Asian Journal of Research in Botany

Volume 8, Issue 4, Page 33-40, 2022; Article no.AJRIB.97660

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

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/97660

Original Research Article

Received: 23/10/2022
Accepted: 29/12/2022
Published: 31/12/2022

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 (*Prosopis 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.

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

1. INTRODUCTION

Mesquite (*Prosopis juliflora*) is a native tree to North America; it has been introduce to several countries to combat desertification [1]. *P. juliflora*, is a thorny, multi stemmed evergreen tree or shrub, which normally reaches heights of 3-12 m, also go up to 20 m in favorable conditions [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]. Pods are sweet fruits formed of 70-75% pericarp and 25-30% seeds [6]. The 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 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]. In general, all researches are related to control mesquite tree, which as described as invasive tree or to study the toxicity of the tree on the other plants, while the present study aiming 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

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

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

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 to reduce the herbicide drift on the soil surface.

2.4 Experimental Design and Data Analysis

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 (Diagram 1). 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

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.

3. RESULTS

3.1 Effect of 2,4-D, on the Number of Pods per Inflorescence

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 Number of Seeds per Pod

All 2,4-D rates dissolved in diesel or water significantly decreased the number of seeds per pod compared to their respective controls. But the number of seeds per pod from three thee sizes treated with all 2,4-D rates dissolved in diesel was decreased than 2,4-D dissolved in water in both seasons (Table 4). The overall mean of seeds per pod was decreased in response to 2,4-D dissolved in a diesel. 2,4-D dissolved in diesel gave (9.54, 9.88 seeds per pod) and (14.06, 12.71 seeds per pod), while 2,4-D dissolved in water gave (12.69, 13.05 seeds per pod) and (16.43, 17.18 seeds per pod) in the two winter and two rainy seasons, respectively (Table 5).

4. DISCUSSION

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].

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

Treatment	2,4-D rate.in (10^3) mg a. i.
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

Diagram 1. Site of the experiment

Block 1	Block II	Block III
2,4-D/ R0 dissolved in water (The exp. unit, consisted of three trees) (small, medium and large)		
2,4-D/ R1 dissolved in water		
2,4-D/ R2 dissolved in water		
2,4-D/ R3 dissolved in water		
2,4-D/ R4 dissolved in water		
2,4-D/ R0 dissolved in diesel		
2,4-D/ R1 dissolved in diesel		
2,4-D/ R2 dissolved in diesel		
2,4-D/ R3 dissolved in diesel		
2,4-D/ R4 dissolved in diesel/		

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

S= Small, M=Medium, L-Large

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

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	16.17bcd	15.07 cdef	13.33defgh	17.77bcd	16.57cde	13.17 fghij	19.20abc	17.30abcd	15.37cdefg	17.67abcde	18.33abcde	17.00bcdef
D2,4-DR1	16.47 bc	7.90klmno	10.87 ghijk	15.33defg	9.83klmn	12.50 ghijk	17.90abcd	17.43abcd	16.37 bcdef	15.33 efg	18.67 abcd	15.63defg
D2,4-DR2	8.00klmno	8.00 klmno	6.83 no	8.07mno	8.67lmno	7.30 nop	13.43efghij	13.30 efghij	11.17hij	11.00 hij	10.00 j	9.50 j
D2,4-DR3	7.70 lmno	6.90 no	6.00 no	6.90 op	7.5 mnop	6.53op	13.0fghij	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	9.79cd	8.93 d	14.75 bc	14.25 bc	13.19 c	13.16c	12.8c	12.1 c
W2,4-DR0	20.93 a	16.30 bcd	18.17 ab	21.03a	18.67abc	20.33 ab	20.53 a	19.00 abc	19.87 ab	19.67 ab	20.67 a	20.67 a
W2,4-DR1	13.00efghi	16.00bcde	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	13.57cdefg	12.43 fghi	11.43 ijkl	14.33efgh	12.33hijk	16.73abcdef	17.57abcd	14.43defghi	17.00bcdef	19.00 abc	16.00cdefg
W2,4-DR3	6.40 no	9.00 jklmn	12.13fghi	6.60 op	12.00 hijk	11.97 hijk	14.77defgh	16.40 bcdef	13.0fghij	15.33 efg	17.67abcde	14.0fgh
W2,4-DR4	6.67 no	9.93 ijklm	11.10 ghij	6.40 op	9.80 klmn	10.23klm	11.33hij	14.37defghi	13.37efghij	13.67ghi	13.67 ghi	11.00 hij
Mean	11.49 b	12.97 a	13.62 a	11.29b	14.09a	13.77a	16.67 a	17.09 a	15.53ab	18.33a	17.07ab	16.13b
SE±	1.54			1.44			1.93			1.61		

S= Small, M=Medium, L-Large

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

Treatments	Seeds per pod			
	Winter		Rainy	
	First	Second	First	Second
D2,4-DR0	14.86b	15.83b	19.29b	16.54 bc
D2,4-DR1	11.74c	12.56c	17.23b	16.54bc
D2,4-DR2	7.61de	8.01 ef	12.63de	10.17e
D2,4-DR3	6.87e	6.98 fg	12.51de	10.06e
D2,4-DR4	6.6e	6.02 g	10.64e	9.10e
Mean	9.54b	9.88b	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	17.33bc
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

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

The results of the present study indicated that, in both seasons (winter and rainy), the two high rates of 2,4-D ($18×10^3$ and $24×10^3$ mg a.i.}dissolved in diesel, decreased pods per inflorescence and seeds per pod which reflected in decreased dispersal of mesquite trees. Therefore we recommended using the auxin-like herbicide 2,4-D at the rate of ($18×10^3$ mg a.i.) to reduce the productivity of the seeds, which is considered the main factor for the spread of invasive mesquite trees.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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