Impact of rainfall extremes and mulch application on maize productivity and nitrogen use in Zimbabwe

A. Bouhenache[1,2,3,@], H. Clivot[1], G. Lashermes[1], R. Chikowo[4,5], A. Shumba[2,4,6], E. Matimba[2], H. Mazungunye[2,4], S. Recous[1], R. Cardinael[2,3,4]

[1] URCA, INRAE, FARE, UMR A 614, Reims, France; [2] CIRAD, UPR AIDA, Harare, Zimbabwe; [3] AIDA, Univ. Montpellier, CIRAD, Montpellier, France; [4] Department of Plant Production Sciences and Technologies, University of Zimbabwe, Harare, Zimbabwe; [5] CIMMYT, Harare, Zimbabwe; [6] FFRI, DR&SS, Harare, Zimbabwe

Context & background

- In Southern Africa, more intense and frequent dry spells interspersed with heavy rains strongly disrupt cropping seasons
- Some practices (*eg* mineral nitrogen (N) fertilization, mulching) are promoted as levers of productivity, mitigation and sustainability of the systems [1, 2]
- Field studies using rainfall manipulation experiments are of high value to assess the interactions with nutrient cycling but remain scarce [3, 4]

Objectives

Quantify rain extremes **impact** on maize **productivity** and **N use** with and without mulch

Identify mulch **decomposition** kinetics under rain extremes and its **effect** on **soil temperature and soil water content (SWC)**

Materials & methods

Study site

Sub-tropical climate & loamy Ferralsol

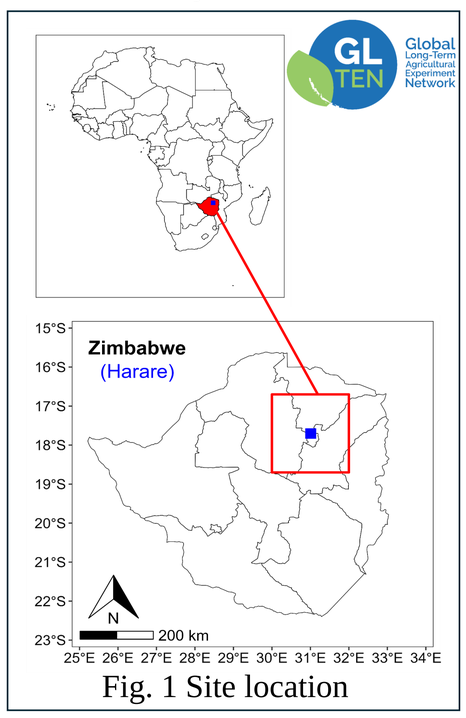


Fig. 1 Site location

Field experiment factors

3 rain treatments

RR — Reduced Rainfall (-30%)

NR — Ambient (Normal) Rainfall

HR — Heavy Rainfall (2 x 100mm/day)

X

2 N fertilization levels

N0: no fertilization
N80: 80 kg N/ha

- Ammonium-nitrate
- "On row" application
- 3 split applications

2 Mulch levels

M0: no mulch
M6: 6 t DM/ha/yr

- Maize residues
- Applied on surface

Data collection

Experimental design

- Split-plot; 3 block replicates; 2 years
- 9 x 7 m individual plots

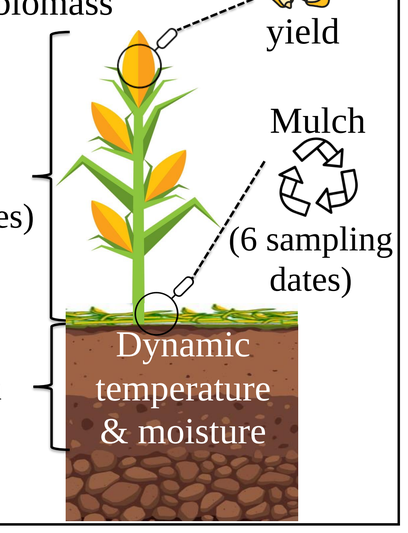
Monitored variables

Aboveground biomass (AGB) & N uptake (4 sampling dates)

yield

Mulch (6 sampling dates)

1, 5 & 15 cm (every 5 min) — Dynamic temperature & moisture



Results & discussion

Plant biomass, yield & N uptake responses

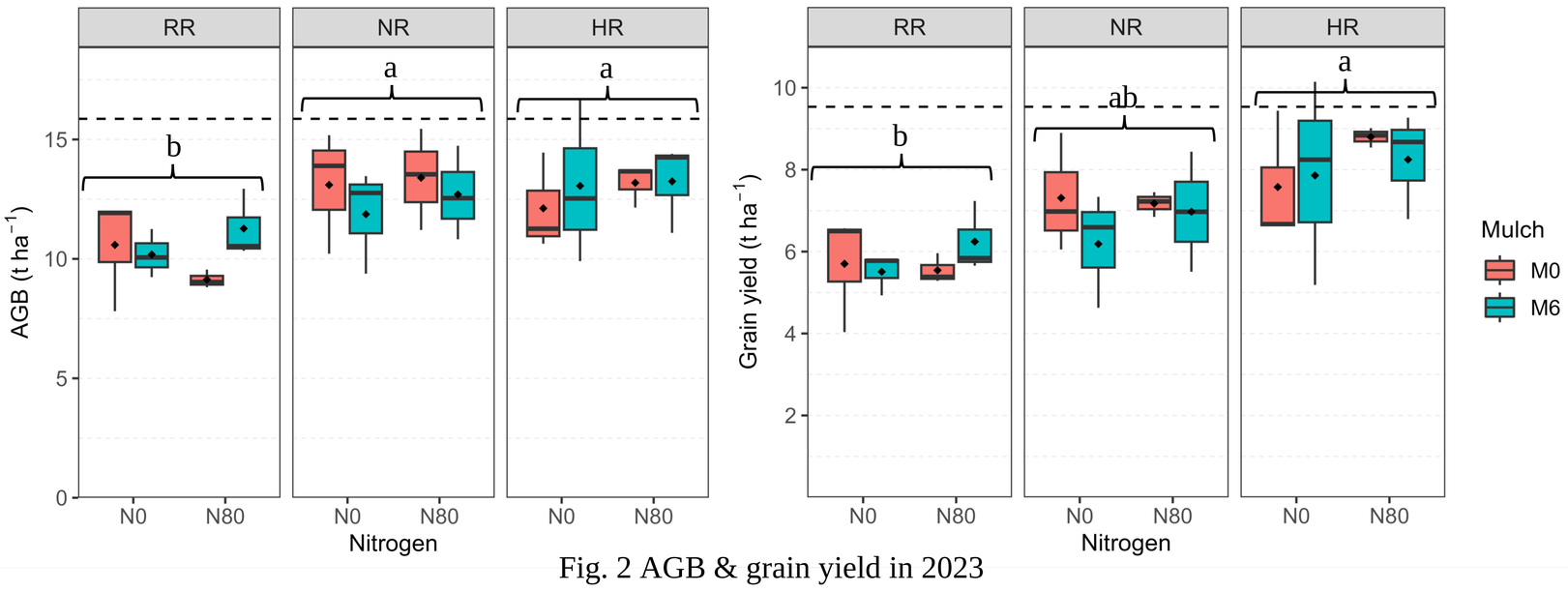


Fig. 2 AGB & grain yield in 2023

- Water limitation decreased maize productivity (-2.5 t/ha of biomass, -1.5 t/ha for yield) & N uptake (-26 kg N/ha) *vs* NR
- Heavy rainfall during a dry spell increased yield (+1.2 t/ha) & N uptake (+10 kg N/ha) *vs* NR
- N fertilization had no effect on AGB & yield, but significantly affected N concentration
- Low N apparent recovery suggests high soil N supply & possible N losses

Crop N uptake (kg N/ha)	RR	NR	HR
N0	102	119	123
N80	120	146	156
Fertilizer apparent recovery (%)	22	33	41

- N uptake was affected by both rain (biomass) & fertilization (N concentration)
- Mulch had no effect on plant variables probably due to in-season rain distribution

Mulch decomposition & effects on soil

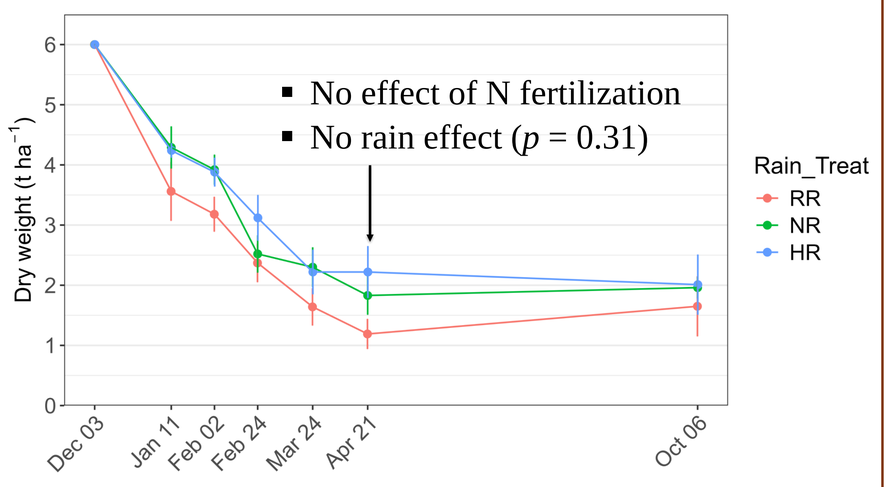


Fig. 3 Mulch decomposition in 2023

Variable	Depth (cm)	in-season Δ mulch – no mulch RR	NR
SWC (%)	1	+ 3.8	+ 3.2
	5	- 0.1	+ 0.6
	15	- 2.2	+ 1.9
Temperature (°C)	1	- 0.9	- 0.5
	5	- 0.5	- 0.3
	15	- 0.6	0

- Main buffering effect at soil surface (1 cm)
- SWC decreased under RR at 5 & 15cm
- Effects on soil processes (*ie* N) are to clarify

Conclusion

- Rain is the dominant factor, with variable impact of extremes depending on their nature & timing of occurrence regarding crop cycle
- The impact of mulch on soil variables does not translate into an effect on the plant variables
- These impacts will be assessed under the 2nd year climatic conditions, with more mechanistic approaches to determine N fertilizer fate (^{15}N tracing & modelling)

@contact:

References
[1] Thierfelder and Wall, (2009), Soil Tillage Res.
[2] Falconnier et al., (2023), Outlook Agric.
[3] Beier et al., (2012), Ecol. Lett.
[4] Grysko et al., (2021), MethodsX

Funded by: