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Research Article

Control of *Calotropis procera* Infestation in Ruaha National Park, Tanzania

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Abstract

A targeted herbicide application was used in this study in Ruaha National Park to control the considerable infestation of *Calotropis procera* and minimize its adverse ecological effects on the ecosystem. A specific plants trial was set up at Msembe site using a Randomized Complete Block Design. The site had an estimate of more than 370 ha infested with *C. procera*. The site was portioned by establishing square sampling plots of 35m x 35m, within which 42 sub-plots (5m x 5m) were randomly distributed. Three replicates of each of seven herbicide treatments were administered using a specific treatment preparation to incisions made to stems and branches of calotropes. Results indicated a significant variation ($p < 0.001$) of calotrope mortality caused by treatments and period of herbicide application. A significant ($p< 0.001$) interaction was observed between treatments and herbicide application period. The main factor that contributed to the interaction was the glyphosate herbicide dilution. High content of glyphosate (50–100%) killed more than 75% of Calotrope when applied before noon while lower content (<50%), i.e. 5% and 12.5% were effective when applied in the noon and afternoon killing about 50% of the Calotrope. Irrespective of glyphosate application period, plant mortality increased with increasing glyphosate content and variation in glyphosate treatments was significant at $p<0.001$. Mixing of glyphosate and 2,4-D herbicides resulted in relatively lower calotrope mortality than glyphosate treatments alone. It was concluded that diluted and concentrated glyphosate herbicide solutions were most effective in controlling calotrope. However, the efficacy of diluted herbicide solutions (<50%) was high when applied in the afternoon and efficacy of concentrated herbicide solutions was high when applied before noon. Mixing of glyphosate and 2, 4-D resulted in low efficacy. It was envisaged that while diluted concentrations of herbicide are more effective, it is plausible to consider best time of effective herbicide application to control specific invasive plant species.

Keywords

Calotrope, Efficacy, Glyphosate, Herbicide, Infestation, Invasive, Mortality

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1. Introduction

Calotropisprocera, commonly known as Calotrope, is a perennial shrub with soft wood, belonging to the Apocynaceae family and the Asclepiadaceae subfamily (milkweed family) [1]. It is native to regions including Africa, the Arabian Peninsula, Western Asia, the Indian Subcontinent, and Indochina. [1]. It has high ability to survive hash environmental condition due to its versatility in adaptation [2-5] is disputed for forming dense thickets especially in alluvial soil that reduce the grazing area and value of pasture land [6]. Dense infestations of calotrope are difficult and uneconomical to control once established [7, 8], been established that Callotrope reduced herbaceous cover and soil pH in the Park [8].

Calotropis procera was not in the list of undesirable plants found in Ruaha national park before 2010. The Ruaha National Park General Management Plan 2009–2019 mentioned several species including rubber tree (*Euphorbia tirucalli*), bamboo (*Bambuseae species*), guava (*Psidium guajava*), banana (*Musa species*), syringa (*Melia azedarach*), and jacaranda (*Jacaranda mimosifolia*), and *Calotropis procera* as undesirable plants in the park. *Calotropis procera* first appeared in the list of undesirable plants in the park in 2017 documented [9]. According to the unpublished data from the rapid vegetation survey, *Calotropis procera* covers more than 1,500 ha in Ruaha National Park (RUNAPA), with more than 400 ha in the Msembe area [8].

Initial efforts to control calotrope spread in Ruaha National Park used physical approaches and was futile. This was followed by the use of concentrated herbicides which effectively killed the plant but the cost was very high. This compelled the need for a more feasible and less costly control. This study was therefore focused at investigating the effectiveness of highly diluted glyphosate herbicides for controlling *C. Procera* vs high concentrations in the context of a protected area particularly a National Park. [10], found that, Glyphosate tightly adheres to soil," thus reducing the risk of the chemical leaching into groundwater or effect on soil biota. Specifically the study aimed at establishing the most effective dilutions of glyphosate on killing Callotrope.

2. Methodology

2.1. Study Area

The research took place in Ruaha National Park, located in the south-central region of Tanzania, between 33°30′ to 36°30′east and 7°00′ to 8°30′south within the Iringa and Mbeya Regions (Figure 1). The area encompasses an extensive area of approximately 20,300 km^2. It is located west of Tanzania's Southern highlands, between the Great Ruaha River in the south-east and the Mzombe River in the north-west. The park was officially designated in 1964, with an extension in 1974 that incorporated a smaller region south-east of the Great Ruaha River. In 2008, the park's territory was further augmented to include the Usangu wetland, thereby defining the current boundaries. The park is surrounded by several game reserves, notably Rungwa, Kisigo, and Muhezi.

Ruaha National Park receives uni-modal rainfall, generally from the end of November to May. The average rainfall in Ruaha varies from 500mm around the Msembe area in the rift Valley, to 800mm in the western high plateau area of the park. The coolest time is normally from June to the end of July. Temperature can range from maximum of 30°C during the day to as low as 8°C at night. The temperature slowly increases over the subsequent months resulting in the hottest time, with day time reaching 40°C and night-time low of approximately 25°C, which is generally just before the beginning of rain in November and December.

The park's altitude varies significantly, ranging from 750m to 1000m, along the Great Ruaha River and the Usangu wetlands. It gradually ascends in the northern and western regions, reaching an average height of 1,400 meters up an escarpment. The highest point, the Isunkaviola Plateau in the park's western corner, reaches an elevation of 1,868 meters.

Ruaha National Park encompasses a diverse array of habitat types, predominantly consisting of woodlands and grasslands [11]. The park is situated at the confluence of northern and southern vegetation zones, resulting in a unique blend of ecological characteristics. Vegetation within the Ruaha Valley spans from open grasslands to mixed Combretum woodlands and areas dominated by Acacia species. The higher escarpment plateau features extensive tracts of mixed Brachystegia woodlands.

In the park's western sector, the Isunkaviola Plateau hosts two notable areas of Drypetes forest situated on elevated ridges, as well as a mixed riverine forest located within the Kilola Valley. The Usangu plains and wetlands further enrich the park's ecological heterogeneity, providing a continuum of habitats that range from highland forests and Miombo woodlands to lowland savannahs with Acacia and mixed woodlands. These expansive wetlands and plains are particularly significant as they support a wide variety of water bird species.

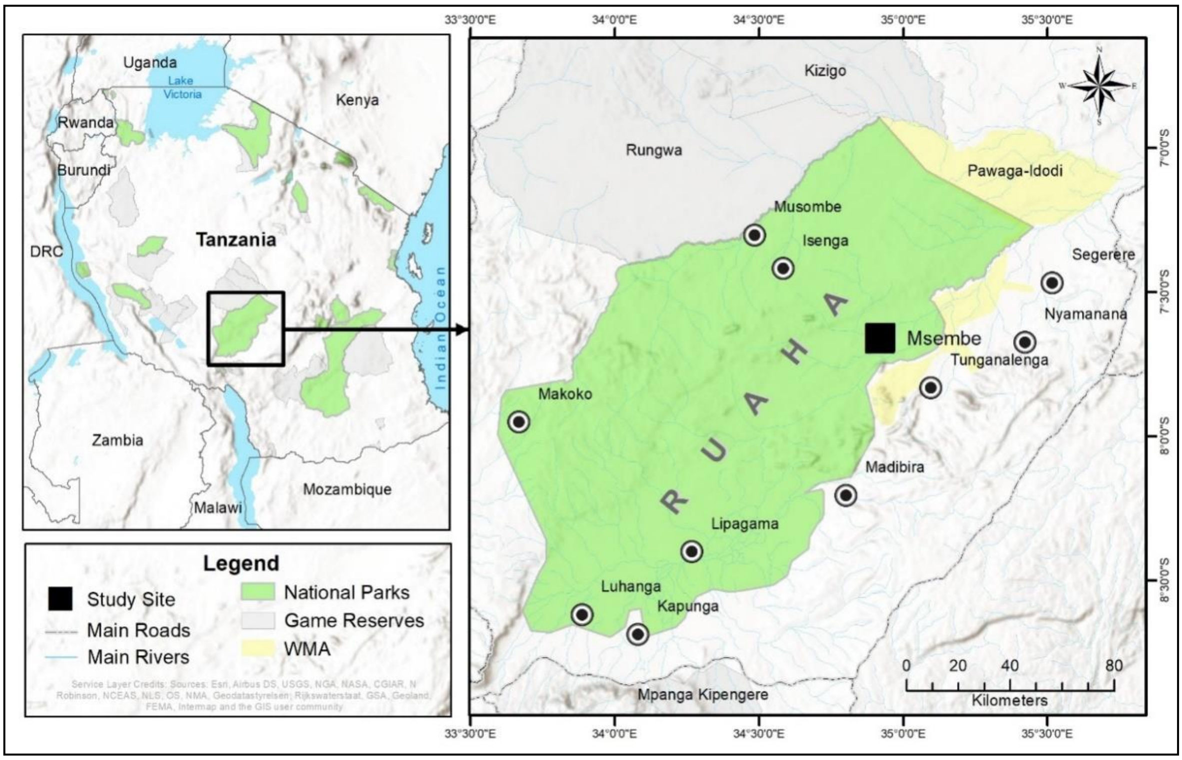

Figure 1. Study site location map.

2.2. Sampling Design

An intact plants control trial was established at Msembe site on 5th December 2022 using a Randomized Complete Block Design. The site had an estimate of 400 ha infested with *Calotropis procera*. The site was portioned by establishing square sampling plots of 35m x 35m dimension randomly distributed within the site. The layout for each plot is shown in figure 2.

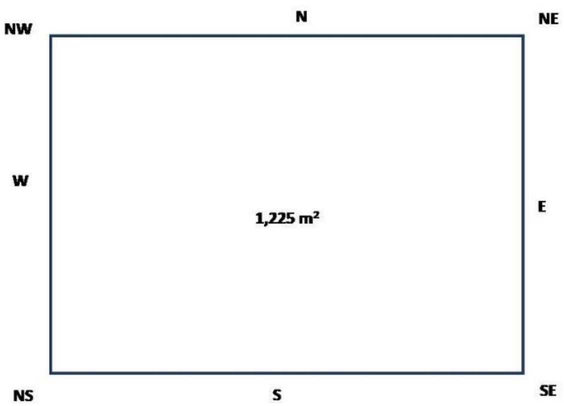

Figure 2. Layout of sampling plot.

Within each of the seven 35m x 35m plots, seven 5m x 5m sub-plots thus making a total of 21 sub-plots, which were marked using a Global Position System Receiver (GPS).

The trial incorporated seven herbicide treatments (Table 1), each one being administered at three of the 5m x 5m sub-plots (three replications).

Table 1. Experimental treatments.

Treatment	Description
T1	5% glyphosate
T2	12.5% glyphosate
T3	50% glyphosate
T4	100% glyphosate
T5	5% mixture of 1:1, glyphosate:2,4-D
T6	10% mixture of 1:1, glyphosate:2,4-D
T7	100% mixture of 1:1, glyphosate:2,4-D

The herbicide treatments were administered by making precise incisions into each stem and branch, with application amounts ranging from 10 to 20 millilitres per incision.

2.3. Data Collection

Environmental variables were measured on three occasions (December 2022, March, and July 2023) on the 42 sub-plots. The environmental parameters recorded in each experimental plot were as follows:

Altitude in meters (at SE), undesirable species name, canopy cover of callotrope abundance, habitat type, number of stems treated, dead plants, partially affected plants and plot photos (three photos taken at SE, first facing the NE, then facing the NS and lastly facing diagonal NW). All general and unique observations were recorded as comments. Other parameters measured included the location, time of day, soil temperature, light intensity, air temperature, humidity, and soil moisture and soil pH. In every subplot, six replicate measurements were recorded, three of them were recorded at 0.2m distance from the stem of a calotrope and the other three recorded at 5m distance from the calotrope.

2.4. Data Analysis

Analysis of data was done using R software version 4.2.2. Shapiro test was used for testing normality of data collected. The effect of treatments and period of herbicide application for controlling Calotrope was analyzed by using Analysis of Variance with type III sum of square. Then, Duncan multiple range test was used to undertake pairwise comparisons of means of all possible treatment combinations.

3. Results

Screening for Suitable Herbicide and Treatment Period

The environmental condition of the study site varied between morning and afternoon (Table 2).

Table 2. *Effect of period on various environmental parameters.*

Variable	Period		P-value	Level of significance
	Ante Meridiem	Post Meridiem		
Soil temperature	29.0°C	31.6°C	3.496×10^{-5}	***
Soil moisture	4.99 mm	4.64 mm	2.3439×10^{0}	NS
Soil pH	7.52	7.58	2.669×10^{-1}	NS
Light intensity	1302.25 cd	1366.70 cd	3.779×10^{-1}	NS
Air temperature	34.6°C	35.9°C	3.022×10^{-2}	*
Humidity	45.56%	38.09%	1.562×10^{-4}	***

The percentage of Calotrope mortality caused by herbicide treatments and period of herbicide application varied significantly ($p < 0.001$). A significant ($p < 0.001$) interaction was observed between herbicide application period and treatments (Table 3).

Table 3. *Anova table on effect of treatments and application period on mortality of calotrope.*

Variable	df	SS	MS	F	P-value	Level of significance
Period	1	2958.3	2958.3	43.879	2.2×10^{-9}	***
Treatment	2	30409.0	15204.5	225.520	2.2×10^{-16}	***
Period*Treatment	2	12246.3	6123.2	90.821	2.2×10^{-16}	***

Key: ***= Highly significant at P<0.001

The main factor that contributed to the interaction was the glyphosate herbicide. Glyphosate concentrations between 50% and 100% resulted in over 75% mortality of *Calotropis procera* when applied in the morning, whereas lower concentrations (< 50%) were most effective when applied in the afternoon, leading to approximately 50% mortality of the plants. (Figure 3a)

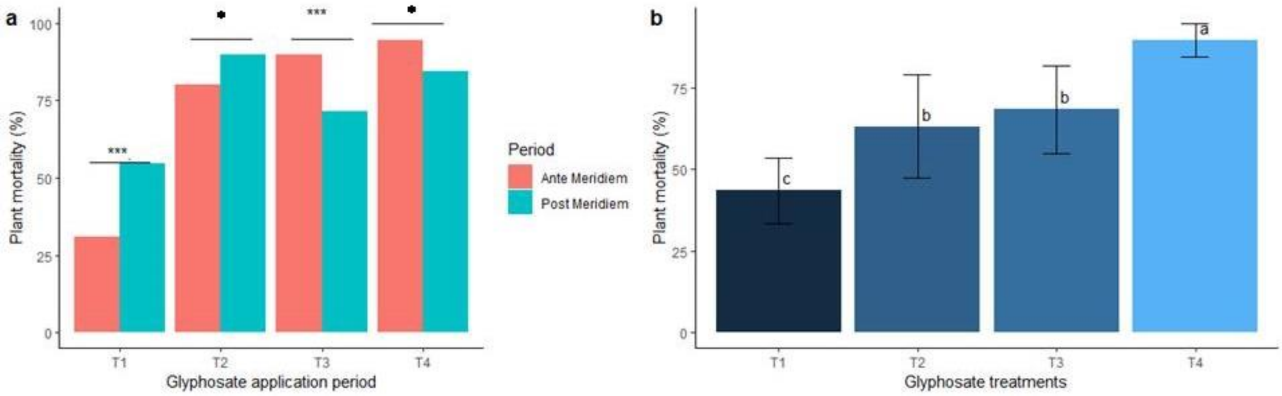

Figure 3. *Effect of glyphosate application period on Calotrope.*

Irrespective of glyphosate application period, plant mortality increased with increasing glyphosate content (Figure 3b) and variation in glyphosate treatments was significant at p< 0.001.

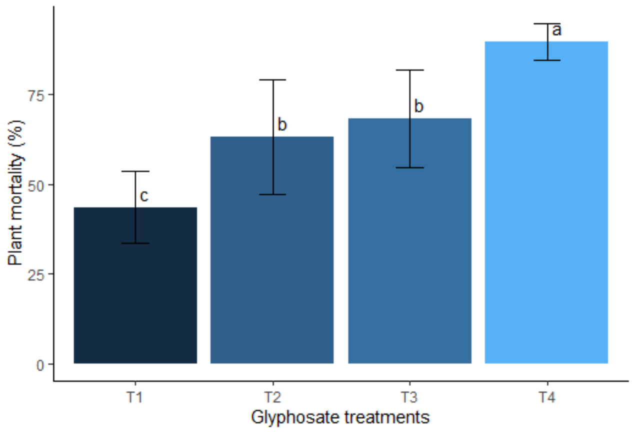

Figure 4. *Effect of glyphosate treatments on calotope mortality.*

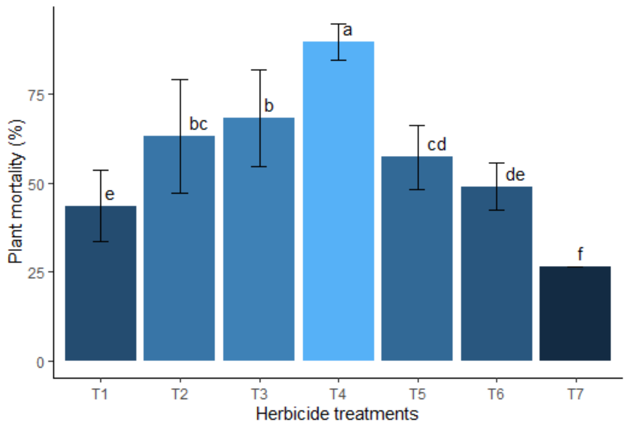

Figure 5. *Effect of herbicides on Calotrope mortality.*

Effectiveness of glyphosate herbicide treatments in calotrope mortality was significantly different at p<0.001 (Figure 4). Mixing of glyphosate and 2,4-D herbicides (T5, T6 and T7) resulted in a decline of calotrope mortality (Figure 5).

4. Discussion

The results suggest that the application of highly diluted, glyphosate can be effective in alleviating calotrope infestation in RUNAPA. This therefore implies that, glyphosate can be cost effective in controlling the spread of callotrope in the area. Callotrope on sub-plots applied with diluted glyphosate (<50%) showed higher death rate when injected in the afternoon. This observation concurs [12] who observed high efficacy of glyphosate on ragweed (*Ambrosia artemisiifolia*) when treated between noon and 18:00 p.m. This has an indication that, the success of herbicides application depends on environmental conditions before, during, and after herbicide application [13], because the environment (ambient temperature, and relative humidity) influences the growth and physiology of plants, as well as herbicide activity and the interaction between plant and herbicide [13-17].

In this study, a high efficacy of concentrated glyphosate (>50%) occurred during ante meridiem. The environmental condition during this period was low temperature and high humidity (Table 2). The observed variations in efficacy of concentrated and diluted glyphosate applied to calotrope during ante meridiem and post meridiem requires an understanding of the physiology of the Callotrope plant. According to [18] demonstrated that higher temperatures alter the composition of the cuticle, reducing ester content by 25% and increasing hydrocarbon content by 11%. Reduction of the wax deposition was correlated with higher efficacy of PROTOX-inhibiting herbicides. The second reason why temperature influences herbicidal activity is due to the fact that temperature is directly associated with the chemical reaction rate. Therefore, photosynthesis, plant metabolism, plant growth, and plant development are dependent on temperature. Temperature also influences evapo-transpiration;

thus, it affects the water condition of the plants, cuticle hydration, and mineral absorption [19]. At high temperatures, the flow of herbicide absorption is favoured due to reduced viscosity of the cuticle waxes and increased rate of herbicide diffusion through the cuticle. When high temperatures are associated with high values of relative humidity, there is strong hydration of the cuticle, which also favours the absorption and the efficacy of PROTOX inhibitors [20].

High relative humidity favours the efficacy of PROTOX inhibitors that include: high hydration of the cuticle, because it favours herbicide absorption; and high plant metabolic activity, as it favours the translocation of the compounds [21]. Presence of light favours efficacy of herbicide due to the presence of free radicals stimulated by light that enables herbicide to destroy cell membranes. Low light conditions reduce the number of free radicals produced, and decrease the harmful effects of PROTOX inhibiting herbicides to plants [22]. On the other hand, interaction among temperature, relative humidity and light intensity showed to favour the agronomic effectiveness of PROTOX inhibiting herbicides [23, 24]. Therefore, it is plausible to consider best time of effective herbicide application to control specific invasive plant species. This is because it is difficult to disentangle the effects of temperature, relative humidity and light intensity on plants physiology in the field. Nevertheless, each plant species has an optimum environmental condition for tissue development. This implies that plant species may respond differently to herbicide application within the same environmental condition. This entails a need to develop herbicide application protocol for specific invasive plant species.

Our study showed that mixing of glyphosate and 2,4-D herbicides resulted in low efficacy. This concurred with [25] who observed low efficacy of 2,4-D (amine/ester) and glyphosate mixture in controlling barnyard grass (*Echinochloa colona*). Low efficacy in herbicides mixture occurs due to synergism or antagonism [26, 27]. The cause of herbicides mixture synergism or antagonism can be due to altered herbicide uptake and/or translocation [26, 28] and metabolism [26, 29].

5. Conclusion

A careful stem application of Glyphosate proved to be effective in controlling Calotropis procera in wildlife Protected Areas, regardless of whether a concentrated or diluted herbicide solution was used. The efficacy of diluted solutions (<50%) was found to be highest when applied before noon, whereas concentrated solutions were most effective when applied in the afternoon.

Additionally, mixing Glyphosate with 2,4-D herbicides resulted in lower efficacy than using Glyphosate alone. Environmental factors, such as temperature, humidity, and light intensity, were also observed to influence the effectiveness of the herbicide treatments, underscoring the importance of considering these variables for optimal control of *Calotropis procera*.

Abbreviations

GPS	Global Position System Receiver
RUNAPA	Ruaha National Park

Author Contributions

Pius Yoram Kavana: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Writing – original draft

Bukombe John Kija: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – review & editing

Norbert Wanzara: Data collection and management, Preliminary analysis and reporting, reviewing the original draft & editing

Emmanuel Pagiti Reuben: Data collection and management, Preliminary analysis and reporting, reviewing the original draft & editing

Baraka Naftal Mbwambo: Data collection and management, Preliminary analysis and reporting, reviewing the original draft & editing

Julius DottoKeyyu: Funding acquisition, Writing – review & editing

Eblate Ernest Mjingo: Funding acquisition, Supervision, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Kaur, A., et al., An Overview of the Characteristics and Potential of Calotropis procera From Botanical, Ecological, and Economic Perspectives. Front Plant Sci, 2021. 12: p. 690806.

[2] Frosi, G., et al., Ecophysiological performance of Calotropis procera: an exotic and evergreen species in Caatinga, Brazilian semi-arid. Acta Physiologiae Plantarum, 2012. 35: p. 335 - 344.

[3] Ramadan, A., et al., Metabolomic Response of Calotropis procera Growing in the Desert to Changes in Water Availability. PLOS ONE, 2014. 9(2): p. e87895.

[4] Rivas, R., et al., Ecophysiological Traits of Invasive C(3) Species Calotropis procera to Maintain High Photosynthetic Performance Under High VPD and Low Soil Water Balance in Semi-Arid and Seacoast Zones. Front Plant Sci, 2020. 11: p. 717.

[5] Rivas, R., et al., Photosynthetic limitation and mechanisms of photoprotection under drought and recovery of Calotropis procera, an evergreen C(3) from arid regions. Plant Physiol Biochem, 2017. 118: p. 589-599.

[6] Parsons, W. T. and E. G. Cuthbertson, Noxious weeds of Australia. 2001: CSIRO publishing.

[7] Grace, B. S., The biology of Australian weeds. 45. Calotropis procera (Aiton) WT Aiton. Plant Protection Quarterly, 2006. 21(4): p. 152.

[8] Bukombe, J., et al., Calotropis procera (Apocynaceae) shrub intrusion on wildlife foraging rangelands in the Ruaha National Park. The Rangeland Journal, 2024.

[9] TANAPA, Guidelines for Invasive Alien Species Management in Tanzania National Parks. 2017.

[10] Sheley, R., et al., Invasive plant management on anticipated conservation benefits: a scientific assessment. Conservation benefits of rangeland practices: assessment, recommendations, and knowledge gaps. USDA Natural Resources Conservation Service, Lawrence, KS, USA, 2011: p. 291-336.

[11] Weladji, R. B. and M. N. Tchamba, Conflict between people and protected areas within the Bénoué Wildlife Conservation Area, North Cameroon. Oryx, 2003. 37: p. 72-79.

[12] Stopps, G. J., R. E. Nurse, and P. H. Sikkema, The Effect of Time of Day on the Activity of Postemergence Soybean Herbicides. Weed Technology, 2013. 27(4): p. 690-695.

[13] Park, H.-H., D.-J. Lee, and Y.-I. Kuk, Effects of Various Environmental Conditions on the Growth of Amaranthus patulus Bertol. and Changes of Herbicide Efficacy Caused by Increasing Temperatures. Agronomy, 2021. 11(9): p. 1773.

[14] Anderson, D., et al., The influence of temperature and relative humidity on the efficacy of glufosinate-ammonium. Weed Research, 1993. 33(2): p. 139-147.

[15] Bailey, S. W., Climate change and decreasing herbicide persistence. Pest Management Science: Formerly Pesticide Science, 2004. 60(2): p. 158-162.

[16] Chandrasena, N., How will weed management change under climate change? Some perspectives. Journal of Crop and Weed, 2009. 5(2): p. 95-105.

[17] Rodenburg, J., H. Meinke, and D. E. Johnson, Challenges for weed management in African rice systems in a changing climate. The Journal of Agricultural Science, 2011. 149(4): p. 427-435.

[18] Hatterman-Valenti, H., A. Pitty, and M. Owen, Environmental Effects on Velvetleaf (Abutilon theophrasti) Epicuticular Wax Deposition and Herbicide Absorption. Weed Science, 2011. 59(1): p. 14-21, 8.

[19] Zanatta, J. F., et al., Teores de água no solo e eficácia do herbicida fomesafen no controle de Amaranthus hybridus. Planta Daninha, 2008. 26: p. 143-155.

[20] Price, C., The effect of environment on foliage uptake and translocation of herbicides. 1983.

[21] Wills, G. D. and C. G. McWhorter, Effect of Environment on the Translocation and Toxicity of Acifluorfen to Showy Crotalaria (Crotalaria spectabilis). Weed Science, 1981. 29(4): p. 397-401.

[22] Krämer, W. and U. Schirmer, Modern crop protection compounds. 2007: Wiley-VCH.

[23] Cieslik, L. F., R. Vidal, and M. Trezzi, Fatores ambientais que afetam a eficácia de herbicidas inibidores da ACCase: Revisão. Planta daninha, 2013. 31: p. 483-489.

[24] Queiroz, R., R. A. Vidal, and A. Merotto Jr, Fatores que possibilitam a redução da dose dos herbicidas inibidores da enzima ALS: Revisão de literatura. Pestic Rev Ecotoxicol Meio Amb, 2013. 23: p. 25-36.

[25] Li, J., et al., 2,4-D antagonizes glyphosate in glyphosate-resistant barnyard grass *Echinochloa colona*. Journal of Pesticide Science, 2020. 45(2): p. 109-113.

[26] Peterson, M. A., et al., 2,4-D Past, Present, and Future: A Review. Weed Technology, 2016. 30(2): p. 303-345.

[27] Damalas, C., Herbicide tank mixtures: common interactions. 2004.

[28] Ou, J., et al., Reduced Translocation of Glyphosate and Dicamba in Combination Contributes to Poor Control of Kochia scoparia: Evidence of Herbicide Antagonism. Scientific Reports, 2018. 8(1): p. 5330.

[29] Han, H., et al., Enhanced herbicide metabolism induced by 2,4-D in herbicide susceptible Lolium rigidum provides protection against diclofop-methyl. Pest Manag Sci, 2013. 69(9): p. 996-1000.