

INFLUENCE OF OSMOPROTECTANT APPLICATION ON GROWTH, PHYSIOLOGICAL TRAITS AND YIELD OF *RABI* SORGHUM UNDER RAINFED CONDITIONS

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ABSTRACT

Rainfed rabi sorghum is exposed to soil-moisture limitation and climatic variability that can restrict crop growth and grain production. A field experiment was conducted during rabi 2024–2025 at the Sorghum Research Station, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, to evaluate foliar osmoprotectant application under four nitrogen levels. Sorghum cv. ParbhaniSupermoti was sown at 45 × 15 cm spacing. Nitrogen treatments were 0, 20, 30 and 40 kg N ha⁻¹ (0, 50, 75 and 100% RDN), while spray treatments comprised absolute control, water spray and an osmoprotectant formulation applied at 30 and 60 days after sowing (DAS). Three replications were reported. The formulation contained malic acid (20 g), oxalic acid (20 g), succinic acid (20 g), fumaric acid (20 g), glycine betaine (40 g) and proline (40 g), made up to 400 ml with distilled water. Grain yield increased from 1,244 kg ha⁻¹ without nitrogen to 1,605 kg ha⁻¹ at 40 kg N ha⁻¹; the 30 kg N ha⁻¹ treatment yielded 1,558 kg ha⁻¹ and was statistically at par with 40 kg N ha⁻¹ based on the reported CD. Osmoprotectant spray produced 1,607 kg grain ha⁻¹, 5,248 kg fodder ha⁻¹ and a benefit:cost ratio of 2.22, compared with 1,297 kg grain ha⁻¹ and a benefit:cost ratio of 1.83 under absolute control. SPAD chlorophyll readings, NDVI and relative leaf water content were also higher with the formulation. The results suggest that the tested osmoprotectant formulation improved rabi sorghum performance under the conditions of this experiment. A 75% RDN rate was economically promising, but the combined nitrogen × spray interaction requires verification from the original statistical analysis.

KEYWORDS: *rabi* sorghum; osmoprotectant; nitrogen; glycine betaine; proline; relative leaf water content; grain yield; rainfed agriculture

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is an important cereal in semi-arid farming systems. Rabi sorghum in Marathwada, Maharashtra, depends substantially on stored soil moisture and may be affected by erratic rainfall, drought, nutrient depletion, low soil organic carbon and other climatic constraints. Such stresses can impair leaf water status, photosynthesis, nutrient uptake, crop growth and grain filling.

Osmoprotectants are compatible solutes that help maintain cellular water balance under osmotic stress. The supplied presentation describes osmoprotectants as small organic molecules with low toxicity at high concentrations and cites Mehta and Vyas (2023). Glycine betaine and proline, together with organic acids, were included in the formulation tested in this experiment. Nitrogen is also essential for canopy development and grain formation; however, the most profitable nitrogen dose in rainfed conditions may be below the full recommended dose.

The objective of this study was to assess the effects of foliar application of an osmoprotectant formulation and nitrogen levels on growth-related physiological traits, yield and economic performance of rainfed rabi sorghum.

2. MATERIALS AND METHODS

2.1 Site, crop and design

The experiment was conducted during rabi 2024–2025 at the Sorghum Research Station, VNMKV, Parbhani, Maharashtra, India. The crop was rabi sorghum cv. ParbhaniSupermoti, planted at 45 × 15 cm spacing. The presentation reports gross plot dimensions of 5.10 × 4.5 m and net plot dimensions of 4.5 × 4.0 m. The trial was rainfed and had three replications. The design is described in the slides as a split-plot design.

2.2 Treatments

Factor	Treatment	Rate / application
Nitrogen	N ₁	0% RDN = 0 kg N ha ⁻¹
Nitrogen	N ₂	50% RDN = 20 kg N ha ⁻¹
Nitrogen	N ₃	75% RDN = 30 kg N ha ⁻¹
Nitrogen	N ₄	100% RDN = 40 kg N ha ⁻¹
Spray	O ₁	Absolute control
Spray	O ₂	Water spray at 30 and 60 DAS
Spray	O ₃	Osmoprotectant formulation at 30 and 60 DAS

2.3 Formulation and observations

The formulation comprised malic acid (20 g), oxalic acid (20 g), succinic acid (20 g), fumaric acid (20 g), glycine betaine (40 g) and proline (40 g), totalling 160 g, dissolved in distilled water and made up to 400 ml. It was sprayed at 30 and 60 DAS. The presentation does not specify spray volume per hectare or any further dilution; these details should be confirmed before submission.

Reported observations included plant height, dry matter, leaf area, grains per cob, test weight, days to 50% flowering, SPAD chlorophyll content, NDVI, relative leaf water content (RLWC), cob length, grain and fodder yield, biological yield, harvest index, economics and selected IRGA variables. RLWC was calculated as $[(FW - DW)/(TW - DW)] \times 100$, where FW = fresh weight, TW = turgid weight and DW = dry weight. Standard errors and critical differences at 5% were transcribed where provided. Raw data and complete ANOVA tables were not supplied.

3. RESULTS AND DISCUSSION

3.1 Nitrogen levels and crop yield

Grain and fodder yield increased as nitrogen rate increased. Grain yield rose from 1,244 kg ha⁻¹ in the zero-nitrogen treatment to 1,347, 1,558 and 1,605 kg ha⁻¹ at 20, 30 and 40 kg N ha⁻¹, respectively. Fodder yield increased from 4,030 to 4,460, 5,027 and 5,293 kg ha⁻¹. The reported CD at 5% was 66 kg ha⁻¹ for grain yield and 365 kg ha⁻¹ for fodder yield. The 47 kg ha⁻¹ difference in grain yield between 30 and 40 kg N ha⁻¹ was below the reported CD, indicating that these treatments were statistically at par for grain yield.

Nitrogen level	Grain yield (kg ha ⁻¹)	Fodder yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	GMR (₹ ha ⁻¹)	NMR (₹ ha ⁻¹)	B:C
0 kg N ha ⁻¹	1244	4030	5274	55640	26691	1.92
20 kg N ha ⁻¹	1347	4460	5807	60517	30491	2.01
30 kg N ha ⁻¹	1558	5027	6585	69597	36510	2.10
40 kg N ha ⁻¹	1605	5293	6898	72053	35905	1.99
SE(m) ±	19	105	103	668	668	—
CD at 5%	66	365	356	2311	2311	—

The 40 kg N ha⁻¹ treatment gave the highest numerical yields, while 30 kg N ha⁻¹ gave the highest reported net monetary return and benefit:cost ratio among nitrogen treatments. Thus, 75% RDN appears economically promising under the reported conditions, subject to validation with complete cost and statistical records.

3.2 Osmoprotectant effects on yield and economics

Osmoprotectant spray (O₃) recorded 1,607 kg grain ha⁻¹ and 5,248 kg fodder ha⁻¹, compared with 1,297 and 4,238 kg ha⁻¹, respectively, under absolute control (O₁). These correspond to increases of approximately 23.9% in grain yield and 23.8% in fodder yield over O₁, calculated from the reported means. The grain-yield difference of 310 kg ha⁻¹ exceeded the reported CD of 42 kg ha⁻¹.

Spray treatment	Grain yield (kg ha ⁻¹)	Fodder yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	GMR (₹ ha ⁻¹)	NMR (₹ ha ⁻¹)	B:C
O ₁ : Absolute control	1297	4238	5535	58116	26414	1.83
O ₂ : Water spray	1411	4622	6033	63263	31060	1.97
O ₃ : Osmoprotectant	1607	5248	6855	71976	39724	2.22
SE(m) ±	15	91	93	592	592	—
CD at 5%	42	258	262	1674	1674	—

The O₃ treatment recorded the highest reported gross monetary return (₹71,976 ha⁻¹), net monetary return (₹39,724 ha⁻¹) and benefit:cost ratio (2.22). Water spray was intermediate. This supports a positive response to the tested formulation, but the result should not be generalized to all osmoprotectant products or formulations.

3.3 Yield components and flowering

Treatment	Grains per cob	Test weight (g)	Days to 50% flowering
0 kg N ha ⁻¹	418.88	25.67	75.09
20 kg N ha ⁻¹	509.63	25.73	73.62
30 kg N ha ⁻¹	585.19	26.36	73.35
40 kg N ha ⁻¹	605.35	26.62	74.7
O ₁ : Absolute control	508.02	25.57	75.17
O ₂ : Water spray	511.81	26.33	74.07
O ₃ : Osmoprotectant	569.46	26.39	73.32
CD at 5%: nitrogen	57.49	NS	NS
CD at 5%: spray	33.93	NS	1.34

Grains per cob increased with nitrogen level, from 418.88 under zero nitrogen to 605.35 at 40 kg N ha⁻¹. O₃ recorded 569.46 grains per cob compared with 508.02 under O₁; the difference exceeded the reported CD of 33.93. Test-weight differences were reported as non-significant. O₃ reached 50% flowering in 73.32 days compared with 75.17 days under O₁, a difference greater than the reported CD of 1.34 days.

3.4 Chlorophyll, NDVI and leaf water status

Treatment	SPAD 30 DAS	SPAD 60 DAS	SPAD 90 DAS	NDVI 30 DAS	NDVI 60 DAS	NDVI 90 DAS
0 kg N ha ⁻¹	31.92	42.89	44.38	0.57	0.72	0.47
20 kg N ha ⁻¹	33.56	44.77	46.33	0.62	0.77	0.52
30 kg N ha ⁻¹	35.23	46.89	48.53	0.69	0.82	0.61
40 kg N ha ⁻¹	35.64	47.59	49.24	0.72	0.87	0.64
O ₁ : Absolute control	32.89	44.32	45.81	0.62	0.77	0.52
O ₂ : Water spray	33.88	45.37	47.02	0.64	0.79	0.55
O ₃ : Osmoprotectant	35.5	46.92	48.54	0.69	0.81	0.61

SPAD values increased with nitrogen at all measured stages. At 90 DAS, the highest reading was 49.24 under 40 kg N ha⁻¹, followed by 48.53 under 30 kg N ha⁻¹. O₃ recorded a SPAD value of 48.54 at 90 DAS compared with 45.81 under O₁. NDVI was also higher under higher nitrogen rates and O₃ than under the unfertilized and absolute-control treatments.

Treatment	RLWC 30 DAS (%)	RLWC 60 DAS (%)	RLWC 90 DAS (%)
0 kg N ha ⁻¹	66.33	68.22	54.94
20 kg N ha ⁻¹	68.1	70.86	57.58
30 kg N ha ⁻¹	72.53	75.28	62.0
40 kg N ha ⁻¹	73.97	76.33	63.05
O ₁ : Absolute control	67.57	71.07	57.79
O ₂ : Water spray	69.71	72.55	59.27
O ₃ : Osmoprotectant	73.42	74.4	61.12

RLWC was higher under increasing nitrogen rates and was generally higher under O₃ than under absolute control. O₃ recorded 73.42, 74.40 and 61.12% at 30, 60 and 90 DAS, respectively, compared with 67.57, 71.07 and 57.79% under O₁. These results are consistent with improved leaf water status, although the physiological mechanism was not directly established.

3.5 IRGA observations and interpretation

The presentation reports comparatively higher stomatal-conductance values and lower vapour-pressure deficit and leaf temperature under higher nitrogen and O₃. Reported leaf temperature at 90 DAS was 33.41°C under 40 kg N ha⁻¹ and 32.18°C under O₃, compared with 35.28°C under O₁. However, the stomatal-conductance labels/units in the slides may be inconsistent with standard conventions, and raw instrument records were not supplied. These data should be checked against the IRGA export before quantitative publication. No numerical claim is made here for photosynthesis or water-use efficiency because validated values were not provided.

4. CONCLUSION

Under the rainfed conditions of the 2024–2025 experiment at Parbhani, foliar application of the tested osmoprotectant formulation at 30 and 60 DAS improved grain and fodder yield, biological yield, SPAD readings, NDVI, RLWC and reported economic returns compared with absolute control. O₃ produced 1,607 kg grain ha⁻¹, 5,248 kg fodder ha⁻¹ and a benefit:cost ratio of 2.22. Although 40 kg N ha⁻¹ gave the highest numerical grain yield, 30 kg N ha⁻¹ was statistically at par for grain yield based on the reported CD and recorded the highest net monetary return and benefit:cost ratio among nitrogen levels. Therefore, 75% RDN with the tested osmoprotectant spray is a promising option for further validation. Because interaction means were not supplied, the best combined nitrogen × osmoprotectant treatment cannot be established from this presentation alone.

5. Information to verify before journal submission

Confirm treatment hierarchy and design labels; the slides use both main-plot and sub-sub-plot terminology.

Confirm whether the second spray was at 60 or 65 DAS, as both timings appear in the presentation.

Provide spray volume per hectare, any dilution details, soil characteristics, rainfall/weather, sowing/harvest dates and crop-management practices.

Add the numerical plant-height, dry-matter, leaf-area and cob-length tables if these traits are to be reported.

Verify the complete ANOVA and interaction means using raw data; check SE(m) and CD values.

Verify IRGA headings and units, and provide full cost assumptions for economic calculations.

Complete the full bibliographic reference for Mehta and Vyas (2023) and add verified primary literature.

REFERENCES

1. Mehta and Vyas (2023). Reference cited in the source presentation for the definition of osmoprotectants. Full title, publication details, pages and DOI/URL were not provided in the slides and must be verified before submission.
2. Experimental data source: “Influence of Osmoprotectant on Growth and Yield of Rabi Sorghum under Rainfed Condition,” presentation supplied by the author. All treatment means and statistical indicators in this draft were transcribed from that presentation; percentage changes were calculated from the reported means.