Modelling Rainfed Pearl Millet Yield Sensitivity to Abiotic Stresses in Semi-AridTanzania, Eastern Africa

Festo R. Silungwe, Frieder Graef, Marcos Lana and Sonoko Dorothea Bellingrath-Kimura

1. Challenge

Drought and heat-tolerant crops, such as Pearl millet (*Pennisetum glaucum L.*), are priority crops for fighting hunger in semi-arid regions. Assessing its performance under future climate scenarios and different management options therefore is critical.
This study intends to unterstand the sensitivity of the local "Okoa" pearl millet variety to abiotic stress under both microdose and non-fertilized practices.

2. Approach

Field experiments were conducted over two consecutive rainy seasons (2015/2016 and 2016/2017) to determine the pearl millet yield responses to microdose fertilizer (DAP) application in a semi-arid region of Tanzania. Data from this experiment were used to calibrate and validate the DSSAT model (CERES Millet). Subsequently, the model evaluated synthetic climate change scenarios for temperature increments and precipitation changes based on historic observations (2010–2018). Temperature increases of +0.5 to +3.0 °C (from baseline), under non-fertilized (NF) and fertilizer microdose conditions were used to evaluate nine planting dates from early (5 December) to late planting (25 February), based on increments of 10 days. The planting date with the highest yields was subjected to 49 synthetic scenarios of climate change for temperature and precipitation changes (of −30% up to +30% from baseline) to simulate yield responses.

3. Results and Discussions

3.1 Model Calibration and Validation

The values for model calibration and validation were very precise, indicating the capability of the model to reproduce both phenology and growth of pearl millet for different seasons. Anthesis occurred within two days of observed dates while maturity occurred within one day of observed dates (Table 1). This implied that the model can be used for further evaluations of the effects of different climate scenarios and planting dates

Table 1 cultivar coefficients and model evaluation for Okoa pearl millet variety.

OkoaPearl Millet Cultivar Coefficients Calculated by GLUE Using Field Measurements (Calibration), Followed by Model Validation Outcomes for Anthesis, Physiological Maturity, Tops Weight and Grain Yield								
P1	P2O	P2R	P5	G1	G4	PHINT	GT	G5
271.9	11.87	126.5	251.5	1.498	1.225	43	1	10
	Calibration (2016)				Validation (2017)			
Variable Name	Observed	Simulated	RRMSE (%)	CRM (%)	Observed	Simulated	RRMSE (%)	CRM (%)
Anthesis day	71	71	0.0	0.00	70	68	2.0	1.45
Maturity day	100	101	0.8	−0.60	100	101	1.2	−0.20
Tops weight (kg DW ha^{-1})	4198	4084	7.3	2.72	4629	4582	3.5	1.02
Grain Yield (kg DW ha^{-1})	1078	1037	6.4	3.84	890	851	11.8	4.54

P1 thermal time from seedling emergence to the end of the juvenile phase (degree days above the base temperature of 8 °C) during which the plant is not responsive to photoperiod, P2O Critical photoperiod or the longest day length (in hours) at which development occurs at a maximum rate. At values greater than P2O, the rate of development is reduced, P2R Extent to which phasic development leading to panicle initiation (expressed in degree days) is delayed for each hour increase in photoperiod above P2O, P5 Thermal time (degree days above a base temperature of 10°C) from beginning of grain filling (3-4 days after flowering) to physiological maturity, G1 Scaler for relative leaf size, G4 Scaler for partitioning of assimilates to the panicle (head), PHINT phyllochron interval = thermal time (degree days) between successive leaf tip appearance, GT Tillering coefficient, equivalent to G1, but on tillers, G5 Potential grain size, mg.

3.2 Yield Simulation for Different Temperature Scenarios and Planting Dates

It was found that pearl millet is sensitive to both temperature and planting dates under microdose and non fertilized practices (Fig. 1).

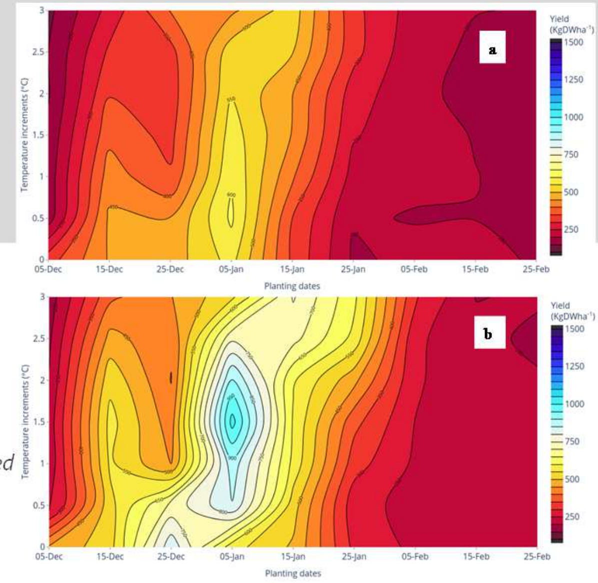

Fig 1. Yield Simulation for Different Temperature Scenarios and Planting Dates for (a) non-fertilized practice (b) microdose practice

Temperature increases affected yields negatively for most planting dates under non-fertilized and fertilizer microdose treatment (Fig. 1). Early and late planting windows were more negatively affected than the normal planting window, implying that temperature increases reduce the length of effective planting window for achieving high yields under both non-fertilized and fertilizer microdose treatments. Better yields were obtained with fertilizer microdosing (Fig. 1).

3.3 Impact of Precipitation Change and Temperature on Yield for same Optimal Planting Date (5th January)

Under fertilizer microdose practice (Fig. 2b), the effects of temperature increments and precipitation change scenarios to yields are higher as compared to non-fertilized (Fig.2a), where isolines are far spaced, implying a high potential of yield improvement especially with increases in precipitation. However, this is only attained at temperatures below 1.5 °C increase .

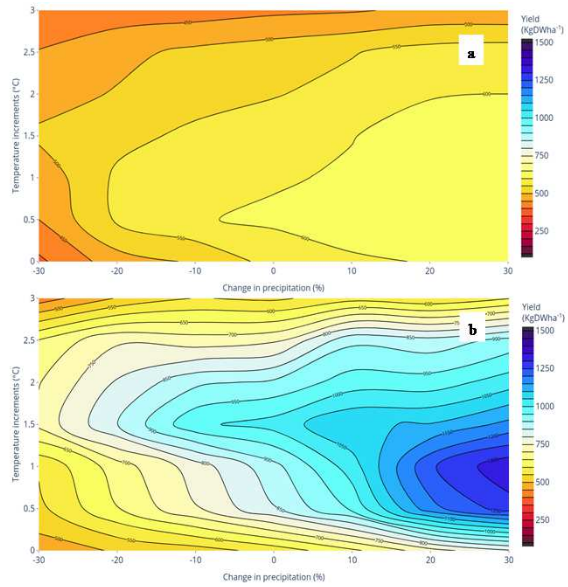

Fig 2. Yield Simulation for Precipitation Change Scenarios for (a) non-fertilized practice (b) microdose practice

4. Conclusions

The tested "Okoa" pearl millet variety produced lower risks of yield loss under microdose practice compared to *non-fertilized practice*. However, higher temperature increases due to climate change exceeding +1.5 °C will reduce the yields of this pearl millet variety.
Therefore, breeding pearl millet varieties tolerant to higher temperatures is recommended.

Contact person: Frieder Graef and Festo Richard Silungwe
Leibniz Centre for Agricultural Landscape Research (ZALF) · Eberswalder Straße 84 · 15374 Müncheberg · Germany
www.zalf.de · [festo.richard@zalf.de · +49 33432 82 [4071] · Date: [May, 16, 2019]