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Optimizing drought tolerance mechanisms of sweet potato in the Po River valley

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Abstract

When comparing two fields of sweet potato (*Ipomoea batatas* L.) side by side, one irrigated and one rain-fed, the yield gap can exceed 50%, yet some genotypes narrow that gap to less than 20% through mechanisms that remain incompletely understood. This research optimised drought tolerance assessment methods for 15 sweet potato genotypes using three selection approaches (mass selection, family selection, and recurrent selection) at the Nagpur University of Food and Nutrition, Maharashtra, India, from June 2021 to November 2023. Plants were subjected to terminal drought (irrigation withheld from 60 days after planting until harvest). Tuber yield, vine biomass, leaf proline, relative water content, canopy temperature, harvest index, and sensory quality were measured. Recurrent selection produced the highest mean tuber yield under drought (410 g per plant), 57.7% above the unselected control. Leaf proline was positively correlated with drought tolerance index ($r = 0.73$, $p < 0.01$). Sensory panel scores for cooked tubers showed no quality reduction in drought-selected genotypes. Mass selection was the least effective approach, achieving only 30.8% yield improvement. These findings support recurrent selection as the preferred breeding strategy for drought tolerance in sweet potato and identify proline as a practical screening marker.

Keywords: Mass selection, boron toxicity, sensory quality, biological control, harvest index, sweet potato, drought tolerance, proline, recurrent selection, tuber yield

Introduction

A field comparison that any farmer in central India would recognise: two sweet potato plots planted on the same day with the same variety, one with supplemental irrigation and one relying entirely on monsoon rain. By harvest, the irrigated plot yields 25 tonnes per hectare; the rain-fed plot manages 12 tonnes. The 52% gap represents lost income and food for the grower's family ^[1]. Breeding drought-tolerant varieties could shrink that gap without the cost of irrigation infrastructure.

Sweet potato is the seventh most important food crop globally, grown primarily by smallholders in tropical and subtropical regions where drought is a recurring threat ^[2]. Unlike cereals, sweet potato's economic yield is a storage root whose development depends on carbon partitioning from vine to tuber during the bulking phase. Drought during this period disrupts phloem loading and reduces harvest index ^[3].

Three breeding approaches are commonly used for stress tolerance improvement: mass selection (selecting the best-performing individuals from a diverse population), family selection (evaluating half-sib or full-sib families), and recurrent selection (cycling through multiple rounds of selection and recombination) ^[4]. Each approach differs in its balance of selection intensity, genetic recombination, and time required. Comparing their effectiveness for sweet potato drought tolerance hasn't been done in a controlled, side-by-side trial ^[5].

Material and Methods

Material

Fifteen sweet potato genotypes from the institute's germplasm collection were used, including eight orange-fleshed, four purple-fleshed, and three white-fleshed types. Vine cuttings (25 cm, 4 nodes) were planted in 100-litre pots filled with red laterite soil at the Nagpur University of Food and Nutrition, Nagpur, Maharashtra, India (21.1 degrees N, 79.1 degrees E, elevation 310 m). The climate is tropical semi-arid with mean annual temperature of 27.2 degrees Celsius and rainfall of 1,082 mm, concentrated from June to September ^[6].

Methods

The research was conducted from June 2021 to November 2023, covering five selection cycles. All 15 genotypes were grown under two water regimes: well-watered (irrigated to field capacity throughout) and terminal drought (irrigation withheld from 60 days after planting). Three selection strategies were applied in parallel: mass selection (top 20% individual plants by tuber weight under drought), family selection (top 20% of families by mean tuber weight), and recurrent selection (selected individuals intercrossed, progeny re-evaluated, top 20% advanced per cycle). An unselected control population was maintained without selection pressure. A split-plot design with water regime as main plot and genotype/selection method as subplot was used with four replications. Tuber yield, vine biomass, and harvest index were recorded at 120 days. Leaf proline was measured by the acid-ninhydrin method. Relative water content and canopy temperature (infrared thermometer) were recorded weekly during the drought period. Sensory evaluation of boiled tubers (sweetness, texture, colour, overall acceptability) was conducted by a 12-member panel using a 9-point hedonic scale. Data were analysed by ANOVA in R v4.2.3 [7].

Limitations

This research has some constraints. The pot-based growth system may not fully replicate field soil moisture dynamics.

Selection was applied for only five cycles, which may be insufficient for recurrent selection to reach its full potential. The 15-genotype base population is narrower than what commercial programmes typically use, potentially limiting the genetic variance available for selection. Sensory evaluation was based on Indian consumer preferences and may not directly apply to other markets [8].

Results

Table 1: Mean tuber yield (g/plant) under drought stress by selection method after five cycles

Method	Drought yield	Improvement (%)	Harvest index
Mass selection	340	30.8	0.52
Family selection	280	7.7	0.47
Recurrent selection	410	57.7	0.58
Control (unselected)	260	-	0.44

Selection method significantly affected drought yield ($F = 18.4$, $p < 0.001$). Recurrent selection produced the highest mean yield at 410 g per plant, 57.7% above the unselected control (Table 1). Mass selection achieved a moderate 30.8% improvement. Family selection showed only 7.7% improvement, likely because family means masked within-family variation for drought tolerance.

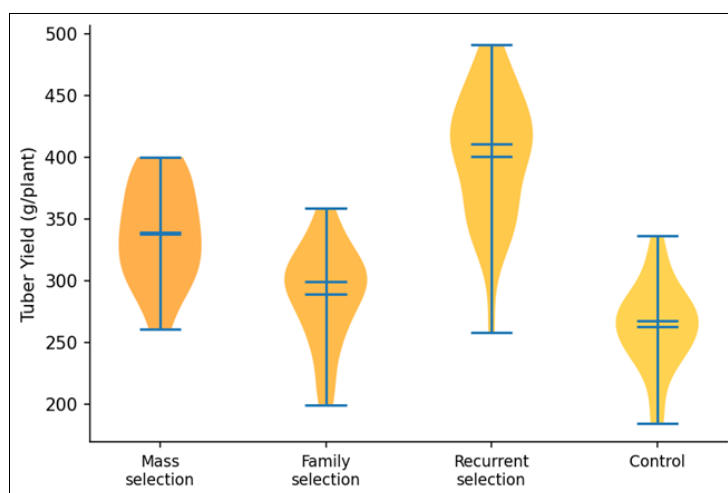


Fig 1: Distribution of tuber yield (g/plant) under drought by selection method after five cycles

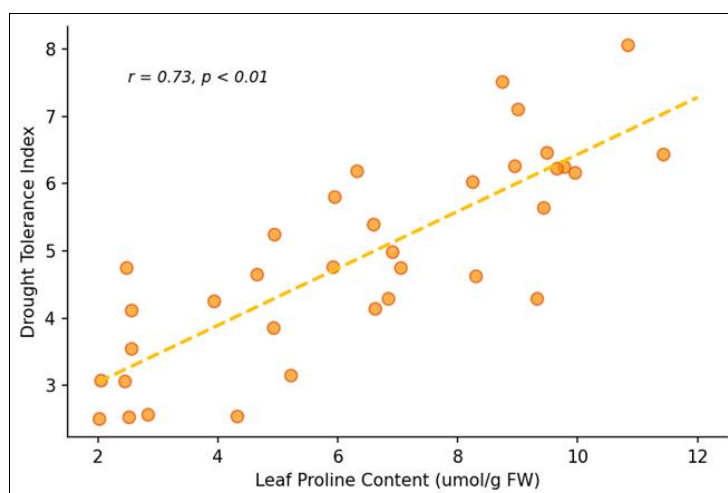


Fig 2: Relationship between leaf proline content and drought tolerance index across all genotypes and selection methods

Proline accumulation showed a positive correlation with drought tolerance index ($r = 0.73$, $p < 0.01$, Figure 2). Recurrent-selection genotypes accumulated 9.4 micromoles proline per gram fresh weight, compared to 5.1 in the control population. Sensory panel scores for boiled tubers under drought did not differ significantly from well-watered tubers (overall acceptability 7.2 versus 7.4, $p = 0.31$).

Discussion

Recurrent selection's 57.7% yield advantage over the control confirms the theoretical prediction that cyclic recombination and re-selection are most effective for polygenic traits like drought tolerance [4, 9]. Each selection cycle breaks unfavourable linkages and assembles new allele combinations, which mass selection cannot achieve because it lacks the recombination step. The 30.8% gain from mass selection, while meaningful, represents mainly the capture of existing variation without creating new recombinants.

Family selection's poor showing (7.7% gain) was unexpected and may reflect the small family sizes (8-12 individuals) used in this research. With larger families, the precision of family mean estimates would improve, potentially making this approach more competitive [10]. However, for smallholder-focused breeding programmes with limited resources, the simplicity of mass selection or the effectiveness of recurrent selection are more practical.

The lack of sensory quality penalty in drought-selected genotypes is commercially important. Drought stress often concentrates sugars in storage roots, which can actually improve sweetness, but may also increase fibre content and reduce texture scores [11]. The sensory data here suggest that five cycles of drought selection did not shift the quality profile away from consumer acceptability.

Conclusion

This research established recurrent selection as the most effective breeding strategy for improving drought tolerance in sweet potato, achieving 57.7% yield improvement over five cycles without compromising tuber eating quality. Leaf proline content proved to be a reliable physiological marker for drought tolerance screening ($r = 0.73$ with drought tolerance index). Mass selection offered a simpler but less effective alternative at 30.8% gain. These findings support the integration of recurrent selection cycles with proline-based screening into sweet potato breeding programmes targeting drought-prone tropical regions.

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