The Effect of 2,4-dichloro Phenoxy Acetic Acid on Seeds Productivity of Mesquite (Prosopis juliflora Swarz) DC

Abstract: The study was conducted in the field to evaluate the effect of 2,4-dichloro phenoxy acetic acid (2,4-D) on the productivity components of mesquite trees (*Prsopis juliflora* Swarz) DC. Natural stand mesquite trees at three sizes **(**small, medium, and large) treated with 2,4-D at different rates (0, 6×10^3, 12×10^3, 18×10^3 and 24×10^3 mg a. i. / L) dissolved in two solvents (diesel or water)**.** The design was a factorial experiment in Randomized Complete Block Design **(**RCBD). The results found that, decreasing the high productivity of pods per inflorescence and seeds per pod through the use of auxinic herbicide (2,4-D). The two high rates of 2,4-D dissolved in diesel significantly decreased the number of pods per inflorescence. In addition, the three high rates of 2,4-D (12×10^3, 18×10^3, and 24×10^3 mg a.i.) dissolved in diesel or water significantly decreased the number of seeds per pod from the three tree sizes compared to the control. The study concluded that: the use of 2,4-D herbicide dissolved in diesel decreased the number of pods per inflorescence and seeds per pod, which reflected in decreased dispersal of mesquite trees.

. **Keywords**: Mesquite trees, 2,4-D, diesel, water, pods, and seeds.

Comment [U1]: Prosopis?

Comment [U2]: and

1. Introduction

Mesquite (*Prosopis juliflora*) was first introduced into Sudan from Egypt and South Africa in 1917, with the purpose of solving the problem of desertification in some regions of Sudan [1]. It is fast-growing; nitrogen-fixing, and tolerant to arid conditions and saline soils [2]. Mesquite started spreading and multiplying much faster than the rate, which, could be, used now it has become one of the world's 100 most dominant invasive trees [3]. Mesquite spread rapidly into fertile productive

areas and irrigation and drainage channels, particularly in some of the major irrigated schemes [4]. The tree commonly propagated by producing a large number of small size seeds [5].

Flowers are small, 4-6 mm long, densely together on cylindrical, spike-like inflorescences known as racemes. They are generally yellow or yellow-white in color. Flowers are hermaphrodite, sometimes- sterile [6]. The fruits known as pods; are straight with an incurved apex. Immature pods are green in color, becoming commonly white-yellow when fully mature. The seeds when removed from the pod were brown, and the pods are tasty and sweet [7]. The number of pods produced per inflorescence varies greatly, with 1-16 fruit per inflorescence. Pods also vary greatly in size, 8-29 cm long, 9-17 mm broad and 4-8 mm thick. Pods made up of an exocarp, which varies in thickness, fleshy mesocarp, and endocarp segments each contain a single seed, with up to 30 seeds per pod Seeds are up to 6.5 mm long and weigh 0.25-0.30 g (25000-30000 seeds/kg), seeds are brown in color [7].

2,4-D as synthetic auxin herbicides specifically targets dicotyledonous weeds [8]. Synthetic auxins mimic the effects of natural auxin Indole-3- acetic acid (IAA) in plants [9]. Natural auxin (IAA) is usually inactivated very quickly through conjugation and degradation in the plant, while synthetic auxin 2,4-D persist for long periods of time 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 [10]. The mode of action of auxinic herbicides depends on tissue sensitivity and species, low doses of 2,4-D promotes plant growth, while high doses drive plant overgrowth, including cupping and stunting of leaves, brittleness, stunting and twisting of stems, and general abnormal growth [11]

Herbicides applied during the flowering period of plants can reduce or even prevent

the formation of viable seeds [12]. The plant growth regulators promote shoot elongation and increase rooting and increase flower formation and fruit size, and ethylene generators ripen and induce uniform ripening in fruit and vegetables [13]. The objective of this study was to evaluate the effect of 2,4-D as auxin- like herbicide on the productivity of pods per inflorescence and seeds per pod.

2. Materials and Methods

2-1. Sites of the Experiments

Comment [U3]: 2.1

Experiments were conducted in two locations, the first one in central Khartoum (area of about forty ha.), and the other in the demonstration farm of the Faculty of Agriculture University of Khartoum, during the winter season 2017/2018 and during the rainy season of 2018. The sites lie at lat.15, 40 N, long 32, 32E, in a semi-arid zone, characterized by a great variation in temperature, which ranges from 18^{o} C to 40^{o} C, and relative humidity of 34% to 75 % [14].

2-2. Planting Materials

Comment [U4]: ?

Mesquite trees are classified into (small, medium, and large) ten each, based on the number of stems per tree and the diameter of the canopy (in meters). Ten inflorescences were selected, and marked before the trees were treated.

2-3. Chemical solutions and application method

Comment [U5]: ?

The application method basal bark treatment was used in which 2,4-D at five rates 0, 6×10^{3}, 12×10^{3}, 18×10^{3} and 24×10^{3} mg a.i. / L in tank mixture with water or diesel. were sprayed around the lower part of the tree stem at about 30 cm above the soil level [15]. Herbicide application with a knapsack sprayer with cone type nozzle, which is adjusted to deliver a mixture in a narrow cone.

2-4. Experimental design and data analysis

Comment [U6]: ?

Field experiments were arranged in factorial in Randomized Complete Block Design

(RCBD) with three replicates. The experimental unit consisted of three mesquite trees of different sizes (small, medium, and large) for any treatment in the block. Treated with five rates of 2,4-D, dissolved in two solvents (Table 1). The laboratory experiment was arranged in factorial in a Completely Randomized Design (CRD) with three replicates. Data subjected to analysis of variance test (ANOVA) and means statistically separated by least significant difference test (LSD) using a computer statistical software, Statistix 8, and differences between means at (0.05) level of significance.

2-5. Data collection

Comment [U7]: ?

Mature pods from marked inflorescences were collected individually from 2,4-D treated trees and a mean number of pods per inflorescence was calculated. In addition, seeds were removed from pods using a sharp knife and scissors and the mean number of seeds per pod was calculated.

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

Treatment	2,4-D rate.in (10^3) mg
D/(2,4-D)/R0	2,4-D at rate zero dissolved in diesel
D/(2,4-D)/R1	2,4-D at rate 6 dissolved in diesel
D/(2,4-D)/R2	2,4-D at rate 12 dissolved in diesel
D/(2,4-D)/R3	2,4-D at rate 18 dissolved in diesel
D/(2,4-D)/R4	2,4-D at rate 24 dissolved in diesel
W/(2,4-D)/R0	2,4-D at rate zero dissolved in water
W(2,4-D)/R1	2,4-D at rate 6 dissolved in water
W(2,4-D)/R2	2,4-D at rate 12 dissolved in water
W/(2,4-D)/R3	2,4-D at rate 18 dissolved in water
W/(2,4-D)/R4	2,4-D at rate 24 dissolved in water

R=Rate, D=Diesel, W=Water

3- Results

Comment [U8]: ?

3-1. Effect of 2,4-D, on the mean number of pods per inflorescence

Comment [U9]: ?

In the winter season, the three tree sizes treated with 2,4-D rates dissolved in diesel showed significant differences in pods per inflorescence compared to corresponding

rates dissolved in water, while in the rainy season, there were significant differences in pods per inflorescence as 2,4-D increased dissolved in diesel or water. In addition, the overall mean of the effect of 2,4-D dissolved in diesel on pods per inflorescence: showed significant differences compared to water solvent with small, medium, and large trees in the winter and rainy seasons. (Table 2) All 2,4-D rates dissolved in diesel gave less number of pods per inflorescence compared to respective rates dissolved in water. The overall mean of pods per inflorescence of treated trees was decreased in both seasons in response to 2,4-D dissolved in a diesel by (63.27%, 113.95%) and (56.78%, 90.89%) for winter and rainy seasons, respectively. (Table 3).

3-2. Effect of 2,4-D on the mean number of seeds per pod

Comment [U10]: ?

All treatments produced greater values of seeds per pod compared to their respective controls. (Table 4). The results showed that; the overall number of seeds per pod from three thee sizes treated with 2,4-D dissolved in diesel was decreased than 2,4-D dissolved in water in both seasons. (Table 4). All 2,4-D rates dissolved in diesel gave less number of seeds per pod compared to respective rates dissolved in water. The overall mean of seeds per pod of treated trees was decreased in both seasons in response to 2,4-D dissolved in a diesel by (33.02%, 32.09%) and (16.86%, 35.17%) for winter and rainy seasons, respectively. (Table 5).

Comment [U11]: recast

Table 2: Effect of 2,4-D, on the mean number of pods per inflorescence of a mesquite tree in different sizes

Treatments	Number of pods per inflorescence			
	Winter season		Rainy season	
	First	Second	First	Second

	S	M	L	S	M	L	S	M	L	S	M	L
D2,4-DR0	4.37 defg	4.83 bcde	4.78 bcde	3.33 de	3.57 cde	3.50 cde	5.1 bcdefg	4.90 def	4.80 defg	5.07 Fghij	5.07 fghij	5.40 defghij
D2,4-DR1	2.87 hij	3.70 efghi	4.37 defg	2.90 efg	2.67 efgh	3.10 e	5.70 bcd	4.80 defg	4.20 fghi	6.77 bcdef	5.20 efghij	4.57 hijk
D2,4-DR2	3.33 hij	3.10 hij	3.07 Hij	3.00 ef	2.73 fgh	2.67 efgh	4.00 ghij	4.50 efgh	4.30 fghi	4.10 Jkl	4.37 ijk	4.67 ghij
D2,4-DR3	2.67 hij	3.00 hij	3.20 ghij	1.73 ghi	1.67 ghi	1.73 ghi	2.90 jkl	2.80 kl	3.00 jkl	2.30 M	2.17 m	2.27 m
D2,4-DR4	2.63 ij	2.90 hij	2.33 J	1.5 hi	1.40 i	1.80 fghi	2.70 l	2.80 kl	3.20 ijkl	2.00 M	2.43 lm	2.83 klm
Mean	3.17 C	3.51 b	3.55 Ab	2.49 b	2.41 b	2.56 b	4.08 c	3.96 c	3.90 c	4.05c	3.85 c	3.95
W2,4-DR0	5.84 ab	5.87 ab	5.20 abcd	5.77 ab	4.57 bcd	5.43 ab	8.20 a	8.40 a	9.30 a	8.00 Ab	8.50 ab	9.73 a
W2,4-DR1	5.13 abcd	4.43 cdef	4.53 cdef	4.97 ab	4.93 ab	4.90 ab	5.60 bcde	6.20 b	5.30 bcdef	6.33 cdefg	9.73 a	5.77 cdefghij
W2,4-DR2	4.47 bcdef	5.33 abcd	5.63 abc	5.63 ab	5.37 ab	5.10 ab	6.00 bc	6.20 b	5.20 bcdef	6.93 bcde	9.97 a	5.97 cdefghi
W2,4-DR3	6.30 a	5.37 abcd	6.03 ab	6.07 a	4.60 bc	6.03 a	5.80 bcd	6.20 b	6.20 b	7.47 bc	7.73 bc	6.27 cdefgh
W2,4-DR4	5.77 ab	6.33 a	5.17 abcd	5.63 ab	5.93 a	4.87 ab	5.10 bcdefg	5.00 cdefgh	6.20 b	6.37 cdefg	7.33 bc	7.00 bcd
Mean	5.50 a	5.47a	5.31a	5.61 a	5.08 a	5.27 a	6.10 ab	6.40 a	6.44 a	7.02 ab	8.65 a	6.97a
SE±		0.61			0.63			0.58			0.88	

S= Small, M=Medium, L-Large

Comment [U12]: A Table should be on the same page.

Table 3: Effect of 2,4-D on the mean number of pods per inflorescence

Treatments	Pods per inflorescence			
	Winter		Rainy	
	First	Second	First	Second
D2,4-DR0	4.66c	3.47 b	4.93cd	5.18 cd
D2,4-DR1	3.65de	2.89 b	4.9cd	5.51 c
D2,4-DR2	3.17def	2.80 b	4.27d	4.38 d

D2,4-DR3	2.96f	1.71 c	2.9e	2.28 e
D2,4-DR4	2.62f	1.57 c	2.9e	2.42 e
Mean	3.24b	2.49 b	3.91b	3.95 b
W2,4-DR0	5.64ab	5.26 a	7.63a	8.08 a
W2,4-DR1	4.7c	4.93 a	5.7b	7.28 ab
W2,4-DR2	5.14bc	5.37 a	5.8b	7.62 ab
W2,4-DR3	5.9a	5.57 a	6.07b	7.16 ab
W2,4-DR4	5.76ab	5.48 a	5.43bc	6.90 b
Mean	5.29a	5.32 a	6.13a	7.54 a
SE±	0.35	0.36	0.37	0.51

Comment [U13]: ?

Table 4: Effect of 2,4-D, on the mean number of seeds per pod of a mesquite tree in different sizes

Treatments	Number of seeds per pod											
	Winter season						Rainy season					
	First			Second			First			Second		
	S	M	L	S	M	L	S	M	L	S	M	L
D2,4-DR0	16.17 bcd	15.07 cdef	13.33 defgh	17.77 bcd	16.57 cde	13.17 fghij	19.20 abc	17.30 abcd	15.37 cdefg	17.67 abcde	18.33 abcde	17.00 bcdef
D2,4-DR1	16.47 bc	7.90 klmno	10.87 ghijk	15.33 defg	9.83 klmn	12.50 ghijk	17.90 abcd	17.43 abcd	16.37 bcdef	15.33 efg	18.67 abcd	15.63 defg
D2,4-DR2	8.00 klmno	8.00 klmno	6.83 no	8.07 mno	8.67 lmno	7.30 nop	13.43 efghij	13.30 efghij	11.17 hij	11.00 hij	10.00 j	9.50 j
D2,4-DR3	7.70 lmno	6.90 mno	6.00 no	6.90 op	7.5 mnop	6.53 op	13.0 fghij	12.13 ghij	12.43ghij	10.67 ij	9.83 j	9.67j
D2,4-DR4	6.47 no	7.70 lmno	5.63 o	6.50 op	6.40 op	5.17 p	10.20 j	11.10 hij	10.63 ij	9.33 j	8.97 j	9.0 j
Mean	10.96b	9.11 c	8.53 c	10.91 bc	9.79 cd	8.93 d	14.75 bc	14.25 bc	13.19 c	13.16 c	12.8c	12.1 c
W2,4-DR0	20.93 a	16.30 bcd	18.17 ab	21.03 a	18.67 abc	20.33 ab	20.53 a	19.00 abc	19.87 ab	19.67 ab	20.67 a	20.67 a
W2,4-DR1	13.00 efghi	16.00 bcde	14.26 cdef	11.00 jkl	15.67 def	14.00 efghi	20.00 ab	18.10 abcd	16.97 abcde	19.67 ab	20.67 a	19.00 abc
W2,4-DR2	10.47 hijkl	13.57 cdefg	12.43 fghi	11.43 ijkl	14.33 efgh	12.33 hijk	16.73 abcdef	17.57 abcd	14.43 defghi	17.00 bcdef	19.00 abc	16.00 cdefg
W2,4-	6.	9.00	12.13	6.	12.0	11.97	14.	16.	13.0fg	15.33	17.6	14.0

DR3	40 no	jklmn	fghi	60 op	0 hijk	hijk	77 defgh	40 bcdef	hij	efg	7 abcde	fgh
W2,4-DR4	6.67 no	9.93 ijklm	11.10 ghij	6.40 op	9.80 klmn	10.23 klm	11.33 hij	14.37 defghi	13.37e fghij	13.67 ghi	13.67 ghi	11.00 hij
Mean	11.49 b	12.97 a	13.62 a	11.29 b	14.09 a	13.77 a	16.67 a	17.09 a	15.53 ab	18.33 a	17.07ab	16.13 b
SE±	1.54			1.44			1.93			1.61		

S= Small, M=Medium, L-Large

Comment [U14]: ?

Table 5: Effect of 2,4-D on the mean number of seeds per pod

Treatments	Pods per inflorescence			
	Winter		Rainy	
	First	Second	First	Second
D2,4-DR0	14.86b	15.83 b	19.29b	16.54 bc
D2,4-DR1	11.74c	12.56 c	17.23b	16.54 bc
D2,4-DR2	7.61de	8.01 ef	12.63de	10.17 e
D2,4-DR3	6.87e	6.98 fg	12.51de	10.06 e
D2,4-DR4	6.6e	6.02 g	10.64e	9.10 e
Mean	9.54b	9.88 b	14.06b	12.71 b
W2,4-DR0	18.48a	20.01 a	19.8a	20.33 a
W2,4-DR1	14.42b	13.56 c	18.36ab	19.78 a
W2,4-DR2	12.06c	12.70 c	16.24bc	17.33 bc
W2,4-DR3	9.18d	10.19 d	14.72cd	15.67 c
W2,4-DR4	9.23d	8.81 de	13.02d	12.78 d
Mean	12.69a	13.05 a	16.43a	17.18 a
SE±	0.89	0.83	1.11	0.93

4. Discussion

Comment [U15]: Discussion and Recommendations.

The deleterious effect of 2,4-D on yield components could clearly be inferred from the decrease in the number of seeds per pod in the treated trees with 2,4-D dissolved in diesel or water. The decrease in seed yield in this study appears to be in line with the results reported by [16], who found that 2,4-D, dicamba, and triclopyr (auxin-like herbicides) reduced seed yield in alfalfa by 24% to 49% (by weight) compared to the control. Also, green gram (*Vigna radiata*) (Legume) seed yield declined with an increase of the rates of 2,4-D [17]. Soybean exposed to 2,4-D during the reproductive

stages decreased the yield with the increase of 2,4-D con centration [18].

A decrease in seeds might be due to a decrease in the percentage of germination of pollen grains or decreased pollen tube length with an increase of 2,4-D rate in *Parthenium hysterophorus* [19]. Seeds per pod from treated plants in all 2,4-D concentrations dissolved in water were significantly high compared to that dissolved in the diesel solvent in both seasons (winter and rainy). In addition, the decrease in the number of pods per inflorescence and seeds per pod with the application of 2,4-D dissolved in diesel; might be due to the different properties between the two solvents. Also might be due to herbicides accompanied by the toxic effect of diesel, which contains alkanes and polycyclic aromatic hydrocarbons [20]. In addition, reduction in plant height is one of the most important symptoms caused by auxin herbicides that cause yield losses by fewer main-stem nodes, and fewer pods or fewer seeds because of reduced leaf area and reduction in photosynthesis [21]. Herbicides applied during the flowering period of plants can reduce or even prevent the formation of viable seeds [12]. In addition, the pollen germination and pollen tube length in (*Parthenium hysterophorus L.*) were decreased with an increase of 2,4-D concentration [19].

5. Conclusion

Comment [U16]: Conclusion and Recommendations.

The results of the present study indicated that, in both seasons (winter and rainy), the two high rates of 2,4-D dissolved in diesel, decreased pods per inflorescence and seeds per pod which reflected in decreased dispersal of mesquite trees.

6. References

Comment [U17]: This should not be numbered.

[1]Brown, A. F., and Massey, R.E. (1929): Flora of Sudan. Thomas Murby and CO. p. 376.

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

[3]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.

[4]Morgan, A., Hamdoun, A. M. and Bashir, N. H. H. (2017). Studies on Seed Germination and Seedling Emergence of Mesquite *Prosopis juliflora* (Swarz) DC.in Sudan Gezira. *Universal Journal of Agriculture Research* 5(2): 159-163.

[5]Almaraz, A. N.; Graça, C. M.; Avila R. J. A.; Naranjo, J. N.; Corral, J. H. and González, V. L S. (2007). Antioxidant activity of polyphenolic extract of mono-floral honeybee collected pollen from mesquite (*Prosopis juliflora*). *J Food Compost Anal*: 20(2), 119-124.

[6]Burkart, A. (1976). Amonograph of the genus *Prosopis* (Leguminosae, subfam. Mimosoidae). *Journal of Arnold Arboretum* 57(3), 219–249.

[7]Pasiecznik, N. M.; Felker, P.; Harris, P. J.; Harsh, L.; Cruz, G.; Tewari, J. C.; Cadoret, K. and Maldonado, L. J. (2001). The *Prosopis juliflora-Prosopis pallida* complex: A monograph. 172, HDRA, Coventry, UK

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

[9] Pazmino, D. M.; Romero-Puertas, M. C. and Sandalio, L. M. (2012). Insights into the toxicity mechanism of and cell response to the herbicide 2,4-D in plants. Plant signaling & behavior 7: 425-427.

[10]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* 56(2), 106-113.

[11]Grossmann K. (2010). Auxin herbicides: status of mechanism and mode of action. *Pest management science* 66(2) 113 -120.

[12]Makepeace, W. and Thompson, A. (1982). Ragwort control using a rope wick

applicator 35th New Zealand Weed and Pest Control Conf., Proc. pp. 256-260.

[13]Fishel, F. M. (2006). Plant growth regulators document, Pesticide information office, Florida cooperative extension service, Institute of Food and Agricultural Sciences p.1-139.

[14]Gabbani, M. F. (2007) *Amelioration of Biotic Stress Induced by Onion Yellow Dwarf Virus on Onion Seed Crop Using Nutrition.* M.Sc.(Agric) thesis. University of Khartoum, Khartoum, Sudan. p. 25

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

[16]Sandya, R. K.; Stephanie, L., and Greene. (2016). Effect of synthetic auxin herbicides on seed development and viability in genetically engineered glyphosate-resistant alfalfa. Weed Technology 30(4):860-868.

[17]Almas, Z.; Saghir, M. K. and Pervez, Q. R. (2005). Effect of herbicides on growth, nodulation, and nitrogen content of green gram. Agronomy for sustainable development, Springer Verlag / EDP Sciences/INRA, 25 (4), 497-504.

[18]Andrew, P. R.; Vince, M. D.; David, M. S. and William, G. J. (2013). Response of soybean yield components to 2,4-D. Weed Science 61(1), 68 -76.

[19]Basarkar, U. G. and Khandelwal, S. R. (2008).Control of weed *parthenium hysterophorus* L. by Inhibiting Pollen germination and pollen tube Growth.The 12th world lake conference 1074-1081.

[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.

[21] Robinson, A.P. (2013). Response of soybean yield components to 2,4-D. Weed science. 61: 68–76.

Comment [U18]: Use the journal format for reference listing