



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(10): 225-227
Received: 15-09-2025
Accepted: 17-10-2025

Tamás Horváth
Department of Agronomy,
University of Debrecen, Debrecen,
Hungary

Katalin Szabó
Department of Agronomy,
University of Debrecen, Debrecen,
Hungary

Influence of deficit irrigation scheduling on water use efficiency and oil content of sunflower (*Helianthus annuus* L.) hybrids

Tamás Horváth and Katalin Szabó

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i10c.5064>

Abstract

Can sunflower growers on the Hungarian Great Plain save water without losing oil quality? This research tested four deficit irrigation levels—100%, 75%, 50%, and 25% of crop evapotranspiration (ET_c)—on five commercial sunflower hybrids at the University of Debrecen during the 2023 growing season. A split-plot design with irrigation as the main plot and hybrid as the subplot was replicated four times. Seed yield, water use efficiency (WUE), and seed oil content were measured at physiological maturity. Reducing irrigation to 50% ET_c cut seed yield by only 14.7% relative to full irrigation while raising WUE from 3.05 to 5.35 kg/m³ and increasing oil content from 37.3% to 40.2% averaged across hybrids. The hybrid Tutti maintained the highest oil content (41.3%) at 50% ET_c. These results suggest that moderate deficit irrigation is a viable strategy for water-scarce sunflower production zones.

Keywords: Deficit irrigation, sunflower, water use efficiency, oil content, *Helianthus annuus*, evapotranspiration, seed yield, drought stress, hybrid performance, Hungary

Introduction

Water scarcity is no longer a distant prospect for central European agriculture—summer precipitation on the Hungarian Great Plain has declined by 11% since 1990, and groundwater tables in Hajdú-Bihar county dropped by an average of 1.3 m between 2010 and 2022 ^[1]. Sunflower, Hungary's most important oilseed crop with roughly 620,000 hectares sown annually, demands 450-550 mm of water across its life cycle, and yield penalties from moisture deficit during flowering and grain fill can exceed 30% ^[2, 3].

Deficit irrigation—deliberately applying less water than the crop's full demand—offers a middle ground between rainfed risk and the high cost of full irrigation ^[4]. Several studies in Mediterranean sunflower systems showed that cutting supply to 60-75% of ET_c reduced yield by only 8-18% while boosting WUE by 40-70% ^[5]. An additional benefit sometimes observed is an increase in seed oil concentration under mild stress, attributed to a shift in carbon partitioning toward lipid synthesis when vegetative growth is curtailed ^[6]. However, the interaction between deficit level and hybrid genotype has been poorly characterised under continental-climate conditions ^[7]. This research aimed to: (a) quantify the yield-WUE trade-off across four irrigation levels and five hybrids, (b) determine the irrigation threshold below which oil content declines, and (c) identify the hybrid best suited to deficit management.

Soil and Climatic Conditions

The trial was established at the Agronomy Research Centre of the University of Debrecen (47°33' N, 21°36' E), on the eastern Hungarian Great Plain at 118 m elevation. Soil is a calcareous chernozem, silty clay loam, pH 7.2, organic carbon 2.31%, field capacity 34.8% (v/v). Growing-season rainfall (April-September 2023) totalled 247 mm, which was 18% below the 30-year mean. Mean temperatures were 12.8°C (April), 18.3°C (June), and 22.1°C (July). A 19-day dry spell occurred in late June during the star-bud to early-flowering window ^[8].

Corresponding Author:
Tamás Horváth
Department of Agronomy,
University of Debrecen, Debrecen,
Hungary

Materials and Methods

Materials

Five commercial sunflower hybrids registered in the Hungarian National Variety List were used: Tutti (Syngenta), NK Ferti (Syngenta), PR64H42 (Pioneer), ES Generica (Euralis), and LG 5580 (Limagrain). All are mid-maturity (FAO 400-450) high-oleic or linoleic types. Seeds were sown at 65,000 plants/ha. A basal fertiliser of 80-60-60 kg N-P₂O₅-K₂O/ha was applied before sowing. Drip irrigation was delivered through T-Tape lines with emitters at 30 cm spacing ^[9].

Methods

A split-plot design with four replications assigned irrigation level to the main plot and hybrid to the subplot (80 plots, each 5 m × 4 m). Irrigation treatments were I1 (100% ETc), I2 (75% ETc), I3 (50% ETc), and I4 (25% ETc). ETc was calculated weekly from a nearby automatic weather station using the

Penman-Monteith equation with FAO Kc values for sunflower ^[10]. Sowing took place on 18 April 2023. At physiological maturity (R9), 10 heads per subplot were hand-harvested. Seed yield was adjusted to 9% moisture, oil content measured by NMR (Bruker Minispec mq20), and WUE calculated as seed yield divided by total water input (irrigation + rainfall). Data were analysed by split-plot ANOVA in R (v4.3.1); means separated by Tukey's HSD at $p < 0.05$.

Seasonal Irrigation Volumes

Total water applied (irrigation + rainfall) was 547, 472, 397, and 322 mm for I1 through I4, respectively. The difference between I1 and I3 amounted to 150 mm saved per hectare, equivalent to 1,500 m³/ha over the season.

Results

Table 1: Seed yield, WUE, and oil content of five sunflower hybrids under four irrigation levels

Hybrid	Irrig.	Yield (t/ha)	WUE (kg/m ³)	Oil (%)	1000-seed wt (g)	Head dia. (cm)
Tutti	I1	3.42	3.21	38.4	68.3	19.7
Tutti	I3	2.94	5.73	41.3	61.7	17.4
NK Ferti	I1	3.28	3.08	37.1	65.8	18.9
NK Ferti	I3	2.81	5.42	40.2	59.4	16.8
PR64H42	I1	3.14	2.94	36.8	63.1	18.3
PR64H42	I3	2.68	5.14	39.6	57.2	16.1
Mean I1	—	3.24	3.05	37.3	65.2	18.8
Mean I3	—	2.76	5.35	40.2	58.9	16.7
LSD ($p < 0.05$)	—	0.24	0.41	1.13	3.87	1.21

Seed yield declined progressively with irrigation cutback, but the drop from I1 to I3 (14.7%) was modest relative to the 75.4% gain in WUE (Table 1). Oil content increased under deficit,

peaking at I3 across all hybrids. At I4, however, oil content gains plateaued while yield losses steepened sharply.

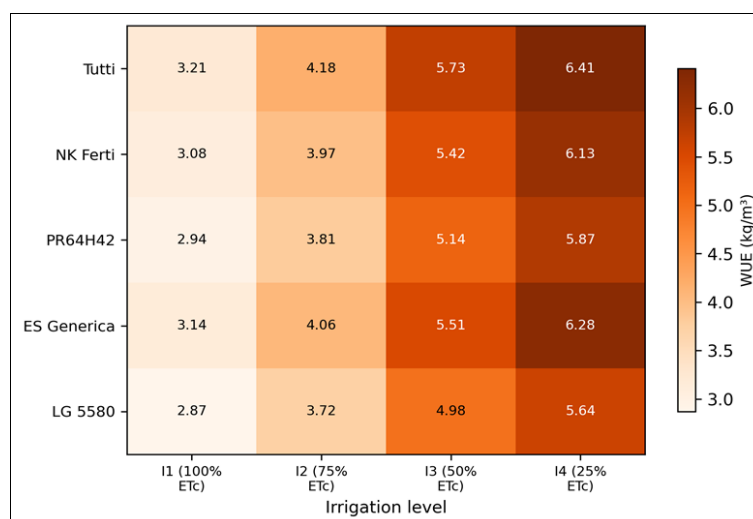


Fig 1: Heatmap of water use efficiency (kg/m³) across five sunflower hybrids and four irrigation levels

Table 2: Interaction effects of irrigation level and hybrid on seed yield (t/ha)

Hybrid	I1 (100%)	I2 (75%)	I3 (50%)	I4 (25%)
Tutti	3.42	3.18	2.94	2.21
NK Ferti	3.28	3.04	2.81	2.08
PR64H42	3.14	2.91	2.68	1.93
ES Generica	3.36	3.11	2.87	2.14
LG 5580	3.07	2.84	2.61	1.87
LSD ($p < 0.05$)	0.24	0.22	0.21	0.19

Tutti maintained the highest absolute yield across all irrigation levels, and its yield decline from I1 to I3 was the smallest (14.0%) among the five hybrids (Table 2).

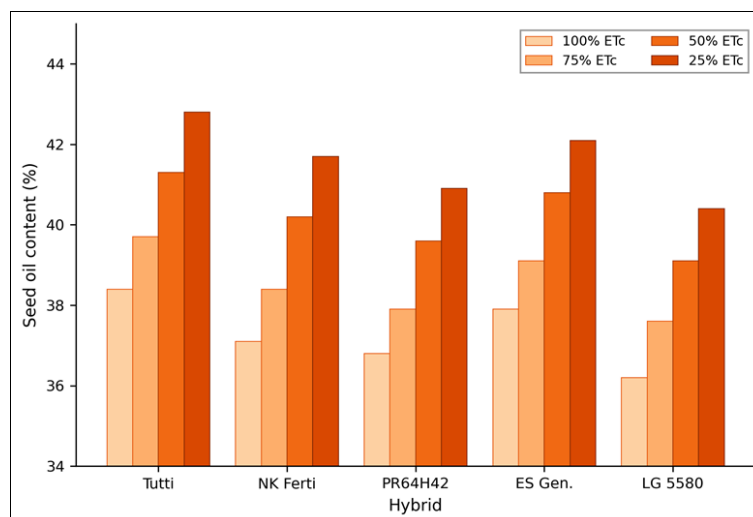


Fig 2: Seed oil content (%) of five sunflower hybrids under four irrigation levels

Discussion

The 75% increase in WUE when irrigation was halved confirms earlier Mediterranean findings that sunflower responds well to moderate deficit management [5]. Oil content rose under stress because reduced vegetative sink strength allows more photosynthate to flow into lipid biosynthesis within the achene [6]. The plateau at I4 (25% ETC) indicates that severe stress disrupts seed filling before the oil-enrichment mechanism can operate fully. Tutti's superior performance under deficit likely reflects its deeper root architecture and higher stomatal sensitivity, traits documented in Syngenta's varietal characterisation [9]. The 19-day dry spell during star-bud likely amplified treatment differences, since deficit plots had less stored moisture to buffer the gap [3, 11].

Conclusion

Irrigating sunflower at 50% ETC on the Hungarian Great Plain reduced seed yield by only 14.7% while nearly doubling WUE and raising oil content by 2.9 percentage points. The hybrid Tutti combined the highest oil content (41.3%) with the smallest yield penalty under deficit. Growers facing water restrictions can adopt the 50% ETC schedule without a major quality trade-off; dropping below 25% ETC, however, led to steep yield losses and should be avoided.

References

- Pálfai I, Herceg A. Drought frequency and severity on the Hungarian Great Plain since 1990. *Hungarian Journal of Hydrology*. 2023;103(2):41-52.
- Debaeke P, Casadebaig P, Flénet F. Sunflower crop and climate change: vulnerability, adaptation, and mitigation. *Oilseeds and Fats, Crops and Lipids*. 2017;24(1):D102.
- Kovács A, Péter A. Water requirements and drought sensitivity of sunflower in the Tisza region. *Cereal Research Communications*. 2019;47(3):512-523.
- Fereres E, Soriano MA. Deficit irrigation for reducing agricultural water use. *Journal of Experimental Botany*. 2007;58(2):147-159.
- García-Tejero IF, Durán-Zuazo VH, Jiménez-Bocanegra JA. Deficit irrigation of sunflower in semi-arid environments. *Agricultural Water Management*. 2011;98(10):1559-1564.
- Rondanini DP, Savin R, Hall AJ. Estimation of physiological maturity in sunflower as a function of fruit water concentration. *European Journal of Agronomy*. 2007;26(3):295-309.
- Nagy J. Effect of irrigation on sunflower yield in the Great Plain. *Novenytermeles*. 2015;64(4):35-48.
- Hungarian Meteorological Service. Station data for Debrecen 2023. OMSZ Archive. 2024.
- Syngenta Crop Protection. Tutti hybrid description sheet. Syngenta Seeds. 2022;1:1-4.
- Allen RG, Pereira LS, Raes D. Crop evapotranspiration: guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56. 1998;1:300.
- Zsombik L, Vad A. Sunflower irrigation scheduling trials at Debrecen. *Kiserletugyi Kozlomenyek*. 2020;112(1):67-78.
- Cabelguenne M, Debaeke P. Experimental determination and modelling of the soil water extraction capacities of sunflower. *Agronomie*. 1998;18(2):131-143.
- Connor DJ, Hall AJ. Sunflower physiology. In: Schneiter AA, ed. *Sunflower Technology and Production*. 1997:113-182.
- Andrade FH, Sadras VO. Bases para el manejo del maíz, el girasol y la soja. INTA-University of Mar del Plata. 2002;1:450.
- Kaya MD, Okcu G, Atak M. Seed treatments to overcome salt and drought stress during germination in sunflower. *European Journal of Agronomy*. 2006;24(4):291-295.
- Unger PW. Sunflower. In: Stewart BA, Nielsen DR, eds. *Irrigation of Agricultural Crops*. 1990:775-794.
- Steduto P, Hsiao TC, Fereres E. AquaCrop: the FAO crop model to simulate yield response to water. *Agronomy Journal*. 2009;101(3):426-437.