AGRONOMIC IMPROVEMENT KNOWLEDGE BASE FOR TOP 8 OILSEED CROPS

This document is designed to be ingested by a Retrieval-Augmented Generation (RAG) system.
For each of the eight major oilseed crops, it lists every feature from the ML dataset, explains its role, and describes practical strategies to move a field from low or medium yield conditions towards high-yield management.
The text is intentionally explicit and structured so it can be chunked and embedded for LLM-based advisory generation.

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CROP: SUNFLOWER
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Overview for sunflower: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for sunflower. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for sunflower:
Role in yield for sunflower: Variety group (early/mid/late) controls total crop duration, ability to
avoid heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of sunflower recommended by local universities or state agriculture departments; choose early types in short-season or terminal-drought
areas and mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed sunflower, match variety duration to length of growing season so that flowering and
pod/seed fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for sunflower:
Role in yield for sunflower: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
sunflower to exploit available moisture and radiation, provided terminal drought or frost risk is
manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for sunflower:
Role in yield for sunflower: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of sunflower with higher base_yield_potential_t_ha from credible sources (ICAR
institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade

management
(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to identify
best performing cultivars of sunflower for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.
Advisory for sunflower:
Role in yield for sunflower: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of sunflower so that the bulk of vegetative growth occurs near the crop's optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of sunflower and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for sunflower:
Role in yield for sunflower: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of sunflower coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for sunflower:
Role in yield for sunflower: Determines overall water availability for the crop; both deficiency and
excess reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of sunflower, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for sunflower:
Role in yield for sunflower: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of sunflower at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust
irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.
Advisory for sunflower:
Role in yield for sunflower: Influences transpiration, disease development and pest dynamics.
Improvement strategies:
- In very high humidity environments, increase row spacing or use paired-row planting in sunflower to
improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for sunflower:
Role in yield for sunflower: Solar radiation drives photosynthesis; good light interception is essential
for high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the sunflower canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of sunflower into low-radiation periods
(e.g., cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for sunflower:
Role in yield for sunflower: Soil pH controls nutrient availability, microbial activity and
root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test
recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including
sunflower.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for sunflower.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for sunflower:
Role in yield for sunflower: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
sunflower to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for sunflower:
Role in yield for sunflower: Clay percentage is largely inherent, affecting water retention and drainage.
Improvement strategies:

- On very sandy, low-clay soils, improve water and nutrient holding for sunflower by adding FYM/compost,
practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow
planting for sunflower to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive
compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for sunflower:
Role in yield for sunflower: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with sunflower.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of sunflower and avoid over-
fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for sunflower:
Role in yield for sunflower: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for sunflower) to enhance biological N supply.
- Split N applications for sunflower into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for sunflower:
Role in yield for sunflower: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for sunflower.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for sunflower:
Role in yield for sunflower: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for sunflower.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may

be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.
Advisory for sunflower:
Role in yield for sunflower: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:
- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too high causes lodging and increased pest/disease incidence in sunflower.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for sunflower:
Role in yield for sunflower: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic deficiencies gradually by repeated balanced applications for sunflower.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for sunflower:
Role in yield for sunflower: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where chloride-sensitive situations demand it, in consultation with local recommendations for sunflower.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering and seed filling.
- Use soil and leaf analysis in high-value sunflower systems to fine-tune K nutrition and prevent hidden deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for sunflower:
Role in yield for sunflower: Sowing date governs how the crop experiences rainfall, temperature and pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for sunflower (e.g., with onset of monsoon for kharif crops or in October–November for rabi crops) to ensure favourable conditions at emergence and flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which exposes sunflower to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for sunflower:

Role in yield for sunflower: Controls competition between plants and determines canopy structure.
Improvement strategies:
- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly higher seed rate next season to achieve recommended stands for sunflower.
- If density is too high, thinning at early stages can reduce competition and improve branching and capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for sunflower:
Role in yield for sunflower: Number and timing of irrigations determine water availability at critical stages.
Improvement strategies:
- Prioritise irrigations at critical stages for sunflower such as branching, flowering and pod/seed filling rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for sunflower:
Role in yield for sunflower: Herbicide use is one tool for weed management; overuse or misuse can harm the crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for sunflower.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high winds or on stressed sunflower plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for sunflower:
Role in yield for sunflower: Insecticide applications protect against key pests but should follow IPM principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest incidence in sunflower crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for sunflower:
Role in yield for sunflower: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:

- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in sunflower.
- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and
official recommendations support their use.
- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing
and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for sunflower:
Role in yield for sunflower: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:
- Aim to keep the first 30–40 days after sowing of sunflower as weed-free as possible using pre-emergence
herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting sunflower.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for sunflower:
Role in yield for sunflower: Persistent or severe insect pest pressure reduces leaf area, flowers, pods
or seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in sunflower: crop rotation, resistant varieties, timely
sowing and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for sunflower:
Role in yield for sunflower: High disease pressure reduces photosynthesis, weakens plants and often
affects seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating sunflower or closely related crops on the same field year
after year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for sunflower:
Role in yield for sunflower: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of sunflower.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young sunflower plants do not face competition for light and
nutrients during early stages.

Feature: ndvi_flowering
Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.
Advisory for sunflower:
Role in yield for sunflower: NDVI near flowering is a strong predictor of final yield because it reflects
canopy size and health at a critical stage.
Improvement strategies:
- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in sunflower; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to
maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for sunflower:
Role in yield for sunflower: Peak NDVI reflects maximum biomass; higher values within an optimum range
are associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of sunflower by
the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for sunflower:
Role in yield for sunflower: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in sunflower.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for sunflower:
Role in yield for sunflower: Vegetation slope describes how quickly the canopy develops from emergence to
peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for sunflower to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose sunflower to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for sunflower:
Role in yield for sunflower: Seed moisture at harvest affects both yield (through shrinkage or losses)
and storability.

Improvement strategies:
- Harvest sunflower when seed_moisture_pct is in the recommended safe range (often 8–12% for long-term
storage; slightly higher at field harvest followed by drying).
- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and
weather-related losses.

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CROP: MUSTARD
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Overview for mustard: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for mustard. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for mustard:
Role in yield for mustard: Variety group (early/mid/late) controls total crop duration, ability to avoid
heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of mustard recommended by local universities
or state agriculture departments; choose early types in short-season or terminal-drought areas and
mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed mustard, match variety duration to length of growing season so that flowering and pod/seed
fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for mustard:
Role in yield for mustard: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
mustard to exploit available moisture and radiation, provided terminal drought or frost risk is manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for mustard:
Role in yield for mustard: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of mustard with higher base_yield_potential_t_ha from credible sources (ICAR institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade management

(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to identify
best performing cultivars of mustard for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.
Advisory for mustard:
Role in yield for mustard: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of mustard so that the bulk of vegetative growth occurs near the crop's optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of mustard and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for mustard:
Role in yield for mustard: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of mustard coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for mustard:
Role in yield for mustard: Determines overall water availability for the crop; both deficiency and excess
reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of mustard, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for mustard:
Role in yield for mustard: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of mustard at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust
irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.
Advisory for mustard:
Role in yield for mustard: Influences transpiration, disease development and pest dynamics.
Improvement strategies:
- In very high humidity environments, increase row spacing or use paired-row planting in mustard to
improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for mustard:
Role in yield for mustard: Solar radiation drives photosynthesis; good light interception is essential
for high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the mustard canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of mustard into low-radiation periods (e.g.,
cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for mustard:
Role in yield for mustard: Soil pH controls nutrient availability, microbial activity and root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test
recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including
mustard.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for mustard.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for mustard:
Role in yield for mustard: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
mustard to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for mustard:
Role in yield for mustard: Clay percentage is largely inherent, affecting water retention and drainage.
Improvement strategies:

- On very sandy, low-clay soils, improve water and nutrient holding for mustard by adding FYM/compost,
practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow
planting for mustard to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive
compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for mustard:
Role in yield for mustard: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with mustard.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of mustard and avoid over-
fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for mustard:
Role in yield for mustard: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for mustard) to enhance biological N supply.
- Split N applications for mustard into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for mustard:
Role in yield for mustard: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for mustard.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for mustard:
Role in yield for mustard: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for mustard.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may

be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.
Advisory for mustard:
Role in yield for mustard: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:
- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too high causes lodging and increased pest/disease incidence in mustard.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for mustard:
Role in yield for mustard: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic deficiencies gradually by repeated balanced applications for mustard.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for mustard:
Role in yield for mustard: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where chloride-sensitive situations demand it, in consultation with local recommendations for mustard.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering and seed filling.
- Use soil and leaf analysis in high-value mustard systems to fine-tune K nutrition and prevent hidden deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for mustard:
Role in yield for mustard: Sowing date governs how the crop experiences rainfall, temperature and pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for mustard (e.g., with onset of monsoon for kharif crops or in October–November for rabi crops) to ensure favourable conditions at emergence and flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which exposes mustard to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for mustard:

Role in yield for mustard: Controls competition between plants and determines canopy structure.
Improvement strategies:
- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly higher seed
rate next season to achieve recommended stands for mustard.
- If density is too high, thinning at early stages can reduce competition and improve branching and
capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and
moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for mustard:
Role in yield for mustard: Number and timing of irrigations determine water availability at critical
stages.
Improvement strategies:
- Prioritise irrigations at critical stages for mustard such as branching, flowering and pod/seed filling
rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve
water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation
events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for mustard:
Role in yield for mustard: Herbicide use is one tool for weed management; overuse or misuse can harm the
crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as
permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for mustard.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of
herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high
winds or on stressed mustard plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for mustard:
Role in yield for mustard: Insecticide applications protect against key pests but should follow IPM
principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest
incidence in mustard crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect
growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and
protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for mustard:
Role in yield for mustard: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:
- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in mustard.

- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and
official recommendations support their use.
- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing
and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for mustard:
Role in yield for mustard: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:
- Aim to keep the first 30–40 days after sowing of mustard as weed-free as possible using pre-emergence
herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting mustard.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for mustard:
Role in yield for mustard: Persistent or severe insect pest pressure reduces leaf area, flowers, pods or
seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in mustard: crop rotation, resistant varieties, timely
sowing and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for mustard:
Role in yield for mustard: High disease pressure reduces photosynthesis, weakens plants and often affects
seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating mustard or closely related crops on the same field year after
year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for mustard:
Role in yield for mustard: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of mustard.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young mustard plants do not face competition for light and nutrients
during early stages.

Feature: ndvi_flowering
Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.

Advisory for mustard:
Role in yield for mustard: NDVI near flowering is a strong predictor of final yield because it reflects
canopy size and health at a critical stage.
Improvement strategies:
- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in mustard; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to
maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for mustard:
Role in yield for mustard: Peak NDVI reflects maximum biomass; higher values within an optimum range are
associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of mustard by
the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for mustard:
Role in yield for mustard: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in mustard.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for mustard:
Role in yield for mustard: Vegetation slope describes how quickly the canopy develops from emergence to
peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for mustard to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose mustard to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for mustard:
Role in yield for mustard: Seed moisture at harvest affects both yield (through shrinkage or losses) and
storability.
Improvement strategies:
- Harvest mustard when seed_moisture_pct is in the recommended safe range (often 8–12% for

long-term
storage; slightly higher at field harvest followed by drying).
- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and
weather-related losses.

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CROP: SOYBEAN
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Overview for soybean: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for soybean. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for soybean:
Role in yield for soybean: Variety group (early/mid/late) controls total crop duration, ability to avoid
heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of soybean recommended by local universities
or state agriculture departments; choose early types in short-season or terminal-drought areas and
mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed soybean, match variety duration to length of growing season so that flowering and pod/seed
fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for soybean:
Role in yield for soybean: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
soybean to exploit available moisture and radiation, provided terminal drought or frost risk is manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for soybean:
Role in yield for soybean: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of soybean with higher base_yield_potential_t_ha from credible sources (ICAR institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade management
(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to

identify
best performing cultivars of soybean for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.
Advisory for soybean:
Role in yield for soybean: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of soybean so that the bulk of vegetative growth occurs near the crop's optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of soybean and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for soybean:
Role in yield for soybean: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of soybean coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for soybean:
Role in yield for soybean: Determines overall water availability for the crop; both deficiency and excess
reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of soybean, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for soybean:
Role in yield for soybean: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of soybean at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust
irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.

Advisory for soybean:
Role in yield for soybean: Influences transpiration, disease development and pest dynamics.
Improvement strategies:
- In very high humidity environments, increase row spacing or use paired-row planting in soybean to
improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for soybean:
Role in yield for soybean: Solar radiation drives photosynthesis; good light interception is essential
for high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the soybean canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of soybean into low-radiation periods (e.g.,
cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for soybean:
Role in yield for soybean: Soil pH controls nutrient availability, microbial activity and root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test
recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including
soybean.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for soybean.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for soybean:
Role in yield for soybean: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
soybean to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for soybean:
Role in yield for soybean: Clay percentage is largely inherent, affecting water retention and drainage.
Improvement strategies:
- On very sandy, low-clay soils, improve water and nutrient holding for soybean by adding FYM/compost,

practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow
planting for soybean to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive
compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for soybean:
Role in yield for soybean: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with soybean.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of soybean and avoid over-
fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for soybean:
Role in yield for soybean: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for soybean) to enhance biological N supply.
- Split N applications for soybean into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for soybean:
Role in yield for soybean: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for soybean.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for soybean:
Role in yield for soybean: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for soybean.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.
Advisory for soybean:
Role in yield for soybean: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:
- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too high causes lodging and increased pest/disease incidence in soybean.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for soybean:
Role in yield for soybean: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic deficiencies gradually by repeated balanced applications for soybean.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for soybean:
Role in yield for soybean: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where chloride-sensitive situations demand it, in consultation with local recommendations for soybean.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering and seed filling.
- Use soil and leaf analysis in high-value soybean systems to fine-tune K nutrition and prevent hidden deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for soybean:
Role in yield for soybean: Sowing date governs how the crop experiences rainfall, temperature and pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for soybean (e.g., with onset of monsoon for kharif crops or in October–November for rabi crops) to ensure favourable conditions at emergence and flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which exposes soybean to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for soybean:
Role in yield for soybean: Controls competition between plants and determines canopy structure.
Improvement strategies:
- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly

higher seed
rate next season to achieve recommended stands for soybean.
- If density is too high, thinning at early stages can reduce competition and improve branching and
capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and
moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for soybean:
Role in yield for soybean: Number and timing of irrigations determine water availability at critical
stages.
Improvement strategies:
- Prioritise irrigations at critical stages for soybean such as branching, flowering and pod/seed filling
rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve
water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation
events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for soybean:
Role in yield for soybean: Herbicide use is one tool for weed management; overuse or misuse can harm the
crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as
permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for soybean.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of
herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high
winds or on stressed soybean plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for soybean:
Role in yield for soybean: Insecticide applications protect against key pests but should follow IPM
principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest
incidence in soybean crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect
growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and
protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for soybean:
Role in yield for soybean: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:
- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in soybean.
- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and
official recommendations support their use.

- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing
and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for soybean:
Role in yield for soybean: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:
- Aim to keep the first 30–40 days after sowing of soybean as weed-free as possible using pre-emergence
herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting soybean.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for soybean:
Role in yield for soybean: Persistent or severe insect pest pressure reduces leaf area, flowers, pods or
seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in soybean: crop rotation, resistant varieties, timely
sowing and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for soybean:
Role in yield for soybean: High disease pressure reduces photosynthesis, weakens plants and often affects
seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating soybean or closely related crops on the same field year after
year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for soybean:
Role in yield for soybean: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of soybean.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young soybean plants do not face competition for light and nutrients
during early stages.

Feature: ndvi_flowering
Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.
Advisory for soybean:
Role in yield for soybean: NDVI near flowering is a strong predictor of final yield because it reflects

canopy size and health at a critical stage.
Improvement strategies:
- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in soybean; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to
maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for soybean:
Role in yield for soybean: Peak NDVI reflects maximum biomass; higher values within an optimum range are
associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of soybean by
the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for soybean:
Role in yield for soybean: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in soybean.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for soybean:
Role in yield for soybean: Vegetation slope describes how quickly the canopy develops from emergence to
peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for soybean to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose soybean to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for soybean:
Role in yield for soybean: Seed moisture at harvest affects both yield (through shrinkage or losses) and
storability.
Improvement strategies:
- Harvest soybean when seed_moisture_pct is in the recommended safe range (often 8–12% for long-term
storage; slightly higher at field harvest followed by drying).
- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or

mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and
weather-related losses.

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CROP: SAFFLOWER
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Overview for safflower: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for safflower. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for safflower:
Role in yield for safflower: Variety group (early/mid/late) controls total crop duration, ability to
avoid heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of safflower recommended by local universities or state agriculture departments; choose early types in short-season or terminal-drought
areas and mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed safflower, match variety duration to length of growing season so that flowering and
pod/seed fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for safflower:
Role in yield for safflower: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
safflower to exploit available moisture and radiation, provided terminal drought or frost risk is
manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for safflower:
Role in yield for safflower: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of safflower with higher base_yield_potential_t_ha from credible sources (ICAR
institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade management
(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to identify
best performing cultivars of safflower for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.
Advisory for safflower:
Role in yield for safflower: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of safflower so that the bulk of vegetative growth occurs near the crop's optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of safflower and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for safflower:
Role in yield for safflower: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of safflower coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for safflower:
Role in yield for safflower: Determines overall water availability for the crop; both deficiency and
excess reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of safflower, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for safflower:
Role in yield for safflower: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of safflower at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust
irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.
Advisory for safflower:
Role in yield for safflower: Influences transpiration, disease development and pest dynamics.
Improvement strategies:

- In very high humidity environments, increase row spacing or use paired-row planting in safflower to
improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for safflower:
Role in yield for safflower: Solar radiation drives photosynthesis; good light interception is essential
for high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the safflower canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of safflower into low-radiation periods
(e.g., cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for safflower:
Role in yield for safflower: Soil pH controls nutrient availability, microbial activity and
root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test
recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including
safflower.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for safflower.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for safflower:
Role in yield for safflower: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
safflower to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for safflower:
Role in yield for safflower: Clay percentage is largely inherent, affecting water retention and drainage.
Improvement strategies:
- On very sandy, low-clay soils, improve water and nutrient holding for safflower by adding FYM/compost,
practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow

planting for safflower to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive
compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for safflower:
Role in yield for safflower: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with safflower.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of safflower and avoid over-
fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for safflower:
Role in yield for safflower: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for safflower) to enhance biological N supply.
- Split N applications for safflower into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for safflower:
Role in yield for safflower: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for safflower.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for safflower:
Role in yield for safflower: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for safflower.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.

Advisory for safflower:
Role in yield for safflower: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:
- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too high causes lodging and increased pest/disease incidence in safflower.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for safflower:
Role in yield for safflower: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic deficiencies gradually by repeated balanced applications for safflower.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for safflower:
Role in yield for safflower: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where chloride-sensitive situations demand it, in consultation with local recommendations for safflower.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering and seed filling.
- Use soil and leaf analysis in high-value safflower systems to fine-tune K nutrition and prevent hidden deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for safflower:
Role in yield for safflower: Sowing date governs how the crop experiences rainfall, temperature and pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for safflower (e.g., with onset of monsoon for kharif crops or in October–November for rabi crops) to ensure favourable conditions at emergence and flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which exposes safflower to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for safflower:
Role in yield for safflower: Controls competition between plants and determines canopy structure.
Improvement strategies:
- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly higher seed

rate next season to achieve recommended stands for safflower.
- If density is too high, thinning at early stages can reduce competition and improve branching and
capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and
moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for safflower:
Role in yield for safflower: Number and timing of irrigations determine water availability at critical
stages.
Improvement strategies:
- Prioritise irrigations at critical stages for safflower such as branching, flowering and pod/seed
filling rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve
water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation
events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for safflower:
Role in yield for safflower: Herbicide use is one tool for weed management; overuse or misuse can harm
the crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as
permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for
safflower.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of
herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high
winds or on stressed safflower plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for safflower:
Role in yield for safflower: Insecticide applications protect against key pests but should follow IPM
principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest
incidence in safflower crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect
growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and
protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for safflower:
Role in yield for safflower: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:
- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in safflower.
- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and

official recommendations support their use.
- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing
and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for safflower:
Role in yield for safflower: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:
- Aim to keep the first 30–40 days after sowing of safflower as weed-free as possible using pre-emergence
herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting safflower.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for safflower:
Role in yield for safflower: Persistent or severe insect pest pressure reduces leaf area, flowers, pods
or seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in safflower: crop rotation, resistant varieties, timely
sowing and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for safflower:
Role in yield for safflower: High disease pressure reduces photosynthesis, weakens plants and often
affects seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating safflower or closely related crops on the same field year
after year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for safflower:
Role in yield for safflower: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of safflower.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young safflower plants do not face competition for light and
nutrients during early stages.

Feature: ndvi_flowering
Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.
Advisory for safflower:
Role in yield for safflower: NDVI near flowering is a strong predictor of final yield because

it reflects
canopy size and health at a critical stage.
Improvement strategies:
- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in safflower; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to
maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for safflower:
Role in yield for safflower: Peak NDVI reflects maximum biomass; higher values within an optimum range
are associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of safflower by
the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for safflower:
Role in yield for safflower: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in safflower.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for safflower:
Role in yield for safflower: Vegetation slope describes how quickly the canopy develops from emergence to
peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for safflower to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose safflower to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for safflower:
Role in yield for safflower: Seed moisture at harvest affects both yield (through shrinkage or losses)
and storability.
Improvement strategies:
- Harvest safflower when seed_moisture_pct is in the recommended safe range (often 8–12% for long-term
storage; slightly higher at field harvest followed by drying).

- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and
weather-related losses.

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CROP: NIGER SEED
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Overview for niger seed: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for niger seed. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for niger seed:
Role in yield for niger seed: Variety group (early/mid/late) controls total crop duration, ability to
avoid heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of niger seed recommended by local universities or state agriculture departments; choose early types in short-season or terminal-drought
areas and mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed niger seed, match variety duration to length of growing season so that flowering and
pod/seed fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for niger seed:
Role in yield for niger seed: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
niger seed to exploit available moisture and radiation, provided terminal drought or frost risk is
manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for niger seed:
Role in yield for niger seed: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of niger seed with higher base_yield_potential_t_ha from credible sources (ICAR
institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade management
(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to identify

best performing cultivars of niger seed for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.
Advisory for niger seed:
Role in yield for niger seed: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of niger seed so that the bulk of vegetative growth occurs near the crop’s optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of niger seed and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for niger seed:
Role in yield for niger seed: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of niger seed coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for niger seed:
Role in yield for niger seed: Determines overall water availability for the crop; both deficiency and
excess reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of niger seed, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for niger seed:
Role in yield for niger seed: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of niger seed at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.
Advisory for niger seed:

Role in yield for niger seed: Influences transpiration, disease development and pest dynamics.
Improvement strategies:
- In very high humidity environments, increase row spacing or use paired-row planting in niger seed to
improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for niger seed:
Role in yield for niger seed: Solar radiation drives photosynthesis; good light interception is essential
for high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the niger seed canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of niger seed into low-radiation periods
(e.g., cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for niger seed:
Role in yield for niger seed: Soil pH controls nutrient availability, microbial activity and
root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test
recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including niger
seed.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for niger seed.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for niger seed:
Role in yield for niger seed: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
niger seed to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for niger seed:
Role in yield for niger seed: Clay percentage is largely inherent, affecting water retention and
drainage.
Improvement strategies:
- On very sandy, low-clay soils, improve water and nutrient holding for niger seed by adding FYM/compost,

practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow
planting for niger seed to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive
compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for niger seed:
Role in yield for niger seed: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with niger seed.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of niger seed and avoid over-
fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for niger seed:
Role in yield for niger seed: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for niger seed) to enhance biological N supply.
- Split N applications for niger seed into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for niger seed:
Role in yield for niger seed: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for niger seed.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for niger seed:
Role in yield for niger seed: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for niger seed.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.
Advisory for niger seed:
Role in yield for niger seed: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:
- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too high causes lodging and increased pest/disease incidence in niger seed.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for niger seed:
Role in yield for niger seed: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic deficiencies gradually by repeated balanced applications for niger seed.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for niger seed:
Role in yield for niger seed: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where chloride-sensitive situations demand it, in consultation with local recommendations for niger seed.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering and seed filling.
- Use soil and leaf analysis in high-value niger seed systems to fine-tune K nutrition and prevent hidden deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for niger seed:
Role in yield for niger seed: Sowing date governs how the crop experiences rainfall, temperature and pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for niger seed (e.g., with onset of monsoon for kharif crops or in October–November for rabi crops) to ensure favourable conditions at emergence and flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which exposes niger seed to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for niger seed:
Role in yield for niger seed: Controls competition between plants and determines canopy structure.
Improvement strategies:

- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly higher seed
rate next season to achieve recommended stands for niger seed.
- If density is too high, thinning at early stages can reduce competition and improve branching and
capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and
moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for niger seed:
Role in yield for niger seed: Number and timing of irrigations determine water availability at critical
stages.
Improvement strategies:
- Prioritise irrigations at critical stages for niger seed such as branching, flowering and pod/seed
filling rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve
water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation
events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for niger seed:
Role in yield for niger seed: Herbicide use is one tool for weed management; overuse or misuse can harm
the crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as
permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for niger
seed.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of
herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high
winds or on stressed niger seed plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for niger seed:
Role in yield for niger seed: Insecticide applications protect against key pests but should follow IPM
principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest
incidence in niger seed crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect
growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and
protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for niger seed:
Role in yield for niger seed: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:
- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in niger seed.

- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and
official recommendations support their use.
- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing
and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for niger seed:
Role in yield for niger seed: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:
- Aim to keep the first 30–40 days after sowing of niger seed as weed-free as possible using pre-
emergence herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting niger seed.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for niger seed:
Role in yield for niger seed: Persistent or severe insect pest pressure reduces leaf area, flowers, pods
or seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in niger seed: crop rotation, resistant varieties, timely
sowing and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for niger seed:
Role in yield for niger seed: High disease pressure reduces photosynthesis, weakens plants and often
affects seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating niger seed or closely related crops on the same field year
after year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for niger seed:
Role in yield for niger seed: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of niger seed.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young niger seed plants do not face competition for light and
nutrients during early stages.

Feature: ndvi_flowering

Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.
Advisory for niger seed:
Role in yield for niger seed: NDVI near flowering is a strong predictor of final yield because it
reflects canopy size and health at a critical stage.
Improvement strategies:
- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in niger seed; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to
maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for niger seed:
Role in yield for niger seed: Peak NDVI reflects maximum biomass; higher values within an optimum range
are associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of niger seed
by the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for niger seed:
Role in yield for niger seed: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in niger seed.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for niger seed:
Role in yield for niger seed: Vegetation slope describes how quickly the canopy develops from emergence
to peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for niger seed to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose niger seed to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for niger seed:
Role in yield for niger seed: Seed moisture at harvest affects both yield (through shrinkage or losses)
and storability.
Improvement strategies:

- Harvest niger seed when seed_moisture_pct is in the recommended safe range (often 8–12% for long-term
storage; slightly higher at field harvest followed by drying).
- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and
weather-related losses.

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CROP: GROUNDNUT
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Overview for groundnut: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for groundnut. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for groundnut:
Role in yield for groundnut: Variety group (early/mid/late) controls total crop duration, ability to
avoid heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of groundnut recommended by local universities or state agriculture departments; choose early types in short-season or terminal-drought
areas and mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed groundnut, match variety duration to length of growing season so that flowering and
pod/seed fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for groundnut:
Role in yield for groundnut: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
groundnut to exploit available moisture and radiation, provided terminal drought or frost risk is
manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for groundnut:
Role in yield for groundnut: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of groundnut with higher base_yield_potential_t_ha from credible sources (ICAR
institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade management

(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to identify
best performing cultivars of groundnut for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.
Advisory for groundnut:
Role in yield for groundnut: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of groundnut so that the bulk of vegetative growth occurs near the crop's optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of groundnut and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for groundnut:
Role in yield for groundnut: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of groundnut coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for groundnut:
Role in yield for groundnut: Determines overall water availability for the crop; both deficiency and
excess reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of groundnut, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for groundnut:
Role in yield for groundnut: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of groundnut at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust
irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.
Advisory for groundnut:
Role in yield for groundnut: Influences transpiration, disease development and pest dynamics.
Improvement strategies:
- In very high humidity environments, increase row spacing or use paired-row planting in groundnut to
improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for groundnut:
Role in yield for groundnut: Solar radiation drives photosynthesis; good light interception is essential
for high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the groundnut canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of groundnut into low-radiation periods
(e.g., cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for groundnut:
Role in yield for groundnut: Soil pH controls nutrient availability, microbial activity and
root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test
recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including
groundnut.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for groundnut.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for groundnut:
Role in yield for groundnut: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
groundnut to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for groundnut:
Role in yield for groundnut: Clay percentage is largely inherent, affecting water retention and drainage.
Improvement strategies:

- On very sandy, low-clay soils, improve water and nutrient holding for groundnut by adding FYM/compost,
practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow
planting for groundnut to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive
compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for groundnut:
Role in yield for groundnut: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with groundnut.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of groundnut and avoid over-
fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for groundnut:
Role in yield for groundnut: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for groundnut) to enhance biological N supply.
- Split N applications for groundnut into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for groundnut:
Role in yield for groundnut: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for groundnut.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for groundnut:
Role in yield for groundnut: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for groundnut.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may

be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.
Advisory for groundnut:
Role in yield for groundnut: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:
- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too
high causes lodging and increased pest/disease incidence in groundnut.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early
flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or
controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for groundnut:
Role in yield for groundnut: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic
deficiencies gradually by repeated balanced applications for groundnut.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise
fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in
acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for groundnut:
Role in yield for groundnut: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where
chloride-sensitive situations demand it, in consultation with local recommendations for groundnut.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering
and seed filling.
- Use soil and leaf analysis in high-value groundnut systems to fine-tune K nutrition and prevent hidden
deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for groundnut:
Role in yield for groundnut: Sowing date governs how the crop experiences rainfall, temperature and
pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for groundnut (e.g., with onset of monsoon for
kharif crops or in October–November for rabi crops) to ensure favourable conditions at emergence and
flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which
exposes groundnut to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered
sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for groundnut:

Role in yield for groundnut: Controls competition between plants and determines canopy structure.
Improvement strategies:
- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly higher seed rate next season to achieve recommended stands for groundnut.
- If density is too high, thinning at early stages can reduce competition and improve branching and capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for groundnut:
Role in yield for groundnut: Number and timing of irrigations determine water availability at critical stages.
Improvement strategies:
- Prioritise irrigations at critical stages for groundnut such as branching, flowering and pod/seed filling rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for groundnut:
Role in yield for groundnut: Herbicide use is one tool for weed management; overuse or misuse can harm the crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for groundnut.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high winds or on stressed groundnut plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for groundnut:
Role in yield for groundnut: Insecticide applications protect against key pests but should follow IPM principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest incidence in groundnut crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for groundnut:
Role in yield for groundnut: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:

- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in groundnut.
- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and
official recommendations support their use.
- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing
and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for groundnut:
Role in yield for groundnut: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:
- Aim to keep the first 30–40 days after sowing of groundnut as weed-free as possible using pre-emergence
herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting groundnut.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for groundnut:
Role in yield for groundnut: Persistent or severe insect pest pressure reduces leaf area, flowers, pods
or seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in groundnut: crop rotation, resistant varieties, timely
sowing and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for groundnut:
Role in yield for groundnut: High disease pressure reduces photosynthesis, weakens plants and often
affects seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating groundnut or closely related crops on the same field year
after year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for groundnut:
Role in yield for groundnut: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of groundnut.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young groundnut plants do not face competition for light and
nutrients during early stages.

Feature: ndvi_flowering
Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.
Advisory for groundnut:
Role in yield for groundnut: NDVI near flowering is a strong predictor of final yield because it reflects
canopy size and health at a critical stage.
Improvement strategies:
- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in groundnut; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to
maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for groundnut:
Role in yield for groundnut: Peak NDVI reflects maximum biomass; higher values within an optimum range
are associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of groundnut by
the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for groundnut:
Role in yield for groundnut: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in groundnut.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for groundnut:
Role in yield for groundnut: Vegetation slope describes how quickly the canopy develops from emergence to
peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for groundnut to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose groundnut to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for groundnut:
Role in yield for groundnut: Seed moisture at harvest affects both yield (through shrinkage or losses)
and storability.

Improvement strategies:
- Harvest groundnut when seed_moisture_pct is in the recommended safe range (often 8–12% for long-term
storage; slightly higher at field harvest followed by drying).
- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and
weather-related losses.

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CROP: CASTOR
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Overview for castor: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for castor. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for castor:
Role in yield for castor: Variety group (early/mid/late) controls total crop duration, ability to avoid
heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of castor recommended by local universities
or state agriculture departments; choose early types in short-season or terminal-drought areas and
mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed castor, match variety duration to length of growing season so that flowering and pod/seed
fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for castor:
Role in yield for castor: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
castor to exploit available moisture and radiation, provided terminal drought or frost risk is manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for castor:
Role in yield for castor: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of castor with higher base_yield_potential_t_ha from credible sources (ICAR institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade management

(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to identify
best performing cultivars of castor for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.
Advisory for castor:
Role in yield for castor: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of castor so that the bulk of vegetative growth occurs near the crop's optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of castor and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for castor:
Role in yield for castor: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of castor coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for castor:
Role in yield for castor: Determines overall water availability for the crop; both deficiency and excess
reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of castor, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for castor:
Role in yield for castor: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of castor at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust
irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.
Advisory for castor:
Role in yield for castor: Influences transpiration, disease development and pest dynamics.
Improvement strategies:
- In very high humidity environments, increase row spacing or use paired-row planting in castor to
improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for castor:
Role in yield for castor: Solar radiation drives photosynthesis; good light interception is essential for
high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the castor canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of castor into low-radiation periods (e.g.,
cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for castor:
Role in yield for castor: Soil pH controls nutrient availability, microbial activity and root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test
recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including castor.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for castor.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for castor:
Role in yield for castor: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
castor to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for castor:
Role in yield for castor: Clay percentage is largely inherent, affecting water retention and drainage.
Improvement strategies:
- On very sandy, low-clay soils, improve water and nutrient holding for castor by adding

FYM/compost,
practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow
planting for castor to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive
compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for castor:
Role in yield for castor: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with castor.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of castor and avoid over-fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for castor:
Role in yield for castor: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for castor) to enhance biological N supply.
- Split N applications for castor into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for castor:
Role in yield for castor: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for castor.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for castor:
Role in yield for castor: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for castor.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.
Advisory for castor:
Role in yield for castor: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:
- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too high causes lodging and increased pest/disease incidence in castor.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for castor:
Role in yield for castor: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic deficiencies gradually by repeated balanced applications for castor.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for castor:
Role in yield for castor: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where chloride-sensitive situations demand it, in consultation with local recommendations for castor.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering and seed filling.
- Use soil and leaf analysis in high-value castor systems to fine-tune K nutrition and prevent hidden deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for castor:
Role in yield for castor: Sowing date governs how the crop experiences rainfall, temperature and pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for castor (e.g., with onset of monsoon for kharif crops or in October–November for rabi crops) to ensure favourable conditions at emergence and flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which exposes castor to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for castor:
Role in yield for castor: Controls competition between plants and determines canopy structure.
Improvement strategies:
- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly higher seed rate next season to achieve recommended stands for castor.

- If density is too high, thinning at early stages can reduce competition and improve branching and
capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and
moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for castor:
Role in yield for castor: Number and timing of irrigations determine water availability at critical
stages.
Improvement strategies:
- Prioritise irrigations at critical stages for castor such as branching, flowering and pod/seed filling
rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve
water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation
events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for castor:
Role in yield for castor: Herbicide use is one tool for weed management; overuse or misuse can harm the
crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as
permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for castor.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of
herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high
winds or on stressed castor plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for castor:
Role in yield for castor: Insecticide applications protect against key pests but should follow IPM
principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest
incidence in castor crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect
growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and
protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for castor:
Role in yield for castor: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:
- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in castor.
- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and
official recommendations support their use.
- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing

and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for castor:
Role in yield for castor: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:
- Aim to keep the first 30–40 days after sowing of castor as weed-free as possible using pre-emergence
herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting castor.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for castor:
Role in yield for castor: Persistent or severe insect pest pressure reduces leaf area, flowers, pods or
seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in castor: crop rotation, resistant varieties, timely sowing
and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for castor:
Role in yield for castor: High disease pressure reduces photosynthesis, weakens plants and often affects
seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating castor or closely related crops on the same field year after
year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for castor:
Role in yield for castor: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of castor.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young castor plants do not face competition for light and nutrients
during early stages.

Feature: ndvi_flowering
Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.
Advisory for castor:
Role in yield for castor: NDVI near flowering is a strong predictor of final yield because it reflects
canopy size and health at a critical stage.
Improvement strategies:

- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in castor; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to
maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for castor:
Role in yield for castor: Peak NDVI reflects maximum biomass; higher values within an optimum range are
associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of castor by
the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for castor:
Role in yield for castor: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in castor.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for castor:
Role in yield for castor: Vegetation slope describes how quickly the canopy develops from emergence to
peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for castor to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose castor to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for castor:
Role in yield for castor: Seed moisture at harvest affects both yield (through shrinkage or losses) and
storability.
Improvement strategies:
- Harvest castor when seed_moisture_pct is in the recommended safe range (often 8–12% for long-term
storage; slightly higher at field harvest followed by drying).
- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and

weather-related losses.

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CROP: SESAME
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Overview for sesame: This section links each ML feature to actionable agronomic levers that a farmer or advisor can adjust to improve yield for sesame. The same feature names are used as in the training dataset so that predicted yield class (low / medium / high) can be mapped directly to domain-specific advice.

Feature: variety_group
Meaning: Maturity class of the variety (early, mid, late); determines crop duration and yield potential.
Advisory for sesame:
Role in yield for sesame: Variety group (early/mid/late) controls total crop duration, ability to avoid
heat, drought or frost, and genetic yield potential.
Improvement strategies:
- Prefer high-yielding, stress-tolerant hybrids or varieties of sesame recommended by local universities
or state agriculture departments; choose early types in short-season or terminal-drought areas and
mid/late types where irrigation or assured rainfall exists.
- Replace older, low-yielding landraces with certified seed each 2–3 years to maintain genetic purity and
vigour.
- For rainfed sesame, match variety duration to length of growing season so that flowering and pod/seed
fill avoid the hottest or driest period.

Feature: maturity_days
Meaning: Number of days from sowing to harvest; controls how long the crop can grow and fill seeds.
Advisory for sesame:
Role in yield for sesame: Longer effective growth period allows more biomass and seed filling, but
increases risk of heat or drought at the end of the season.
Improvement strategies:
- If maturity_days are too low (very early harvests), consider slightly longer-duration varieties of
sesame to exploit available moisture and radiation, provided terminal drought or frost risk is manageable.
- If maturity_days are very high and crop suffers from terminal heat or drought, shift to earlier sowing
or slightly shorter-duration varieties so that flowering and seed filling occur in cooler, moist
conditions.
- Use staggered sowing of different duration groups on the farm to spread risk from weather extremes and
pests.

Feature: base_yield_potential_t_ha
Meaning: Genetic yield potential of the chosen variety under ideal conditions.
Advisory for sesame:
Role in yield for sesame: Indicates the genetic ceiling of yield under ideal management; actual yield
will be lower if constraints exist.
Improvement strategies:
- Select varieties of sesame with higher base_yield_potential_t_ha from credible sources (ICAR institutes, SAUs, or seed corporations) while also checking resistance to key local pests and diseases.
- When shifting to varieties with higher base yield potential, simultaneously upgrade management
(nutrients, plant protection, irrigation) to allow expression of that potential.
- Periodically participate in frontline demonstrations or cluster front line demonstrations to identify
best performing cultivars of sesame for the local agro-climatic zone.

Feature: mean_temp_gs_C
Meaning: Average air temperature over the whole growing season.

Advisory for sesame:
Role in yield for sesame: Season-long mean temperature influences photosynthesis rate, phenology and
stress; extremes reduce yield.
Improvement strategies:
- Align sowing window of sesame so that the bulk of vegetative growth occurs near the crop's optimum
temperature range (often 20–30 °C for kharif crops and 15–25 °C for rabi crops).
- Use mulching, residue retention and conservation tillage in very hot zones to moderate soil temperature
and reduce evaporative losses.
- In extremely hot regions, explore heat-tolerant varieties of sesame and consider evening or night
irrigation to reduce canopy stress around peak heat periods.

Feature: temp_flowering_C
Meaning: Average temperature around flowering, when yield is most sensitive.
Advisory for sesame:
Role in yield for sesame: Temperature at flowering strongly affects pollination, flower retention and
pod/seed set.
Improvement strategies:
- Adjust sowing date so that flowering of sesame coincides with relatively cooler, less stressful
temperatures in the season for the region.
- Under high heat risk, maintain optimum soil moisture using life-saving irrigation at bud and flowering
stages to reduce canopy temperature stress.
- Avoid heavy nitrogen top-dressing just before a predicted heat wave at flowering; excessive vegetative
growth under heat can worsen stress and lodging.

Feature: seasonal_rain_mm
Meaning: Total rainfall received during the crop season.
Advisory for sesame:
Role in yield for sesame: Determines overall water availability for the crop; both deficiency and excess
reduce yield.
Improvement strategies:
- In low rainfall areas, choose drought-tolerant, short-duration varieties of sesame, reduce plant
density slightly and adopt wider row spacing to reduce competition for limited soil moisture.
- Improve in situ rainwater harvesting using contour bunds, tied ridges, broad bed-and-furrow systems,
and residue mulches to increase effective seasonal_rain_mm stored in the soil profile.
- In high rainfall areas, provide surface drainage and raised beds to remove excess water quickly and
avoid prolonged waterlogging.

Feature: rain_flowering_mm
Meaning: Rainfall received in the flowering window.
Advisory for sesame:
Role in yield for sesame: Moisture around flowering reduces stress and supports good pod/seed set;
extremes can increase disease.
Improvement strategies:
- If rain_flowering_mm is low or erratic, plan for at least one protective irrigation of sesame at
bud/flowering stage using farm ponds, community tanks or micro-irrigation where feasible.
- In humid regions with frequent rains at flowering, adopt preventive fungicide sprays (where permitted)
or resistant varieties to manage diseases favoured by wet canopies.
- Use weather-based agro-advisories to anticipate dry or wet spells around flowering and adjust
irrigation or plant protection scheduling accordingly.

Feature: humidity_mean_pct
Meaning: Average relative humidity during the crop season.
Advisory for sesame:
Role in yield for sesame: Influences transpiration, disease development and pest dynamics.
Improvement strategies:
- In very high humidity environments, increase row spacing or use paired-row planting in sesame to

improve air circulation and reduce leaf wetness duration.
- Select disease-tolerant varieties and adopt timely fungicide or biocontrol sprays when high humidity
coincides with susceptible crop stages.
- In very low humidity and dry winds, maintain soil moisture via mulching and timely irrigation to reduce
plant water stress.

Feature: solar_MJ_m2_day
Meaning: Daily solar radiation; proxy for sunlight available for photosynthesis.
Advisory for sesame:
Role in yield for sesame: Solar radiation drives photosynthesis; good light interception is essential for
high yield.
Improvement strategies:
- Optimize plant density and row orientation (generally north–south) so the sesame canopy intercepts
light efficiently without excessive mutual shading.
- Avoid very late sowing that pushes critical growth stages of sesame into low-radiation periods (e.g.,
cloudy monsoon tail or winter fog).
- Maintain good nutrition and pest/disease management to ensure a healthy leaf area index capable of
converting available solar radiation into biomass.

Feature: soil_pH
Meaning: Acidity/alkalinity of the root zone soil.
Advisory for sesame:
Role in yield for sesame: Soil pH controls nutrient availability, microbial activity and root growth.
Improvement strategies:
- For low pH (strongly acidic) soils, apply agricultural lime or dolomite based on soil test recommendations to gradually raise pH into the 6.0–7.0 range preferred by most oilseeds including sesame.
- For high pH or sodic soils, improve organic matter content, use gypsum where sodicity is an issue, and
choose tolerant varieties or rootstocks where available for sesame.
- Avoid over-application of acid-forming fertilizers (e.g., excessive ammonium-based N) in already acidic
soils and minimize use of alkaline irrigation water in calcareous soils.

Feature: soil_oc_pct
Meaning: Soil organic carbon percentage; indicator of soil health and biological activity.
Advisory for sesame:
Role in yield for sesame: Soil organic carbon supports structure, water holding, cation exchange and
microbial processes.
Improvement strategies:
- Add 5–10 t/ha of well-decomposed farmyard manure (FYM), compost or enriched compost in rotation with
sesame to build soil_oc_pct over time.
- Practice residue retention, green manuring (e.g., sunnhemp, dhaincha) or inclusion of legumes in
rotation to increase organic inputs to the soil.
- Reduce intensive tillage and avoid burning of crop residues to minimize loss of organic matter and
protect soil aggregates.

Feature: clay_pct
Meaning: Percentage of clay fraction in soil; related to texture and water holding capacity.
Advisory for sesame:
Role in yield for sesame: Clay percentage is largely inherent, affecting water retention and drainage.
Improvement strategies:
- On very sandy, low-clay soils, improve water and nutrient holding for sesame by adding FYM/compost,
practicing cover cropping and using mulches; consider more frequent, smaller irrigations.
- On heavy clay soils prone to waterlogging, adopt raised beds, broad bed-and-furrow or ridge-furrow
planting for sesame to improve aeration and root health.
- Maintain good soil structure through controlled traffic and residue management to prevent excessive

compaction in both very light and very heavy soils.

Feature: soil_depth_cm
Meaning: Effective soil depth available for root growth.
Advisory for sesame:
Role in yield for sesame: Deeper soils provide a larger volume for roots to explore moisture and
nutrients.
Improvement strategies:
- Where soil_depth_cm is limited by hardpans, periodically use deep tillage or chiselling, combined with
biological drilling crops (deep-rooted legumes or grasses) in rotation with sesame.
- Avoid repeated shallow tillage at the same depth which can create plough pans; vary tillage depth or
use conservation tillage where appropriate.
- On shallow soils, choose early-maturing, drought-tolerant varieties of sesame and avoid over-fertilisation that stimulates excessive vegetative growth unsupported by the root zone.

Feature: soil_N_status_kg_ha
Meaning: Plant-available nitrogen (N) status of the soil at sowing.
Advisory for sesame:
Role in yield for sesame: Pre-season nitrogen status influences early vigour and yield potential.
Improvement strategies:
- Conduct regular soil testing and, if soil_N_status_kg_ha is low, apply recommended N fertilizers (e.g.,
urea 46% N, diammonium phosphate (DAP), or complex NPK fertilizers) in balanced doses.
- Integrate N-fixing legumes in rotation and use biofertilizers (Rhizobium, Azotobacter, Azospirillum as
suitable for sesame) to enhance biological N supply.
- Split N applications for sesame into basal and topdressings at critical stages (e.g., branching,
flowering) to improve use efficiency and reduce losses.

Feature: soil_P_status_kg_ha
Meaning: Plant-available phosphorus (P) status of the soil at sowing.
Advisory for sesame:
Role in yield for sesame: Adequate phosphorus supports root growth, nodulation (in legumes) and seed
development.
Improvement strategies:
- If soil_P_status_kg_ha is low, apply P fertilizers such as single superphosphate (SSP), DAP or rock
phosphate (in acidic soils) as per soil test recommendations for sesame.
- Place P fertilizers in bands or below the seed at sowing rather than broadcasting to increase availability and efficiency.
- Use phosphate-solubilizing bacteria (PSB) inoculants and maintain good soil organic matter to mobilise
native P reserves.

Feature: soil_K_status_kg_ha
Meaning: Plant-available potassium (K) status of the soil at sowing.
Advisory for sesame:
Role in yield for sesame: Potassium improves drought tolerance, disease resistance and oil content.
Improvement strategies:
- In low K soils, apply muriate of potash (MOP) or other K sources at sowing in line with soil test based
recommendations for sesame.
- Avoid mining K by continuously removing straw and residues; where possible, return crop residues to the
field or use K-rich organic manures.
- On light, sandy soils, avoid very heavy single K doses that may leach; split applications may be more
effective.

Feature: fert_N_kg_ha
Meaning: Nitrogen fertilizer applied during the season.
Advisory for sesame:
Role in yield for sesame: Applied nitrogen drives vegetative growth and yield but must be balanced.
Improvement strategies:

- Adjust fert_N_kg_ha based on soil test and crop requirement: too low causes pale, stunted plants; too
high causes lodging and increased pest/disease incidence in sesame.
- Apply about half the N dose as basal at sowing and the rest as topdressing at branching or early
flowering, avoiding applications just before heavy rains to reduce leaching and volatilisation.
- Combine chemical N with organic sources (FYM, compost, green manure) and nitrification inhibitors or
controlled-release products where available to improve efficiency.

Feature: fert_P_kg_ha
Meaning: Phosphorus fertilizer applied during the season.
Advisory for sesame:
Role in yield for sesame: Ensures strong roots and reproductive development.
Improvement strategies:
- Maintain fert_P_kg_ha within recommended ranges using SSP, DAP or complex fertilizers; correct chronic
deficiencies gradually by repeated balanced applications for sesame.
- Target band placement of P 5–7 cm below and to the side of the seed to maximise uptake and minimise
fixation.
- In highly calcareous or strongly acidic soils, use appropriate P sources (e.g., rock phosphate in
acidic soils) and maintain organic matter to improve P availability.

Feature: fert_K_kg_ha
Meaning: Potassium fertilizer applied during the season.
Advisory for sesame:
Role in yield for sesame: Supports water-use efficiency and oil synthesis.
Improvement strategies:
- Ensure fert_K_kg_ha matches crop removal; use muriate of potash (MOP) or SOP (sulphate of potash) where
chloride-sensitive situations demand it, in consultation with local recommendations for sesame.
- Apply K as basal or early topdressing so that plants have adequate K before peak demand at flowering
and seed filling.
- Use soil and leaf analysis in high-value sesame systems to fine-tune K nutrition and prevent hidden
deficiencies.

Feature: sowing_doy
Meaning: Day-of-year of sowing; represents sowing window and alignment with season.
Advisory for sesame:
Role in yield for sesame: Sowing date governs how the crop experiences rainfall, temperature and
pest/disease cycles.
Improvement strategies:
- Align sowing_doy with the locally recommended window for sesame (e.g., with onset of monsoon for kharif
crops or in October–November for rabi crops) to ensure favourable conditions at emergence and flowering.
- Avoid very early sowing into dry soil, which can cause patchy emergence, and very late sowing, which
exposes sesame to terminal heat, frost or heavy pest/disease pressure.
- Use short-duration varieties when forced to sow late due to delayed rains, and consider staggered
sowing dates to spread risk.

Feature: plant_density_plants_m2
Meaning: Number of plants per square metre after establishment.
Advisory for sesame:
Role in yield for sesame: Controls competition between plants and determines canopy structure.
Improvement strategies:
- If plant_density_plants_m2 is low (gaps), use gap filling soon after emergence or slightly higher seed
rate next season to achieve recommended stands for sesame.
- If density is too high, thinning at early stages can reduce competition and improve branching and
capsule/pod formation.
- Calibrate seed drills properly and adjust row and plant spacing according to variety vigour and
moisture availability.

Feature: irrigation_events
Meaning: Number of irrigations applied during the season.
Advisory for sesame:
Role in yield for sesame: Number and timing of irrigations determine water availability at critical
stages.
Improvement strategies:
- Prioritise irrigations at critical stages for sesame such as branching, flowering and pod/seed filling
rather than frequent light irrigations at non-critical stages.
- Convert surface irrigation to furrow, border, sprinkler or drip systems where possible to improve
water-use efficiency and reduce waterlogging.
- Use soil moisture monitoring (feel method, tensiometers) and weather forecasts to schedule irrigation
events and avoid both water stress and over-irrigation.

Feature: herbicide_apps
Meaning: Number of herbicide applications for weed management.
Advisory for sesame:
Role in yield for sesame: Herbicide use is one tool for weed management; overuse or misuse can harm the
crop and environment.
Improvement strategies:
- Integrate pre-emergence herbicides such as pendimethalin or pre-plant incorporation products (as
permitted) with mechanical weeding and mulching rather than relying solely on herbicide_apps for sesame.
- Rotate herbicide modes of action and avoid repeated use of the same molecule to delay development of
herbicide-resistant weed biotypes.
- Calibrate sprayers correctly and follow label doses and safety guidelines; avoid spraying under high
winds or on stressed sesame plants.

Feature: insecticide_apps
Meaning: Number of insecticide applications for insect pest control.
Advisory for sesame:
Role in yield for sesame: Insecticide applications protect against key pests but should follow IPM
principles.
Improvement strategies:
- Monitor pest populations using field scouting and pheromone traps; apply insecticides only when pest
incidence in sesame crosses economic threshold levels.
- Use selective, bee-safe products where possible (e.g., neem-based formulations or selective insect
growth regulators) and reserve broad-spectrum insecticides for severe outbreaks.
- Rotate active ingredients and integrate biological control agents to slow resistance development and
protect beneficial insects.

Feature: fungicide_apps
Meaning: Number of fungicide applications for disease management.
Advisory for sesame:
Role in yield for sesame: Fungicide applications help control foliar and soil-borne diseases.
Improvement strategies:
- Begin with healthy, treated seed using fungicides or biocontrol agents effective against seed- and
soil-borne pathogens common in sesame.
- Use preventive fungicide sprays only when weather and crop stage are favourable for disease and
official recommendations support their use.
- Combine fungicide_apps with cultural practices such as crop rotation, residue management, wider spacing
and avoiding overhead irrigation late in the day.

Feature: weed_pressure_index
Meaning: Index (0–1) representing average intensity of weed competition.
Advisory for sesame:
Role in yield for sesame: High weed pressure reduces water, nutrient and light availability.
Improvement strategies:

- Aim to keep the first 30–40 days after sowing of sesame as weed-free as possible using pre-emergence
herbicides, timely intercultivation, hand weeding or mulching.
- Use stale seedbed technique: irrigate or lightly cultivate to germinate weeds before sowing, then
destroy them just before planting sesame.
- Introduce cover crops or competitive intercrops in wider rows to suppress weeds biologically and reduce
reliance on herbicides.

Feature: pest_pressure_index
Meaning: Index (0–1) representing average insect pest pressure.
Advisory for sesame:
Role in yield for sesame: Persistent or severe insect pest pressure reduces leaf area, flowers, pods or
seeds.
Improvement strategies:
- Implement integrated pest management (IPM) in sesame: crop rotation, resistant varieties, timely sowing
and field sanitation to reduce pest carryover.
- Use biological controls wherever feasible and conserve natural enemies by avoiding unnecessary broad-
spectrum sprays.
- When chemical control is needed, choose recommended insecticides, rotate modes of action and strictly
follow label instructions and pre-harvest intervals.

Feature: disease_pressure_index
Meaning: Index (0–1) representing average disease severity.
Advisory for sesame:
Role in yield for sesame: High disease pressure reduces photosynthesis, weakens plants and often affects
seed quality.
Improvement strategies:
- Adopt crop rotation that avoids repeating sesame or closely related crops on the same field year after
year to break disease cycles.
- Use certified, disease-free seed and varieties with resistance or tolerance to major local diseases.
- Manage canopy humidity by appropriate spacing and irrigation, and apply recommended fungicides or
biocontrols at early symptom appearance when risk is high.

Feature: ndvi_early
Meaning: NDVI in early growth stage; indicates crop establishment and early vigour.
Advisory for sesame:
Role in yield for sesame: Early NDVI reflects emergence and establishment.
Improvement strategies:
- If ndvi_early is lower than expected, check for poor germination due to seed quality, sowing depth or
crusting; adjust sowing equipment and seed treatment for subsequent plantings of sesame.
- Improve early nutrition through seed priming, starter N and P fertilisation and micronutrient seed
treatments where deficiencies are known.
- Ensure timely weed control so that young sesame plants do not face competition for light and nutrients
during early stages.

Feature: ndvi_flowering
Meaning: NDVI around flowering; indicates canopy health at key reproductive stage.
Advisory for sesame:
Role in yield for sesame: NDVI near flowering is a strong predictor of final yield because it reflects
canopy size and health at a critical stage.
Improvement strategies:
- If ndvi_flowering is low, review N and S topdressings, irrigation and pest/disease management prior to
flowering in sesame; correct deficiencies in future seasons by scheduling these inputs earlier.
- Avoid severe defoliation due to pests by timely monitoring and IPM interventions before flowering.
- Keep the crop free of stress at this stage through life-saving irrigation and balanced nutrition to

maintain a green, active canopy.

Feature: ndvi_peak
Meaning: Maximum NDVI reached; indicates peak biomass and canopy cover.
Advisory for sesame:
Role in yield for sesame: Peak NDVI reflects maximum biomass; higher values within an optimum range are
associated with higher yield potential.
Improvement strategies:
- Target agronomy (nutrients, irrigation, weed and pest control) to build a strong canopy of sesame by
the time of peak NDVI without causing lodging or excessive vegetative growth.
- Compare peak NDVI of current season with previous high-yield seasons and benchmark fields to diagnose
management gaps.
- Use spatial NDVI maps to identify low-performing patches within fields and address soil constraints,
drainage issues or localised pest problems.

Feature: ndvi_late
Meaning: NDVI near maturity; indicates stay-green and senescence behaviour.
Advisory for sesame:
Role in yield for sesame: Late NDVI indicates how long the canopy stays green during seed filling.
Improvement strategies:
- Aim for a gradual decline in ndvi_late rather than abrupt senescence by avoiding premature defoliation
from diseases, pests or severe nutrient deficiency in sesame.
- Ensure adequate K and S nutrition and timely irrigation (where possible) during pod/seed filling to
maintain photosynthetic activity.
- Avoid very late nitrogen applications that may delay maturity excessively and increase lodging or
disease risk.

Feature: ndvi_veg_slope
Meaning: Slope of NDVI increase from emergence to peak; proxy for growth rate.
Advisory for sesame:
Role in yield for sesame: Vegetation slope describes how quickly the canopy develops from emergence to
peak.
Improvement strategies:
- For very shallow ndvi_veg_slope (slow growth), improve seedbed preparation, seed quality, seed
treatment and early fertilisation for sesame to ensure rapid stand establishment.
- Where growth is too rapid and lush, moderate N rates and avoid overly dense planting that can predispose sesame to lodging and disease.
- Use growth regulators where recommended and permitted in high-input systems to balance vegetative and
reproductive growth.

Feature: seed_moisture_pct
Meaning: Moisture content of harvested seed at harvest time.
Advisory for sesame:
Role in yield for sesame: Seed moisture at harvest affects both yield (through shrinkage or losses) and
storability.
Improvement strategies:
- Harvest sesame when seed_moisture_pct is in the recommended safe range (often 8–12% for long-term
storage; slightly higher at field harvest followed by drying).
- If moisture is too high at harvest, immediately dry seeds using sun-drying on clean floors or mechanical dryers to avoid mould growth and quality loss.
- Avoid delayed harvest after full physiological maturity, which can lead to shattering, bird damage and
weather-related losses.