Global Oilseed Yield Benchmarking & Agronomic Practice Summary

This document was auto■generated from a synthetic agronomic dataset containing eight oilseed crops:

sunflower, mustard (rapeseed–mustard), soybean, safflower, niger seed, groundnut (peanut), castor and sesame.

For each crop, we: 1. Identify three benchmark countries that currently achieve among the highest national average yields, based on FAOSTAT and recent synthesis reports (values are indicative, not exact rankings). 2. Analyse the top■yielding 25% of records for that crop in the synthetic dataset and report the range of key management and environmental variables. 3. Summarise the cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI patterns that characterise high■yield systems in those benchmark countries.

These summaries can be used as structured knowledge for an oilseed■focused advisory or RAG system.

CASTOR

Benchmark high■yield countries (indicative): India, China, Brazil

In the synthetic dataset, the top 25% of castor records by yield have **yield_t_ha** ≥ **0.99 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	110.00 – 149.00 (median 130.00)
base_yield_potential_t_ha	2.97 – 5.24 (median 4.62)
mean_temp_gs_C	12.10 – 31.98 (median 22.52)
temp_flowering_C	10.01 – 34.93 (median 20.88)
seasonal_rain_mm	250.10 – 947.70 (median 554.20)
rain_flowering_mm	0.40 – 249.80 (median 130.50)
humidity_mean_pct	35.00 – 89.90 (median 61.80)
soil_pH	4.51 – 8.50 (median 6.50)
soil_oc_pct	0.20 – 1.80 (median 1.18)
soil_texture	loam (37.7%); sandy (31.8%); clay (30.5%)
clay_pct	5.00 – 60.00 (median 24.70)
soil_depth_cm	40.50 – 149.90 (median 99.40)
soil_N_status_kg_ha	80.40 – 219.30 (median 145.30)
soil_P_status_kg_ha	5.00 – 39.80 (median 22.50)
soil_K_status_kg_ha	80.70 – 399.80 (median 237.10)
fert_N_kg_ha	40.20 – 259.50 (median 145.20)
fert_P_kg_ha	10.10 – 80.00 (median 44.00)
fert_K_kg_ha	0.90 – 119.50 (median 58.50)
sowing_doy	60.00 – 259.00 (median 155.00)
irrigation_events	0.00 – 5.00 (median 3.00)
ndvi_early	0.20 – 0.80 (median 0.62)
ndvi_flowering	0.30 – 0.90 (median 0.77)
ndvi_peak	0.46 – 0.90 (median 0.83)
ndvi_late	0.25 – 0.84 (median 0.64)
ndvi_veg_slope	0.00 – 0.03 (median 0.00)
seed_moisture_pct	7.00 – 19.90 (median 12.50)
soil_moisture_pct	25.56 – 36.07 (median 27.30)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

High■yield castor systems in India, China and Brazil typically exhibit:

• Cultivation & varieties: High■yielding hybrids with determinate or semi■determinate growth, designed for mechanized harvesting in Brazil and parts of India; selection for resistance to Fusarium wilt and other soil■borne diseases.
• Sowing: Sown on well■drained, medium to deep soils at onset of rainy season or early in dry season under irrigation; wide spacing (60–90 cm between rows, 45–60 cm within rows) to accommodate large canopy.
• Fertilizers & soil: Tolerates relatively poor soils but high yields require 60–120 kg N/ha and 30–60 kg P2O5/ha, plus K where deficient; responds well to organic manures and castor■cake; pH range 5.5–7.5 is ideal.
• Irrigation & water: Deep■rooted and drought■tolerant, yet responds strongly to 3–6 irrigations at branching, flowering and capsule■filling stages; waterlogging must be avoided.

• Pest & disease management: Seed treatment and crop rotation to manage wilt; monitoring for semiloopers, capsule borers and sucking pests; removal of volunteer castor plants that harbour pests.
• NDVI & canopy: Strong vegetative growth gives high NDVI_peak (~0.8–0.9) when the canopy is fully developed; stress or nutrient deficiency appears as reduced NDVI_veg_slope and patchy low NDVI zones.
• Harvest & processing: Staggered harvest of mature racemes; careful handling and mechanical decortication; strict safety protocols during oil extraction because of ricin and allergenic dust.

GROUNDNUT

Benchmark high■yield countries (indicative): China, Egypt, United States

In the synthetic dataset, the top 25% of groundnut records by yield have **yield_t_ha** ≥ **1.13 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	110.00 – 149.00 (median 129.00)
base_yield_potential_t_ha	3.02 – 5.25 (median 4.58)
mean_temp_gs_C	12.05 – 31.99 (median 22.00)
temp_flowering_C	10.00 – 34.93 (median 20.99)
seasonal_rain_mm	250.00 – 948.50 (median 564.10)
rain_flowering_mm	0.40 – 249.90 (median 121.90)
humidity_mean_pct	35.00 – 90.00 (median 63.40)
soil_pH	4.50 – 8.50 (median 6.53)
soil_oc_pct	0.20 – 1.80 (median 1.15)
soil_texture	sandy (33.9%); loam (33.1%); clay (33.0%)
clay_pct	5.00 – 59.90 (median 24.90)
soil_depth_cm	40.20 – 150.00 (median 96.70)
soil_N_status_kg_ha	80.20 – 219.70 (median 143.50)
soil_P_status_kg_ha	5.00 – 40.00 (median 22.50)
soil_K_status_kg_ha	80.20 – 399.70 (median 226.70)
fert_N_kg_ha	40.20 – 260.00 (median 136.90)
fert_P_kg_ha	10.10 – 80.00 (median 43.10)
fert_K_kg_ha	0.00 – 119.70 (median 57.90)
sowing_doy	60.00 – 259.00 (median 160.00)
irrigation_events	0.00 – 5.00 (median 2.00)
ndvi_early	0.20 – 0.80 (median 0.62)
ndvi_flowering	0.30 – 0.90 (median 0.77)
ndvi_peak	0.45 – 0.90 (median 0.83)
ndvi_late	0.20 – 0.85 (median 0.64)
ndvi_veg_slope	0.00 – 0.03 (median 0.00)
seed_moisture_pct	7.00 – 20.00 (median 12.90)
soil_moisture_pct	27.08 – 39.83 (median 29.13)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

China, Egypt and the USA illustrate high■yield groundnut (peanut) systems:

• Cultivation & varieties: High■yielding Virginia or Spanish bunch varieties with resistance to foliar diseases (late leaf spot, rust) and tolerance to drought; use of certified seed and optimal seed size.
• Sowing: Sown at soil temperatures >18–20 °C; row spacing 30–45 cm with 18–22 plants/m²; proper depth (5–7 cm) for uniform emergence; often on raised beds or broad■bed furrows in irrigated systems.
• Fertilizers & soil: Well■drained sandy loam to loam soils with pH 5.8–7.2; calcium and gypsum at pegging for pod filling; basal P and K based on soil tests (e.g. 20–40 kg P2O5/ha and 40–80 kg K2O/ha); moderate N (15–25 kg/ha) plus Rhizobium inoculation.
• Irrigation & water: In irrigated high■yield systems, 5–8 irrigations with special focus on pegging and pod■filling stages; in

rainfed systems, moisture conservation practices (residue mulching, tied ridges).
• Pest & disease management: Preventive fungicide schedules for leaf spots and rust; IPM for Spodoptera, thrips, aphids, white grubs and termites; crop rotation with cereals or cotton to reduce soil■borne inoculum.
• NDVI & canopy: Uniform, prostrate canopy covering the inter■row space by 35–45 days after sowing (NDVI_early ~0.5–0.7); high NDVI_peak (~0.8) maintained through pod■fill; sharp NDVI drops before maturity usually indicate disease or drought stress.
• Harvest & curing: Uprooting at optimum maturity (70–75% pods with dark inner shell); windrowing and field curing for 2–3 days, followed by mechanical threshing and rapid drying to ~8% moisture.

MUSTARD

Benchmark high■yield countries (indicative): Canada (rapeseed–mustard), Germany, France

In the synthetic dataset, the top 25% of mustard records by yield have **yield_t_ha** ≥ **1.00 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	100.00 – 139.00 (median 119.00)
base_yield_potential_t_ha	1.44 – 3.15 (median 2.62)
mean_temp_gs_C	12.00 – 32.00 (median 22.16)
temp_flowering_C	10.02 – 34.97 (median 20.98)
seasonal_rain_mm	250.50 – 950.00 (median 564.50)
rain_flowering_mm	0.00 – 249.90 (median 121.95)
humidity_mean_pct	35.00 – 90.00 (median 62.60)
soil_pH	4.50 – 8.50 (median 6.49)
soil_oc_pct	0.20 – 1.80 (median 1.19)
soil_texture	clay (33.9%); sandy (33.2%); loam (33.0%)
clay_pct	5.00 – 59.90 (median 25.05)
soil_depth_cm	40.00 – 150.00 (median 97.20)
soil_N_status_kg_ha	80.00 – 219.90 (median 144.00)
soil_P_status_kg_ha	5.00 – 40.00 (median 22.20)
soil_K_status_kg_ha	80.00 – 399.90 (median 229.70)
fert_N_kg_ha	40.10 – 260.00 (median 129.40)
fert_P_kg_ha	10.00 – 80.00 (median 43.30)
fert_K_kg_ha	0.00 – 119.90 (median 60.20)
sowing_doy	60.00 – 259.00 (median 155.50)
irrigation_events	0.00 – 5.00 (median 3.00)
ndvi_early	0.20 – 0.80 (median 0.64)
ndvi_flowering	0.30 – 0.90 (median 0.79)
ndvi_peak	0.45 – 0.90 (median 0.84)
ndvi_late	0.20 – 0.85 (median 0.65)
ndvi_veg_slope	0.00 – 0.03 (median 0.00)
seed_moisture_pct	7.00 – 20.00 (median 12.90)
soil_moisture_pct	25.60 – 42.00 (median 31.77)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

In high■yield rapeseed–mustard systems in Canada, Germany and France (benchmarks for Indian mustard), common practices include:

• Cultivation & varieties: Hybrid and double■low (low erucic acid, low glucosinolate) cultivars with strong winter hardiness (in temperate regions) and good lodging resistance.
• Sowing: Fine, firm seedbed; precision drilling at 30–45 cm row spacing with 60–80 plants/m²; sown in cool conditions (soil temperature ~8–12 °C). In Indian rabi systems, sowing is typically in October–November.
• Fertilizers & soil: pH 6.0–7.5; high available P and K; N split (e.g. 140–200 kg N/ha in temperate systems; 80–150 kg N/ha in semi■arid) with sulphur (20–40 kg/ha) and sometimes boron and zinc; good drainage to avoid waterlogging.
• Irrigation & water: In rainfed temperate systems, stored soil moisture and winter precipitation dominate; in South Asia, 2–3

critical irrigations at rosette, flowering and pod■filling stages are used when rainfall is insufficient.
• Pest & disease management: Seed treatment and crop rotation to manage clubroot and white rust; timely fungicide where disease risk is high; IPM for mustard aphid, flea beetles and pod borers.
• Canopy & NDVI: Uniform, dense stands with NDVI_early ~0.3–0.5, rising rapidly to 0.7–0.85 near full flowering; NDVI_late declines gradually as pods mature, avoiding early defoliation from aphids or diseases.
• Harvest & post■harvest: Swathing or desiccation at 30–40% seed moisture to reduce shattering; combine harvesting when seed moisture drops to about 8–10%, followed by rapid drying and cleaning.

NIGER SEED

Benchmark high■yield countries (indicative): India, Ethiopia, Uganda

In the synthetic dataset, the top 25% of niger seed records by yield have **yield_t_ha ≥ 0.74 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	110.00 – 149.00 (median 129.00)
base_yield_potential_t_ha	3.17 – 5.24 (median 4.56)
mean_temp_gs_C	12.01 – 31.98 (median 22.04)
temp_flowering_C	10.02 – 34.99 (median 20.91)
seasonal_rain_mm	250.70 – 949.60 (median 559.00)
rain_flowering_mm	0.60 – 249.50 (median 124.10)
humidity_mean_pct	35.00 – 89.90 (median 62.80)
soil_pH	4.51 – 8.49 (median 6.48)
soil_oc_pct	0.20 – 1.80 (median 1.19)
soil_texture	loam (36.2%); sandy (32.0%); clay (31.8%)
clay_pct	5.20 – 59.90 (median 25.00)
soil_depth_cm	40.20 – 149.90 (median 98.40)
soil_N_status_kg_ha	80.50 – 219.40 (median 146.10)
soil_P_status_kg_ha	5.00 – 40.00 (median 22.10)
soil_K_status_kg_ha	80.30 – 400.00 (median 234.90)
fert_N_kg_ha	40.30 – 259.30 (median 131.40)
fert_P_kg_ha	10.10 – 80.00 (median 43.90)
fert_K_kg_ha	0.10 – 120.00 (median 62.70)
sowing_doy	60.00 – 259.00 (median 155.00)
irrigation_events	0.00 – 5.00 (median 3.00)
ndvi_early	0.20 – 0.80 (median 0.60)
ndvi_flowering	0.30 – 0.90 (median 0.75)
ndvi_peak	0.44 – 0.90 (median 0.83)
ndvi_late	0.20 – 0.85 (median 0.64)
ndvi_veg_slope	0.00 – 0.03 (median 0.00)
seed_moisture_pct	7.00 – 19.90 (median 12.60)
soil_moisture_pct	22.83 – 29.44 (median 24.02)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

In India, Ethiopia and East African countries such as Uganda, high■yield niger seed systems typically involve:

• Cultivation & land type: Grown on light black to red loam soils, often on marginal lands but highest yields come from well■drained, medium■fertility fields with good moisture conservation (broad■bed furrows, contour sowing).
• Sowing: Shallow sowing (2–3 cm) at the onset of monsoon or cool■dry season; 25–30 cm row spacing with 8–10 kg seed/ha for sole crop; often intercropped with cereals or pulses to share risk.
• Fertilizers & soil: Modest fertilizer use (e.g. 20–40 kg N/ha and 20–30 kg P2O5/ha) greatly increases yield compared with traditional unfertilized systems; application of farmyard manure improves soil structure and moisture storage.
• Irrigation & water: Mostly rainfed; yield is closely linked to 400–800 mm seasonal rainfall well distributed over vegetative and flowering stages; supplementary irrigation around flowering can significantly boost yield where feasible.

• Pest & disease management: Generally less pest■prone, but monitoring for leaf■eating caterpillars and sucking pests is important; seed treatments and crop rotation help manage soil■borne diseases.
• NDVI behaviour: Low initial NDVI (~0.2–0.4) but rapid increase to ~0.6–0.75 during peak vegetative and early flowering stages in high■yield fields; early senescence or patchy stands appear as low NDVI_veg_slope and low NDVI_peak.
• Harvest: Harvest when the majority of capitula turn brown and seeds are hard; timely drying and cleaning are essential because of the small seed size.

SAFFLOWER

Benchmark high■yield countries (indicative): Kazakhstan, United States, Mexico

In the synthetic dataset, the top 25% of safflower records by yield have **yield_t_ha** ≥ **0.91 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	110.00 – 149.00 (median 128.00)
base_yield_potential_t_ha	2.95 – 5.25 (median 4.54)
mean_temp_gs_C	12.06 – 31.94 (median 22.11)
temp_flowering_C	10.01 – 34.96 (median 20.82)
seasonal_rain_mm	251.90 – 949.20 (median 555.00)
rain_flowering_mm	0.40 – 248.30 (median 120.80)
humidity_mean_pct	35.00 – 90.00 (median 61.70)
soil_pH	4.51 – 8.47 (median 6.57)
soil_oc_pct	0.20 – 1.80 (median 1.25)
soil_texture	loam (34.7%); sandy (33.4%); clay (31.8%)
clay_pct	5.10 – 60.00 (median 25.50)
soil_depth_cm	40.00 – 149.90 (median 98.60)
soil_N_status_kg_ha	80.00 – 219.70 (median 140.60)
soil_P_status_kg_ha	5.00 – 40.00 (median 22.00)
soil_K_status_kg_ha	80.10 – 399.80 (median 227.20)
fert_N_kg_ha	40.20 – 258.90 (median 139.20)
fert_P_kg_ha	10.00 – 79.90 (median 42.80)
fert_K_kg_ha	0.50 – 119.90 (median 58.50)
sowing_doy	60.00 – 259.00 (median 160.00)
irrigation_events	0.00 – 5.00 (median 3.00)
ndvi_early	0.20 – 0.80 (median 0.61)
ndvi_flowering	0.30 – 0.90 (median 0.77)
ndvi_peak	0.40 – 0.90 (median 0.83)
ndvi_late	0.20 – 0.84 (median 0.64)
ndvi_veg_slope	0.00 – 0.03 (median 0.01)
seed_moisture_pct	7.00 – 20.00 (median 13.00)
soil_moisture_pct	24.69 – 33.59 (median 26.51)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

High■yield safflower systems in Kazakhstan, the USA and Mexico share these characteristics:

• Cultivation & rotation: Grown mainly in semi■arid, low■rainfall regions as a deep■rooted crop in cereal■based rotations; helps break disease and weed cycles.
• Sowing: Sown early in spring (temperate) or at the onset of cool■dry season (semi■arid tropics); moderate plant population (25–40 plants/m²) with 30–60 cm row spacing; seed priming to improve emergence under cool soils.
• Fertilizers & soil: Tolerant to moderately saline soils; optimal pH 6.0–8.0; modest N (40–80 kg/ha) to avoid excessive vegetative growth; adequate P and K based on soil tests.
• Irrigation & water: Mostly rainfed but benefits from one or two irrigations at branching and early flowering in very dry years; deep rooting enables extraction of water from >1 m soil depth.

• Pest & disease management: Rotation and residue management to control root rots and foliar diseases; monitoring of safflower flies, aphids and cutworms; targeted insecticide use when thresholds are exceeded.
• NDVI & canopy: Slow early growth (NDVI_early ~0.3–0.5) followed by a strong increase to ~0.7–0.8 at full canopy; maintenance of green leaves during flowering and early seed■fill is critical for oil content.
• Harvest: Harvest when most heads turn brown and seed moisture is about 10–12%; attention to spiney varieties which require careful handling and machinery adjustment.

SESAME

Benchmark high■yield countries (indicative): China, Nigeria, Tanzania

In the synthetic dataset, the top 25% of sesame records by yield have **yield_t_ha** ≥ **0.80 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	110.00 – 149.00 (median 129.00)
base_yield_potential_t_ha	3.00 – 5.25 (median 4.59)
mean_temp_gs_C	12.00 – 31.92 (median 21.86)
temp_flowering_C	10.02 – 34.95 (median 20.99)
seasonal_rain_mm	250.50 – 949.20 (median 587.00)
rain_flowering_mm	0.30 – 249.90 (median 124.40)
humidity_mean_pct	35.10 – 89.90 (median 62.50)
soil_pH	4.50 – 8.49 (median 6.44)
soil_oc_pct	0.20 – 1.80 (median 1.17)
soil_texture	sandy (36.0%); loam (32.2%); clay (31.8%)
clay_pct	5.00 – 60.00 (median 24.50)
soil_depth_cm	40.10 – 150.00 (median 97.20)
soil_N_status_kg_ha	80.40 – 220.00 (median 140.90)
soil_P_status_kg_ha	5.00 – 40.00 (median 21.60)
soil_K_status_kg_ha	81.30 – 399.90 (median 235.20)
fert_N_kg_ha	40.40 – 259.90 (median 131.40)
fert_P_kg_ha	10.00 – 79.60 (median 43.80)
fert_K_kg_ha	0.20 – 119.70 (median 59.10)
sowing_doy	60.00 – 259.00 (median 162.00)
irrigation_events	0.00 – 5.00 (median 2.00)
ndvi_early	0.20 – 0.80 (median 0.64)
ndvi_flowering	0.30 – 0.90 (median 0.79)
ndvi_peak	0.46 – 0.90 (median 0.84)
ndvi_late	0.23 – 0.84 (median 0.65)
ndvi_veg_slope	0.00 – 0.03 (median 0.00)
seed_moisture_pct	7.00 – 19.90 (median 13.00)
soil_moisture_pct	23.46 – 31.79 (median 25.03)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

High■yield sesame systems in China, Nigeria and Tanzania show:

• Cultivation & varieties: High■yielding, often semi■dwarf varieties with improved shattering resistance and tolerance to drought; use of quality seed and appropriate seed rate.
• Sowing: Fine, moist seedbed; line sowing at 30–45 cm row spacing and 8–10 kg seed/ha; sown at onset of rains or early kharif / wet season; thinning to maintain 25–35 plants/m².
• Fertilizers & soil: Best on well■drained sandy loams to loams with pH 5.5–7.5; modest but balanced fertilization (e.g. 30–60 kg N/ha, 20–40 kg P2O5/ha, 20–40 kg K2O/ha) plus sulphur in deficient soils; FYM or compost to improve structure.
• Irrigation & water: Mostly rainfed but highly sensitive to waterlogging; supplementary irrigation at branching and flowering in deficit seasons greatly improves yield; good field drainage is critical.

• Pest & disease management: Seed treatment and crop rotation to manage wilt and phyllody; timely control of leaf■eating caterpillars, mirid bugs, gall midge and sucking pests; removal of diseased plants.
• NDVI & canopy: After a slow start (NDVI_early ~0.3–0.5), high■yield crops show a rapid NDVI rise to ~0.7–0.8 at peak vegetative stage, remaining relatively high through capsule filling; premature leaf drop or phyllody results in early NDVI decline.
• Harvest & post■harvest: Harvest when majority of capsules turn yellow and lower capsules begin to open; use of improved, less■shattering varieties allows slightly delayed harvest; quick drying and threshing to avoid losses and maintain seed quality.

SOYBEAN

Benchmark high■yield countries (indicative): Turkey, United States, Brazil

In the synthetic dataset, the top 25% of soybean records by yield have **yield_t_ha** ≥ **1.29 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	95.00 – 124.00 (median 110.00)
base_yield_potential_t_ha	1.90 – 3.67 (median 3.13)
mean_temp_gs_C	12.00 – 31.99 (median 21.87)
temp_flowering_C	10.03 – 34.94 (median 20.85)
seasonal_rain_mm	250.20 – 949.90 (median 565.10)
rain_flowering_mm	0.20 – 249.90 (median 123.50)
humidity_mean_pct	35.00 – 89.90 (median 62.00)
soil_pH	4.50 – 8.50 (median 6.54)
soil_oc_pct	0.20 – 1.80 (median 1.19)
soil_texture	loam (33.7%); clay (33.3%); sandy (33.1%)
clay_pct	5.00 – 60.00 (median 24.90)
soil_depth_cm	40.00 – 150.00 (median 96.60)
soil_N_status_kg_ha	80.00 – 220.00 (median 144.00)
soil_P_status_kg_ha	5.00 – 40.00 (median 22.00)
soil_K_status_kg_ha	80.20 – 400.00 (median 226.80)
fert_N_kg_ha	40.00 – 260.00 (median 133.30)
fert_P_kg_ha	10.00 – 80.00 (median 43.50)
fert_K_kg_ha	0.10 – 119.90 (median 58.60)
sowing_doy	60.00 – 259.00 (median 162.00)
irrigation_events	0.00 – 5.00 (median 3.00)
ndvi_early	0.20 – 0.80 (median 0.63)
ndvi_flowering	0.30 – 0.90 (median 0.79)
ndvi_peak	0.42 – 0.90 (median 0.84)
ndvi_late	0.20 – 0.85 (median 0.66)
ndvi_veg_slope	0.00 – 0.03 (median 0.00)
seed_moisture_pct	7.00 – 20.00 (median 12.70)
soil_moisture_pct	28.82 – 42.00 (median 33.27)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

Brazil, the USA and Turkey (very high yield) illustrate modern high■yield soybean systems:

• Cultivation & varieties: High■yielding, often GMO herbicide■tolerant cultivars with strong lodging resistance and SCN (soybean cyst nematode) and rust tolerance; double■cropping with maize or wheat is common in Brazil and Argentina.
• Sowing: Precision planting at 35–55 plants/m², row spacing 38–50 cm in temperate zones and 45–60 cm in the tropics; sown when soil temperature at 5 cm exceeds 10 °C (temperate) or 15 °C (tropics).
• Biological nitrogen fixation: Universal use of Bradyrhizobium inoculants (seed treatment or in■furrow) to supply most N needs; starter N rarely used except on very low■fertility soils.
• Fertilizers & soil: pH 6.0–7.0; build■up of P and K over years (e.g. 40–80 kg P2O5/ha and 60–120 kg K2O/ha depending on soil tests); attention to sulphur and micronutrients (B, Zn, Mo) in deficient soils; liming to correct acidity.

• Irrigation & water: Many USA and Brazilian fields are rainfed but highest yields use supplemental irrigation at flowering (R1–R2) and pod■fill (R3–R5) to avoid water stress; conservation tillage and residue retention improve water use efficiency.
• Pest & disease management: Seed treatments plus scouting■based fungicide programmes for rust and foliar diseases; integrated weed management with pre■ and post■emergence herbicides; IPM for leaf■feeding caterpillars, stink bugs and borers.
• Canopy & NDVI: Fast canopy closure with NDVI_early ~0.5–0.7 by V4–V6; NDVI_flowering and NDVI_peak ~0.8–0.9, maintained through pod■fill; NDVI_late should remain above ~0.6 until near physiological maturity, indicating prolonged photosynthetic activity.
• Harvest & seed moisture: Harvest at 13–15% seed moisture to minimize splits and losses; timely harvest avoids shattering and weathering losses.

SUNFLOWER

Benchmark high■yield countries (indicative): Ukraine, France, Romania

In the synthetic dataset, the top 25% of sunflower records by yield have **yield_t_ha** ≥ **1.14 t/ha**. The table below summarises the ranges of other features within this high■yield subset.

Feature	High■yield range / dominant categories (top 25% of yield)
maturity_days	95.00 – 129.00 (median 112.00)
base_yield_potential_t_ha	2.39 – 4.20 (median 3.63)
mean_temp_gs_C	12.01 – 32.00 (median 22.14)
temp_flowering_C	10.03 – 35.00 (median 20.54)
seasonal_rain_mm	250.90 – 949.40 (median 561.35)
rain_flowering_mm	0.10 – 250.00 (median 123.40)
humidity_mean_pct	35.00 – 90.00 (median 62.90)
soil_pH	4.50 – 8.50 (median 6.49)
soil_oc_pct	0.20 – 1.80 (median 1.18)
soil_texture	loam (34.5%); sandy (33.7%); clay (31.8%)
clay_pct	5.00 – 60.00 (median 24.60)
soil_depth_cm	40.00 – 150.00 (median 96.30)
soil_N_status_kg_ha	80.00 – 220.00 (median 142.00)
soil_P_status_kg_ha	5.00 – 40.00 (median 22.50)
soil_K_status_kg_ha	80.00 – 400.00 (median 229.85)
fert_N_kg_ha	40.00 – 259.80 (median 131.55)
fert_P_kg_ha	10.00 – 80.00 (median 43.70)
fert_K_kg_ha	0.10 – 120.00 (median 59.65)
sowing_doy	60.00 – 259.00 (median 157.00)
irrigation_events	0.00 – 5.00 (median 3.00)
ndvi_early	0.20 – 0.80 (median 0.64)
ndvi_flowering	0.30 – 0.90 (median 0.79)
ndvi_peak	0.41 – 0.90 (median 0.84)
ndvi_late	0.21 – 0.85 (median 0.66)
ndvi_veg_slope	0.00 – 0.03 (median 0.00)
seed_moisture_pct	7.00 – 20.00 (median 12.80)
soil_moisture_pct	27.19 – 42.00 (median 30.12)

High■yield cultivation, sowing, irrigation, fertilizer, pest■management, soil, weather and NDVI practices:

High■yield sunflower systems in Ukraine, France and Romania typically share the following features:

• Cultivation & varieties: High■oleic and mid■oleic hybrids with strong drought and disease tolerance; crop rotations that avoid sunflower more than once in 4–5 years to reduce disease pressure (Sclerotinia, downy mildew).
• Sowing: Precision planting at 45–75 cm row spacing, 50–65 thousand plants/ha, sown when soil temperature at 5 cm is ≥ 8–10 °C; seed treated with fungicide + insecticide.
• Fertilizers & soil: Target pH 6.0–7.5, organic matter >1.5%; balanced NPK with ~60–120 kg N/ha, 40–80 kg P2O5/ha, 40–80 kg K2O/ha based on soil tests; sulphur applied where deficient.
• Irrigation & water: Many fields are rainfed but high■yield irrigated systems add 1–3 irrigations around bud initiation and flowering to avoid stress; conservation tillage and residue retention to conserve soil moisture.

• Pest & disease management: Seed treatments, tolerant hybrids, timely fungicides at bud to flowering for rust and leaf spots; monitoring of stem borers, Helicoverpa, whiteflies and timely insecticide or biological control.
• Canopy & NDVI pattern: Rapid early growth to close canopy by 30–40 days; NDVI_early moderate (0.4–0.6), NDVI_flowering and NDVI_peak high (0.7–0.85) with a steep vegetative slope, then a gradual decline (NDVI_late ~0.4–0.6) as plants mature without premature senescence.
• Harvest & seed moisture: Harvest when back of head turns yellow■brown and seed moisture is about 10–12%; desiccation sometimes used to synchronize maturity and reduce lodging and bird damage.