**Use of Auxin-like herbicide for Mesquite (*Prosopis juliflora***) **Control in Sudan**

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**Abstract:** Afield experiments were conducted during two consecutive winter seasons and rainy seasons to evaluate the effect of 2,4-dichloro phenoxy acetic acid (2,4-D) dissolved in two different solvents on mesquite (*Prosopis juliflora*) mortality percent. Natural stand mesquite trees in three sizes (small, medium, and large) treated with 2,4-D at five rates, (0, 6×103, 12×103, 18×103 and 24×103 mg), dissolved in diesel or water. 2,4-D mixtures were sprayed around the lower part of the tree stem at about 30 cm above the soil level. The design was a factorial experiment inRandomized Complete Block Design **(**RCBD). The results showed that; in both seasons the three tree sizes treated with rates of (24×103 mg a. i.) dissolved in the diesel gave a 100 % mortality percentage. The performance of 2,4-D dissolved in diesel was better than that of water, which gave (98.89%, 100%) and (100%, 97.78%) for the two winter and two rainy seasons, respectively. In addition, the large tree size showed a high mortality percentage compared to the other sizes. The study concluded that: using 2,4-D herbicide at the rate of 24×103 mg a. i. / L diesel for mesquite tree control, gave a 100% mortality percentage after a year of application.

**Keywords**: 2,4-D, mesquite, mortality percent, water, and diesel

**1- Introduction**

Mesquite (*Prosopis juliflora* was) first introduced into Sudan from Egypt and South Africa in 1917 to solve the problem of desertification in some regions of Sudan (Brown and Hamdoun, 1929). Mesquite spread rapidly into fertile productive areas, irrigation, and drainage channels, particularly in some of the major irrigated schemes (Morgan *et al.* 2017*)* Mesquite spread and multiplied, and now it has become one of the world's 100 most dominant invasive trees (Becker *et al.* 2016). *Prosopis* species have been noxious, invasive weeds in Ethiopia, Kenya, Sudan, Eritrea, Iraq, Pakistan, India, Australia, South Africa, the Caribbean, the Atlantic Islands, Bolivia, Brazil, the Dominican Republic, El Salvador, Nicaragua, the United States of America (USA), and Uruguay (Pasiecznik *et al.* 2004). Mesquite inhibits the seed germination of other species of plants that lie in its vicinity (Muturi *et al.*2017). It also discourages other species of plants to grow near it. It releases allelochemicals from its leaves, roots, and fruits to achieve this (Noor *et al.* 1995). Phenolic compounds present in mesquite have biological toxicity towards many plants and can cause disturbances in various processes by interfering with the enzymology of the target plants (Thoyabet *et al.* 2009). Cytotoxic alkaloids found in mesquite pods cause intoxication to cattle, horses, sheep, and goats in diets containing high levels of pods (>50%). The dry leaves are very rich in flavonoids, containing as much as 3.6% (Ibrahim *et al.* 2013). In addition, the leaves carry high concentrations of alkaloids (2.2%) (Damasceno *et al.* 2017). The sharp thorns cause gangrene. In addition, leaves fall on potable water, which makes the water bitter (Walter and Armstrong, 2014). Pollens of *P. juliflora* trigger allergic asthma, rhinitis, and skin allergy (Dousti *et al.* 2016).

2,4‐Dused to control dicotyledonous annual in weeds in wheat, maize, rice, and other similar cereal crops (Gervais *et al.* 2008). There are two types of formulations of 2,4-D: amine salts and esters. (Peterson *et al.* 2016). The mode of action of auxinic herbicides depends on tissue sensitivity and species, low doses of 2,4-D promote plant growth while high doses drive plant over and abnormal growth (Grossmann, 2010). The uptake and translocation of 2,4-D are greater under conditions of higher temperatures and humidity, also, sensitive species translocate more 2,4-D than tolerant species. (Peterson *et al.* 2016). 2,4-D mimics the natural plant hormone indole - 3- acetic acid (natural auxin) and activates auxin response genes (Korasick *et al.* 2015). Natural auxin IAA is degraded in the plant, while 2,4-D persists for long periods within the plant, this phenomenon is described as an auxin overdose which leads to an imbalance in auxin and interactions with other hormones at the tissue level (Song, 2014). 2,4-D activates the synthesis of amino cyclopropane 1-carboxylic acid, which leads to ethylene biosynthesis (Eduardo *et al.* 2017). Ethylene is stimulated by H2O2, which is considered the second messenger in the abscisic acid (ABA) synthesis; ABA is an essential sign in mediating stomata closure to reduce water loss (Vanderauwera *et al.* 2011). Use of herbicides for mesquite control applied in different ways, basal bark treatment, which involves spraying herbicides around the entire stem up to 30 cm from the ground, this method should be used during the growing season (March to November) (Geesing *et al.* 2004). There are many factors, that increase the efficacy of herbicide, these include, type and rate of application, health, stage of the plant, and environmental variables (Kumar and Singh, 2010). In general, all studies related to the mesquite tree described the toxicity effect of the tree on another plant, and few of these studies aimed to control mesquite seedlings, while the objective of this study was to evaluate the effect of (2,4-D) dissolved in two different solvents on mesquite tree mortality under field conditions.

**2- Materials and Methods**

**2- 1 Sites of the Experiments and Plant Materials**

Afield experiments were conducted in two locations in Khartoum Sudan in an area of about forty ha. The two sites. Naturally grown mesquite trees were selected randomly and districted to three spots, thirty mesquite trees for each spot were classified for three sizes, (small, medium, and large) ten in each, based on the number of stems per tree and diameter of the canopy (in meters).

**2- 2 Chemical solutions and application method**

2, 4-dichloro phenoxy acetic acid (2,4-D), at five rates (Table 1) 0, 6×103, 12×103, 18×103 and 24×103 mg / L dissolved individually in two solvents (water or diesel). The rates of mixtures (2,4-D mixed with water or diesel) were in the rate ranging from 80-90 ml, 140-160 ml, and 244-308 ml for small, medium, and large trees respectively. 2,4-D dissolved in diesel or water was applied only one time around the lower part of the stem at about 30 cm. above the soil level (Geesing *et al.* 2004). The herbicide treatment application is done with a knapsack sprayer with a cone-type nozzle, which is adjusted to deliver a mixture in a narrow cone.

Table 1: The different treatments and 2,4-D rates

|  |  |
| --- | --- |
| Treatments | 2,4-D rates 102mg a.i. |
| D/2,4-DR0 | 2,4-D at rate 0 dissolved in diesel |
| D/2,4-DR1 | 2,4-D at rate 6 dissolved in diesel |
| D/2,4-DR2 | 2,4-D at rate 12 dissolved in diesel |
| D/2,4-DR3 | 2,4-D at rate 18 dissolved in diesel |
| D/2,4-DR4 | 2,4-D at rate 24 dissolved in diesel |
| W/2,4-DR0 | 2,4-D at rate 0 dissolved in water |
| W/2,4-DR1 | 2,4-D at rate 6 dissolved in water |
| W/2,4-DR2 | 2,4-D at rate 12 dissolved in water |
| W/2,4-DR3 | 2,4-D at rate 18 dissolved in water |
| W/2,4-DR4 | 2,4-D at rate 24 dissolved in water |

**2-3 Experimental desig**n **and data analysis**

 The experiments were conducted in factorial in Randomized Complete Block Design (RCBD) with three replicates, treatments were shaped to allow for the comparison of three different factors (2,4-D concentrations, mesquite sizes, and solvents types) and to enable the assessment of interactions effect of these factors. The analysis of variance test (ANOVA) and means statistically separated by least significant difference (LSD) test using a computer statistical software, Statistix 8, and differences between means at (0.05) level of significance.

**2-4 Data Collection**

 Mortality percent is calculated after one year of application to allow sufficient time in different climatic conditions around the year. Mortality percent estimated by counting the number of dead stems, which appear 100 % defoliated, had no living tissue, and no re-sprouts from ground buds as follows:$ $

$ \frac{No. of dead stems }{No. of stems per tree}$×100

**3- Results**

In both seasons, the three tree sizes treated with different rates of 2,4-D dissolved in diesel showed a significant increase in mortality percentage compared to the corresponding 2,4-D rates dissolved in the water. The high rate of 2,4-D (24×103 mg a.i.) gave 100% mortality, while the control showed a lower mortality percentage. In the rainy seasons, the high rate of 2,4-D (24×103 mg a.i.) dissolved in water significantly increased the mortality percentage of the three tree sizes compared to the control (Tables 2 and 3).

Table 2: Effect of 2,4-D and solvent types on mortality percentage of mesquite trees in different sizes in the two winter seasons

|  |  |
| --- | --- |
| Treatments | Mortality percentage |
| First winter season | Second winter season |
| Small  | Medium  | Large | Small  | Medium  | Large |
| D2,4-DR0 | 33.33 de | 33.33 de | 0.00 f | 16.67 ef | 16.67 f | 13.33 f |
| D2,4-DR1 | 76.33 abc | 55 cd | 66.67 bc | 83.33 abc | 56.67def | 53.33cde |
| D2,4-DR2 | 76.33abc | 93.33 ab | 93.33 ab | 53.33cde | 93.33 ab | 56.67bcd |
| D2,4-DR3 | 96.33 ab | 100 a | 100 a | 100 a | 100 a | 93.33 ab |
| D2,4-DR4 | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| W2,4-DR0 | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f |
| W2,4-DR1 | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f |
| W2,4-DR2 | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f |
| W2,4-DR3 | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f | 0.00 f |
| W2,4-DR4 | 0.00 f | 0.00 f | 000f | 0.00 f | 0.00 f | 0.00 f |
| SE± | 14.95 | A16.14 |

Figures in a column followed by the same letter (s) are not significantly different according to the least significant differences (LSD)

D= Diesel, W=Water, R= Rate

Table 3: Effect of 2,4-D and solvent types on mortality percentage of mesquite trees in different sizes in the two rainy seasons

|  |  |
| --- | --- |
| Treatments | Mortality percentage |
| First rainy season | Second rainy season |
| Small  | Medium  | Large | Small  | Medium  | Large |
| D2,4-DR0 | 46.67 b | 46.67 b | 50.0 b | 46.67bc | 48.33b | 50.0 b |
| D2,4-DR1 | 93.33 a | 93.33 a | 100 a | 100 a | 93.33a | 100 a |
| D2,4-DR2 | 93.33 a | 93.33 a | 100 a | 100 a | 93.33a | 100 a |
| D2,4-DR3 | 93.33 a | 100 a | 100 a | 93.33a | 100 a | 100 a |
| D2,4-DR4 | 100 a | 100 a | 100 a | 100 a | 100 a | 100 a |
| W2,4-DR0 | 0.00d | 0.00d | 0.00d | 0.00 f | 0.00 f | 0.00 f |
| W2,4-DR1 | 0.00d | 0.00d | 0.00d | 0.00 f | 0.00 f | 0.00 f |
| W2,4-DR2 | 0.00d | 0.00d | 0.00d | 0.00 f | 000 f | 0.00 f |
| W2,4-DR3 | 0.00d | 0.00d | 0.00d | 0.00 f | 0.00 f | 0.00 f |
| W2,4-DR4 | 16.67 c | 13.33cd | 33.33 b | 16.67 de | 33.33cd | 53.33b |
| SE± | 6.88 | 7.00 |

Figures in a column followed by the same letter (s) are not significantly different according to the least significant differences (LSD)

D= Diesel, W=Water, R= Rate

The diesel solvent increased the performance of 2,4-D which increased the mortality percentage. All rates of 2,4-D dissolved in diesel significantly increased the mortality percent of three sizes of the tree compared to the control (diesel only), which gave (29.44% and 15.56% in the two winter seasons respectively, while in the two rainy seasons, the diesel only gave 47.22%). In both rainy seasons, all 2,4-D rates dissolved in diesel gave high mortality percentages compared to the same rates of 2,4-D in both winter seasons (Table 4).

Table 4: Effect of 2,4-D and solvent types on mortality percentage of mesquite trees

|  |  |
| --- | --- |
| Treatments | Mortality % |
| First season | Second season |
| Winter | Rainy | Winter | Rainy |
| Diesel | Water | Diesel | Water | Diesel | Water | Diesel | Water |
| 2,4-DR0 | 29.44c | 0.00d | 47.22b | 0.00d | 15.56c | 0.00c | 47.22b | 0.00d |
| 2,4-DR1 | 66.67b | 0.00d | 95.56a | 0.00d | 64.44b | 0.00c | 97.78a | 0.00d |
| 2,4-DR2 | 67.78b | 0.00d | 95.56a | 0.00d | 67.78b | 0.00c | 97.78a | 0.00d |
| 2,4-DR3 | 96.67a | 0.00d | 100a | 0.00d | 97.87a | 0.00c | 97.78a | 0.00d |
| 2,4-DR4 | 98.89a | 0.00d | 100a | 24.44c | 100 a | 0.00c | 97.78a | 28.88c |
| SE± | 9.63 | 3.81 | 9.32 | 3.68 |

Figures in a column followed by the same letter (s) are not significantly different according to the least significant differences (LSD)

Results in (Table 5) showed the effect of 2,4-D irrespective of other factors on the mortality percentage of the three tree sizes, which increased with the increase of the 2,4-D rate.

Table 5: Effect of 2,4-D Rates on mortality percentage of mesquite trees

|  |  |
| --- | --- |
| Treatment | Mortality % |
| First season | Second season |
| Winter | Rainy | Winter | Rainy |
| Large | Medium | Small | Large | Medium | Small | Large | Medium | Small | Large | Medium | Small |
| 22,4-DR0 | 0.00 d | 16.67cd | 16.67cd | 25.0 d | 23.34 d | 23.34 d | 6.67c | 8.34.c | 8.34 c | 25.0d | 24.17 d | 23.34 d |
| 2,4-DR1 | 33.34abc  | 27.5 bc | 38.17abc | 50.0 bc | 46.67 c | 46.67 c | 26.67abc | 28.34abc | 41.67 ab | 50.0c | 46.67 c | 50.00c |
| 2,4-DR2 | 46.67ab  | 46.67ab | 38.17abc | 50.0 bc | 46.67 c | 46.67 c | 28.34abc  | 46.67 a | 26.67abc | 50.0c | 50.00c | 50.00c |
| 2,4-DR3 | 50.00 ab | 50.0 ab | 45.0ab | 50.0 bc | 50.0 bc | 46.67c | 46.67 a | 50.00 a | 50.00 a | 50.0c | 58.34 b | 46.67 c |
| 2,4-DR4 | 54.17a | 54.17 a | 48.17ab | 66.67 a | 56.57 b | 58.34 b | 50.00 a | 50.00 a | 50.00 a | 76.67 a | 66.67 ab | 46.67 c |
| SE± | 11.79 | 4.67 | 11.41 | 4.95 |

Figures in a column followed by the same letter (s) are not significantly different according to the least significant differences (LSD)

**4- Discussion**

The combination of 2,4-D and the diesel solvent significantly increased mortality percent compared to the water solvent, this reflects the variable responses of mesquite trees to the different solvents used in this study. This result is supported by the finding of many researchers who studied the effect of herbicides of the phenoxy acetic acid group, (which 2,4-D belong to this group) for mesquite control. They concluded that the use of the phenoxy acetic acid group gave good results in mesquite control when mixed with diesel oil. Similar results were found by (Abdelaziz, 2009) who found that; the auxinic herbicide triclopyr applied at the rate of 4 g a. i./ tree as basal bark treatment gave 100% morality of mesquite trees. In addition, triclopyr applied at 18-20% for mesquite tree basal bark treatment gave 100 % mortality after one year of application (Abdelaziz *et al.* 2014). Also, (Shanwad *et al.* 2015) found that the mortality % increased as 2,4-D increased in combination with glyphosate and applied as a foliar spray. 2,4-D mimics the natural plant hormone indole - 3- acetic acid (natural auxin) and activates auxin response genes (Korasick *et al.* 2015). This is thought to be due to the mode of action of 2,4-D herbicide at low concentrations. However, 2,4-D at high concentration, which acts as herbicide and persists for a long time in the plant, is described as an auxin overdose, which leads to an imbalance in auxin and interaction with other hormones (Song, 2014). Auxinic herbicides lead to oxidative stress through the unregulated generation of reactive oxygen species (ROS) such as hydrogen peroxide (H2O2). 2,4-D as auxinic herbicide synthesis of 1-carboxylic acid, which is the key enzyme in ethylene biosynthesis, which stimulated H2O2 (Lin and Grierson, 2009). H2O2 is considered the second messenger for the synthesis of abscisic acid (ABA), which leads to stoma closure and limiting CO2 assimilation followed by a reduction in photosynthesis (Grossmann, 2010). H2O2 at low concentrations acts as a signal molecule and regulates the expression of a large number of genes involved in cell response to different stress conditions and development (Mittler *et al.* 2011). However, a high accumulation of H2O2 promotes oxidative damage to proteins, lipids, and nucleic acids (Sandalio *et al.* 2012). Diesel toxicity is due to alkanes and polycyclic aromatic hydrocarbons (PAHs) which are toxic to plants (Adam and Duncan, 1999). (Alkio *et al.* 2005) Observed several effects of PAHs in *Arabidopsis*, including a reduction in the growth of the stem and the root, production of hydrogen peroxide (H2O2), and cellular death. Toxic hydrocarbon molecules inhibit the activities of amylase and starch phosphorylase (Achuba, 2006). In addition, reduction in photosynthesis, and respiration, and an increase in stress related to the phytohormone (Adenipekun *et al,* 2008). The performance of 2,4-D in the rainy season was better than in the winter season in mortality percent, this may have been due to high humidity in the rainy season which increased the uptake and translocation of 2,4-D to the roots and thus increased mortality percent (Peterson *et al.* 2016).

**5- Conclusion**

1/ This study proved that it is possible to control this invasive tree under field conditions and confirms that: the tree does not grow again until one year of application.

2/ During the two seasons, the three tree sizes treated with the high rate of 2,4-D (24×103 mg of a.i.) dissolved in diesel showed a 100% mortality percent.

3/ The study discussed this result with the recommendation of using the herbicide 2,4-D at this rate for mesquite tree control.

**6- References**

Abdelaziz, E. A. (2009). *Studies* *on Some Aspects of Mesquite [Prosopis. juliflora (Swartz)* DC] Biology and Management. Ph. D. (Agric) thesis. Sudan Academy of Sciences (SAS). P 84-85.

Abdelaziz, E. A.; Osman, A. S.; Abdulgadir, H., Zahran; E. B. and Babiker, A. E. (2014). Herbicidal efficacy of Trilina 48 EC (Triclopyr) on control of mesquite. The 90th Meeting of the National Pest and Diseases Committee June. pp1-8.

Achuba, F. I. (2006). The effect of sub-lethal concentrations of crude oil on the growth and metabolism of Cowpea (*Vigna unguiculata*) seedlings. *Environment Systems and Decisions.* 26 (1), 17-20.

Adam, G., and Duncan, H. (1999). Effect of diesel fuel on the growth of selected plant species. Environmental Geochemistry and Health. 21(4), 353–357.

Adenipekun, C. O.; Oyetunji, O. J. and Kassim, L. S. (2008). Effect of spent engine oil on the growth parameters and chlorophyll content of (*Corchorus olitorius* L) The. Environmentalist. 28(4), 446–450.

Alkio, M.; Tabuchi, T. M.; Wang, X. and Colón-Carmona, A. (2005). Stress responses to polycyclic aromatic hydrocarbons in Arabidopsis include growth inhibition and hypersensitive response-like symptoms. *Journal of Experimental Botany.* 56 (421), 2983-2994.

Becker, M.; Alvarez, M.; Heller, G.; Leparmarai, P.; Maina, D.; Malombe, I.; Bollig, M. and Vehrs, H. (2016). Land-use changes and the invasion dynamics of shrubs in Baringo. *Journal of Eastern African Studies.* 10(1), 111–129.

Brown, A. F. and Massey, R. E. Flora of Sudan. Thomas Murby and CO. 1929, p. 376.

Damasceno, G. A. B.; Ferrari, M., and Giordani, R. B. (2017). *Prosopis juliflora* (SW) an invasive species at the Brazilian Caatinga: phytochemical, pharmacological, toxicological and technological overview *Journal of Photochemistry Reviews.* 16(2), 309–331.

Dousti, F.; Assarehzadegan, M. A.; Morakabati, P.; Khosravi, G. R. and Akbari, B. Molecular cloning and expression of Pro J1: (2016). A new allergen of *Prosopis Juliflora* pollen. *Iranian Journal of Allergy, Asthma, and Immunology.* 15(2), 122–131.

Eduardo, F. M.; Bruno, E. C. S.; Amana, M. M.O.; Flávio, B. C. and Dimas, M. R. (2017). Ethylene synthesis and photosynthetic responses in bean and maize plants exposed to auxins. *Revista Brasileira Herbicidas.* 16(2), 130-141.

Geesing, D.; Al-Khawlani, M., and Abba, M. L. (2004). Management of introduced *Prosopis juliflora* species: can economic exploitation control an invasive species Unasylva? 55 (217), 36-44.

Gervais, J. A.; Luukinen, B.; Buhl, K. and Stone, D. 2,4-D Technical fact sheet; 2008, National pesticide information Center, Oregon State University Extension Services.

Grossmann K. Auxin herbicides: Current Status of mechanism and mode of action. *Pest Management Science* 2010, 66 (2), 113 -120.

Ibrahim, M. M.; Nadir, A. M.; Ali, A. T.; Ahmad, V. U. and Rasheed, E. R. (2013). Phytochemical analyses of *Prosopis juliflora. Pakistan Journal of Botany.* 45(6), 2101-2104.

Korasick, D. A.; Jez, J. M. and Strader, L. C. (2015). Reﬁning the nuclear auxin response pathway through structural biology. Current Opinion in Plant Biology 2015, 27: 22–28.

Kumar, S. and Singh, A. K. (2010). A review on herbicide 2,4-D damage reports in wheat (*Triticum aestivum* L.). *Journal of Chemical and Pharmaceutical Research* 2010, 2(6), 118-124.

Lin, Z.; Zhong, S. and Grierson, D. (2009). Recent advances in ethylene research. *Journal of Experimental Botany.* 60(12), 3311–3336.

Mittler, R.; Vanderauwera, S.; Suzuki, N.; Miller, G. A. D.; Tognetti, V. B.; Vandepoele, K.; Gollery, M.; Shulaev, V. and Van Breusegem, F. (2011). ROS signaling: the new wave. Trends in Plant Science. 16(6), 300–309.

Morgan, A.; Hamdoun, A. M. and Bashir, N. H. (2017). Studies on Seed Germination and Seedling Emergence of Mesquite *Prosopis juliflora* (Swartz) DC in Sudan. *Universal Journal of Agricultural Research*. 5(2), 159-163.

Muturi, G. M.; Poorter, L.; Bala, P. and Mohren, G. M. (2017). Unleached *Prosopis* litter inhibits germination but leached stimulates seedling growth of dry woodland species. *Journal of Arid Environments.* 138: 44–50.

Noor, M., Salam, U., and Khan A. M. (1995). Allelopathic effect of *Prosopis juliflora* Swartz *J. Arid. Environ.* 31: 83-90.

Pasiecznik, N. M.; Harris, J., and Smith, S. J. (2004). Identifying tropical *Prosopis* Species: afield guide. HDRA, Coventry, UK.

Peterson, M. A.; McMaster, S. A.; Riechers, D. A.; Skelton, J., and Stahlman, P. W. (2016). 2,4-D past, present, and future: A review. Weed Technology. 30(2), 303-345.

Sandalio, L. M.; Rodriguez-Serrano, M.; Gupta, D. K.; Archilla, A.; Romero-Puertas, M. C. and Rio, L. A. (2012). Reactive oxygen species and nitric oxide in plants under cadmium stress: From Toxicity to Signaling in the book: Environmental Adaptations and Stress Tolerance of Plants in the Era of Climate Change. Bertin: Springer. pp.199-215.

Shanwad, U. K.; Chittapur, B. M.; Honnalli, S. N.; Shankergoud, I. and Gebremedhin, T. (2015). Management of *Prosopis juliflora* through chemicals: A case study in India. *Journal of Biology, Agriculture and Healthcare.*  5(23), 30-38.

Song, Y. L. (2014). Insight into the mode of action of 2,4-dichloro phenoxy acetic acid (2,4-D) as an herbicide. *Journal of Integrative Plant Biology* 2014, 56(2), 106-113.

Thoyabet, S. A.; Ray, R. H.; Sven, V. and George, S. E. (2009). Effects of leaf extract of *Zizyphus spinachristi* and *Prosopis juliflora* on each other seedlings roots. *Allelopathy Journal.* 23(1), 111-118.

Vanderauwera, S.; Suzuki, N.; Miller, G.; van de Cotte, B.; Morsa, S. and Ravanat, J. L. (2011). Extranuclear protection of chromosomal DNA from oxidative stress. Proceedings of the National Academy of Sciences USA. 108(4), 1711 – 1716.

Walter, K. J. and Armstrong, K. V. (2014). Benefits, threats, and potential of *Prosopis* in South India. Forests, Trees, and Livelihoods. 23(4), 232–247.