THE MAIZE TRUST

Reg no. IT8214/98

c/o L&L Agricultural Services
Grain Building Agri-hub
477/478 Witherite Street
THE WILLOWS
0184

P.O. Box 74626
LYNNWOOD RIDGE
Pretoria
0040

Tel: +27 (12) 807-3958
e-mail: beatrix@agrimanage.co.za

Annual Final Report – Production Research

Title of Research Project:	Annual efficacy evaluation of registered pre-emergence herbicides for the control of grass weeds
Name and Trading Name of the Institution/Employer:	ARC-Grain Crops
Name of Lead Researcher:	Dr Maryke Craven
Contact details of Lead Researcher ***E-mail address:*** ***Phone:***	CravenM@arc.agric.za 018 2996346 O83 3663662
Duration of Proposed Study:	Two-years 1 April 2022 - 31 March 2024
Maize Trust funding received for current year:	R87 995 (April 2023-March 202)(2nd year)
Are there changes to the original project proposal (yes/no)	No

1. Summary of Progress

Please provide the main findings of the project during the funding year and the remaining challenges. Please do so at hand of the Gantt Chart submitted during the application process.

The efficacy of selected pre-emergent herbicides to control grasses were evaluated across two consecutive seasons (2022/23 and 2023/24). In both seasons, an early ("Trial 1") and late ("Trial 2") application date were evaluated at two sites i.e. Bethlehem (16% clay) and Potchefstroom (35% clay). Trials were laid out as a randomized complete block design with four replicates. Each treatment plot was flanked by an untreated control plot. Percentage ground cover (%) ratings were recorded approximately every two weeks for a period of 10 to 14 weeks. Linear, exponential and logistic regression analyses were conducted by plotting % grass cover per plot against time. The best fitted model was selected per plot and the time it took each treated plot and its respective dirty control plots to reach 10% weed cover (or 90% weed control) deducted (referred to as "T90"). *Extended control* (ExtCrl) was subsequently calculated which is the weeks of additional control achieved by the treated plot compared to its adjacent untreated control plots. Analysis of variance was conducted using the ExtCrl parameter as variable for each trial respectively (P=0.05). The wetter 2022/23 resulted in only Trial 1 of each site being analysed statistically. At both sites no significant differences were observed between the herbicides. With the drier 2023/24, Trial 1 of both sites did not give significant differences between the various herbicides. Trial 2 at Bethlehem did yield significant differences which were preliminary attributed to leaching. At Potchefstroom (2023/24), the presence of *Rottboellia conchinchinensis* severely hampered the efficacy of the herbicides as none of them are registered for its control. With early season application, some grass control were observed during both seasons, whereas later applications were totally insufficient. Although no problematic cases were identified where specific products consistently underperformed compared to their counterparts, large variation in all trials emphasised the need to re-evaluate of research protocols and statistical analyses pertaining to comparative pre-emergent herbicide studies. The data as analysed and presented represents the most suited approached to date but can be improved through further studies.

Annexure A represents the final report on research findings of project.

2. Additional information

(*e.g. Tables; Figures; Contributions by co-workers; Brief discussion of accomplishments*)

The gantt chart as submitted during the project proposal phase is presented in Figure 1.

2.1. Acknowledgements

ARC-Grain Crops would like to acknowledge the following companies for their generous contributions in the form of products supplied:

AECI, BASF, Philagro, Syngenta and VillaCrop

3. Please report on the deliverables and milestones:

(As presented in section 6 of Application)

The main objectives for the set period (1April 2023 – 15 June 2024) were

- Two field trials (early and late) were initiated at Potchefstroom (35% clay) and Bethlehem (16%) respectively.
- Trials were monitored for a period of approximately two months after which data was analysed and analyses of variance conducted on each trial respectively.

4. Changes to project

Describe changes to the project, provide justification for the changes and impact on outcomes.

None

5. Scientific Outputs

(*Give full references and indicate poster or oral presentation for conference contributions*)

Scientific papers:	None
Technical reports:	Annual report submitted during June 2024 Craven M. 2024. Efficacy of graminicide-glyphosate tank mixtures and optimal application time for long term couch grass control in maize-soybean rotation systems. Maize Trust Annual report. 15 June 2024. (P05000145)
Articles in industry magazines:	1. Craven, M. 2023. ‘n Lewe met weerstandige onkruid. SA Graan/Grain. December 2023. Pp8-11. 2. Craven,M. 2024. Best practice to curb herbicide resistant weeds. SA Graan/Grain. March 2024. Pp 58-62
Conference contributions:	1. Craven, M., Mofokeng, P., Manzini, S.N. Saayman-du Toit, A.E.J. 2024. Glyphosate resistance survey of *Conyza* species and herbicide efficacy evaluation. 22-25 January 2024. Wildernis Hotel, George. 2. Craven, M., Mofokeng, P., Manzini, S.N. Saayman-du Toit, A.E.J. 2024. Efficacy evaluation of spray programmes for the control of glyphosate resistant *Conyza* species under conservation agriculture. Wildernis Hotel, George. 3. Bello ZA, **Craven M, Manzini** S, Mashingaidze K. 2024 Evaluating germination rate and development of exotic lines of pigeon pea. ARC-DALRRD Conference. 12-14 February 2024. ARC-VIMP. Roodeplaat, Pretoria.
Human capacity development:	
Technology transfer:	1) **Manzini SN,** 14-18 August 2023. NWDARD TRAINING: PROGRAMME. Weed control strategies. Two presentations given: 42 attendees 2) **Mofokeng**, P.21-25 August 2023. NWDARD TRAINING: PROGRAMME. Weed control strategies. Two presentations given: 22 attendees 3) **Manzini SN,** 28-01 September 2023. NWDARD TRAINING: PROGRAMME. Weed control strategies. Two presentations given:21 attendees 4) **Manzini SN**, 2-6 September 2023 . NWDARD TRAINING: PROGRAMME. Weed control strategies. Two presentations given:43 attendees 5) Rhode, O, Thobakgale, M., Mokhele, A., **Manzini, S.,** Letlojane, P., Snijman, W., Trained 9 farmers on NWDARD Accredited Training Crop Production Course for farmers at Tladistad Library, North West on 2-6 October 2023. 6) Rhode, O, Thobakgale, M., Mokhele, A., **Manzini, S.,** Letlojane, P., Snijman, W., Trained 15 farmers on NWDARD Accredited Training Crop Production

	Course for farmers at Tladistad Community Hall, North West on 2-6 October 2023. 7) Rhode, O, Thobakgale, M., Mokhele, A., **Manzini, S.,** Letlojane, P., Snijman, W., Trained 24 farmers on NWDARD Accredited Training Crop Production Course for farmers at Thutlwane North West on 9-13 October 2023. 8) Rhode, O, Thobakgale, M., Mokhele, A., **Manzini, S.,** Letlojane, P., Snijman, W., Trained 11 farmers on NWDARD Accredited Training Crop Production Course for farmers at Mothotlung, North West on 16-20 October 2023.
Other outputs (Procedures, Methods, Databases, etc):	None

6. Personnel / Management / Risk factors that influenced progress and lessons learned (*if applicable*)

N/A

7. Budget and budget justification for the next year of project

Please present the detailed budget for the full duration of the study, per individual year, as well as co-funding. Please indicate the annual amounts requested from the Maize Trust for the duration of the project. State how each item of expenditure is relevant to the project, and how the amounts have been calculated (e.g. give a breakdown of travel costs per km, number of trips, etc. instead of only a total for travel cost).

The following items are not eligible for funding:

Item	Project total amount	Amount requested from MT	Maize Trust %	Justification
Year 1 (Finalised)				
Project Budget Total	R282 369	R141 185	50%	Detailed in Table 3
Subtotal year 1	R282 369	R141 185		
Year 2 (Finalised)				
Project Budget Total	R175 990	R87 995	50%	Detailed in Table 3
Subtotal year 2	R175 990	R87 995		
Total of Project over 2 years	**R458 359**	**R229 180**		

8. Conclusions and Comments you wish to share with the Trust

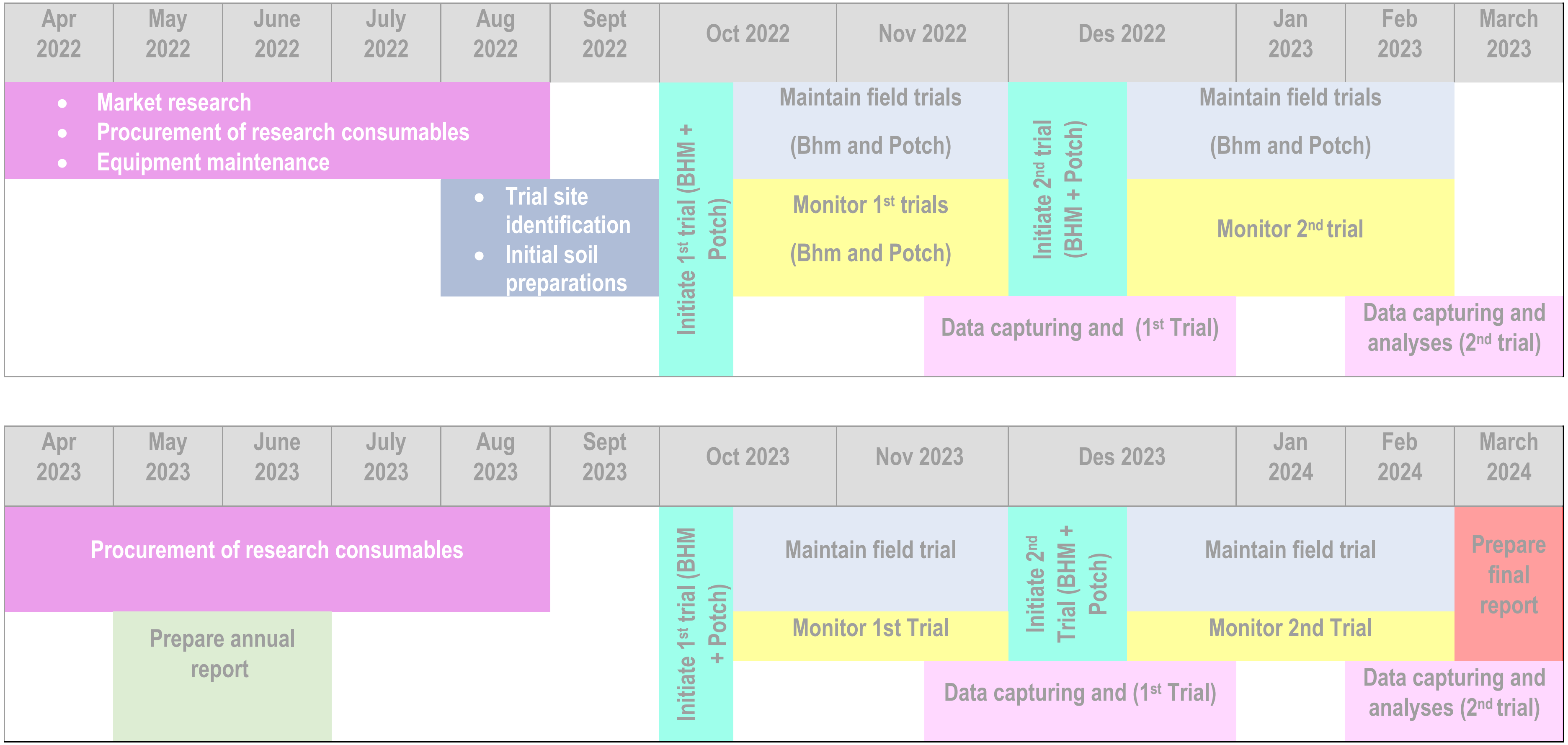
The challenging climatic condition experienced during especially the extremely wet first season (2022/23) did provide valuable insight regarding the efficacy of pre-emergent herbicides under such conditions. How data is generated and subsequently analysed in such pre-emergent herbicide studies also highlighted the short cummings of various approaches. The data as analysed and presented in the Final report (Annexure A) represents the most suited approached to date, but can be improved through further studies. The current project aimed to compare various pre-emergent herbicide products for their efficacy. Although none of the analyses across the various trials indicated any significant differences observed between the products, large variation between replicates of the same treatment were evident in all trials. Either this is the result of monitoring and data analyses that still need to be optimised, or there is much more to how actives react in the soil in response to external influences.

Should the Maize Trust see the value in the type of data generated through these pre-emergent herbicide evaluation trials, it will be possible for ARC-Grain Crops to continue with them as per recommendation/or request by the Maize Trust.

9. Signature of Project Leader

MCraven

Name, Signature, Place and Date



Apr 2022	May 2022	June 2022	July 2022	Aug 2022	Sept 2022	Oct 2022	Nov 2022	Des 2022	Jan 2023	Feb 2023	March 2023
Market research Procurement of research consumables Equipment maintenance						Initiate 1st trial (BHM + Potch)	Maintain field trials (Bhm and Potch)	Initiate 2nd trial (BHM + Potch)	Maintain field trials (Bhm and Potch)		
				Trial site identification Initial soil preparations			Monitor 1st trials (Bhm and Potch)		Monitor 2nd trial		
							Data capturing and (1st Trial)			Data capturing and analyses (2nd trial)	

Apr 2023	May 2023	June 2023	July 2023	Aug 2023	Sept 2023	Oct 2023	Nov 2023	Des 2023	Jan 2024	Feb 2024	March 2024
Procurement of research consumables						Initiate 1st trial (BHM + Potch)	Maintain field trial	Initiate 2nd Trial (BHM + Potch)	Maintain field trial		Prepare final report
	Prepare annual report						Monitor 1st Trial		Monitor 2nd Trial		
							Data capturing and (1st Trial)			Data capturing and analyses (2nd trial)	

Figure 1: Gantt chart submitted during application process of March 2021. All activities have been completed and final report attached as Annexure A.

Annexure A

Final Report:

Annual efficacy evaluation of registered pre-emergence herbicides for the control of grass weeds

ARC: Project reference number P05000151

Abstract

The efficacy of selected pre-emergent herbicides to control grasses were evaluated across two consecutive seasons (2022/23 and 2023/24). In both seasons, an early (“Trial 1”) and late (“Trial 2”) application date were evaluated at two sites i.e. Bethlehem (16% clay) and Potchefstroom (35% clay). Trials were laid out as a randomized complete block design with four replicates. Each treatment plot was flanked by an untreated control plot. Percentage ground cover (%) ratings were recorded approximately every two weeks for a period of 10 to 14 weeks. Linear, exponential and logistic regression analyses were conducted by plotting % grass cover per plot against time. The best fitted model was selected per plot and the time it took each treated plot and its respective dirty control plots to reach 10% weed cover (or 90% weed control) deducted (referred to as “T90”). *Extended control* (ExtCrl) was subsequently calculated which is the weeks of additional control achieved by the treated plot compared to its adjacent untreated control plots. Analysis of variance was conducted using the ExtCrl parameter as variable for each trial respectively (P=0.05). The wetter 2022/23 resulted in only Trial 1 of each site being analysed statistically. At both sites no significant differences were observed between the herbicides. With the drier 2023/24, Trial 1 of both sites did not give significant differences between the various herbicides. Trial 2 at Bethlehem did yield significant differences which were preliminary attributed to leaching. At Potchefstroom (2023/24), the presence of *Rottboellia conchinchinensis* severely hampered the efficacy of the herbicides as none of them are registered for its control. With early season application, some grass control were observed during both seasons, whereas later applications were totally insufficient. Although no problematic cases were identified where specific products consistently underperformed compared to their counterparts, large variation in all trials emphasised the need to re-evaluate of research protocols and statistical analyses pertaining to comparative pre-emergent herbicide studies. The data as analysed and presented represents the most suited approached to date but can be improved through further studies.

Introduction

The use of pre-emergent herbicides help maximize yields through the early, effective and lasting weed control they provide. The weed competition free environment created during the initial, critical growth stages of the crops, aids in subsequently ensuring better crop establishment. Their use can in addition help to minimize post-emergence herbicide applications or protect against early-season weed competition when the timely post-emergence application is prohibited due to weather or busy work schedules. It is furthermore foreseen that with the worldwide increase in resistance to post-emergent herbicides, pre-emergent herbicides will play an increasingly important role in weed management.

Due to patent expiration, current day producers have access to a vast range of more affordable weed control options in the form of generic herbicides. Although generic versions of a brand name have the same active ingredient, such products may not necessarily constitute the same quality or amount of active ingredient as its brand name counterpart, potentially performing less effective. No independent platform currently exist in which generic pre-emergent herbicides can be evaluated for their efficacy. Protocols for such comparative evaluation is also lacking on the international platforms.

Weed interference can cause between 20% and 50% yield losses in maize (Kropff and Spitters, 1991; Ngouajio *et al.,* 1999; Kim *et al.*, 2002). Locally, weed control annually constitutes approximately 9% of input costs (Fourie, 2021) and as economic pressure on producers is increasing, producers have little leeway for ineffective or substandard weed control. Owing to economic pressure experienced by producers, it is essential to ensure the most effective weed control programme at the most economically justifiable means. Due to the extensive range of generic products on the market, producers have greater access to more affordable weed control, but have voiced the need at various platforms in the past that the efficacy of such products be compared. The need for the evaluation of efficacy of grass control achieved by generic products by an independent institution accordingly exists that would ensure unbiased results which would aid producers in management practices and decisions. Information generated through such a project would aid producers in their management practices and decision making processes.

A generic herbicides refers to herbicides that contain the same chemical substance as an herbicide that was originally protected by patent rights. Due to limited or no research costs associated with their development, generic herbicides often have a lower initial product cost than their brand name counterparts. According to McFalls *et al*., 2015, purchase price of herbicides should, however, not be the only aspect of importance when selecting an herbicide, with factors such as effectiveness, application rates and/or procedures as well as product availability all requiring consideration. Whilst generic products have the same active ingredients than the original brand name herbicides, generic and brand name herbicides are not required to have the same inactive ingredients (McFalls *et al*., 2015). For soil applied herbicides, the inactive ingredients would as an example influence handling and mixing properties of the formulation (McFalls *et al*., 2015). The formulation of a generic product's active ingredient may accordingly differ from that of the brand name whilst generic manufacturers may use different technologies to produce active ingredients.

Generic and brand name herbicides can furthermore differ from each other regarding the physical form of the active ingredient, for example where the elements of the molecules are arranged slightly differently with the s- and r- isomers of metolachlor being an example of the latter. S-isomeres are more active than r-isomeres, and will accordingly, if applied at the same concentration, be more effective that the r-isomere counterpart. McFalls *et al*. (2015) states that the generic product may have a cheaper price but may thus not include the same amount and quality of active ingredient as the brand-name product. More of the generic material may need to be used or more applications required in order to achieve an equivalent rate of active ingredient, thereby potentially eliminating whatever cost savings was realized at the initial purchase of the generic product.

According to Preston (2023) the complexity of behaviour of pre-emergent herbicides and the rainfall required to activate the different products can however also result in different results in different years. Producers would accordingly often view pre-emergent herbicides as unreliable or ineffective. Used on its own, pre-emergent herbicides will not do much to control weeds in the long term but used as part of an integrated weed control approach, will assist in addressing weed control in the new era which saw the rise of super weeds. They offer an alternate mode of action to many post-emergent options whilst they can also assist in reducing selection pressure on subsequent post-emergent herbicide applications. The removal of early season weed competitive pressure by this type of herbicides often protects crop yield better than later applied post-emergent applications (Preston, 2023). Knowing the crucial role pre-emergent herbicides will play in future weed control, getting a better understanding of their efficacy across various environments will assist in better application or integration of their use in weed management systems.

The objective of the current study was to evaluate and compare efficacy of pre-emergent herbicides on grass control in maize through field trials conducted at two application times (early and late) on two soil types (16% clay and 35% clay) across two seasons.

Materials and methods

Year 1: 2022/23

An early- and late application date trial respectively was initiated at two sites during the 2022/23 season (Bethlehem - 16% clay, Potchefstroom - 35% clay). Fields which have laid fallow for the last three years were selected. The two Bethlehem trials were initiated on 23 November 2022 (referred to as "Trial 1") and 22 December 2022 (referred to as "Trial 2") respectively. Severe and continuous rainfall at especially Potchefstroom made timeous seedbed preparation and herbicide application challenging. Trial 1 at Potchefstroom was initiated on 9 December 2022 and the second on 9 February 2023 (Trial 2). Fields were previously under maize cultivation.

Trials were laid out as completely randomised designs with four replicates. Each plot was 12.5m^2 in size and flanked at the bottom and top sides by control plots (12.5m^2 each). To control broad leaves a standard application of bendioxide (Basagran - 3 ℓ /ha) at Potchefstroom and bromoxynil (Voloxynil -1.5 ℓ /ha, for *Amaranthus* control) at Bethlehem was applied. Pre-emergent herbicide applications were made with a CO^2 knapsack operated sprayer and boom (2.5m boom width 4x 8004 teejet nozzles, calibrated to apply 240 ℓ ha^{-1}).

Eighteen products were tested with Trial 1 at both Bethlehem and Potchefstroom, whilst a total of 20 products were tested in Trial 2 at both sites. All products included were divided into 6 groups, with each group representing a similar a.i. concentration (g ℓ$^{-1}$). Where possible products with the same a.i. and concentration were applied at similar rates (as per label instruction), with the lowest rates within the label ranges selected where possible for each soil type (Table 1).

Year 2: 2023/24

An early- and late application date trial was initiated respectively at two sites during the 2023/24 season (Bethlehem - 16% clay, Potchefstroom - 35% clay). The two Bethlehem trials were initiated on 14 November 2023 (referred to as “Trial 1”) and 5 December 2023 (referred to as “Trial 2”) respectively. Trial 1 of Potchefstroom was initiated on 10 November 2023 and Trial 2 on 21 December 2023.

Trials were laid out as completely randomised designs with four replicates. Each plot was 12.5m^2 in size and flanked at the bottom and top sides by control plots (12.5m^2 each). To control broad leaves a standard application of bendioxide (Basagran - 3 ℓ ha^{-1}) at Potchefstroom and bromoxynil (Classic - 35 g ha^{-1}) at Bethlehem was applied. Pre-emergent herbicide applications were made with a CO^2 knapsack operated sprayer and boom (2.5m boom width 4x 8004 teejet nozzles, calibrated to apply 260 ℓ ha^{-1}).

Each trial consisted of 21 treatments (products). All products included were divided into seven groups, with each group representing a similar a.i. concentration (g ℓ$^{-1}$). Where possible products with the same a.i. and concentration were applied in similar rates (as per label instruction), with the lowest rates within the label ranges selected where possible for each soil type (Table 2).

Screening and data analyses

Plots were monitored approximately every second week over a 10 to 12-week period and the % increase in weed cover over time established. A minimum of four screening dates were conducted per trial. In addition to the capturing of area covered by grass (%), grass species’ contribution were recorded as far as possible. Percentage area covered by grass in general was however used as the main parameter for efficacy evaluation.

For the current study 10% weed cover was set as the benchmark for sufficient control, as this represents 90% control. With the current study, the aim was accordingly to ascertain through the use of regression analyses the time it took each plot (of both treated and control plots) to reach 10% weed cover. The latter parameter will be referred to as “T90” = time to reach 90% control. Regression analyses were conducted by plotting the screening data points per plot against time using Genstat. Linear, exponential and logistic models were plotted, and the best fitted model selected to calculate “T90”. The best fitted model was selected based on the coefficient of determination (R^2) and the mean square error (MSE). *Extended control* (ExtCrl) was subsequently calculated which is the weeks of additional control achieved between the period in which the control plot reached 90% control and the treated plot reached 90% control. The extended control parameter is accordingly a comprehensible measure which express how long a specific plot benefitted from the herbicide application compared to the adjacent control plots.

Extended control (ExtCrl) was calculated through formula [1] and was expressed in weeks.

$$\text{Extended control}_{(\text{weeks})} = (\text{T90}_{(\text{treatment})} - \text{T90}_{(\text{control plots})})/7 \qquad [1]$$

Analysis of variance was then conducted on ExtCrl achieved by the various treatments for each trial separately.

Where greater clarity was required regarding results generated, Canonical variate analysis and biplots were used. All analyses were conducted by the Biometry unit of the ARC to ensure that all model requirements are adhered to for correct interpretation of the graphs.

Results

Year 1 (2022/23)

An extremely wet 2022/23 season was experienced, with 796.5 mm and 925.6 mm being recorded for the period of 1 November 2022 till 30 April 2023 at Bethlehem and Potchefstroom respectively (Moeletsi et al. 2024). From Figure 1 and Figure 2 it is evident that excessive rain fell directly after the various application times at each site. Leaching of chemicals as well as waterlogged and cloudy conditions which hampered weed germination and growth subsequently became evident from the data generated in all trials.

Grass species identified in the respective trials are indicated in Table 3. As none of the products tested can control couch grass (*Cynodon dactylon*), note was taken regarding the area covered by this weed per plot and deducted from the total area covered by grass (%) for each screening date.

Trial 1 – Bethlehem and Potchefstroom (early application date)

Despite the various challenges brought about by heavy rainfall, Trial 1 of both Bethlehem and Potchefstroom were moderately successful. Although it was evident that less grass growth was observed in both trials compared to past studies conducted during 2017/18 to 2019/20 as part of a Maize Trust-co funded project (P05000023: Improved grass control systems in maize), sufficient grass cover (%) developed that allowed T90 values to be calculated via regression analyses. Large variation did however occur at especially on the sandy soils of Bethlehem. This was evident from the lack of statistical significance despite great differences in ExtCrl achieved by the various treatments.

Analyses of variance indicated that none of the products applied at either of the two sites differed significantly regarding the weeks of extended control achieved. On average between one and 5.6 weeks of extended control were achieved by the pre-emergent herbicides at Bethlehem (Figure 3). At Potchefstroom, weeks of extended control were much shorter than that of Bethlehem, and varied between 0.6 to 2.3 weeks (Figure 4).

Guinea fowl grass (*Rottboellia conchinchinensis*) was one of the most prominent grass weeds at Potchefstroom (Photo 1). *R. conchinchinensis* is an erect, profusely tillering annual grass that grows up to a height of 4 m or more. It is extremely competitive with annual crops such as soybean, maize, cotton, peanut and sugarcane. It has brace roots near the base of the plant, a cylindrical spikelet seedhead and siliceous hairs on the leaf sheath that can penetrate and irritate the skin. Recorded to be an aggressive, significant weed in more than 40 countries, this annual grass is listed as a Federal Noxious Weed in the USA, and is suggested to be possibly the most harmful invasive plant in Mexico. Locally Botha (2010) report the weed to be especially problematic in sugar cane plantations and maize cultivation.

To date, nicosulfuron (as post-emergent herbicide) are the only active registered in maize for the control of Guinea fowl grass in South Africa. It was accordingly of interest to evaluate how well the pre-emergent herbicides faired in controlling this weed. Although analysis of variance did indicate significant differences between the various products applied (Figure 5), only 1.6 weeks of extended control was achieved by the top performing product, Yamato (pyroxasulfone @ 76.8 g ha^{-1}). Intelex (dimethenamid-P+Saflufenacil @ 720 g ha^{-1}), Cantron (mesotrione “2”@ 100 g ha^{-1}) and Metagan Gold (s-metolachor “2” @ 336 g ha^{-1}) provided control similar to that of Yamato.

Photo 1. Rottboellia cochinchinensis (Guinea fowl grass)

Trial 2 - Bethlehem and Potchefstroom (late application)

With Trial 2 of both sites, grass growth stagnated, resulting in the plots not reaching sufficient % cover in the plots (>10%) within the set evaluation period. Grasses which did manage to germinate died off sooner, which in addition, did not allow for extended rating periods. Analyses could accordingly not be conducted on either of the late application trials. The lack of grass germination and growth could possibly be attributed to unfavorable environmental conditions such as prolonged cloudy weather, extended waterlogged conditions and lower average temperatures that are normally associated with extended cloudy and rainy weather conditions.

Year 2 (2023/24)

A much drier season was experienced during 2023/24 with 389mm and 527mm being recorded for the period of 1 November 2023 till 30 April 2024 at Bethlehem and Potchefstroom respectively (Bethlehem 2022/23 = 796.5 mm; Potchefstroom 2022/23 = 925.6 mm). Sufficient rainfall fell after each application to ensure that herbicides were sufficiently washed in (Figure 6 and Figure 7). Photo 2 provides a visual account of activities and trials.

Grass species identified in the respective trials are indicated in Table 4. As none of the products tested has the ability to control couch grass (*Cynodon dactylon*), note was taken regarding the area covered by this weed per plot and deducted from the total area covered by grass (%) for each screening date.

Bethlehem field trials (Trial 1 and Trial 2)

Between 4.2 and 7.7 weeks of extended control was achieved in the 21 treatments with Trial 1, with no significant differences being observed between the treatments.

Between 0.49 and 6.5 weeks of extended control were achieved in the 21 treatments of Trial 2. Significant differences were observed between the treatments ($LSD_{(P=0.05)}$ = 23.01). With the interpretation of the results, products with the same a.i. applied *at the same rate* were compared to see whether any significant differences were recorded as to how they were able to suppress weed germination under reigning environmental conditions. The acetochlor cluster, as an example, consists of Acetochlor 900 EC, Guardian 840, Acetoclor 700 EC, Leap and Lion 700 which were all applied at 966 g a.i. ha^{-1}. Statistically, they did not differ from each other regarding the extended weeks of control they gave (Figure 9). Only Smeeto 915 EC in the s-metolachlor cluster applied at 640 g a.i. ha^{-1} and Frontier Optima in the dimethenamid-P applied at 540 g a.i. ha^{-1} cluster gave significantly lower grass control compared to their counterparts.

Canonical Variate Analysis (CVA) was used to determine which of the grass species (excluding *Cynodon dactylon*) identified in the treated plots of Trial 2 at 61 DAT (Table 4), discriminated the most between the treatments. This is to assist in creating a visual representation of the results, that might explain the differences observed in the efficacy of the various products. According to the CVA (Figure 10) the horizontal axis explained 58% of the measured variation between the various treatments. *Eleusine coracana* was subsequently identified as being responsible for the variation between the points on the horizontal axis (r = -0.927). Due to the correlation being negative, points placed to the right of the graph had lower than trial average *E. coracana* soil cover (%), and those to the left of the graph, higher that trial average. The vertical axis explained only 13.4% of the variation observed with *Urochloa panicoides* (0.65) followed by *Setaria sp.* (0.51) having the highest correlation. Points placed in the upper region of the graph accordingly had higher than average ground cover by these two species, and those below the middle line, lower than trial average cover 61 DAT. Based in the CVA, Callisto 480 followed by Cantron 480 SC had higher than trial average *E. coracana* soil cover (%) at 61DAT in Trial 2. Frontier Optima had higher than trial average *U. panicoides* and *Setaria sp,* whilst Acetochlor 900 EC had higher than trial average *U. panicoides, Setaria sp*. as well as *E. coracana.* The significant poorer performance of Smeeto 915, compared to its s-metolachlor counter parts applied at 640 g a.i. ha^{-1} (Figure 9), is not evident from the CVA.

According to Yan and Tinker (2006) a biplot is a scatter plot that approximates and graphically displays a two-way table by both its row and column factors, such that the relationships among the row factors, relationships among column factors and the underlying interactions between the row and column factors can be visualized simultaneously. The biplot generated for treatments and weed species ground cover (%) at 61 DAT for Trial 2 is interpreted based on the principles of biplot analysis as stipulated by Yan and Tinker (2006)(Figure 11). *E. coracana* and *U. panicoides* were the most discriminating of the weed species (longest vector lines – distance from origin to data point), implying that they were the most informative regarding the plotting of the treatments. Based on distance from the biplot origin to the data point (vector length), Frontier Optima yielded a poorer than average performance regarding the control of *U. panicoides* (and *Echinochloa sp*. to a lesser extend). Similarly, Callisto 480 followed by Cantron 480 SC gave poorer than average control of *Eleusine coracana.* According to the biplot, Smeeto 915 EC gave poorer than average control in *U. panicoides* and *Panicum sp.* (to a lesser extend).

Potchefstroom field trials (Trial 1 and Trial 2)

Between 1.1 and 10.8 weeks of extended control was achieved in the 21 treatments with the early application trial (Trial 1). Only ten of the 21 treatments managed give some form of weeks of extended control. Larger variation between replications was evident in both trials, with the presence of guinea fowl grass (*R. conchinchinensis)* most probably being a contributing factor. Figure 12 and 13 reflects the weed species contribution in the various treatments as observed with the final rating date. The late application trial was mostly dominated by guinea fowl grass, which subsequently affected the extended week of control achieved.

No significant differences were observed between the treatments in either of the two trials. Analysis of variance was conducted on the guinea fowl grass contribution only to establish whether any of the treatments resulted in significant greater control (if any control at all). None of the analyses were however significant.

Discussion

According to Congeve and Cameron (2023), the availability of a pre-emergent herbicide is dependent on the interaction between 1) the solubility of the herbicide, 2) how tightly it is bound onto soil colloids and organic matter, 3) soil factors such as structure, 4) cation exchange capacity and pH, 5) herbicide volatility, 6) the environment and particularly soil water, and 7) the rate of herbicide applied. A single factor which is present in extreme, can however, have an overriding influence on the overall balance and can alter what normally happens in the field.

With the current study the efficacy of pre-emergent herbicides for grass control in maize was evaluated and compared through field trials conducted at two application times (early and late) on two soil types (16% clay and 35% clay) across two seasons. Although climatic conditions and local weed species composition dictated the degree of efficacy achieved by the various products, very few cases were identified where one or more products underperformed compared to its counterparts. What was however evident in all trials, is the large variation associated with the type of research data generated. Visual estimation of weed cover together with the fitting of data into regression curves before a usable parameter (T90 in this instance) was generated and analyzed, might have contributed to the large variation observed. Interactions at plot level such as micro-climate conditions which are not always evident or minor changes in application rate (temporary laps in walking speed of the knapsack operator), could however also have contributed to the inconsistency in data generated. With the current study, four replicates were included. For future studies, a minimum of 6 replicates is suggested.

During 2022/23, climatic conditions were such that weeds did not germinate sufficient in both treated and dirty control plots with the later application date trials (Trial 2). Heavy rainfall together with cloudy weather hampered and impaired general weed growth to such an extent that no analyses could be performed on the data generated. Extending the evaluation period also did not yield usable results, as what little weed that were present, simply died off, without any new growth developing.

During the second season (2023/24), Bethlehem Trial 2 yielded significant differences between some the herbicide clusters created. *E. coracana*, followed by *U. panicoides* and *Setaria sp*. being identified as weed species which were ineffectively controlled by some products. Recorded weather data indicate a total of 123 mm rain fell within 14 days after application, which could have resulted in leaching and/or runoff of actives, and thus general poorer performance of herbicides. This together with the always present high variation between replicates, could have resulted in significant differences being observed, without it being the fault of the product formulation *per se*. Note must however be taken of various observations. Even with the large amount of rainfall that fell within two weeks after application, quite a few products still managed to achieve up to four weeks of extended control. Based on comparative analyses (not shown in this report), the dirty plots of both Trial 1 and Trial 2 (at Bethlehem) took approximately 3 weeks to reach 10% weed cover, whilst the two trials had the same species composition. Weed pressure were accordingly very similar between the two trials irrespective of the climatic conditions. Despite this similarities, two mesotrione products achieved the poorest performance across the whole trial, both struggling to control *E.*

coracana specifically whilst a dimethenamid-P product was less effective to control *U. panicoides* compared to its counterpart.

Both mesotrione and dimethenamid-P are actives known for their high solubility (>501mg ℓ^{-1} @ 20°C). Solubility is a measure of how much herbicide can dissolve in water (Congreve and Cameron, 2023). The best performing product Yamato (2)(76.8 g a.i. ha^{-1}) contains pyroxasufone which has low solubility (3.5 mg ℓ^{-1}). Herbicides with low water solubility often require larger volumes of rainfall to achieve incorporation and tend to be less available in the soil moisture than more soluble products. Typically, for optimum performance, herbicides with low solubility need good moisture conditions after application and also for the period of desired weed control. According to Congreve and Cameron (2023) a highly soluble herbicide will have a tendency to move with the soil moisture, and be more likely to leach or cause off-target effects.

Seen as both products which gave significantly lower control compared to its counterparts belonged to actives which have high solubility and most likely to leach in especially sandy soil, leaching of actives was the most probable cause of the differences observed.

As significant differences were only present in this one trial, care must be taken to make assumptions as to the efficacy of products. Note is accordingly taken regarding the observations made in this trial. Additional analyses which include CVA and Biplots for all trials will aid in establishing whether the observations made in this trial is part of a trend observed in all trials, or whether it is just a combination of large variation and climatic conditions which resulted in the observed differences in products. Ideally additional continued evaluation of pre-emergent herbicides would cast greater light on the how various pre-emergent herbicides react under various climatic conditions.

Guinea fowl grass formed part of the natural occurring weed species spectrum at Potchefstroom, which represented the clay soil site (35% clay). This grass weed is notoriously difficult to control, with none of the products evaluated in the study registered for its control. Yet it was interesting to note that general grass control was still achieved to some degree with the early applications, whereas later applications (Trial 2), limited to no control was achieved by the various products, due to the overwhelming presence of guinea fowl grass. A preliminary deduction is that better control was achieved early in the season by the products, due to the presence of the more common grass weed species such as *E. coracana, U panicoides, Brachiaria sp* and *Eragrostis sp*. With the later application date trial, the weed species' profile has shifted to primarily guinea fowl grass which could not be controlled by the pre-emergence herbicides. This species apparently was able to germinate to a greater extend than the other grass later during the season thus allowing it to dominate

Conclusion

The current project aimed to compare various pre-emergent herbicide products for their efficacy at two application times in two soil types. Climatic conditions and weed species composition affected the efficacy of the products evaluated. A total of eight field trials were conducted in the current study. Of these, climatic conditions resulted in two trials being excluded from analyses. Only one of the five remaining trials yielded significant differences between products. The general large variation observed between replicates of the same treatments were however evident in all trials. The conclusion of the current study however is that no consistent loss of efficacy was evident in any of the pre-emergent herbicides evaluated across seasons and localities. Future research studies regarding the comparison of pre-emergent herbicides should included a greater number of replicates, screening dates as well as a more wholistic approach regarding the type of analyses used to interpret data. In this regard greater use can be made of multivariate analysis such as CVA and Biplots.

Acknowledgements

AECI, BASF, Philagro, Syngenta and VillaCrop for donation of products.

Reference list

Botha, C., 2010. Common weeds of crops and gardens in Southern Africa. Agricultural Research Council, Potchefstroom.

Congreve, M. and Cameron, J. (eds) (2023). Soil behaviour of pre-emergent herbicides in Australian farming systems – a national reference manual for advisers. 3rd Edition. GRDC publication, Australia.

Fourie, P., 2021. Preliminary production cost and budgets fro the new season. Grain SA presentation.

Kim, T.J., Neal, J.C., Ditomaso, J.M. & Rossi, F.S., 2002. A survey of weed scientists' perceptions on the significance of crabgrasses (*Digitaria* spp.) In the United States. *Weed Technology*, 16: 239 - 242.

Kropff, M.J. & Spitters, C.J.T., 1991. A simple model of crop yield loss from early observations on relative leaf area of the weeds. *Weed Research*, 31: 97 - 105.

McFalls, J., Yi Y-J, Li, M-H & Senseman, S. 2015. Evaluation of generic and branded herbicides: Technical report. Texas &M transportation institute College Station, Texas, http://tti.tamu.edu/documents/0-6733-1.pdf)

Moeletsi, M.E., Myeni, L., Kaempffer, L.C., Vermaak, D., de Nysschen, G., Henningse, C., Nel, I., Rowswell, D., 2024. Climate dataset for South Africa by the Agricultural Research Council. Data, 7(8) 1 – 7. For weather data provide for Bethlehem and Potchefstroom 2023/24 season.

Ngouajio, M., Lemieux, C. & Le Roux, G.D., 1999. Prediction of corn (*Zea mays*) yield loss from early observations of the relative leaf area and the relative leaf cover of weeds. *Weed Science*, 74: 297 - 304.

Preston, C.2023. A summary of pre-emergent herbicide performance. Hart Trial results 2023. Pp 65-67. Available online https://www.hartfieldsite.org.au.

Yan, W, Tinker, Tinker, N.A. 2006. Biplot analysis of mulit-environment trial data: Principles an applications. Canadian Journal of Plant Science, 86: 623-645.

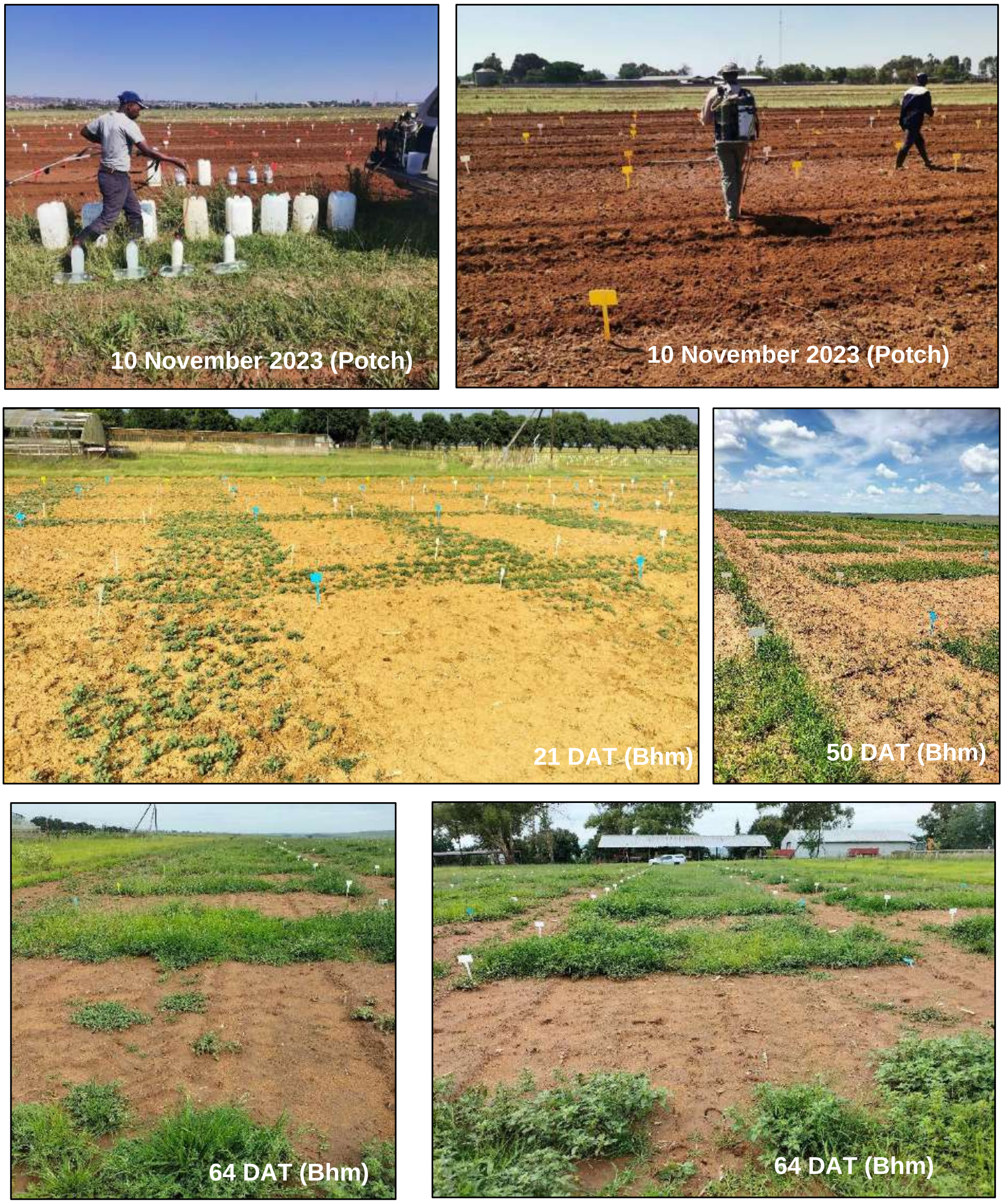


Photo 2: Spray and rating activities conducted at Bethlehem and Potchefstroom to evaluate 21 pre-emergent herbicides for their efficacy to control grasses.

Table 1: Pre-emergent herbicides and dose rates applied at Bethlehem (16% clay) and Potchefstroom (35% clay) during 2022/23.

			Recommended dose (ℓ ha^{-1})		**Applied dose**			
					16% clay		**35% clay**	
Product name	**A.i**	**Formulation (g ℓ$^{-1}$)**	**16% clay**	**35% clay**	**Dose (ℓ ha^{-1})**	**A.i. (g ha^{-1})**	**Dose (ℓ ha^{-1})**	**A.i. (g ha^{-1})**
Acetochlor 900	acetochlor	900	0.9-1.2	1.2-1.8	1.07	966	1.54	1386
Guardian 840	acetochlor	840	1-1.3	1.65-1.8	1.15	966	1.65	1386
Wenner 700 S	acetochlor	700	1.1-2.1	1.7-2.7	1.38	966	1.98	1386
Leap	acetochlor	840	1.15-1.3	1.65-1.8	1.15	966	1.65	1386
Lion 700	acetochlor + dichlormid	700	1.1-2.1	1.7-2.7	1.38	966	1.98	1386
Platinum Plus	metolachlor +benoxacor	915	1.1-1.3	1.6-1.8	1.10	1006.5	1.60	1464
Metolachlor 915	metolachlor +benoxacor	915	1.1-1.3	1.6-1.8	1.10	1006.5	1.60	1464
Palladium Plus	s-metolachlor+benoxacor	915	0.7-0.9	1.0-1.2	0.70	640	1.00	915
Smeeto 915 EC	s-metolachlor+benoxacor	915	0.7-0.9	0.9-1.0	0.70	640	1.00	915
Dual Gold	s-metolachlor	915	0.4-0.9	0.6-1.0	0.70	640	1.00	915
Metagan Gold	s-metolachlor	960	0.3	0.35-0.5	0.30	288	0.35	336
Pentium 960[b]	s-metolachlor	960	0.3	0.3-0.35	0.30	288	0.35	336
Camix[a]	mesotrione/**S-metolachlor**	416.7	--------- 0.9-1.5 ----------		0.90	375	0.90	375
Callisto 480[a]	mesotrione	480	------- 0.104-0.26 -------		0.21	100	0.21	100
Cantron 480	mesotrione	480	------- 0.21-0.26 --------		0.21	100	0.21	100
Camix[a]	**mesotrione**/S-metolachlor	83.3	-------- 0.9-1.5 -----------		1.20	100	1.20	100
Yamato[a]	pyroxasulfone	480	--------- 0.105 ------------		0.11	50.4	0.11	50.4
Yamato[a]	pyroxasulfone	480	--------- 0.160 ------------		0.16	76.8	0.16	76.8
Intelex	dimethenamid-P + saflufenacil	600	0.9-1.2	1.2-1.5	0.90	540	1.20	720
Frontier Optima[b]	dimethenamid-P	720	0.5-0.75	1-1.25	0.75	540	1.00	720

[a] – dose rate not influenced by soil clay percentage (%)

[b] – only included in second trials at Bethlehem and Potchefstroom

Table 2: Pre-emergent herbicides and dose rates applied at Bethlehem (16% clay) and Potchefstroom (35% clay) during 2023/24.

			Recommended dose (ℓ ha^{-1})		Applied dose			
					16% clay		35% clay	
Product name	**A.i.**	**Formulation (g ℓ$^{-1}$)**	**16% clay**	**35% clay**	**Dose (ℓ ha^{-1})**	**A.i. (g ha^{-1})**	**Dose**	**A.i. (g ha^{-1})**
Alanex	Alachlor	480	3.60	4.00	3.60	1728	4	1920
Acetochlor 900 ED	acetochlor	900	0.9-1.2	1.2-1.8	1.07	966	1.54	1386
Guardian 840	acetochlor	840	1-1.3	1.65-1.8	1.15	966	1.65	1386
Acetochlor 700 S	acetochlor	700	1.1-2.1	1.7-2.7	1.38	966	1.98	1386
Leap	acetochlor	840	1.15-1.3	1.65-1.8	1.15	966	1.65	1386
Lion 700	acetochlor + dichlormid	700	1.1-2.1	1.7-2.7	1.38	966	1.98	1386
Platinum Plus 915^{b}	metolachlor +benoxacor	915	1.1-1.3	1.6-1.8	1.10	1006.5	1.60	1464
Metolachlor 915	metolachlor +benoxacor	915	1.1-1.3	1.6-1.8	1.10	1006.5	1.60	1464
Palladium Plus 915	s-metolachlor+benoxacor	915	0.7-0.9	1.0-1.2	0.70	640	1.00	915
Smeeto 915 EC	s-metolachlor+benoxacor	915	0.7-0.9	0.9-1.0	0.70	640	1.00	915
Dual Gold	s-metolachlor	915	0.4-0.9	0.6-1.0	0.70	640	1.00	915
Metagan Gold	s-metolachlor	960	0.3	0.35-0.5	0.30	288	0.35	336
Pentium 960^{b}	s-metolachlor	960	0.3	0.3-0.35	0.30	288	0.35	336
Camix^{a}	mesotrione/**S-metolachlor**	416.7	------------- 0.9-1.5 -----------		0.90	375	0.90	375
Callisto 480^{a}	mesotrione	480	---------- 0.104-0.26 ---------		0.21	100	0.21	100
Cantron 480 SC^{a}	mesotrione	480	----------- 0.21-0.26 --------		0.21	100	0.21	100
Camix^{a}	**mesotrione**/S-metolachlor	83.3	-------------- 0.9-1.5 ----------		1.20	100	1.20	100
Yamato^{a}	pyroxasulfone	480	------------- 0.105 ------------		0.11	50.4	0.11	50.4
Yamato^{a}	pyroxasulfone	480	------------- 0.160 ------------		0.16	76.8	0.16	76.8
Intelex	dimethenamid-P + saflufenacil	600	0.9-1.2	1.2-1.5	0.90	540	1.20	720
Frontier Optima	dimethenamid-P	720	0.5-0.75	1-1.25	0.75	540	1.00	720

[a] – dose rate not influenced by soil clay percentage (%)

[b] – only included in second trials at Potchefstroom

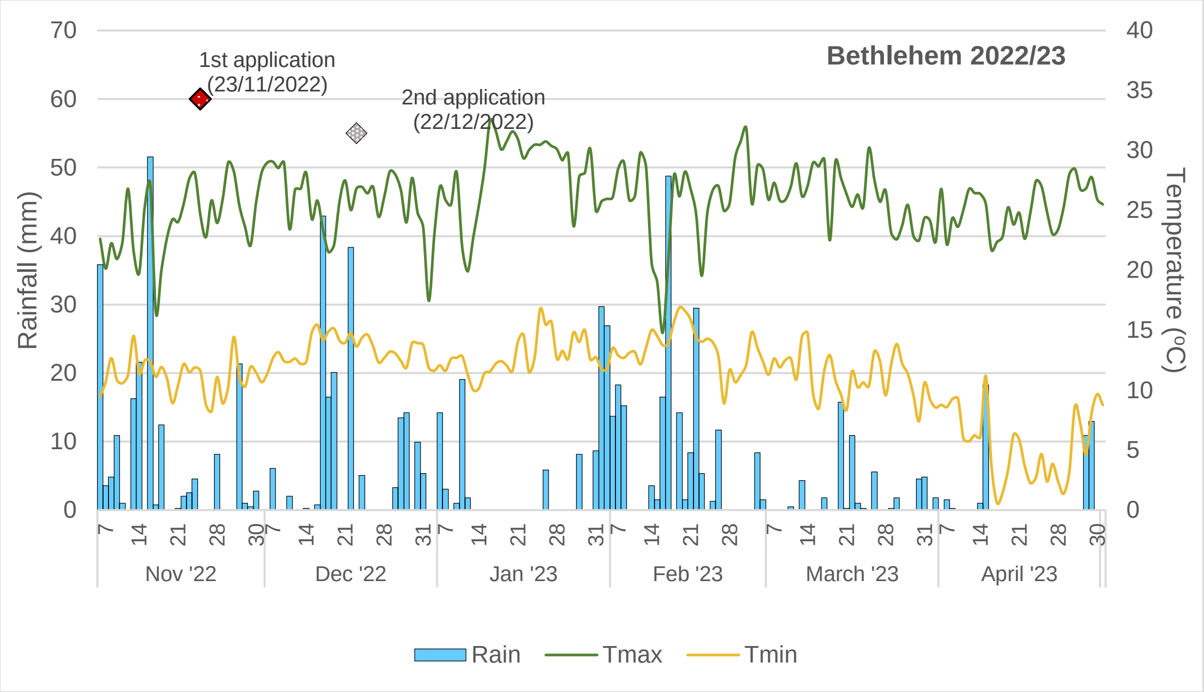


Figure 1: Rainfall and temperature data for Bethlehem (October 2022 – April 2023).

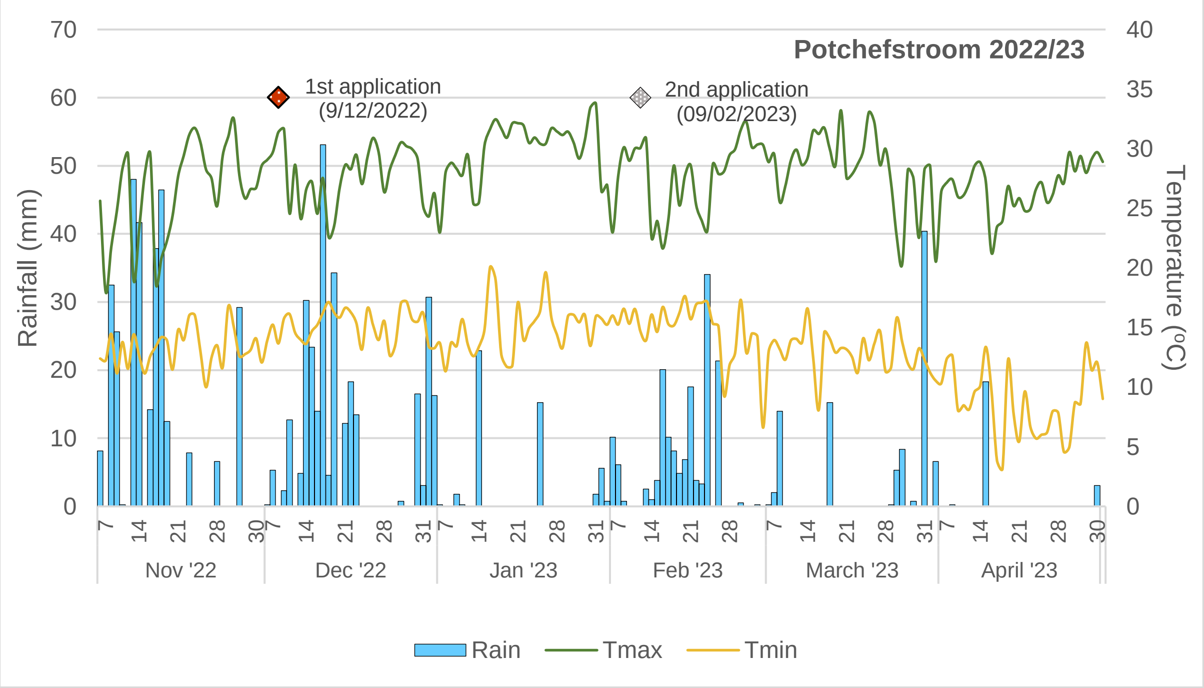


Figure 2: Rainfall and temperature data for Potchefstroom (October 2022 – April 2023).

Table 3: Grass species observed at Bethlehem (16% clay) and Potchefstroom (35% clay) trial sites during 2022/23.

Bethlehem		**Potchefstroom**	
Trial 1 (November 2022)	**Trial 2 (December 2022)**	**Trial 1 (December 2022)**	**Trial 2 (February 2023)**
Chloris sp.	*Cynodon dactylon*	*Cynodon dactylon*	*Cynodon dactylon*
Cynodon dactylon	*Echinochloa sp.*	*Digitaria sanguinalis*	*Digitaria sanguinalis*
Digitaria sanguinalis	*Eleusine coracana*	*Echinochloa sp.*	*Echinochloa sp.*
Echinochloa sp.	*Urochloa panicoides*	*Panicum sp.*	*Panicum sp*
Eleusine coracana		*Rottboellia conchinchinensis*	*Rottboellia conchinchinensis*
Eragrostis sp.		*Urochloa panicoides*	*Urochloa panicoides*
Panicum sp.			
Urochloa panicoides			

Table 4: Grass species observed at Bethlehem (16% clay) and Potchefstroom (35% clay) trial sites during 2023/24.

Bethlehem		**Potchefstroom**	
Trial 1 (November 2023)	**Trial 2 (December 2023)**	**Trial 1 (November 2023)**	**Trial 2 (December 2023)**
Chloris sp.	*Cynodon dactylon*	*Brachiaria sp.*	*Brachiaria sp.*
Cynodon dactylon	*Digitaria sanguinalis*	*Cynodon dactylon*	*Cynodon dactylon*
Digitaria sanguinalis	*Echinochloa sp.*	*Digitaria sanguinalis*	*Digitaria sanguinalis*
Eleusine coracana	*Eleusine coracana*	*Eragrostis sp.*	*Rottboellia conchinchinensis*
Eragrostis sp.	*Eragrostic sp.*	*Rottboellia conchinchinensis*	*Urochloa panicoides*
Panicum schinzii	*Panicum schinzii*	*Urochloa panicoides*	
Urochloa panicoides	*Urochloa panicoides*		
Setaria pallide-fusca	*Setaria pallide-fusca*		

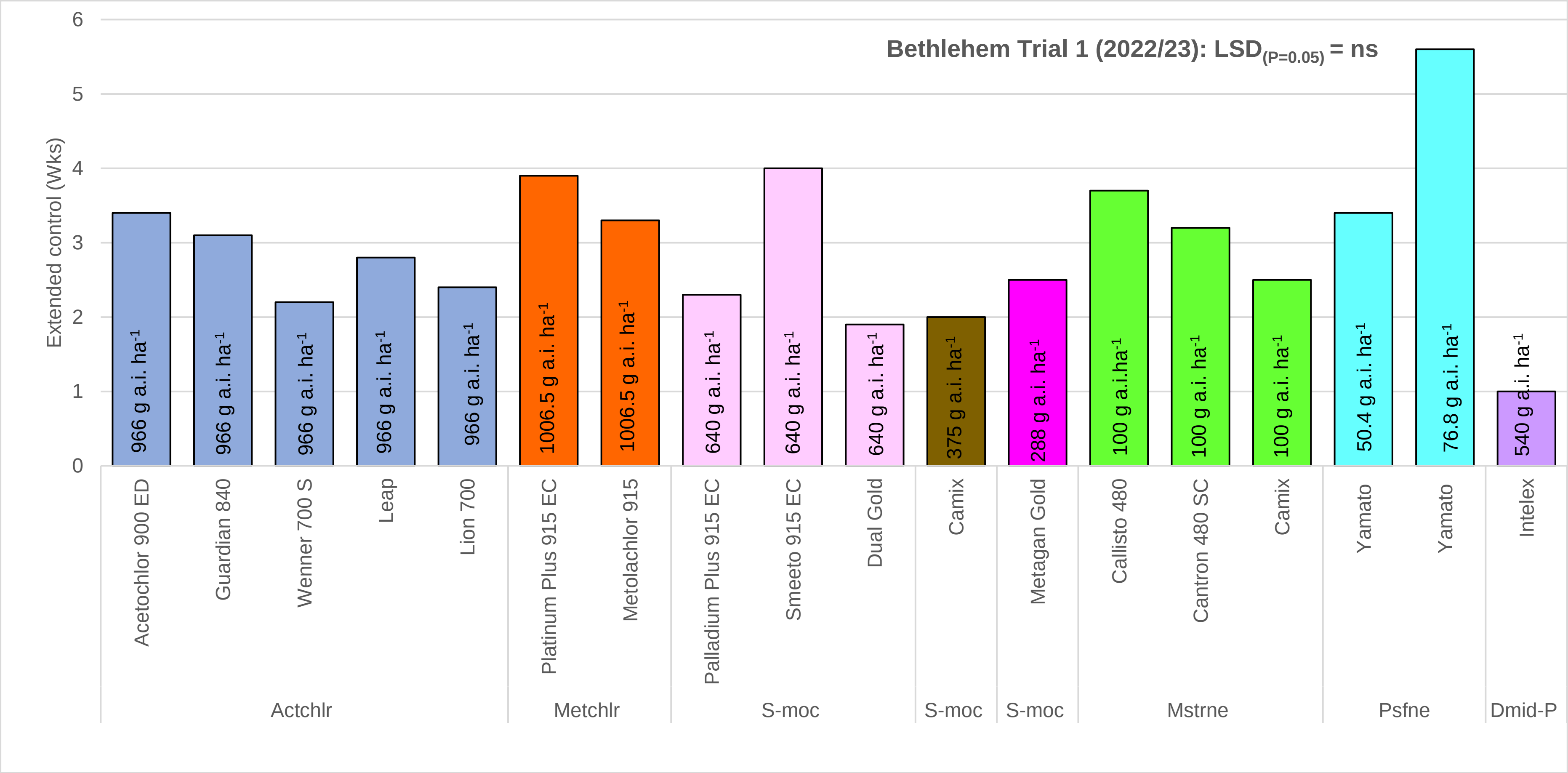


Figure 3: Weeks of extended control achieved by 18 pre-emergent herbicides evaluated on a 16% clay soil at Bethlehem applied on 23 November 2022 (Trial 1) compared to the untreated controls. (LSD$_{(P=0.05)}$ = ns). (Actchlor = acetochlor; Metchlr = Metolachlor; S-moc = S-metolachlor; Mstrne = mesotrione; Psfne = pyroxasufone; Dmid-P = dimethenamid-P)

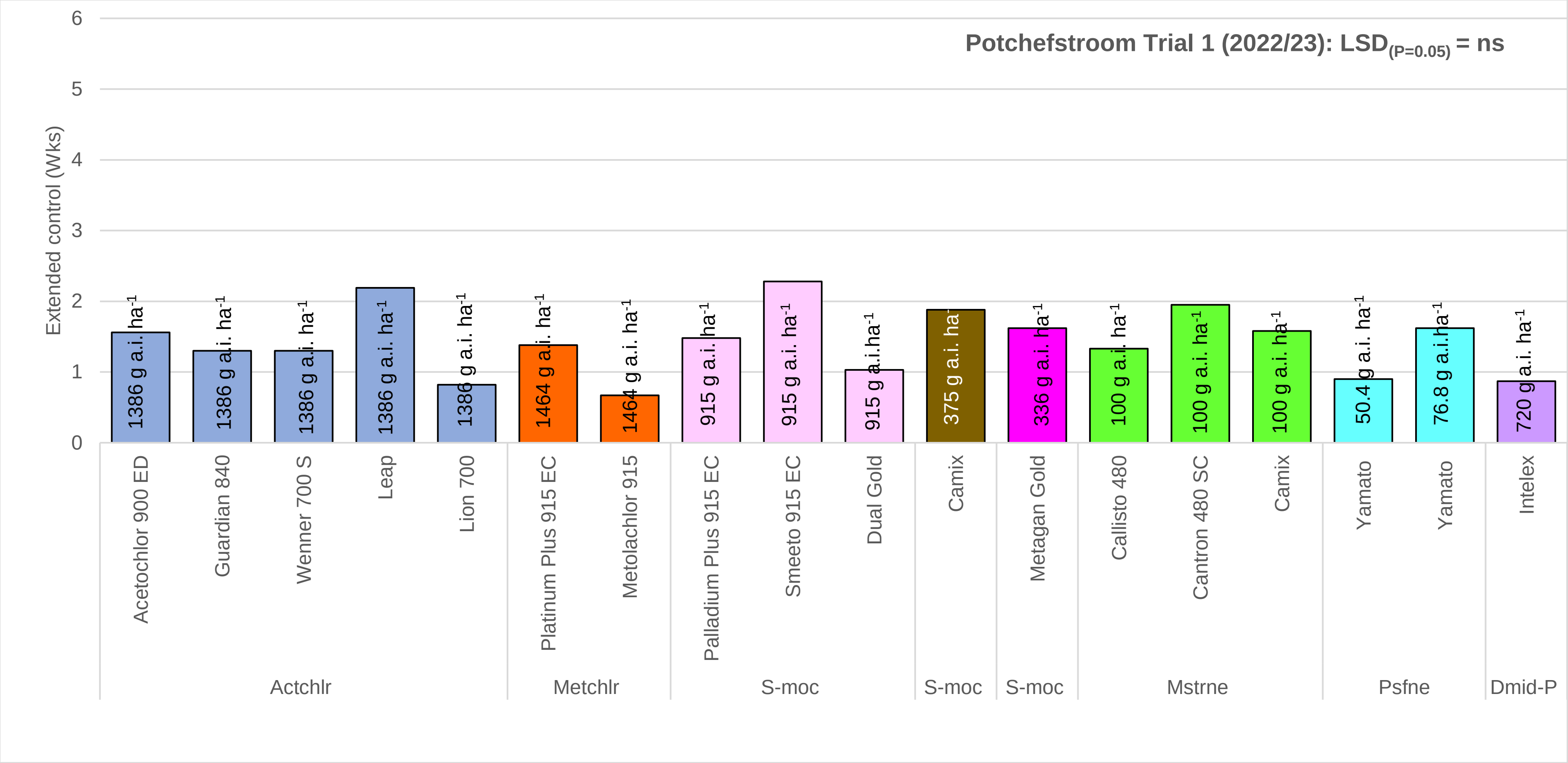


Figure 4: Weeks of extended control achieved by 18 pre-emergent herbicides evaluated on a 35% clay soil at Potchefstroom applied on 9 December 2022 (Trial 1) compared to the untreated controls. ($LSD_{(P=0.05)}$ = ns). (Actchlor = acetochlor; Metchlr = Metolachlor; S-moc = S-metolachlor; Mstrne = mesotrione; Psfne = pyroxasufone; Dmid-P = dimethenamid-P)

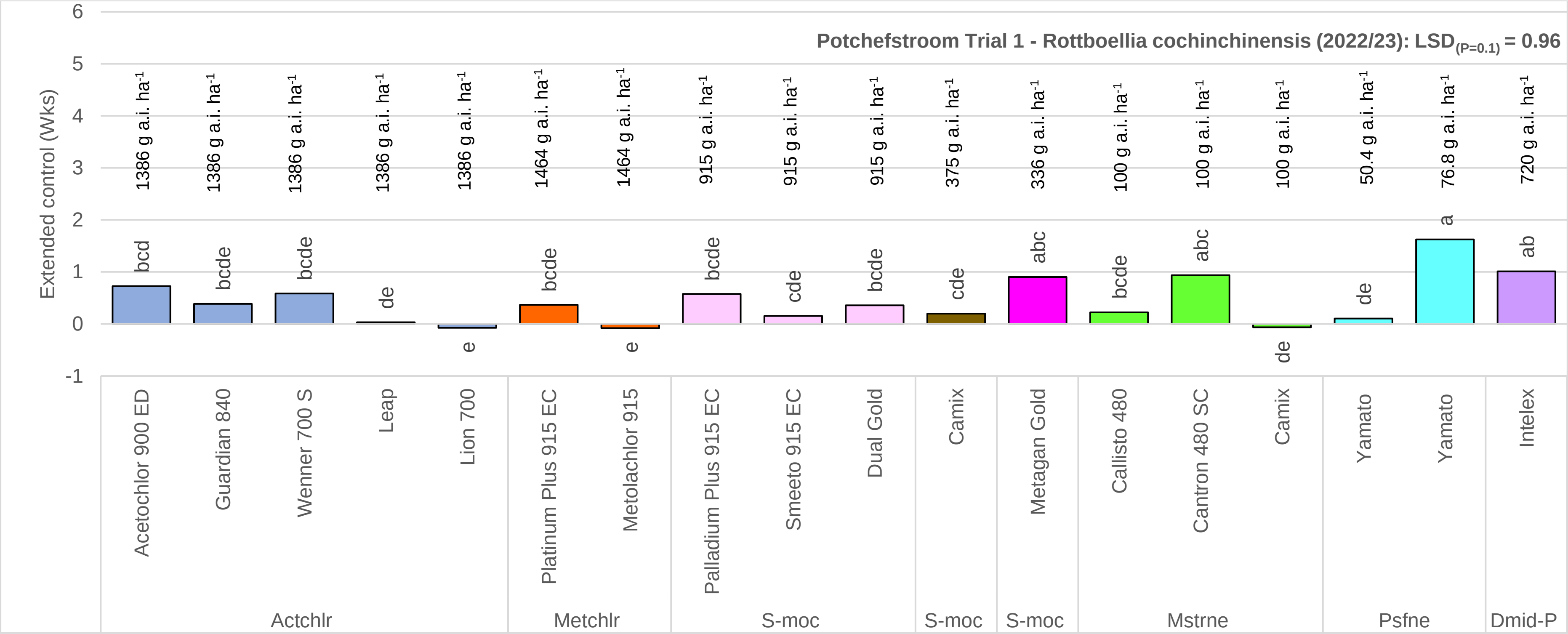


Figure 5: Weeks of extended control achieved for *Rottboellia conchinchinensis* by 18 pre-emergent herbicides evaluated on a 35% clay soil at Potchefstroom applied on 9 December 2022 compared to the untreated controls. (LSD$_{(P=0.1)}$ = 0.96). (Actchlor = acetochlor; Metchlr = Metolachlor; S-moc = S-metolachlor; Mstrne = mesotrione; Psfne = pyroxasufone; Dmid-P = dimethenamid-P)

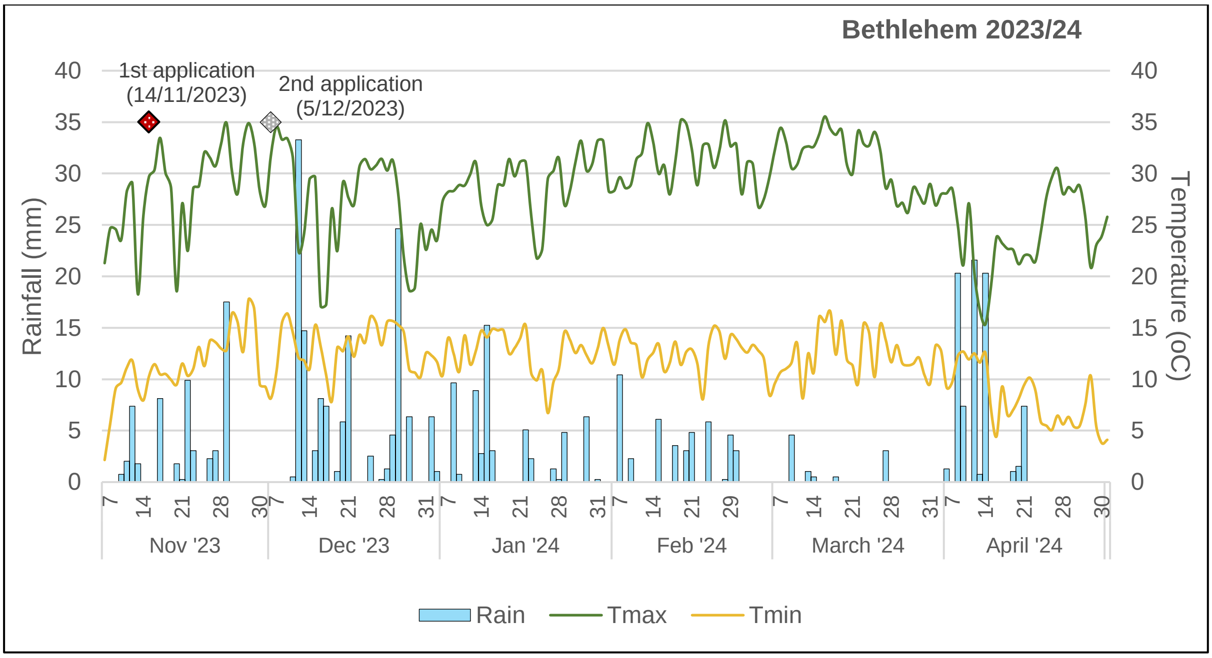


Figure 6: Rainfall and temperature data for Bethlehem (November 2023 – April 2024).

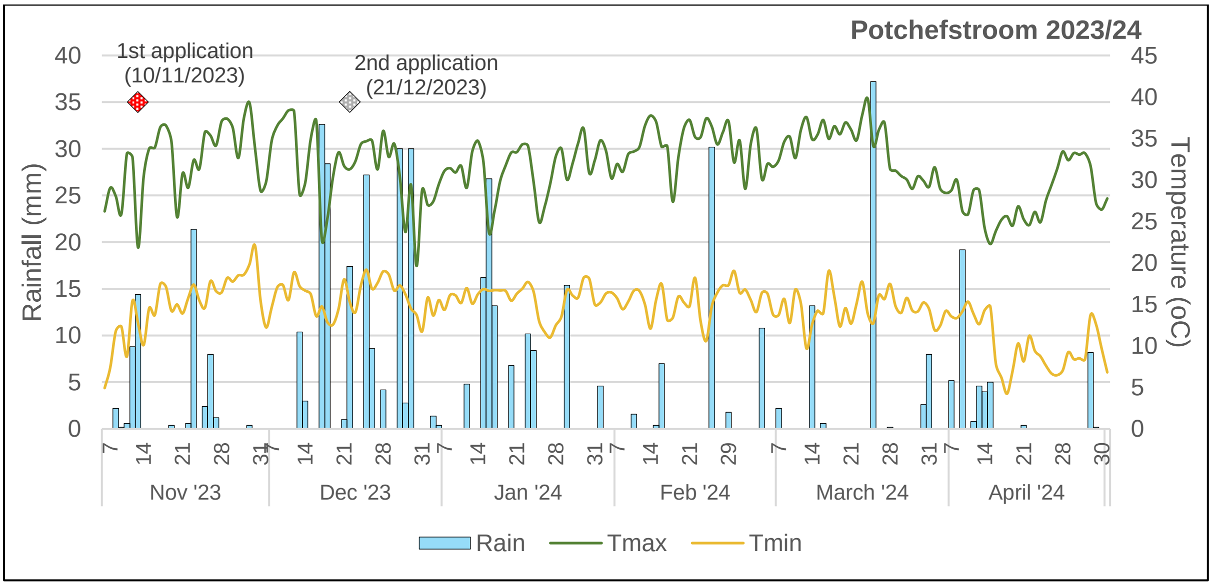


Figure 7: Rainfall and temperature data for Potchefstroom (November 2023 – April 2024).

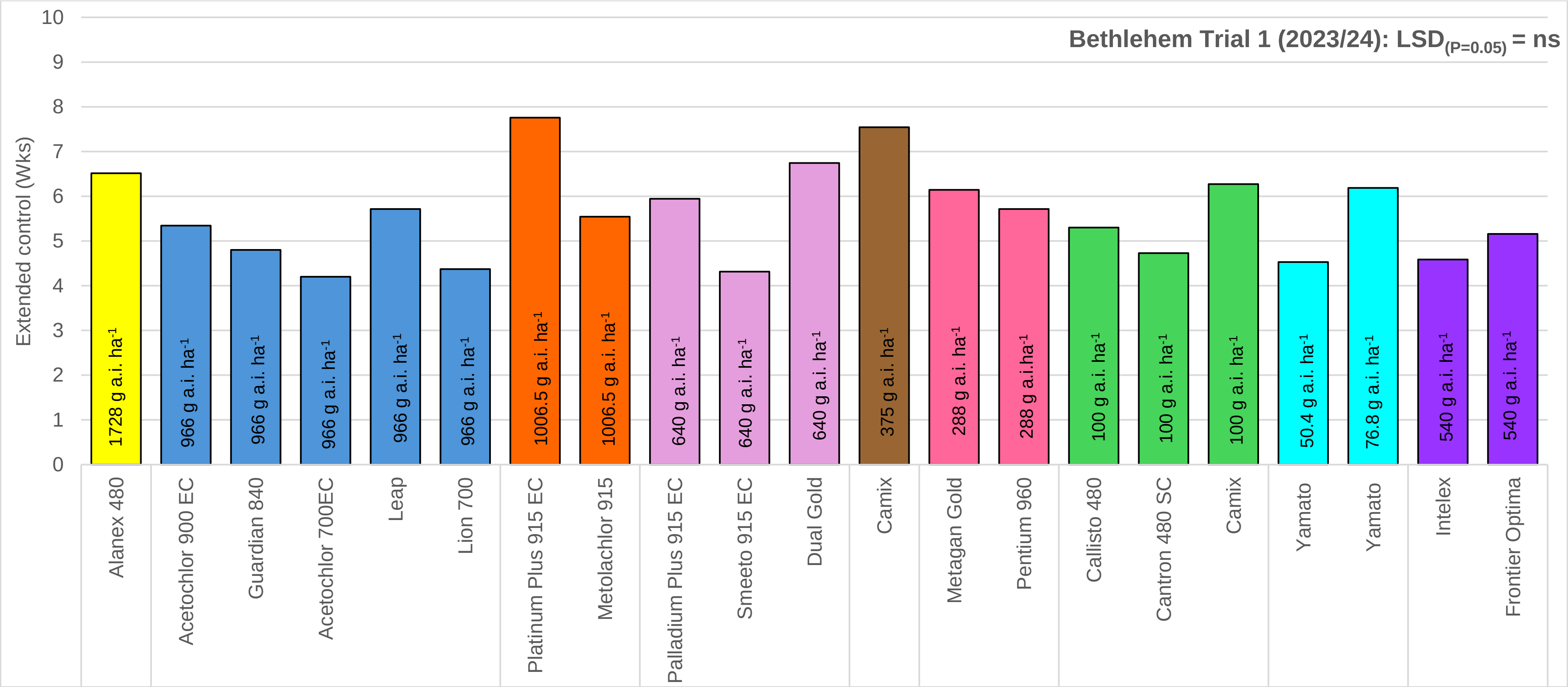


Figure 8: Extended weeks of control achieved with 21 pre-emregent herbicides applied with a early application date (Trial 1) at Bethlehem during 2023/24. (Alchrl = alachlor; Actchlor = acetochlor; Metchlr = Metolachlor; S-moc = S-metolachlor; Mstrne = mesotrione; Psfne = pyroxasufone; Dmid-P = dimethenamid-P)

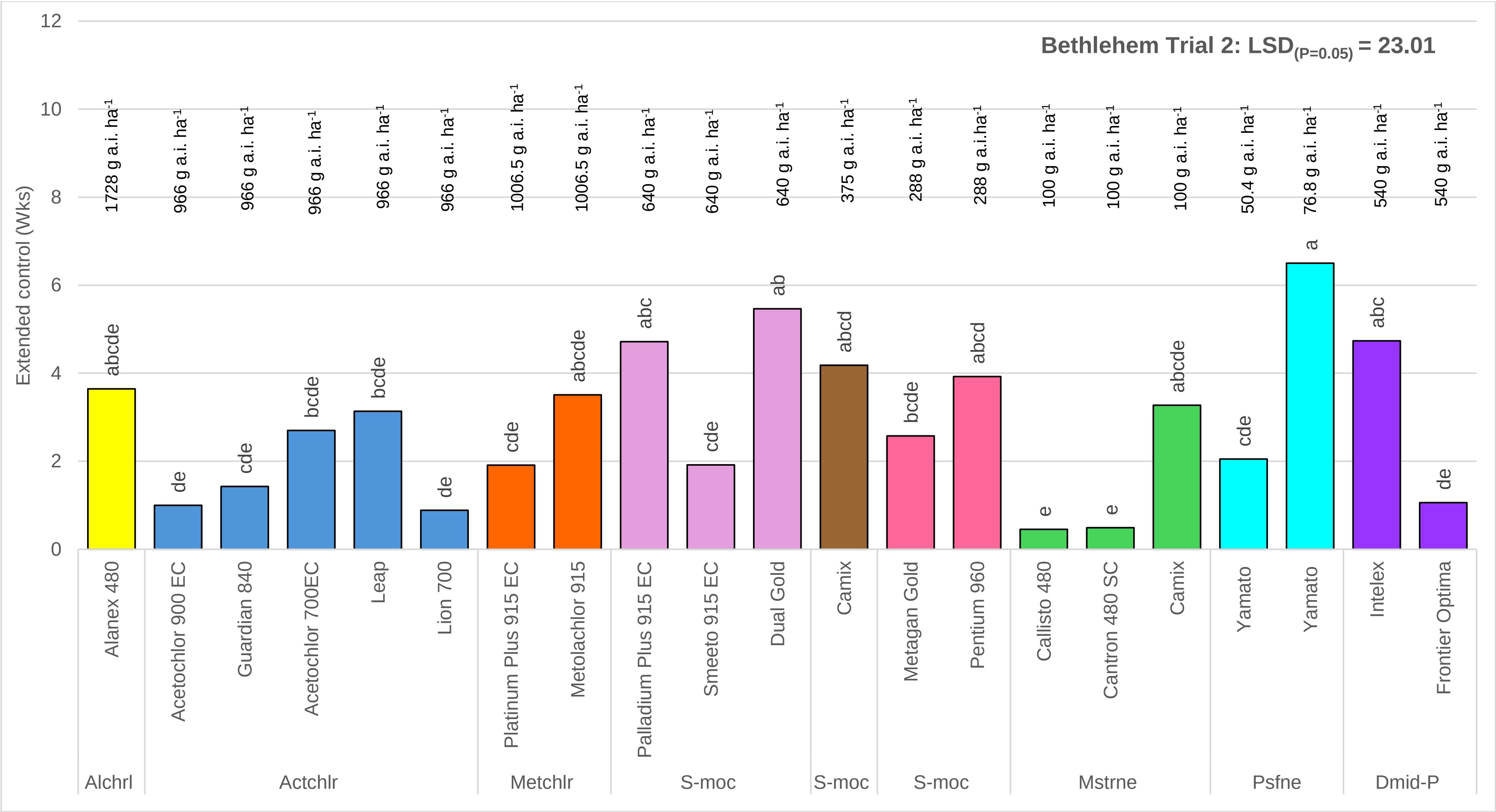


Figure 9: Extended weeks of control achieved with 21 pre-emregent herbicides applied with a late application date (Trial 2) at Bethlehem during 2023/24. (Alchrl = alachlor; Actchlor = acetochlor; Metchlr = Metolachlor; S-moc = S-metolachlor; Mstrne = mesotrione; Psfne = pyroxasufone; Dmid-P = dimethenamid-P). Products with the same alphabetic letter do not differ significantly from each other.

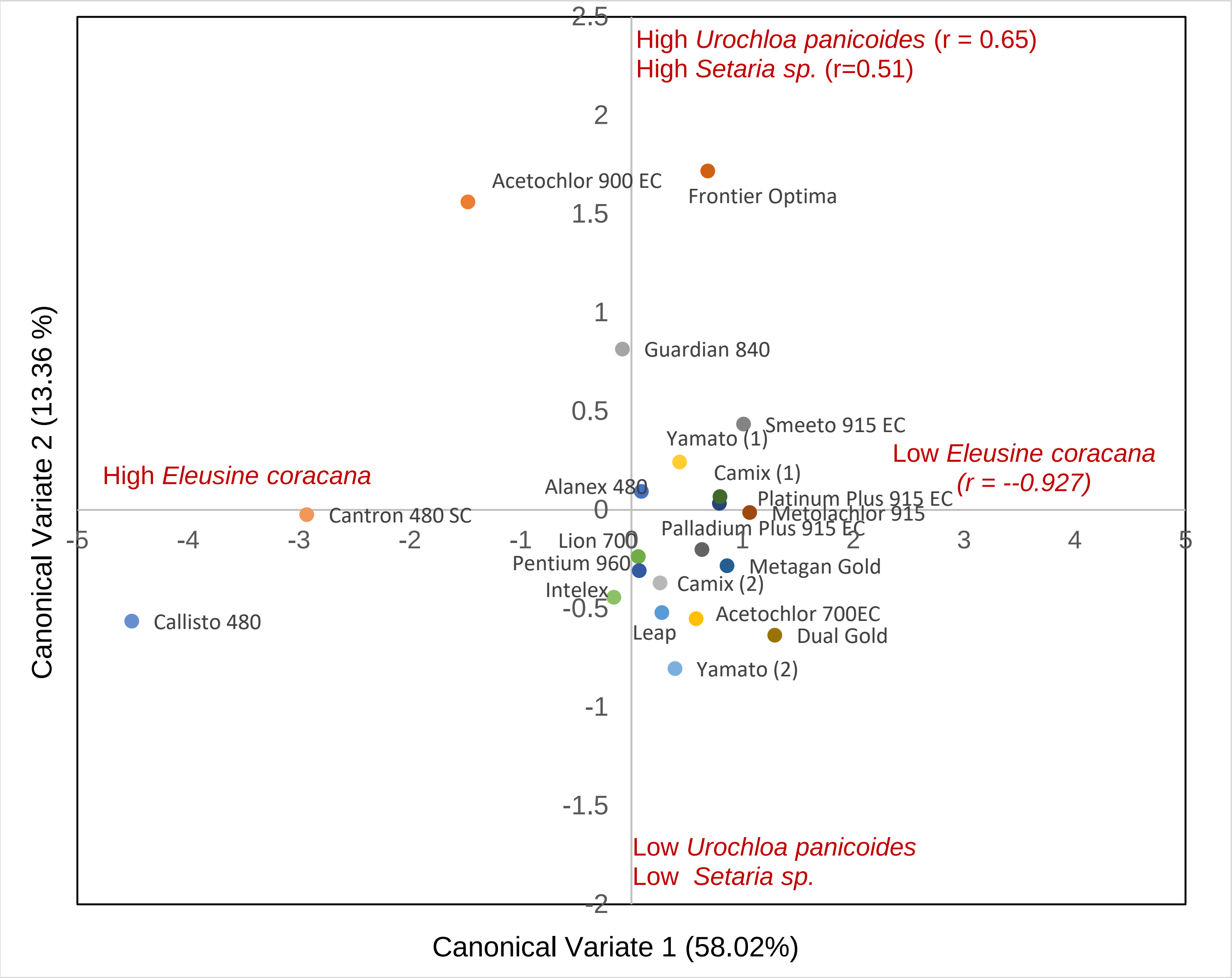


Figure 10: Canonical variate analysis (CVA) demonstrating the effect of the various pre-emergent treatments had on weed species levels in treated plots as observed at 61 days after treatment (DAT)

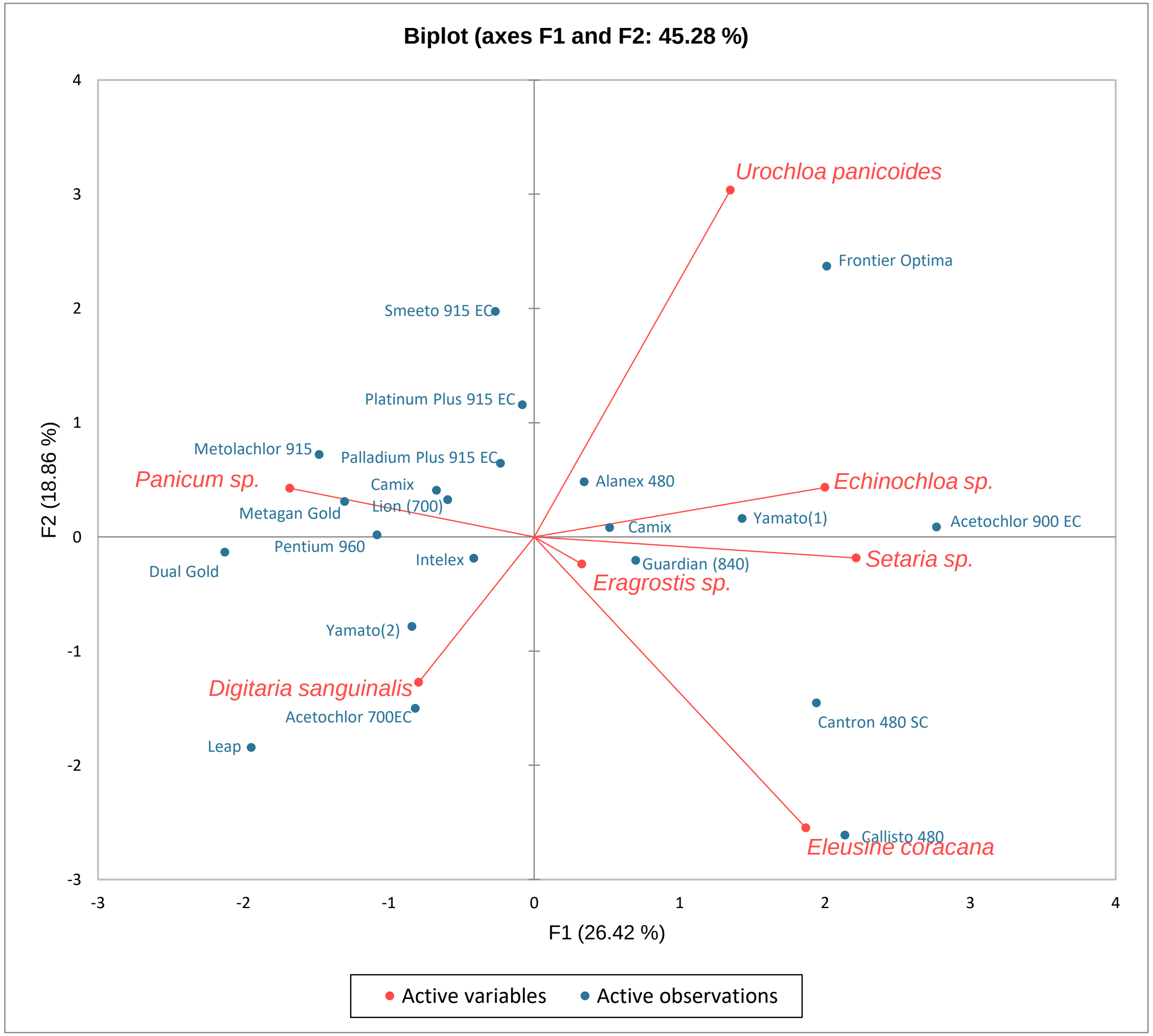


Figure 11: Biplot of principal component analyis (PCA) of seven weed species and pre-emergent herbicides where they showed prefalence to occur in at higher than trial average at 61 Days after treatment in Trial 2 at Bethlehem (2023/24).

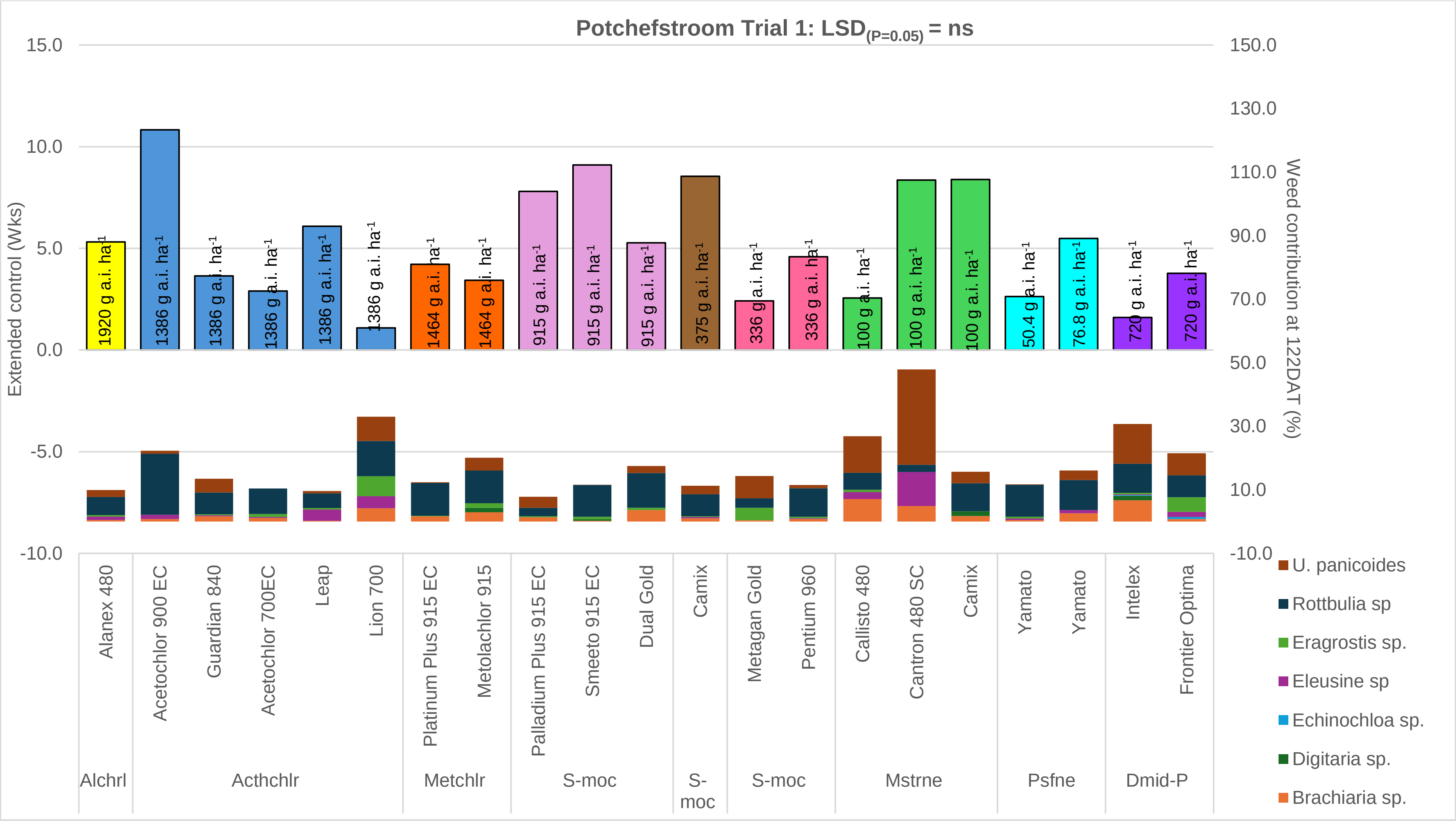


Figure 12: Extended weeks of control achieved with 21 pre-emregent herbicides applied at an early application date at Potchefstroom during 2023/24 (Trial 1). The secondary axis reflects the weed species contribution at 122 days after treatment in the treated plots. (Alchrl = alachlor; Actchlor = acetochlor; Metchlr = Metolachlor; S-moc = S-metolachlor; Mstrne = mesotrione; Psfne = pyroxasufone; Dmid-P = dimethenamid-P)

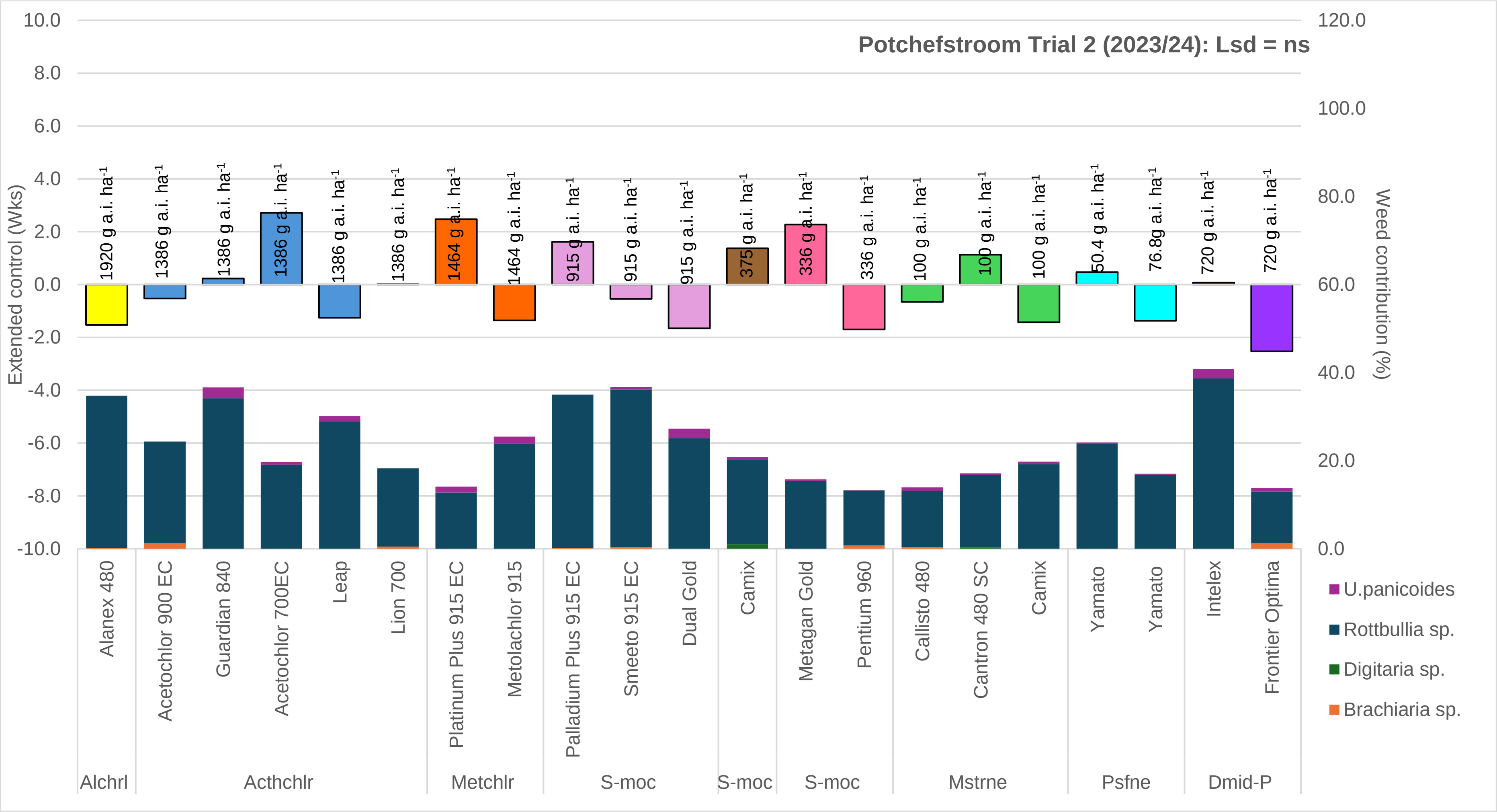


Figure 13: Weeks of extended control achieved by 21 pre-emergent herbicides evaluated on a 35% clay soil at Potchefstroom applied on 9 December 2023 (Trial 2) compared to the untreated controls (LSD$_{(P=0.05)}$ = ns). The secondary axis reflects the weed species contribution at 122 days after treatment in the treated plots. Alchrl = alachlor; Actchlor = acetochlor; Metchlr = Metolachlor; S-moc = S-metolachlor; Mstrne = mesotrione; Psfne = pyroxasufone; Dmid-P = dimethenamid-P)