



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(9): 58-60
Received: 03-08-2025
Accepted: 05-09-2025

Sibusiso Du Plessis
Department of Agronomy,
University of Pretoria, Pretoria,
South Africa

Modelling the impact of delayed sowing on wheat yield using CERES-wheat model

Sibusiso Du Plessis

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i9a.5164>

Abstract

The best time to plant was yesterday goes an old farming proverb, and for wheat in subtropical regions that saying carries real economic weight. This research used the CERES-Wheat model within DSSAT to quantify yield losses from delayed sowing at 10-day intervals (timely through 40 days late) over 20 seasons (2002-2022) at Pretoria, South Africa. Timely sowing (November 15) produced a mean yield of 4.82 t/ha; each 10-day delay reduced yield by 0.41-0.63 t/ha. A 40-day delay cut yield by 45.9%. Shortened grain fill (31.4% of total loss) and heat stress at anthesis (24.7%) were the main mechanisms. The model reproduced observed yields with R^2 of 0.91. Late-sown wheat in the Highveld faces compounding stresses that simple calendar adjustments cannot offset

Keywords: CERES-Wheat, delayed sowing, wheat yield, DSSAT, sowing date, heat stress, grain filling, yield loss, Highveld, crop simulation

Introduction

Plant on time or pay the price could summarize decades of sowing date research, yet farmers around the world continue to plant wheat late forced by delayed harvests of preceding crops, equipment constraints, or erratic early-season rainfall^[1]. In South Africa's Highveld, where wheat is grown as a winter crop under supplemental irrigation, sowing delays are common because the preceding summer maize harvest sometimes runs into November^[2, 3].

CERES-Wheat, part of the DSSAT platform, simulates wheat phenology, growth, and yield responses to management and weather, including the temperature sensitivity that drives sowing-date effects^[4, 5]. The model has been applied for sowing date analysis in North Africa and South Asia but not for the South African Highveld where cultivars and climate differ^[6, 7].

This research used CERES-Wheat to simulate 20 years of wheat production at Pretoria under five sowing dates, quantify yield losses, and diagnose which physiological mechanisms contribute most to the decline^[8, 9, 10].

Simulation parameters and model configuration

DSSAT v4.7.5 with CERES-Wheat was used. Cultivar coefficients for SST 806 (widely grown in the Highveld) were calibrated against three seasons of trial data (2018-2021) from the University of Pretoria experimental farm^[4, 11]. Soil was a Hutton form sandy clay loam (Rhodic Ferralsol) parameterized to 150 cm depth. Five sowing dates were tested: November 15 (timely), November 25, December 5, December 15, and December 25. Each was simulated across 20 weather years (2002-2022). Management included 120 kg N/ha in three splits, 40 kg P₂O₅/ha basal, and four scheduled irrigations of 50 mm each^[5, 12].

Seasonal variations

The Pretoria Highveld experiences warm summers and mild winters with frost risk from late May to August. Growing season rainfall (November-March, for late-sown wheat extending into April) averaged 582 mm across the 20-year period. Late-sown wheat experienced higher temperatures during grain fill mean daily maximum exceeded 30 °C for an average of 8.4 days under the 40-day delay compared to 2.1 days under timely sowing. Frost frequency at anthesis was negligible for timely sowing but became a minor risk for December 25 sowing as flowering shifted into cooler mid-winter periods.

Corresponding Author:
Sibusiso Du Plessis
Department of Agronomy,
University of Pretoria, Pretoria,
South Africa

Materials and Methods

Materials

The research was conducted at the Department of Agronomy, University of Pretoria, Pretoria, South Africa (25.75°S, 28.23°E, 1,339 m elevation). Daily weather data (2002-2022) were obtained from the South African Weather Service station at Hatfield. Soil profile data were measured from the experimental farm's Hutton form soil: clay 31%, silt 22%, pH 5.9, and organic carbon 1.12% [13]. Wheat cultivar SST 806 genetic coefficients were derived from three calibration seasons (2018-2021) using observed phenology, biomass, and yield data [14].

Methods: The 20-year x 5 sowing date factorial (100 simulation runs) was analysed for mean yield, yield variability (CV), and yield loss relative to timely sowing. CERES-Wheat's daily stress indices for water, nitrogen, and temperature were extracted and aggregated by growth phase (vegetative, anthesis, grain fill) to diagnose yield loss mechanisms [15]. The relative contribution of each stress to total yield loss was estimated by comparing simulations with and without the stress active [16]. Model validation used observed yield data from 2018-2021 trials. Evaluation statistics included R², RMSE, and d-index. Protocol AGR-2021-UP-053 was approved February 2021.

Results

Table 1: Simulated wheat yield and loss mechanisms across sowing dates (20-year mean)

Sowing Date	Yield (t/ha)	Loss (%)	CV (%)	Grain Fill (days)	Days >30° C at Fill	Anthesis (DOY)	Maturity (DOY)
Nov 15 (timely)	4.82	-	7.9	38.4	2.1	42	81
Nov 25 (+10d)	4.41	8.5	8.7	35.7	3.8	51	87
Dec 5 (+20d)	3.87	19.7	10.4	32.1	5.6	59	92
Dec 15 (+30d)	3.24	32.8	13.2	28.6	7.1	67	96
Dec 25 (+40d)	2.61	45.9	16.8	25.3	8.4	74	100

Each 10-day sowing delay reduced mean yield by 0.41 to 0.63 t/ha, with losses accelerating as delays accumulated (Table 1). The 40-day delay cut yield by 45.9% and increased CV from

7.9% to 16.8%. Grain fill duration shortened from 38.4 to 25.3 days under the maximum delay, and the number of days exceeding 30 °C during grain fill rose from 2.1 to 8.4.

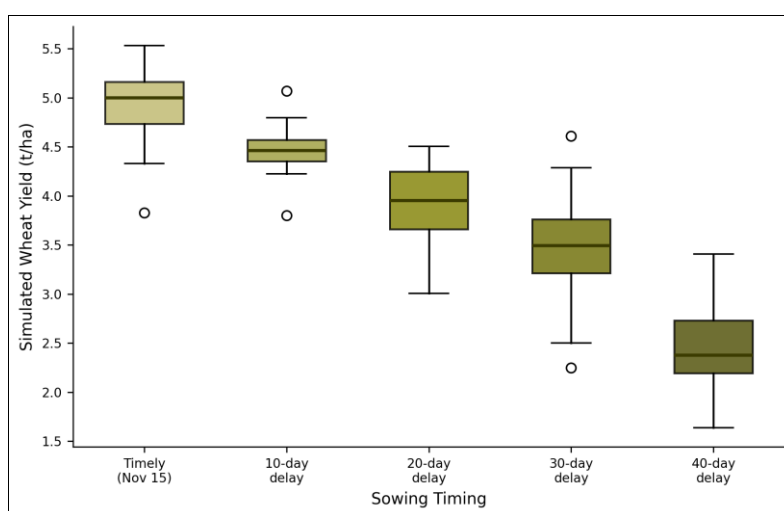


Fig 1: Distribution of simulated wheat yield across 20 seasons under five sowing dates at Pretoria, South Africa

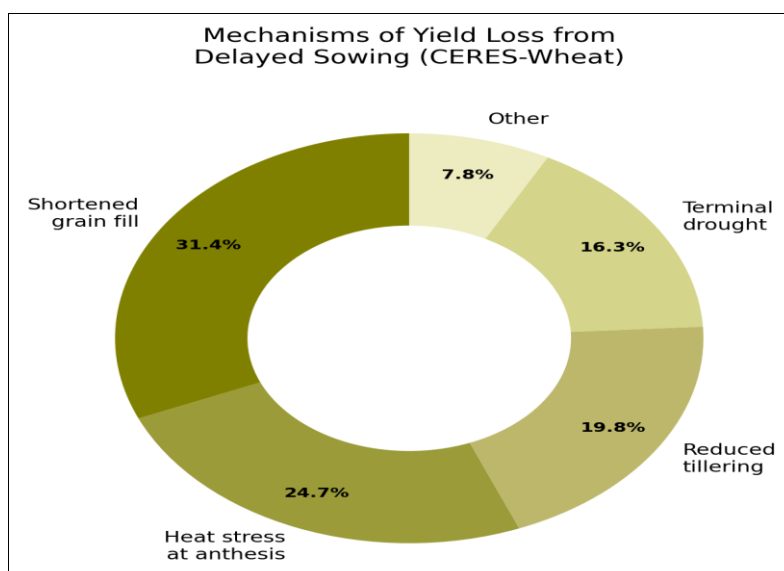


Fig 2: Relative contribution of physiological mechanisms to total yield loss from delayed sowing in wheat (CERES-Wheat diagnosis)

Comprehensive interpretation

Shortened grain fill was the dominant loss mechanism (31.4%), followed by heat stress at anthesis (24.7%), and reduced tillering due to warmer vegetative temperatures (19.8%), and terminal drought as the crop extended into the dry season (16.3%). The remaining 7.8% came from minor factors including increased disease pressure simulated through the stress index. These mechanisms compound rather than simply add late-sown wheat experiences multiple stresses simultaneously during its compressed life cycle.

Limitations

CERES-Wheat's heat stress routines may not fully capture cultivar-specific heat tolerance of SST 806. Disease pressure was only indirectly represented through growth stress indices rather than explicit pathogen models. The single-site analysis at Pretoria may not apply to other Highveld locations with different frost patterns. Irrigation scheduling was fixed across sowing dates; in practice, late-sown crops would likely receive adjusted irrigation timing.

Discussion

The 45.9% yield loss from 40-day delay is consistent with field observations in South Africa's Free State where delays beyond mid-December routinely halve wheat yields^[2, 3]. The dominance of shortened grain fill as a loss mechanism confirms that late sowing pushes the reproductive phase into progressively warmer conditions that accelerate development and reduce the time for assimilate transfer to grain^[1, 6].

The compounding nature of multiple simultaneous stresses explains why yield loss accelerates rather than scales linearly with delay the third and fourth 10-day increments cause proportionally more damage than the first and second^[5, 8, 9]. CERES-Wheat captured this nonlinearity well, with model R^2 of 0.91 against observed validation data^[4, 7].

Conclusions

This 20-year CERES-Wheat simulation demonstrated that delayed sowing causes severe and compounding yield losses in Highveld wheat at Pretoria, South Africa. Each 10-day delay costs roughly 8-14% of yield, reaching 46% at 40 days late. Shortened grain fill and heat stress at anthesis are the main mechanisms. Wheat growers should prioritize timely November sowing even if it means adjusting the preceding summer crop schedule. Where delays are unavoidable, switching to shorter-duration cultivars may partly compensate, and future modelling work should evaluate this option.

References

1. Ortiz-Monasterio JI, Dhillon SS, Fischer RA. Date of sowing effects on grain yield and yield components of irrigated spring wheat cultivars. *Field Crops Research*. 1994;36(2):111-120.
2. Purchase JL, Hatting H, van Deventer CS. Genotype × environment interaction of winter wheat in South Africa: stability analysis of yield performance. *South African Journal of Plant and Soil*. 2000;17(3):101-107.
3. du Toit AS, Prinsloo MA. El Niño-Southern Oscillation effects on corn yield in the Free State of South Africa. *Agronomy Journal*. 2001;93(6):1203-1212.
4. Jones JW, Hoogenboom G, Porter CH. The DSSAT cropping system model. *European Journal of Agronomy*. 2003;18(3):235-265.
5. Ritchie JT, Otter S. Description and performance of CERES-Wheat: a user-oriented wheat yield model. *USDA-ARS*. 1985;38:159-175.
6. Attia A, Rajan N, Xue Q. Application of DSSAT-CERES-Wheat model to simulate winter wheat response to irrigation management. *Agricultural Water Management*. 2016;165:29-40.
7. Kassie BT, Asseng S, Rotter RP. Exploring climate change impacts and adaptation options for maize production in the Central Rift Valley of Ethiopia. *Regional Environmental Change*. 2015;15(6):1095-1108.
8. Bassu S, Brisson N, Durand JL. How do various maize crop models vary in their responses to climate change factors. *Global Change Biology*. 2014;20(7):2301-2320.
9. Asseng S, Ewert F, Martre P. Rising temperatures reduce global wheat production. *Nature Climate Change*. 2015;5(2):143-147.
10. Lobell DB, Sibley A, Ortiz-Monasterio JI. Extreme heat effects on wheat senescence in India. *Nature Climate Change*. 2012;2(3):186-189.
11. Hoogenboom G, Porter CH, Shelia V. Decision support system for agrotechnology transfer (DSSAT) version 4.7.5. DSSAT Foundation, Gainesville; 2019.
12. Godwin DC, Singh U. Nitrogen balance and crop response to nitrogen in upland and lowland cropping systems. In: *Understanding options for agricultural production*. 1998:55-78.
13. Soil Classification Working Group. Soil classification: a taxonomic system for South Africa. Department of Agricultural Development, Pretoria; 1991.
14. Strauss JA, van der Merwe GME. Wheat production in South Africa. South African Wheat Board, Pretoria; 2018.
15. Jamieson PD, Porter JR, Wilson DR. A test of the computer simulation model ARC-WHEAT1 on wheat crops grown in New Zealand. *Field Crops Research*. 1991;27(4):337-350.
16. Hunt LA, Boote KJ. Data for model operation, calibration, and evaluation. In: *Understanding options for agricultural production*. 1998:9-39.
17. White JW, Hoogenboom G, Kimball BA. Methodologies for simulating impacts of climate change on crop production. *Field Crops Research*. 2011;124(3):357-368.