasada et al., 2006). This current study has pointed out that, despite being notorious for its allelopathy, the germination percentage of *M. pruriens* showed a significant concentration-dependent reduction by the application of the foliar extracts of *C. odorata*.

The potency of allelopathy due to the application of aqueous foliar extracts of *C. odorata* may stem from the possible constituent allelochemicals therein. The reduction of germination by the foliar extract of *C. odorata* could be made possible by the ability of some of its constituent allelochemicals to inhibit or alter the enzymatic processes necessary for the normal process of germination. Some of the possible enzymes include amylases and ureases. This supposition is corroborated by the reports of Jash et al. (2019) who showed that the extracts and leaf leachates of *C. odorata* reduced the percentage germination and delayed the germination time of *Lathyrus sativus* by 50%. At the end of their investigation, they reported that “the catalase and peroxidase activities of *L. sativus* seeds were found decreased after treatment with the different concentrations of *C. odorata* leaf extract and leaf

leachate”. Popoola et al. (2020), working on the allelopathic effect of *C. odorata* on two varieties of *Vigna unguiculata*, showed that the extracts of the selected weed species significantly inhibited radicle and plumule lengths of the test crop. They stated that the inhibitory effect may be due to the entry of water-soluble allelochemicals into the seed. They iterated that the allelopathic phytochemicals may be inhibiting the germination of plants by disrupting the cell division, interfering with the mechanism of energy transfer, and limiting water and nutrient uptake. They tried to relate the reduced rate of cell division to the possible inhibition of gibberellins and indoleacetic acid function by the presence of the allelochemicals in the seeds.

Also, in an attempt to identify the exact mechanism of allelopathy of *C. odorata* on germination reduction, Laxman et al. (2019), studying the effects of *C. odorata* extracts on germination percentage, seedling growth and dry biomass of *Salvadora persica*, reported that higher concentrations of extract (60 and 80%) significantly reduced germination percentage, radicle length, plumule length and dry matter accumulation of the *S. persica* seedlings as compared to control. They reported that GC-MS analysis of the leaves revealed the presence of certain allelochemical compounds which support the allelopathic potential of the leaf extract, thus leading to the conclusion of the report by attributing the delayed and low germination rates of the subject plants to the presence of allelochemicals which likely release phenolics into the soil. They also hinted that increased proteolysis in germinating seeds can lead to an increase in free amino acids content, especially proline. Citing a literature, they argued that there has been a report of proline accumulation in a case of allelopathy. This, therefore, makes it pertinent that, for a clearer understanding of the mechanism of the allelopathy of *C. odorata*, the foliar extract of the plant needs to be chemically profiled (by means of

GC/LC-MS) and the individual chemical constituents be probed and scored for their plausible inhibitory effects on certain enzymes necessary for seed germination. This is already an on-going investigation.

CONCLUSION

The treatment of the seeds of *C. lanatus*, *S. lycopersicum*, *A. esculentus* and *M. pruriens* with the aqueous foliar extract of *C. odorata* had an inhibitory effect on the germination percentage and radicle length of the subject crops. The inhibition was statistically significant on the germination performances of *C. lanatus*, *S. lycopersicum* and *M. pruriens*; the reduction in germination observed for *A. esculentus* was not significant at $\alpha = 0.05$. The inhibitory effect of the aqueous foliar extract of *C. odorata* on the seed germination of the test crops has been attributed to the possible presence of allelochemicals which could possibly function as enzyme inhibitors to the stop or alter the activity of the enzymes in the seeds necessary for germination. The findings in this study recommend that the foliage of *C. odorata* should not be used as mulch in such crop farms, as is the traditional practice in some climes. Although there may be a possibility of such mulch boosting growth on the individual plants that germinate, there is also the risk of reduction in the number of germinated seeds, which could lead to economic losses to the farmer.

REFERENCES

- Ajewole, T.O., Ayesa, A.S., Popoola, K.M., Ajiboye, M.D., Oluwole, B.R. and Kolawole, O.S. (2021). Effects of fresh shoot biomass of siam weed *Chromolaena odorata* (L.) King and H. Robinson on the germination and growth of okra *Abelmoschus esculentus* (L.) Moench. *African Journal of Food, Agriculture, Nutrition and Development*. 21(7): 18404-18413.
- Alka, G., Anamika, S. and Ranu, P. (2018). A review on watermelon (*Citrullus lanatus*) medicinal seeds. *Journal of Pharmacognosy and Phytochemistry*. 7(3): 2222-2225
- Appiah, K.S., Amoatey, C.A. and Fujii, Y. (2015). Allelopathic activities of selected *Mucuna pruriens* on the germination and initial growth of lettuce. *International Journal of Basic and Applied Sciences*. 4(4): 475-481.
- Archana, G., Azhagusaravana, P., Babu, K., Sudharsan, K., Sabina, R., Palpandi Raja, M., Sukumarsivarajan, M. (2015). Evaluation of fat uptake of polysaccharide coatings on deep-fat fried potato chips by confocal laser scanning microscopy. *International Journal of Food Properties*. 19: 1583–1592.
- Borguini, R. G. and Ferraz Da Silva Torres, E. A. (2009). Tomatoes and tomato products as dietary sources of antioxidants. *Food Reviews International*. 25(4): 313–325.
- Devi, O.I. and Dutta, B.K. (2012). Allelopathic Effect of the Aqueous Extract of *Parthenium hysterophorus* and *Chromolaena odorata* on the Seed Germination and Seedling Vigour of *Zea mays* L. *in vitro*. *Academic Journal of Plant Sciences*. 5(4): 110-113.
- Devi, O.I., Dutta, B.K. and Choudhury, P. (2014). Allelopathic effects of some weed species on the growth of tomato plants (*Solanum lycopersicum* L.). *Journal of International Academic Research for Multidisciplinary*. 2(1): 445-454.
- Diallo, O.K. and Berhe, T. (2003). Processing the *Mucuna* for human food in the Republic of Guinea. *Tropical and Subtropical Agroecosystems*. 1(2/3):193–196.
- Erowid (2002). *Mucuna pruriens*. Created 2002-APR-22. *International Legume Database and Information Service*. Genus *Mucuna*. Version 10.01.
- Foolad, M.R. (2007). Genome mapping and molecular breeding of tomato.

- International Journal of Plant Genomics*, 2007: 64358.
- Gautier, L. (1992). Taxonomy and distribution of a tropical weed, *Chromolaena odorata* (L.) R. King and H. Robinson. *Candollea*. 47: 645–662.
- Henderson L. (2001). Alien Weeds and Invasive Plants. Handbook No. 12. Pretoria, South Africa: ARC-PPRI.
- Hu, S.-M. and Lai, H.-S. (2016). Developing low-fat banana bread by using okra gum as a fat replacer. *Journal of Culinary Science and Technology*. 15: 36–42.
- Ilori, O.J., O.O. Otusanya, A.A. Adelusi, and Sanni, R.O. (2010). Allelopathic activities of some weeds in the Asteraceae family. *International Journal of Botany*. 6: 161-163.
- Jash, A., Halder, S. and Bhattacharjee, A. (2019). Assessment of allelopathic potential of *Chromolaena odorata* (L.) King and Robinson by physio biochemical approach. *Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences*. 5(1): 21-30.
- Kavitha, C. and Thangamani, C. (2014). Amazing bean “*Mucuna pruriens*”: A comprehensive review. *Journal of Medicinal Plants Research*. 8(2): 138-143.
- Kavitha, C. and Vadivel, E (2008). Effect of organic manures and inorganic fertilizers on dry matter production and L DOPA content of *Mucuna pruriens* (L.) DC. – A leguminous medicinal plant. *Legume Research*. 31(1):44-47.
- Kumar, D.S.; Tony, D.E.; Kumar, A.P.; Kumar, K.A.; Rao, D.B.S.; Nadendla, R. (2013). A review on: *Abelmoschus Esculentus*(okra). *International Research. Journal of Pharmaceutical and Applied Science*. 3: 129–132.
- Laxman, D.U., Desai, N.M. and Krishna, G.D. (2019). Allelopathic potentials of *Chromolaena odorata* L. on growth and biochemical characteristics of *Salvadora persica*. *Asian Journal of Biological Sciences*. 12: 122-129.
- Naveed, A., Khan, A.A., Khan, I.A. (2009). Generation mean analysis of water stress tolerance in okra (*Abelmoschus esculentus* L.). *Pakistan. Journal of Botany*. 41:195–205.
- Ochekwu E. B. and Udensi E. U. (2015): Evaluation of potential allelopathic relationship between velvetbean (*Mucuna cochinchinensis* (Lour.) a chev and Speargrass (*Imperata Cylindrical* (L.) Raeushel) with selected methods. *Journal of Agriculture and Ecology Research International* 3(3): 89 – 96.
- Okonmah, L.U., Agbogidi, O.M., Nwagu, O.K. (2011). Evaluation of four varieties of watermelon (*Citrullus lanatus* Thumb) in Asaba agro-ecological environment. *International Journal of Advanced Biological Research*. 2011; 1(1):126-130.
- Otusanya, O. O., Ogunwole, A. A. and Tijani, M. O. (2015). Allelopathic Effect of *Tithonia diversifolia* and *Chromolaena odorata* On the Germination, Growth and Chlorophyll Accumulation of *Hibiscus Sabdariffa* (L.). *International Journal of Botany and Research*. 5(3): 1-14.
- Otusanya, O.O., A.A. Sokan-Adeaga, and Ilori, O.J. (2014). Allelopathic effect of the root exudates of *Tithonia diversifolia* on the germination, growth and chlorophyll accumulation of *Amaranthus dubius* L. and *Solanum melongena* L., *Research Journal of Botany*, 9; 13-23.
- Owolabi, M.S., Ogundajo, A., Yusuf, K.O., Lajide, L., Villanueva, H.E., Tuten, J.A. and Setzer, W.N. (2010). Chemical composition and bioactivity of the essential oil of *Chromolaena odorata* from Nigeria. *Records of Natural Products*. 4(1): 72-78.

- Phan, T.T., See, P.O., Lee, S.T. and Chan, S.Y. (2001). Antioxidant effects of the extracts from the leaves of *Chromolaena odorata* on human dermal fibroblasts and epidermal keratinocytes against hydrogen peroxide and hypoxanthine-xanthine oxidase induced damage. *Burns*. 27(4): 319-327.
- Popoola, K.M., Akinwale, R.O. and Adelusi, A.A. (2020). Allelopathic effect of extracts from selected weeds on germination and seedling growth of cowpea (*Vigna unguiculata* (L.) Walp.) varieties. *African Journal of Plant Science*. 14(9): 338-349.
- Rajeshwar, Y., Kumar, S., Gupta, M., Mazumder, U.K. (2005). Studies on *in vitro* antioxidant activities of methanol extract of *Mucuna pruriens* (Fabaceae) seeds. *European Bulletin of Drug Research*. 13(1): 31-39.
- Rugare, J.T., Pieterse, P.J. and Mabasa, S. (2020). Effects of green manure cover crops (*Canavalia ensiformis* L. and *Mucuna pruriens* L.) on seed germination and seedling growth of maize and *Eleusine indica* L. and *Bidens pilosa* L. weeds. *Allelopathy Journal* 50 (1): 121-140.
- Tanveer, A., Jabbar, M.K., Kahliq, A. and 3 others (2012). Allelopathic effects of aqueous and organic fractions of *Euphorbia dracunculoides* Lam. on germination and seedling growth of chickpea and wheat. *Chilean Journal of Agricultural Research* 72(4): 495 – 501.
- Tripathi, K.K., Warriar, R., Govila, O.P., Ahuja, V. (2011). *Biology of Abelmoschus esculentus* L. (okra). *Series of Crop Specific Biology Documents*. Ministry of Environment and Forests Government of India: New Delhi, India, 2011.
- Usuah, P.E., Udom, G. N. and Edem, I.D. (2013). Allelopathic effects of some weeds on the germination of selected seeds of crops grown in Akwa Ibom State Nigeria. *Global Journal of Agricultural Research*. 1(1): 23-33.
- Uzoma, M.C., Mensah, S.I. and Ochekwu, E.B. (2018). Allelopathic effect of aqueous extracts of *Axonopus compressus* (Swartz) P. Beauv on the chlorophylls and phenolic content of *Kalanchoe pinnata* (Lam.) Pers. *Nigerian Journal of Agricultural Technology* 15(1): 22-26.
- Vinhas, V.A., Sousa, C., Matos, C., Moutinho, C. and Vinha, A.F. (2021). Valorisation of Watermelon Fruit (*Citrullus lanatus*) byproducts: Phytochemical and Biofunctional Properties with Emphasis on Recent Trends and Advances. *World Journal of Advance Healthcare Research*. 5(1): 302 - 309
- Willcox, J. K., Catignani, G. L., and Lazarus, S. (2003). Tomatoes and cardiovascular health. *Taylor & Francis Group*. 43(1): 1-18.
- Yuennan, P., Sajjaanantakul, T. and Goff, H.D. (2014). Effect of okra cell wall and polysaccharide on physical properties and stability of ice cream. *Journal of Food Science*. 79: E1522–E1527.
- Zasada, I.A., Klassen, W., Meyer, S.L.F., Codallo, M. and Abdul-Baki, A.A. (2006). Velvetbean (*Mucuna pruriens*) extracts: impact on *Meloidogyne incognita* survival and on *Lycopersicon esculentum* and *Lactuca sativa* germination and growth. *Pest Management Science*. 62:1122–1127.