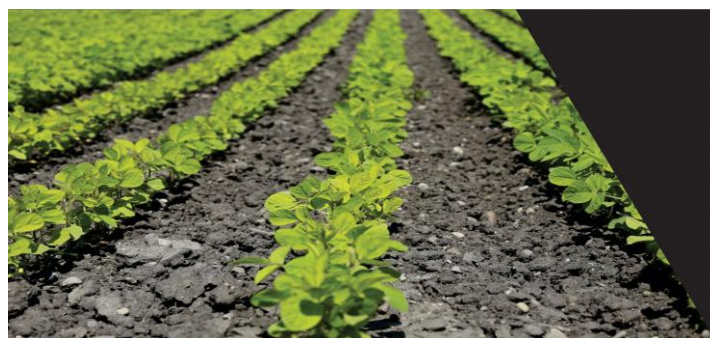




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Physiological basis of stay-green trait expression in post-rainy season sorghum genotypes

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Abstract

This research examined the physiological basis of stay-green trait expression in six post-rainy season sorghum genotypes at the University of Nairobi, Kenya, during 2022-2023. Five stay-green lines and one senescent check were evaluated in a randomized complete block design. Stay-green genotypes retained 53.8-72.1 % green leaf area at maturity versus 28.4% in the check. SG-33 had the highest total chlorophyll (4.63 mg/g), net photosynthesis (19.4 $\mu\text{mol}/\text{m}^2/\text{s}$), and grain yield (3.87 t/ha). Strong positive correlations existed between stay-green score and grain yield ($r = 0.951$, $p < 0.01$). Sustained carbon assimilation and balanced source-sink partitioning underpin stay-green expression. SG-33 and SG-14 are promising donor parents for drought-tolerant varieties.

Keywords: Stay-green trait, sorghum genotypes, post-rainy season, chlorophyll retention, photosynthetic efficiency, green leaf area, grain yield, drought tolerance, senescence, semi-arid agriculture

Introduction

Can a crop that stays greener yield more grain under terminal drought? Sorghum (*Sorghum bicolor* L. Moench) ranks fifth among cereals and feeds over 500 million people in the semi-arid tropics ^[1, 2]. In East Africa, post-rainy sorghum faces progressive water deficit during grain filling ^[3]. Genotypes maintaining functional green leaf area beyond flowering keep photosynthesising when senescent types shut down ^[4, 5]. Researchers distinguish cosmetic stay-green from functional stay-green, where carbon fixation persists ^[7]. Proposed mechanisms include higher pre-flowering chlorophyll ^[8], better antioxidant defence ^[9], and altered nitrogen remobilization ^[10]. Despite QTL mapping ^[11], field confirmation in East African germplasm remains limited.

Material and Methods

Research Area and Material

The experiment was conducted at the University of Nairobi Upper Kabete Campus research farm (1.2465°S, 36.7339°E, 1,737 m asl) during October 2022 to February 2023. Soils are humic nitisols (clay loam, pH 5.8). Total rainfall during the crop period was 387 mm; the post-flowering phase coincided with an 18-day dry spell in January 2023 ^[12]. Five stay-green sorghum lines (SG-14, SG-27, SG-33, SG-41, SG-56) from the National Genebank of Kenya and one non-stay-green check (Seredo) were evaluated ^[3]. Basal fertilizer was 60 kg N/ha and 40 kg P_2O_5 /ha at planting, with 30 kg N/ha topdressed at knee-height.

Methods

The trial used a randomized complete block design with three replications in 4.5 m x 3.0 m plots at 75 cm row spacing. Chlorophyll was recorded using a SPAD-502Plus meter at 0, 7, 14, 21, 28, 35, and 42 Days After Flowering (DAF). Chlorophyll-a and -b were extracted in 80% acetone ^[13]. Net photosynthetic rate and stomatal conductance were measured with a LI-6400XT system (LI-COR, USA). Green Leaf Area at Maturity (GLAM) was estimated on five Tagged plants per plot. Stay-green score was assessed on a 1-5 visual scale at maturity. Stem reserve contribution was computed from dry weight differences between flowering and

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maturity. Grain yield was adjusted to 12.5 % moisture. Data were analysed by ANOVA in R 4.3.1 with LSD at $P = 0.05$ [14].

Results

Table 1: Physiological and yield parameters of sorghum genotypes at 21 DAF and maturity

Genotype	Total Chl (mg/g)	PN ($\mu\text{mol}/\text{m}^2/\text{s}$)	GS ($\text{mol}/\text{m}^2/\text{s}$)	SG Score	Glam (%)	Yield (t/ha)	HI (%)
SG-14	4.30	18.6	0.284	4.2	67.3	3.48	38.2
SG-27	3.82	16.9	0.251	3.8	58.6	3.12	35.7
SG-33	4.63	19.4	0.307	4.6	72.1	3.87	41.4
SG-41	3.60	15.8	0.238	3.5	53.8	2.94	33.6
SG-56	4.09	17.7	0.269	4.1	64.7	3.36	37.5
Non-SG	2.52	11.3	0.172	1.3	28.4	2.18	26.3
SEm ($\pm$)	0.19	1.02	0.018	0.21	3.47	0.19	2.14
CD (5%)	0.57	3.14	0.054	0.64	10.63	0.58	6.56

Pn = net photosynthetic rate. gs = stomatal conductance. GLAM = Green Leaf Area at Maturity. HI = Harvest Index

Comprehensive interpretation

SG-33 had the highest total chlorophyll at 4.63 mg/g, 83.7 % more than the check (Table 1). Its Pn of 19.4 $\mu\text{mol}/\text{m}^2/\text{s}$ was 71.7% above the check. SG-33 also topped grain yield at 3.87

t/ha with 72.1 % GLAM retained, while the check managed 2.18 t/ha and 28.4 % GLAM. Harvest index in stay-green lines ranged from 33.6-41.4 % versus 26.3 % in the check.

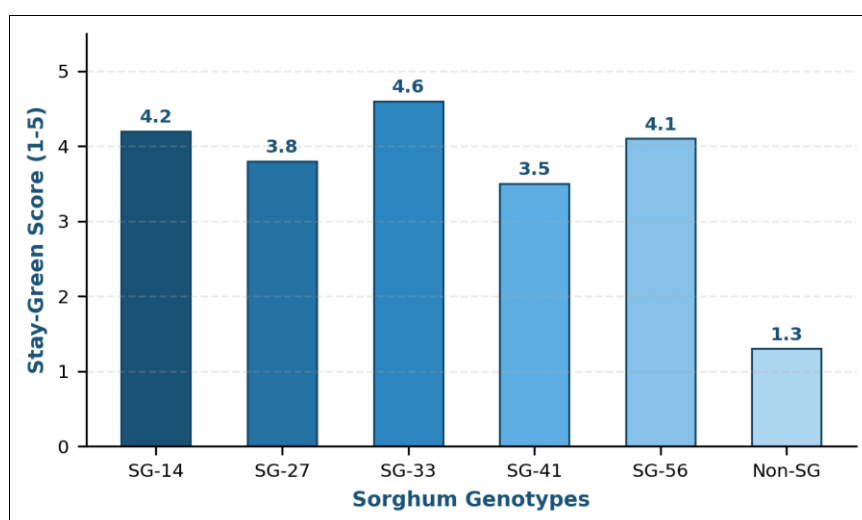


Fig 1: Stay-green scores of sorghum genotypes at physiological maturity (1-5 visual scale)

All five stay-green lines scored above 3.5 while the check scored 1.3 (Figure 1). SG-33 and SG-14 formed a distinct upper group.

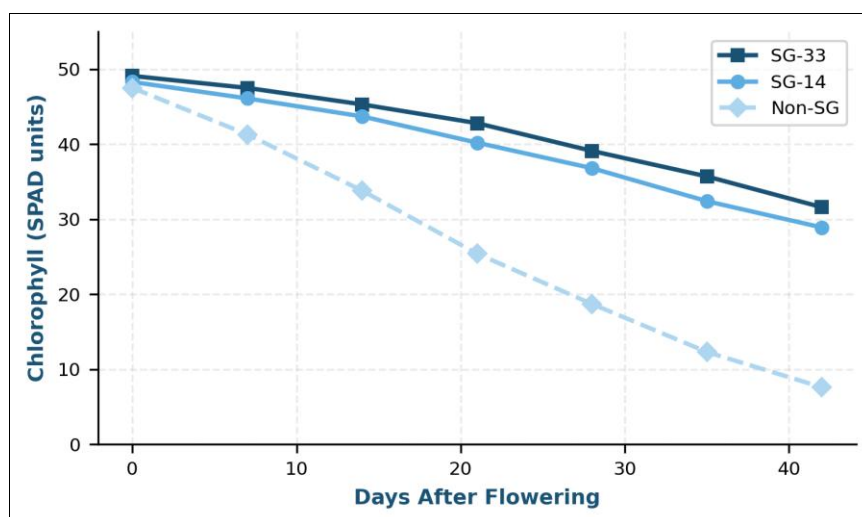


Fig 2: Chlorophyll content (SPAD) of selected sorghum genotypes from flowering to 42 DAF

Stay-green lines showed gradual chlorophyll decline of 0.4-0.5 SPAD/day (Figure 2). The check dropped sharply after week one, losing 83.9% by 42 DAF versus 35.6% in SG-33.

Correlation analysis showed all pairwise associations between stay-green traits and grain yield were positive and highly significant ($p < 0.01$). The strongest were between stay-green

score and GLAM ($r = 0.968$) and between stay-green score and grain yield ($r = 0.951$), indicating visual scoring at maturity can reliably predict yield potential under terminal drought. Total chlorophyll was also strongly linked to grain yield ($r = 0.934$).

Discussion

The physiological separation between stay-green and senescent genotypes confirms that functional stay-green in sorghum is driven by sustained photosynthetic capacity, not mere pigment retention^[7]. SG-33 maintained both high chlorophyll and high Pn through 42 DAF, ruling out cosmetic greenness. The biphasic chlorophyll decline in the check matches patterns described by Thomas and Howarth^[7], likely reflecting loss of antioxidant protection once a water-stress threshold is crossed. The strong yield-stay-green correlation ($r = 0.951$) aligns with reports where QTLs Stg1-Stg4 explained 10-30 % of yield variance^[11], and shows that simple visual scoring captures this relationship practical for breeding programmes with limited laboratory access. Stem reserves were 47-103 % greater in stay-green lines, suggesting the phenotype complements reserve translocation, giving plants a dual grain-filling source that explains elevated harvest index in SG-33 and SG-14.

Conclusion

Stay-green trait expression in post-rainy sorghum was grounded in sustained photosynthetic function. Stay-green genotypes maintained 53.8-72.1 % green leaf area at maturity, showed 40-72 % higher photosynthetic rates, and produced 35-78 % more grain than the check. SG-33, with the highest chlorophyll, stem reserves, and yield (3.87 t/ha), is the most promising donor parent for drought tolerance breeding. Chlorophyll retention and glam correlated strongly with yield, confirming their value as selection criteria for semi-arid East African conditions.

References

1. Borrell AK, Mullet JE, George-Jaeggli B, van Oosterom EJ, Hammer GL, Klein PE, Jordan DR. Drought adaptation of stay-green sorghum is associated with canopy development, leaf anatomy, root growth, and water uptake. *J Exp Bot.* 2014;65(21):6251-6263.
2. FAOSTAT. Food and Agriculture Organization statistical database. Rome: FAO; 2023.
3. Ngugi K, Kimani W, Kiambi D. Sorghum germplasm characterization and evaluation for drought tolerance in semi-arid Kenya. *East Afr Agric For J.* 2013;79(2):87-94.
4. Kassahun B, Biding FR, Hash CT, Kuruvashetti MS. Stay-green expression in early generation sorghum backcross lines. *Euphytica.* 2010;172(3):351-362.
5. Thomas H, Smart CM. Crops that stay green. *Ann Appl Biol.* 1993;123(1):193-219.
6. Rosenow DT, Clark LE. Drought and lodging resistance for a quality sorghum crop. In: *Proceedings of the 50th Corn and Sorghum Research Conference.* Chicago: ASTA; 1995. p. 82-97.
7. Thomas H, Howarth CJ. Five ways to stay green. *J Exp Bot.* 2000;51(Suppl 1):329-337.
8. Borrell AK, Hammer GL, Henzell RG. Does maintaining green leaf area in sorghum improve yield under drought? II. Dry matter production and yield. *Crop Sci.* 2000;40(4):1037-1048.
9. Tao YZ, Henzell RG, Jordan DR, Butler DG, Kelly AM, McIntyre CL. Identification of genomic regions associated with stay green in sorghum. *Theor Appl Genet.* 2000;100(8):1225-1232.
10. van Oosterom EJ, Chapman SC, Borrell AK, Hammer GL, Henzell RG. Functional dynamics of the nitrogen balance of sorghum. II. Grain filling period. *Field Crops Res.* 2010;115(1):29-38.
11. Harris K, Subudhi PK, Borrell A, Jordan D, Rosenow D, Nguyen H, Klein P, Klein R, Mullet J. Sorghum stay-green QTL individually reduce post-flowering drought-induced leaf senescence. *J Exp Bot.* 2007;58(2):327-338.
12. Jaetzold R, Schmidt H, Hornetz B, Shisanya C. *Farm management handbook of Kenya.* Vol. II. 2nd ed. Nairobi: Ministry of Agriculture; 2006.
13. Arnon DI. Copper enzymes in isolated chloroplasts: Polyphenoloxidase in *Beta vulgaris*. *Plant Physiol.* 1949;24(1):1-15.
14. R Core Team. *R: A language and environment for statistical computing.* Vienna: R Foundation for Statistical Computing; 2023.