Colegio de Postgraduados

Effect of Adjuvants in Herbicides for Weed Control in Maize (*Zea mays* L.) Crop

Arispe-Vázquez, José L.[1*]; Ramírez-Sánchez, Susana E.[2*]; Tamayo-Esquer, Luis M.[3]; Díaz-Nájera, José F.[4]; Terrones-Salgado, José[5]; Zárate-Martínez, William[6]; Toledo-Aguilar, Rocío[1]; Noriega-Cantú, David H.[1]; Cadena-Zamudio, Daniel, A.[7]; Ayvar-Serna, Sergio[4], Apáez -Barrios, M.[4]

[1] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Iguala, Km 2.5 Carretera Iguala-Tuxpan, Colonia Centro Tuxpan C. P. 40000, Iguala de la Independencia Guerrero, México.
[2] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental-Centro Altos de Jalisco, Av. Biodiversidad 2470 C. P. 47600, Tepatitlán de Morelos, Jalisco, México.
[3] INIFAP-CIRNO–Campo Experimental Norman E. Borlaug, Cd. Obregón, Sonora, México.
[4] Colegio Superior Agropecuario del Estado de Guerrero, Iguala de la Independencia, Guerrero, México. C. P. 40000.
[5] Decanato de Ciencias de la Vida y la Salud, Escuela de Ingeniería en Agronomía, Centro de Investigación en Horticultura y Plantas Nativas, UPAEP University, 21 sur No. 1103, Puebla, Puebla CP. 72410.
[6] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Saltillo, Carretera Saltillo-Zacatecas Km 8.5 No. 9515, Col. Hacienda de Buenavista, C. P. 25315, Saltillo, Coahuila, México.
[7] Interdisciplinary Research Group of *Sechium edule* in México (GISeM), Agustín Melgar 10, Texcoco, Estado de México, C.P. 56153 Mexico.
* Corresponding author: arispe.jose@inifap.gob.mx; ramirez.susana@inifap.gob.mx

Citation: Arispe-Vázquez, J. L., Ramírez-Sánchez, S. E., Tamayo-Esquer, L. M., Díaz-Nájera, J. F., Terrones-Salgado, J., Reveles-Hernández, M., Toledo-Aguilar, R., Noriega-Cantú, D. H., Cadena-Zamudio, D., A., Ayvar-Serna, S., & Apáez -Barrios, M. (2025). Effect of Adjuvants in Herbicides for Weed Control in Maize (*Zea mays* L.) Crop. *Agro Productividad*. https://doi.org/10.32854/n075fx11

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: May 29, 2024.
Accepted: April 30, 2025.
Published on-line: June XX, 2025.

Agro Productividad, 18(5). May. 2025. pp: 215-226.

ABSTRACT

Objective: This study aimed to evaluate the effect of paraffin oil combined with a mixture of oil-soluble surfactants (APMT) and vegetable oil plus polyalkylene oxide siloxane (ASOP) as adjuvants to enhance the efficacy of herbicides for the control of *Melochia nodiflora* and *Cynodon* species in maize (*Zea mays* L.) crop.
Design/Methodology/Approach: The experiment involved the use of synthetic chemical herbicides and a bioherbicide, applied at two dosage levels (50% and 100%), with or without the inclusion of either of the two adjuvants under evaluation. The experimental design was a randomized complete block with a factorial arrangement: factor A (herbicides) included seven levels, factor B (adjuvants) comprised four levels, and factor C (evaluation dates) involved eight levels. Each block covered an area of 12 m^2. Weed control effectiveness was assessed weekly using the scale proposed by the European Weed Research Society (EWRS). Data were expressed as percentages and subjected to arcsine transformation for statistical analysis. A three-way factorial ANOVA (A×B×C) and Tukey's mean comparison test ($\alpha \leq 0.05$) were conducted using SAS software.
Results: In factor A, the highest weed control effectiveness was observed with glyphosate, BH2 (bioherbicide), and dicamba+atrazine, achieving average control rates of 77.93%, 66.30%, and 54.91%, respectively. For factor B, the highest control rates were obtained with 50% herbicide doses combined with adjuvants, particularly APMT (55.85%) followed by ASOP (43.20%). Regarding factor C, the treatments exhibited their peak effectiveness during the third evaluation, conducted 21 days after application.
Limitations/Implications: The findings highlight the potential to improve the control of the studied weed species in maize crop and underscore the need to explore alternatives to glyphosate use.

Findings/Conclusions: The application of paraffin oil and a mixture of oil-soluble surfactants significantly enhanced the efficacy of herbicides, especially at the 50% dosage, for controlling weeds such as ammonium glufosinate, dicamba+atrazine, carfentrazone ethyl, and glyphosate. Notably, the combination with dicamba+atrazine showed the greatest improvement. Additionally, the use of vegetable oil plus polyalkylene oxide siloxane was particularly effective in enhancing the performance of 2,4-D+carfentrazone ethyl and BH2.

Keywords: Bioherbicide, effectiveness, chemical herbicides, adjuvants.

INTRODUCTION

Maize (*Zea mays* L.), like other crops, is susceptible to various pests, including weeds, insects, and fungi, which significantly impact grain production. Among these, weeds are particularly critical, as inadequate or untimely control leads to competition with crops for essential resources such as light, water, nutrients, and carbon dioxide (Aguilar, 2003; Esqueda *et al.*, 2009; Reséndiz *et al.*, 2016). Weeds can reduce yields by up to 80%, increase harvest costs, and affect product quality (Hernández-Ríos *et al.*, 2022). Currently, agricultural production has shown consistent growth, largely driven by the use of chemical products for pest, disease, and weed control. In this context, *Melochia nodiflora* (broadleaf: Malvaceae) and *Cynodon* species (narrowleaf: Poaceae) are commonly found in crop fields in Guerrero, Mexico, causing significant economic losses for farmers. Weed management in maize crop primarily relies on the application of synthetic chemical herbicides (Kandel *et al.*, 2019), including glyphosate ($C_3H_8NO_5P$), dicamba ($C_8H_6Cl_2O_3$), 2,4-D amine ($C_8H_6Cl_2O_3$), metolachlor ($C_{15}H_{22}ClNO_2$), atrazine ($C_8H_{14}ClN_5$), pendimethalin ($C_{13}H_{19}N_3O_4$), nicosulfuron ($C_{15}H_{18}N_6O_6S$), bentazon ($C_{10}H_{12}N_2O_3S$), and prosulfuron ($C_{15}H_{16}F_3N_5O_4S$) (INTAGRI, 2016). However, the repeated use of the same active ingredients has led to the development of resistance or multiple resistance in several weed species, posing a significant challenge to the sustainability of agriculture. Both in Mexico and globally, cases of herbicide-resistant weeds have been reported (Heap, 2024). Given this scenario, adopting more integrated and sustainable weed management approaches is essential. This includes the use of adjuvants, which optimize the efficacy of applied herbicides (Zimbdahl, 2000; Woznica *et al.*, 2007; Castro *et al.*, 2018; Bell *et al.*, 2019; Arispe-Vázquez *et al.*, 2024). Adjuvants are additives that enhance herbicide absorption and effectiveness, allowing for lower application doses and reducing the potential for leaching into groundwater, thus contributing to environmental preservation (Alva and Singh, 1991; Pannacci, 2010). There are three main categories of adjuvants: surfactants, oil-based adjuvants, and spray utility agents (Bell *et al.*, 2019). Examples include paraffin oil, vegetable oil, and polyalkylene oxide siloxane (a silicon-derived compound), commonly used as adjuvants in herbicide formulations (AB, 2025). Research is needed to identify effective adjuvants for herbicide mixtures to optimize weed control in the field while reducing the amount of active ingredients required (An *et al.*, 2024). Therefore, the aim of this study was to evaluate the effect of paraffin oil and a mixture of oil-soluble surfactants (APMT), as well as vegetable oil plus polyalkylene oxide siloxane (ASOP), as adjuvants to enhance herbicide efficacy for the control of *Melochia nodiflora* and *Cynodon* species in maize crop. The research hypothesis proposed that the use of adjuvants would have a synergistic effect on at least one of the herbicides under study.

MATERIALS AND METHODS

Study site

The research was conducted during the 2024 Spring-Summer cycle in a maize plot at the vegetative stage (V10), located at the National Institute of Forestry, Agricultural and Livestock Research – Iguala Experimental Field (INIFAP-CEIGUA) (Figure 1). The study site is situated at coordinates 17° 52' 54" N and 98° 45' 25" W, at an altitude of 750 meters above sea level.

Weed identification in the maize plot

The predominant weed species present in the maize plot prior to herbicide application were *Melochia nodiflora* Sw. (aquiche chiquito, Malvaceae) and later *Cynodon* species (stargrass, Poaceae), with plant heights ranging from 10 cm to 23 cm.

Experimental design

The experiment followed a randomized complete block design with a factorial arrangement and three replicates. Factor A (products) included seven levels, factor B (adjuvants) consisted of four levels, and factor C (evaluation dates) involved eight levels. Due to the plot dimensions, each experimental unit (block) measured 4 m in width by 3 m in length.

Treatment application

Synthetic chemical herbicides and one bioherbicide were applied at 50% and 100% dosage levels, with and without the use of adjuvants (Table 1, Figure 3). The water used for treatment application had a pH of 7.96 and an electrical conductivity of 0.62.

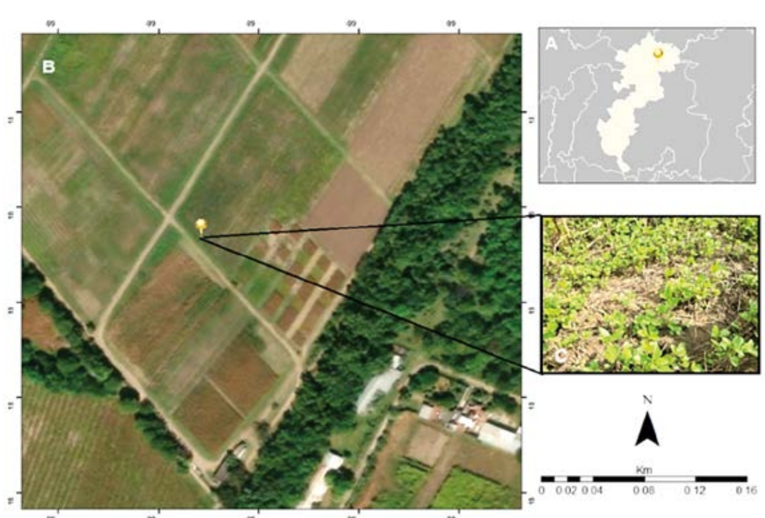

Figure 1. Geographic location of the experiment for weed control in the maize plot. A) Municipality of Iguala de la Independencia, Guerrero. B) Maize plot. C) Presence of weeds.

Table 1. Treatments applied for weed control in maize.

Active ingredient of the herbicide (factor A)	Dose (mL • 1 L^{-1})	Dose (%)	Adjuvant* (factor B)
Ammonium glufosinate	7.5	100	—
	3.75	50	—
	3.75	50	ASOP
	3.75	50	APMT
Dicamba+atrazine	5.62	100	—
	2.81	50	—
	2.81	50	ASOP
	2.81	50	APMT
2,4-D+carfentrazone ethyl	4.75	100	—
	2.37	50	—
	2.37	50	ASOP
	2.37	50	APMT
BH2 (bioherbicide)	15	100	—
	7.5	50	—
	7.5	50	ASOP
	7.5	50	APMT
Carfentrazone ethyl	0.375	100	—
	0.1875	50	—
	0.1875	50	ASOP
	0.1875	50	APMT
Glyphosate	15	100	—
	7.5	50	—
	7.5	50	ASOP
	7.5	50	APMT
Control	—	—	—
			—
			—
			—

BH2: bioherbicide based on mullein, coconut oil, pine resin, Puccinia fungus, and papain; ASOP: vegetable oil and polyalkylene oxide siloxane; APMT: paraffin oil and a mixture of oil-soluble surfactants; The application dose for both adjuvants was 2 mL·L^{-1} of water.

Weed control percentage

The evaluation was carried out weekly (a total of eight assessments), following the scale established by the European Weed Research Society (EWRS), expressed in percentage terms, where: 1=99-100% control; 2=96.5-99.0%, very good control; 3=93.0-96.5%, good control; 4=87.5-93.0%, sufficient control; 5=80.0-87.5%, moderate control; 6=50.0-80.0%, regular control; 7=50.0-70.0%, poor control; 8=1.0-50.0%, very poor control; and 9=0.0-1.0%, no effect (Champion, 2000).

Data analysis

The results were handled in percentage terms, and data adjustment was performed using arcsine transformation. A three-factor factorial analysis (A×B×C) was conducted, where A=herbicides (seven levels), B=doses (four levels), and C=evaluation dates (eight assessments). A mean comparison test was performed using Tukey's method ($\alpha \leq 0.05$), with the analyses conducted using SAS software (SAS Institute, 2012).

RESULTS AND DISCUSSION

There were significant differences observed across the three factors ($P<.0001$), with a coefficient of variation of 36.72. In factor A, the highest weed control effects were recorded with glyphosate, BH2, and dicamba+atrazine, with mean control rates of 77.93%, 66.30%, and 54.91%, respectively (Figure 2). Glyphosate [N-phosphonomethylglycine] functions through competitive inhibition of the enzyme 5-enolpyruvyl-shikimate-3-phosphate synthase, while dicamba+atrazine acts as a post-emergence herbicide for broadleaf weed control, with two active ingredients: dicamba, which disrupts growth by acting as a synthetic auxin, and atrazine, which inhibits photosynthesis at photosystem II (PSII) (HRAC, 2025). In contrast, BH2 is a systemic and contact bioherbicide with broad-spectrum activity, used for post-emergence control of both broadleaf and grassy weeds (BioTech, 2024). It is worth noting that the mode of action of organic herbicides tends to be less persistent and milder compared to synthetic chemical herbicides (Sigma, 2024). In this study, BH2 was the second most effective treatment in factor A, highlighting its potential as an alternative to glyphosate in maize crop. Excessive glyphosate use has led to an increase in the number of resistant weed biotypes (Steed *et al.*, 2013; Placido *et al.*, 2014), with 350 cases of glyphosate-resistant weeds reported worldwide (Arispe-Vázquez *et al.*, 2023). Therefore, alternatives to glyphosate are essential for achieving sustainable production systems that contribute to improving maize yields. Without effective weed control, yield losses can be severe or even total (Figure 3).

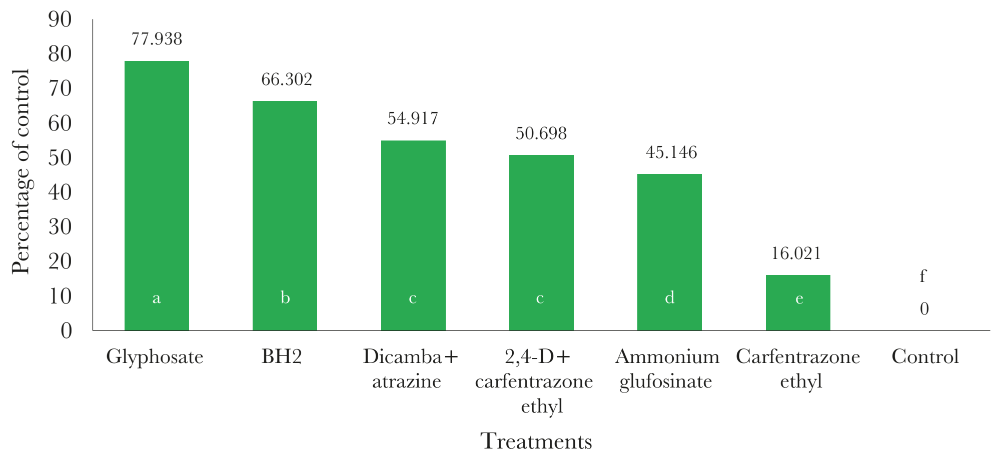

Figure 2. Factor A. Synthetic herbicides and bioherbicide used for weed control in maize crop. Treatments sharing the same letter are statistically similar (Tukey, 0.05).

Figure 3. Corn plot without adequate weed control.

In factor B, the use of adjuvants significantly enhanced the effectiveness of both herbicides and the bioherbicide. The application of herbicides at a 50% dose combined with adjuvants, particularly APMT and subsequently ASOP, resulted in higher weed control effectiveness, achieving 43.20% and 41.25%, respectively. In contrast, the treatments applied at a 50% dose without the use of adjuvants yielded the lowest control levels, with an effectiveness of only 37.41% (Figure 4).

To enhance efficacy, many post-emergence herbicides can be applied together with adjuvants, and some authors suggest that herbicide doses can be reduced when combined with adjuvants, achieving similar or even better effects compared to using the herbicide at full strength (Hart *et al*., 1992; Bunting *et al*., 2004; Bautista *et al*., 2020; Arispe-Vázquez *et al*., 2024). Several factors can influence herbicide application effectiveness, such as wind speeds greater than 15 km·h^{-1}, pH levels, high temperatures, and low relative humidity, which can promote droplet evaporation, leading to the loss of active ingredients and reduced control efficacy, as well as adverse environmental impacts (Farrera, 2004; Etchegoyen, 2017). In this study, applications were carried out at 8:00 a.m. under calm conditions, with wind speeds of only 3 km/h. Regarding factor C, the treatments reached their peak effectiveness during the third evaluation (21 days after application), with an average control rate of 60.29%. Although treatment effectiveness decreased in subsequent

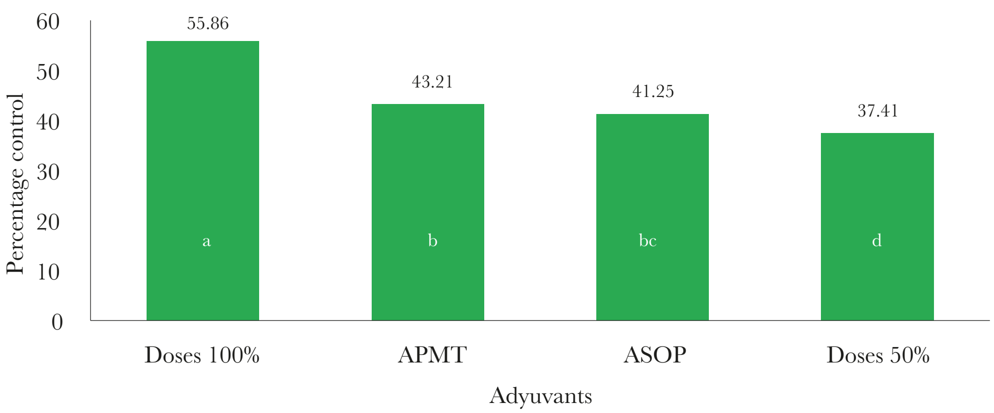

Figure 4. Factor B. Adjuvants used for weed control in maize crop. Treatments sharing the same letter are statistically similar (Tukey, 0.05).

evaluations, high control rates were still observed during the fifth evaluation (35 days after application) (Figure 5, Figure 6). Similarly, Rodríguez (2011), in an evaluation of post-emergence herbicides in maize in Jalisco, including tembotrione, aminopyralid+2,4-D, ammonium glufosinate, and dicamba+atrazine, reported a decline in effectiveness beginning at 30 days after application.

In the interaction between factors A*B, the glyphosate and dicamba+atrazine treatments stood out as the most effective for weed control in maize. For glyphosate, the 100% dose (15 mL L^{-1} water) achieved the highest control at 87.875%, followed by the 50% dose (7.5 mL L^{-1} water) combined with APMT, which reached 80.833%. In the case of dicamba+atrazine, the 100% dose achieved 82.917% control, while the 50% dose (2.81 mL L^{-1} water) combined with APMT resulted in 72.167% control. Notably, in both cases, the use of the herbicide at 50% combined with the APMT adjuvant provided a higher weed control effect compared to the 50% herbicide dose applied without adjuvant (Table 2). These results align with those reported by Brankov *et al.* (2023), who indicated that low herbicide doses combined with adjuvants showed no significant differences in effectiveness compared to full herbicide doses without adjuvant addition. Reducing herbicide amounts through the use of adjuvants decreases chemical input into the environment, thereby reducing potential contamination of soil, water, and air, and lowering the risk of adverse effects on non-target organisms such as beneficial insects, birds, and other wildlife.

It is important to emphasize that not all herbicides should be applied with any adjuvant, as synergistic results are not always guaranteed. Certain herbicides may be incompatible with specific adjuvants, and their combination may lead to unpredictable interactions or interference between their modes of action (Espinoza *et al.*, 2012). Such antagonistic reactions can reduce weed control efficacy (Holshouser and Coble, 1990; Burke *et al.*, 2002). Therefore, it is recommended to review existing information about the specific herbicide and adjuvant combination before use. In the absence of documented compatibility, a small preliminary test is advised before full-scale application. In the interaction between factors B*C, the highest control effect was observed with the 100% dose during the second evaluation, achieving 72.857%. The second-best result corresponded to the use of APMT during the third evaluation week, with 59.429% control (Table 2). Finally, in the interaction

Figure 5. Factor C. Evaluation dates for weed control in maize crop. Treatments sharing the same letter are statistically similar (Tukey, 0.05).

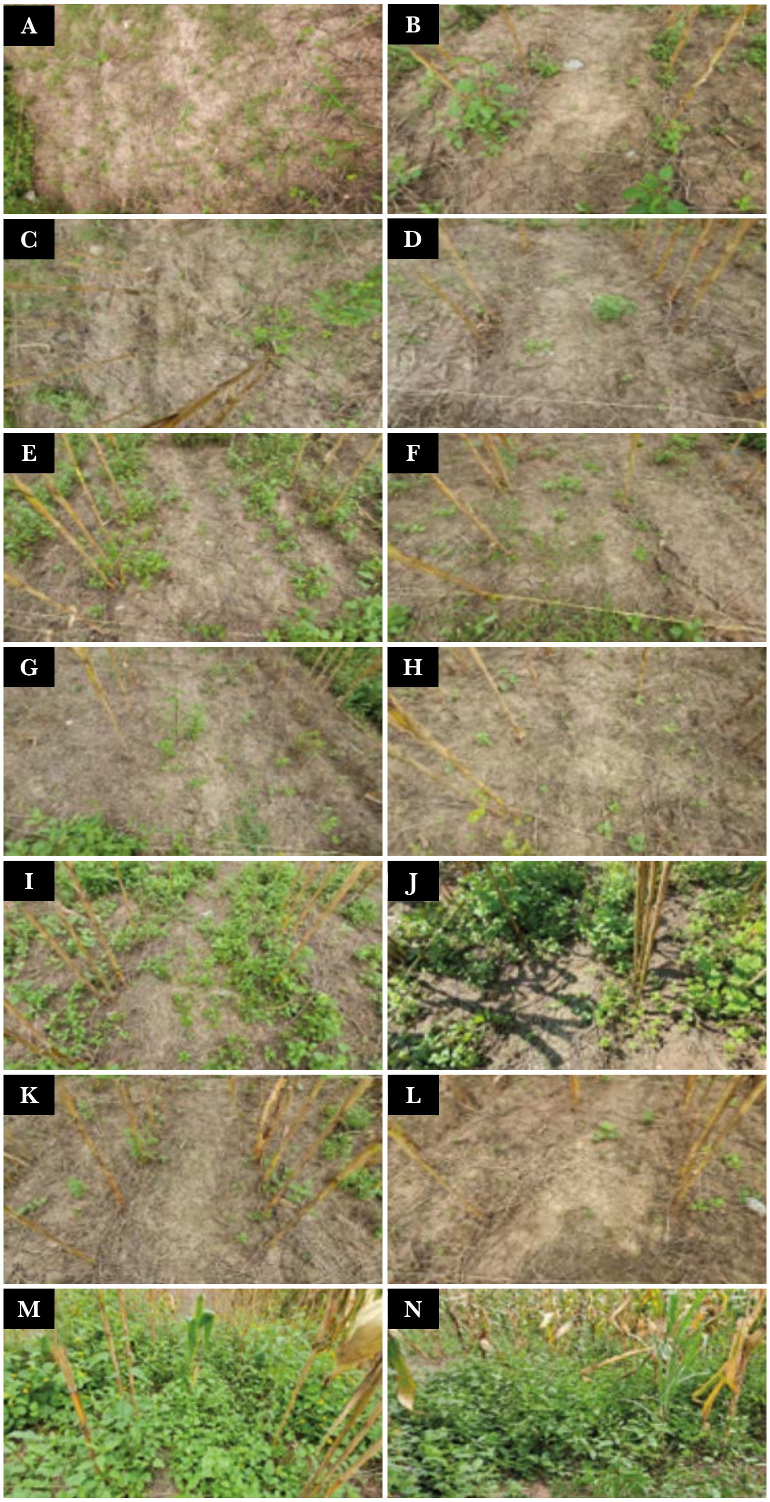

Figure 6. Effect of treatments during the fifth evaluation (35 days after application). A=ammonium glufosinate at 50%; B=ammonium glufosinate+APMT (2 mL L^{-1} of water); C=dicamba+atrazine at 50%; D=dicamba+atrazine at 50%+APMT (2 mL L^{-1} of water); E=2,4-D+carfentrazone ethyl at 50%; F=2,4-D+carfentrazone ethyl at 50%+ASOP (2 mL L^{-1} of water); G=BH2 at 50%; H=BH2 at 50%+ASOP (2 mL L^{-1} of water); I=carfentrazone ethyl at 50%; J=carfentrazone ethyl at 50%+APMT (2 mL L^{-1} of water); K=glyphosate at 50%; L=glyphosate at 50%+APMT (2 mL L^{-1} of water); MN=control (some weeds taller than the maize plants).

between factors A*C, the treatments showing the highest weed control were glyphosate and BH2 during the third evaluation week, achieving 96.417% and 80.0% control, respectively (Table 2). It is important to note that glyphosate is a synthetic chemical herbicide, while BH2 is a bioherbicide. Typically, bioherbicides exhibit milder action and tend to decompose more rapidly in the environment (Sigma, 2024).

Table 2. Interaction between factors A, B and C in weed control in corn crops.

AB	Average	Sg	BC	Average	Sg	AC	Average	Sg
61	87.875	a	12	72.857	a	63	96.417	a
21	82.917	ab	13	72.286	a	64	95.75	ab
64	80.833	ab	14	71.667	a	62	94.917	abc
41	73.292	abc	11	62.952	ab	61	89.167	abcd
63	73.167	abc	15	60.524	abc	43	88.000	abcd
43	73.125	abc	43	59.429	abc	44	87.667	abcd
42	72.417	abc	32	58.429	abc	65	85.917	abcde
24	72.167	abc	33	58.143	abc	42	85.000	abcde
62	69.875	abc	44	57.857	abc	33	77.333	abcdef
31	65.792	bcde	42	57.095	abcd	34	77.083	abcdef
33	60.667	bcde	34	55.476	abcde	66	75.75	abcdef
11	54.042	defg	23	51.333	bcdef	22	72.167	abcdefg
14	52.458	defg	16	50.952	bcdefg	11	72.083	abcdefg
12	49.583	efg	22	50.952	bcdefg	23	71.75	abcdefg
44	46.375	fg	41	50	bcdefg	45	70.917	abcdefg
23	46.042	fg	24	49.857	abcdefg	24	70.250	abcdefg
32	39.25	gh	31	47.714	bcdefgh	12	70.250	abcdefg
34	37.083	gh	35	44.619	bcdefgh	32	68.833	bcdefg
51	27.083	hi	21	44.571	bcdefgh	41	68.417	bcdefg
13	24.500	hi	45	43.667	cdefgh	13	65.667	defgh
22	18.542	i	25	38.286	defghi	46	62.917	defghi
54	13.542	ij	46	37.857	efghij	14	62.75	defghi
52	12.208	ij	36	32.762	fghijk	35	60.417	efghij
53	11.25	ij	17	32.048	ghijk	25	60.167	efghij
71	0	j	26	30.476	hijk	21	54.667	fghijk
72	0	j	47	23.81	ijk	67	51.833	fghijkl
73	0	j	18	23.571	ijkl	26	48.583	ghijklm
74	0	j	37	20.238	ijkl	36	46.5	ghijklm
-	-	-	27	19.048	jkl	47	40	hijklmn
-	-	-	48	15.952	kl	15	39.583	hijklmn
-	-	-	28	14.762	kl	51	39	hijklmn
-	-	-	38	12.619	l	31	35.833	hijklmn
-	-	-	-	-	-	27	35.5	jklmno
-	-	-	-	-	-	68	33.75	jklmno

Table 2. Continues...

AB	Average	Sg	BC	Average	Sg	AC	Average	Sg
-	-	-	-	-	-	52	27.667	klmnop
-	-	-	-	-	-	48	27.5	lmnop
-	-	-	-	-	-	16	27.5	lmnop
-	-	-	-	-	-	28	26.25	lmnopq
-	-	-	-	-	-	37	22.917	mnopq
-	-	-	-	-	-	53	22.917	mnopq
-	-	-	-	-	-	54	17.5	nopq
-	-	-	-	-	-	38	16.667	nopq
-	-	-	-	-	-	17	13.75	nopq
-	-	-	-	-	-	55	10.417	nopq
-	-	-	-	-	-	18	9.583	q
-	-	-	-	-	-	56	4.833	q
-	-	-	-	-	-	58	3.333	q
-	-	-	-	-	-	57	2.5	q
-	-	-	-	-	-	71	0	q
-	-	-	-	-	-	72	0	q
-	-	-	-	-	-	73	0	q
-	-	-	-	-	-	74	0	q
-	-	-	-	-	-	75	0	q
-	-	-	-	-	-	76	0	q
-	-	-	-	-	-	77	0	q
-	-	-	-	-	-	78	0	q

Sg: Statistical grouping. Treatments sharing the same letter are statistically similar (Tukey, 0.05).

CONCLUSIONS

The use of paraffin oil combined with a mixture of oil-soluble surfactants enhanced the weed control effect when herbicides were applied at 50%, particularly with ammonium glufosinate, dicamba+atrazine, carfentrazone ethyl, and glyphosate, with dicamba+atrazine standing out as the most effective. In contrast, the combination of vegetable oil plus polyalkylene oxide siloxane improved the effectiveness of 2,4-D+carfentrazone ethyl and BH2. The use of adjuvants in herbicide applications may offer multiple benefits; however, it also presents challenges that must be addressed to maximize their effectiveness and sustainability.

ACKNOWLEDGMENTS

The authors would like to thank INIFAP for the project Alternatives to the use of glyphosate for weed control in Mexico 2024 (12555536716), and the technical staff involved in this research. The authors also express their gratitude for the valuable comments and suggestions from the anonymous reviewers, which have undoubtedly helped to strengthen this article. Special thanks to Suleika Susana Aquino Ramírez for creating the map.

REFERENCES

AB (2025). AgroBase aceite parafínico. https://agrobaseapp.com/australia/pesticide/paraffinic-oil

Aguilar, C.A. (2003). Control pre emergente de arvenses en maíz. Tesis de Licenciatura. Colegio Superior Agropecuario del Estado de Guerrero CSAEGro. Iguala, Gro. p. 80.

Alva, A.K., & Singh, M. (1991). Use of adjuvants to minimize leaching of herbicides in soil. *Environmental Management* 15: 263-267. https://doi.org/10.1007/BF02393858

An, K., Feng, X., Ji, J., Wang, X., Pang, M., Liu, T., Wang, S., Shi, H., Dong, J., & Liu, Y. (2024). Synergistic mechanism and environmental behavior of tank-mix adjuvants to topramezone and atrazine. *Environmental science and pollution research international 31*(13): 20246-20257. https://doi.org/10.1007/s11356-024-32389-9

Arispe-Vázquez, J.L., Cadena-Zamudio, D.A., Tamayo-Esquer, L.M., Noriega-Cantú, D.H., Toledo-Aguilar, R., Felipe-Victoriano, M., Barrón-Bravo, O.G., Reveles-Hernández, M., Ramírez-Sánchez, S.E., & Espinoza-Ahumada, C.A. (2023). A review of the current panorama of glyphosate resistance among weeds in Mexico and the rest of the world. *Agroproductividad*. https://doi.org/10.32854/agrop.v16i7.2618

Arispe-Vázquez, J.L., Noriega-Cantú, D.H., Toledo Aguilar, R., & Flores-Hernández, L.A. (2024). The Impact of Polydimethylsiloxane as a Herbicide Adjuvant for Weed Control in the *Lime citrus*×*aurantifolia* (Christm.) Swingle Plot. *Journal of Agricultural Science* 16: 22-33.

Bautista, C.P., Guadalupe, J., Travlos, I., Tataridas, A., & Prado, R.D. (2020). Effect of adjuvant on glyphosate effectiveness, retention, absorption and translocation in *Lolium rigidum* and *Conyza canadensis*. *Plan Theory* 9: 297. https://doi.org/10.3390/plants9030297

BioTech, (2024). ¿Como funciona Herbitech? https://biotechmexico.com/herbitech

Brankov, M., Vieira, B.C., Alves, G.S., Zaric, M., Vukoja, B., Houston T., & Kruger, G.R. (2023). Adjuvant and nozzle effects on weed control using mesotrione and rimsulfuron plus thifensulfuron-methyl. *Crop Prot*. 167: 106209. https://doi.org/10.1016/j.cropro.2023.106209

Bunting, J.A., Sprague, C.L., & Riechers, D.E. (2004). Absorption and activity of foramsulfuron in giant foxtail (*Setaria faberi*) and woolly cupgrass (*Eriochloa villosa*) with various adjuvants. *Weed Sci* 52: 513-517. https://doi.org/10.1614/WS-03-135R

Burke, I.C., Wilcut, J.W. & Porterfield, D. (2002). CGA 362622 antagonizes annual grass control with clethodim. *Weed Technology* 16: 749-754.

Castro, E., Carbonari, C., Velini, E., Gomes, G., y Belapart, D. (2018). Influencia de los adyuvantes en la tensión superficial, la deposición y la eficacia de los herbicidas en las plantas de pulgas. *Planta daninha* 36: e018166251.

Champion, G.T. (2000). Bright and the field scale evaluations herbicides tolerant. GM Trials. *AICC Newsletter*, December.

Espinoza, V.E.E., Pitty, A., Trabanino, R. (2012). Efectividad de dos Formulaciones de Clethodim en el Control de Gramíneas y su Antagonismo con Bentazon. *Ceiba 53*(1): 57-64. https://doi.org/10.5377/ceiba.v53i1.2016

Esqueda, E.V.A., Rosales, R.E., & Tosquy, V.O.H. (2009). Efectividad de aminopyralid+2,4-D sobre cuatro especies de arvenses en pastizales tropicales. *Agronomía Mesoamericana* 20: 71-79.

Etchegoyen, J. (2017). Recomendaciones técnicas para aplicaciones eficientes. http://tropfen.com.ar

Farrera, R. (2004). Acerca de los plaguicidas y su uso en la agricultura. CENIAP HOY, 6.

Hart, S.E., Kells, J.J., & Penner, D. (1992). Influence of adjuvants on the efficacy, absorption, and spray retention of primisulfuron. *Weed Technol* 6: 592-598. https://doi.org/10.1017/S0890037X00035855

Heap, I. (2024). The International Herbicide-Resistant Weed Database. www.weedscience.org

Hernández-Ríos, I., Osuna-Ceja, E.S., Pimentel-López J., & García-Saucedo, P. (2022). Control de malezas en maíz, frijol, girasol y sorgo: Efecto de métodos de control bajo dos sistemas de siembra. *Agro-Divulgación 2*(6): 1-7. https://doi.org/10.54767/ad.v2i6.137

Holshouser, D.L. & Coble, H.D. (1990). Compatibility of sethoxydim with five postemergence broadleaf herbicides. *Weed Technology* 4:128-133.

HRAC, (2025). 2024 HRAC Global Herbicide MoA Classification. https://hracglobal.com/tools/2024-hrac-global-herbicide-moa-classification

INTAGRI, (2016). Manejo de herbicidas en maíz, Serie cereales. Núm. 17. Artículos técnicos de INTAGRI. México. 4 p.

Jourdan, M.B., Dotray, P., & Grichar, G. (2019). Adjuvants: Why are adjuvants important and what is the difference between adjuvants?. Texas A&M AgriLife Research and Extension. SCS-2019-12 pp. 1-3. https://oaktrust.library.tamu.edu/server/api/core/bitstreams/cd895b19-eb57-406a-97be-016270bc384d/content

Kandel, G., Adhikari, B., Adhikari, R. & Kandel, B. (2019). Evaluation the growth, productivity, and profitability of rice (Sukhadhan-3 variety) under different methods of weed management. *Journal of Research in Weed Science* 2: 381-392.

Pannacci, E., Mathiassen, S.K., & Kudsk, P. (2010). Effect of adjuvants on the rainfastness and performance of tribenuron-methyl on broadleaved weeds. *Weed Biol Manage* 10: 126-31. https://doi.org/10.1111/j.1445-6664.2010.00376.x

Placido, H., González-Torralva, F., Martins, A., Paiola, A., Menéndez, J., y De Prado, R. 2014. Resistencia a glifosato en biotipos de *Chloris polydactyla* (L.) SW. recolectados en Brasil. *Revista Agropecuaria y Forestal 2*(1): 19-22 .

Reséndiz, R.Z., López, S.J.A., Osorio, H.E., Estrada D.B., Pecina, M.J.A., Mendoza, C.M.C. & Reyes, M.C.A. (2016). Importancia de la resistencia del maíz nativo al ataque de larvas de lepidópteros. *Temas de Ciencia y Tecnología*, 20: 3-14.

Rodríguez, D.E. (2011). Evaluación de herbicidas postemergentes en lotes de producción de semilla de maíz en Sayula, Jalisco. Tesis de Licenciatura. UAAAN. pp. 1-124

SAS Institute, (2012). SAS/STAT User's Guide: Software Version 9.4. Statistical Analysis System Institute. Cary, North Carolina, USA.

Sigma, (2024). Herbicidas Orgánicos para Agricultura Sostenible. https://sigma-agro.com/agroquimico/herbicidas-orgnicos-para-agricultura-sostenible

Steed, S.T., Robert, H.S., & Rodrigo, D. (2013). Uso Apropiado y manipulación de Glifosato en viveros de plantas: ENH1209 EP470, 2 2013". EDIS. Gainesville, FL. https://doi.org/10.32473/edis-ep470-2013.

Woznica, Z., Idziak R., Waniorek W. (2007) Effect of adjuvants on possibility of herbicide rate reduction for weed control in sugar beet. *Frag Agron* 24: 261-6.

Zimbdahl, R.L. (2000). Herbicide formulation. *J Toxicol Clin Toxicol* 38:129-35.