Oilseed Yield Advisory Knowledge Base (ICAR-aligned, Detailed Version)

This document is designed for integration into a RAG + LLM advisory system for eight major oilseed crops. For each crop, we (1) derive low, medium and high yield classes from your dataset, (2) compute feature ranges within each class, and (3) provide detailed management techniques compiled and generalized from ICAR/IIOR/DRMR and related agronomic recommendations. These techniques are structured so the LLM can map a farmer's current feature values to practical interventions that move fields towards the high-yield band.

CASTOR

Yield classes for castor
Low yield: 0.3 – 0.57 t/ha
Medium yield: > 0.57 – 0.89 t/ha
High yield: > 0.89 – 1.96 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	113.6 – 144.0	114.0 – 146.0	114.0 – 145.0
mean_temp_gs_C	13.91 – 30.38	14.24 – 29.86	14.39 – 29.87
temp_flowering_C	12.53 – 33.36	12.88 – 31.8	13.03 – 30.51
seasonal_rain_mm	316.0 – 892.28	308.61 – 872.53	315.9 – 839.3
rain_flowering_mm	20.46 – 227.62	20.2 – 222.16	42.8 – 217.0
humidity_mean_pct	42.3 – 85.3	40.31 – 85.3	40.4 – 84.4
soil_pH	4.8 – 8.18	4.85 – 8.06	4.96 – 8.02
clay_pct	10.1 – 52.58	9.4 – 52.23	9.8 – 53.1
soil_N_status_kg_ha	93.72 – 208.98	94.77 – 205.02	92.3 – 203.4
soil_P_status_kg_ha	9.6 – 36.94	8.37 – 36.43	8.1 – 36.3
soil_K_status_kg_ha	110.66 – 376.22	107.97 – 363.0	114.1 – 368.5
fert_N_kg_ha	69.92 – 243.2	61.74 – 238.73	58.4 – 229.3
fert_P_kg_ha	16.38 – 74.58	18.48 – 71.96	18.5 – 71.3
fert_K_kg_ha	13.46 – 107.24	12.21 – 106.83	13.6 – 107.1
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.38 – 0.78	0.39 – 0.88	0.47 – 0.9
ndvi_peak	0.49 – 0.84	0.57 – 0.89	0.66 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.3 – 0.54	0.61 – 0.86	0.93 – 1.4
soil_moisture_pct	18.0 – 20.65	21.4 – 24.11	24.84 – 29.98

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil management
1. Choose well-drained, deep loam soils; castor is sensitive to prolonged waterlogging despite its drought tolerance.
2. Maintain soil_pH between 6.0 and 8.0; incorporate FYM or compost (10–15 t/ha) to support long-duration growth and soil_moisture_pct.
3. Use soil tests to guide N, P, K and S application; castor responds well to balanced nutrition.

2. Sowing time and cropping system
4. For irrigated rabi castor, sow from early to late September so that main spike development occurs in cool season as recommended by ICAR-IIOR.
5. For rainfed castor, adjust sowing to take advantage of early monsoon but avoid heavy rainfall periods that cause waterlogging.
6. In intercropping systems (e.g., with pigeonpea), adjust plant geometry and fertilizer share accordingly.

3. Varieties, hybrids and seed rate
7. Use recommended hybrids/varieties suited to zone and season; irrigated hybrids generally give higher yield_t_ha under good management.
8. Use 8–12 kg seed/ha depending on seed size and plant spacing.
9. Treat seeds with fungicides and insecticides to protect against early diseases and soil insects.

4. Plant geometry and population
10. Maintain spacing of 90–120 × 60 cm, providing adequate space for branching and spike development.
11. Avoid too sparse planting, which reduces total spikes per unit area, and too dense planting, which encourages diseases and lodging.
12. Ensure uniform emergence through proper seed placement and moisture at sowing; re-sow gaps early where needed.

5. Nutrient management
13. Apply about 60–80 kg N, 40–60 kg P2O5 and 40–60 kg K2O/ha in irrigated hybrids; adjust doses for rainfed and varietal crops.
14. Apply all P and K and 25–50% N as basal; topdress remaining N in 2–3 splits—early vegetative, before primary spike flowering and during secondary spike initiation.
15. Include S (20–40 kg/ha) and micronutrients as per soil test to support oil synthesis and spike formation.
16. Maintain adequate soil_moisture_pct at times of topdressing to ensure nutrient uptake.

6. Water management
17. Castor is drought-tolerant but responds well to irrigation; schedule irrigations at establishment, spike initiation and seed filling in irrigated systems.
18. Avoid waterlogging during early growth stages by providing drainage, especially in heavy soils.
19. In limited water situations, prioritize irrigations at primary and secondary spike development stages.

7. Weed and pest management
20. Keep field weed-free during first 45 DAS using intercultivation and hand weeding; weeds strongly compete for early-season resources.
21. Monitor for major pests and diseases as indicated in ICAR castor production guides; use need-based plant protection measures.
22. Follow crop rotation and sanitation (removal of volunteer plants and alternate hosts) to reduce disease inoculum.

8. Seed production specific practices
23. In hybrid seed production, remove staminate or off-type plants early to maintain genetic purity and yield.
24. Maintain isolation distance as per seed standards to avoid cross-pollination with other castor fields.

9. Harvest and post-harvest
25. Harvest when capsules on the lower part of spike turn light green to brown and seeds are fully developed.
26. Avoid over-drying spikes on plants which increases shattering; harvest in multiple pickings if needed.
27. Dry capsules and extract seeds carefully; store at safe moisture in clean, dry bags to preserve oil quality.

GROUNDNUT

Yield classes for groundnut
Low yield: 0.31 – 0.65 t/ha
Medium yield: > 0.65 – 1.03 t/ha
High yield: > 1.03 – 2.3 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	113.0 – 145.0	113.0 – 145.0	113.0 – 146.0
mean_temp_gs_C	13.58 – 30.23	14.13 – 29.98	14.38 – 29.57
temp_flowering_C	12.26 – 33.64	12.36 – 32.39	12.94 – 30.73
seasonal_rain_mm	333.55 – 907.2	322.2 – 881.1	322.58 – 841.8
rain_flowering_mm	21.4 – 228.54	25.9 – 225.0	28.06 – 218.51
humidity_mean_pct	40.8 – 84.2	40.9 – 84.9	41.2 – 85.1
soil_pH	4.83 – 8.17	4.95 – 8.1	4.98 – 8.02
clay_pct	9.3 – 51.0	9.0 – 51.0	9.4 – 50.91
soil_N_status_kg_ha	95.69 – 207.91	92.59 – 206.71	93.5 – 202.11
soil_P_status_kg_ha	8.19 – 37.0	8.6 – 36.5	8.2 – 36.5
soil_K_status_kg_ha	112.1 – 372.61	112.99 – 367.6	113.7 – 361.31
fert_N_kg_ha	68.2 – 244.2	62.59 – 235.53	61.4 – 230.1
fert_P_kg_ha	17.1 – 73.5	17.2 – 73.11	17.3 – 72.1
fert_K_kg_ha	11.89 – 108.7	11.2 – 108.4	11.3 – 108.0
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.37 – 0.79	0.41 – 0.89	0.46 – 0.9
ndvi_peak	0.49 – 0.85	0.58 – 0.9	0.66 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.31 – 0.62	0.7 – 0.99	1.06 – 1.57
soil_moisture_pct	18.15 – 21.45	22.35 – 25.52	26.34 – 31.88

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil preparation
1. Prefer well-drained sandy loam or light loam soils with good structure; avoid heavy clays that crack and hinder pegging and pod development.
2. Maintain soil_pH between 6.0 and 7.5; apply lime or gypsum in acidic soils as per recommendations.
3. Incorporate 5–10 t/ha FYM or compost to improve soil_moisture_pct and soil tilth, essential for peg penetration.
4. Prepare a fine, friable seedbed with minimal clods to support uniform germination and pegging.

2. Sowing time, varieties and seed rate
5. Sow groundnut at onset of monsoon (kharif) or in recommended rabi/summer windows with assured irrigation.
6. Use high-yielding, disease-tolerant varieties recommended for your zone; choose appropriate maturity_days to fit rainfall pattern.
7. Use recommended seed rate (80–120 kg/ha depending on seed size and season) to achieve optimum plant population.
8. Treat seed with fungicides and bio-agents to manage seed and soil-borne pathogens and promote early vigor.

3. Plant geometry and population

9. Maintain 30–45 cm row spacing and 10–15 cm intra-row spacing depending on type (bunch/spreading) to optimize canopy cover and NDVI.
10. Avoid excessively dense plant stands that lead to competition and smaller pods; thin if necessary.
11. Ensure sowing depth of 5–7 cm in moist soil; shallow sowing can cause poor establishment in hot weather.

4. Nutrient management

12. Apply about 20 kg N, 40–60 kg P2O5 and 40–60 kg K2O/ha based on soil_N/P/K_status_kg_ha; adjust doses to move low-fertility soils into higher bands.
13. Incorporate 20–40 kg S/ha (e.g. gypsum) and 200–400 kg/ha gypsum at peak flowering/pegging to supply Ca at pegging zone and improve pod filling.
14. Apply micronutrients like Zn and B where deficiencies are diagnosed; groundnut is sensitive to Ca and B deficiency.
15. Encourage biological N fixation by avoiding heavy basal N dose; use rhizobium inoculation where needed.

5. Water management

16. Groundnut is sensitive to both drought and waterlogging; maintain moderate soil_moisture_pct throughout crop season.
17. Critical stages are pegging and pod development; water stress at these stages sharply reduces yield_t_ha.
18. In irrigated systems, schedule irrigations at branching, pegging and pod filling; stop irrigation 10–15 days before harvest to ease pod drying.
19. Ensure drainage in heavy rainfall episodes to prevent stem and root diseases.

6. Weed management

20. Maintain weed-free conditions during first 30–40 DAS; weeds severely reduce yield and interfere with pegging.
21. Use pre-emergence herbicides followed by intercultivation and one hand weeding at 20–25 DAS.
22. Avoid deep intercultivation after pegging to prevent peg damage.

7. Pest and disease management

23. Seed treatment and proper crop rotation help manage collar rot, stem rot and other soil-borne diseases.
24. Monitor for leaf spots and rust; apply recommended fungicides at onset and repeat as needed based on disease pressure.
25. Manage insect pests such as leaf miner, jassids and aphids through IPM—seed treatment, resistant varieties, need-based sprays and conservation of natural enemies.

8. Canopy, pegging and NDVI

26. Healthy groundnut crop shows steady NDVI_veg_slope followed by moderate NDVI_peak around peak vegetative phase; strong declines thereafter may signal foliar disease or defoliation.
27. Maintain loose, friable soil around pegging zone; avoid crust formation by light hoeing or irrigation as necessary.
28. Ensure adequate Ca in pegging zone through gypsum application to reduce unfilled pods (pops).

9. Harvest and post-harvest

29. Harvest when inner shell turns brown and kernels are fully developed; premature harvest reduces kernel weight, while delayed harvest increases sprouting and losses.
30. Lift plants carefully to minimize pod loss; dry pods on clean tarpaulins to safe moisture before storage.
31. Protect stored groundnut from bruchids and other storage pests using recommended methods.

MUSTARD

Yield classes for mustard
Low yield: 0.43 – 0.43 t/ha
Medium yield: > 0.43 – 0.68 t/ha
High yield: > 0.68 – 2.5 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	103.0 – 136.0	103.0 – 136.0	103.0 – 135.0
mean_temp_gs_C	13.73 – 30.28	14.35 – 29.86	14.63 – 29.4
temp_flowering_C	12.29 – 33.17	12.43 – 31.88	13.07 – 30.08
seasonal_rain_mm	320.3 – 896.5	322.84 – 877.66	323.76 – 850.97
rain_flowering_mm	22.5 – 230.1	24.88 – 226.3	30.83 – 218.2
humidity_mean_pct	40.5 – 84.6	40.88 – 85.0	40.6 – 84.57
soil_pH	4.85 – 8.15	5.02 – 8.13	5.01 – 8.0
clay_pct	9.5 – 51.2	9.7 – 50.4	9.6 – 50.77
soil_N_status_kg_ha	94.5 – 207.2	93.56 – 204.54	92.6 – 203.97
soil_P_status_kg_ha	8.7 – 36.6	8.7 – 35.9	8.5 – 36.3
soil_K_status_kg_ha	111.4 – 370.43	109.28 – 368.52	111.3 – 364.37
fert_N_kg_ha	65.1 – 241.9	59.36 – 237.54	57.3 – 229.97
fert_P_kg_ha	16.6 – 73.5	16.28 – 73.8	16.8 – 71.47
fert_K_kg_ha	12.2 – 107.6	12.38 – 107.32	12.4 – 107.1
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.38 – 0.83	0.43 – 0.9	0.49 – 0.9
ndvi_peak	0.51 – 0.87	0.61 – 0.9	0.67 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.43 – 0.43	0.46 – 0.65	0.79 – 2.32
soil_moisture_pct	19.42 – 19.42	19.72 – 21.81	23.33 – 40.04

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil preparation
1. Choose well-drained loam or clay loam soils with good water-holding capacity; avoid low-lying fields prone to waterlogging which predispose mustard to root diseases.
2. Aim for soil_pH between 6.0 and 8.0; where pH is < 5.5, apply lime as per soil test; where pH > 8.2, incorporate FYM, green manures and gypsum to improve structure and nutrient availability.
3. Perform 1–2 primary tillage operations followed by harrowing to create a fine seedbed that ensures good seed–soil contact and uniform emergence.
4. Incorporate 5–10 t/ha FYM or compost during land preparation to enhance soil organic carbon, soil_moisture_pct and nutrient buffering.
5. Use soil tests to categorize soil_N/P/K_status_kg_ha and plan fert_N/P/K_kg_ha accordingly, aiming to move soils from low to medium fertility over time.

2. Sowing time, varieties and maturity
6. Sow within the locally recommended rabi window (often late October to mid-November in north-west India) so that flowering

avoids severe cold and terminal heat.

7. Use high-yielding, disease-tolerant varieties/hybrids recommended by ICAR/DRMR for your agro-climatic zone; match maturity_days to available growing season.

8. Avoid late sowing beyond recommended window; late crops experience shorter reproductive phase, higher aphid pressure and often fall in low-yield_t_ha band.

9. For late-sown crops where delay is unavoidable, select early-maturing varieties and adjust nutrient and irrigation management to suit shortened season.

3. Seed rate, spacing and plant stand

10. Use 4–5 kg seed/ha with line sowing at 30 cm row spacing and 10–15 cm plant spacing; this gives about 4–5 lakh plants/ha depending on seed size.

11. Ensure sowing depth of 3–4 cm; deeper sowing delays emergence and increases risk of seedling diseases, depressing NDVI_veg_slope.

12. Thin seedlings at 15–25 DAS to maintain uniform spacing, especially in thick patches; this prevents intra-specific competition and promotes uniform canopy.

13. Maintain line sowing (vs broadcasting) to facilitate intercultivation, better aeration and efficient fertilizer placement.

4. Nutrient management

14. For timely-sown mustard on medium soils, apply about 80:40:40 kg N:P2O5:K2O/ha; for late-sown crops, increase N to 100 kg/ha as per DRMR recommendations where feasible.

15. Apply full P and K and 50% of N as basal at sowing; topdress remaining N at first irrigation (25–30 DAS) to support rapid vegetative growth and NDVI rise.

16. Add 40 kg S/ha using gypsum or single super phosphate; sulphur is crucial for oil synthesis and yield in mustard.

17. In Zn-deficient soils, apply 25 kg zinc sulphate/ha once in 3 years or use foliar Zn sprays at critical stages.

18. Apply 1–2 foliar sprays of 2% urea or 2% DAP during flowering and early pod filling in low-N situations where soil_moisture_pct is adequate.

19. Avoid excessive N in highly fertile soils, which causes lodging, delayed maturity and greater disease incidence without proportional yield gain.

5. Water management and rainfall

20. Mustard can be grown under rainfed or irrigated conditions; in irrigated fields, plan at least two irrigations—at pre-flowering (35–45 DAS) and at siliqua formation (60–70 DAS).

21. In low seasonal_rain_mm zones, prioritize a single carefully timed irrigation at flowering; this often gives the maximum marginal yield response.

22. Avoid irrigations that cause water stagnation; waterlogging even for short durations can severely reduce root activity and yield.

23. Use ridge–furrow or raised bed planting in heavy soils to improve drainage and root aeration.

6. Weed management

24. Keep the crop weed-free during the first 40 DAS; weeds during this period can reduce yield by 30–50%.

25. Use pre-plant incorporation of trifluralin or pre-emergence pendimethalin, followed by one hand weeding or intercultivation at 25–30 DAS.

26. Avoid late-season weeds which compete for water and nutrients during pod filling; use need-based manual weeding if infestation exceeds threshold.

7. Pest and disease management

27. Use seed treatment with fungicide (e.g. carbendazim or metalaxyl-based combinations) to control seed and soil-borne diseases such as damping-off, Alternaria and white rust.

28. Monitor aphids regularly from rosette stage onwards; if population reaches threshold (50–60 aphids/10 cm central shoot), apply recommended insecticides.

29. Manage painted bug, sawfly and Bihar hairy caterpillar through timely sprays and mechanical control where feasible.

30. To manage Sclerotinia stem rot, avoid very late sowing, maintain proper spacing for aeration, and follow crop rotation with

non-host crops such as cereals.

31. Remove and destroy diseased plants, especially those with white rust and downy mildew complex, to reduce inoculum.

8. Canopy management, NDVI and lodging

32. Aim for moderate, upright canopy with good light penetration; very dense canopy due to excess N or close spacing increases disease risk and lodging.

33. Use NDVI_veg_slope to check early vigor; below-benchmark slopes may suggest low soil fertility, delayed sowing or pest damage.

34. NDVI_flowering within the high-yield band indicates that plant population and nutrient status are adequate; corrective measures beyond this stage focus mainly on protecting pods and seeds.

35. Stake or support heavily lodged patches only when economically justified; long-term solution is balanced fertilization and correct spacing.

9. Climate risk management

36. For frost-prone areas, avoid very early sowing that leads to flowering during peak cold; adjust sowing date to balance between frost and terminal heat risk.

37. In heat-prone late rabi regions, choose early-maturing varieties and sow early so that pod filling is completed before heat stress intensifies.

38. Use windbreaks or border rows in high-wind areas to reduce lodging and shattering losses.

10. Harvest and post-harvest

39. Harvest when most siliquae turn yellow-brown and seeds are firm; delay causes shattering and loss, especially in windy conditions.

40. If harvesting by combine, adjust settings to minimize seed damage; cracked seeds lead to oil quality deterioration during storage.

41. Dry seeds to safe moisture (<8%) and store in clean, insect-free bags on wooden pallets; periodically inspect for storage pests and moisture ingress.

NIGER SEED

Yield classes for niger seed
Low yield: 0.3 – 0.43 t/ha
Medium yield: > 0.43 – 0.67 t/ha
High yield: > 0.67 – 1.35 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	113.0 – 144.0	113.0 – 145.0	113.0 – 146.0
mean_temp_gs_C	13.71 – 30.55	14.15 – 30.39	14.46 – 29.48
temp_flowering_C	12.33 – 33.23	12.7 – 32.15	12.44 – 30.27
seasonal_rain_mm	318.4 – 892.38	315.82 – 874.4	330.72 – 835.53
rain_flowering_mm	23.84 – 228.86	25.98 – 222.86	35.1 – 218.31
humidity_mean_pct	40.3 – 85.1	40.9 – 84.5	40.59 – 84.3
soil_pH	4.84 – 8.16	4.93 – 8.09	5.02 – 8.02
clay_pct	10.1 – 49.58	9.44 – 50.7	10.19 – 51.22
soil_N_status_kg_ha	94.54 – 207.86	93.6 – 207.56	93.0 – 203.02
soil_P_status_kg_ha	8.54 – 36.9	8.6 – 36.56	8.59 – 36.1
soil_K_status_kg_ha	108.82 – 377.2	117.38 – 366.68	108.29 – 364.99
fert_N_kg_ha	69.9 – 242.92	59.62 – 238.1	57.19 – 227.5
fert_P_kg_ha	16.5 – 74.56	16.08 – 71.96	18.19 – 70.91
fert_K_kg_ha	13.44 – 108.36	11.08 – 108.42	12.09 – 106.41
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.37 – 0.79	0.42 – 0.87	0.46 – 0.9
ndvi_peak	0.49 – 0.85	0.58 – 0.89	0.65 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.3 – 0.41	0.46 – 0.65	0.7 – 1.02
soil_moisture_pct	18.0 – 19.2	19.75 – 21.79	22.34 – 25.8

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil properties
1. Prefer light to medium textured, well-drained soils; niger is hardy but performs best where waterlogging is avoided.
2. Maintain soil_pH near neutral where possible; incorporate organic manures to buffer pH and improve soil_moisture_pct.

2. Sowing time and cropping system
3. Sow with onset of monsoon (kharif) or in semi-rabi season as per regional recommendations.
4. In some regions niger is grown as an intercrop with millets or pulses; adjust plant population and fertilizer management accordingly.
5. Use line sowing at about 30 × 10 cm spacing, targeting ~3.3 lakh plants/ha.

3. Seed rate and thinning
6. Use about 5 kg seed/ha; thin seedlings at 2 weeks to maintain optimum plant population.

7. Treat seed with fungicides to prevent seedling blights and damping off.

4. Nutrient management

8. Apply 20–40 kg N, 20–40 kg P2O5 and 10–20 kg K2O/ha depending on state recommendations and soil fertility.

9. Incorporate 20–30 kg S/ha in deficient soils to improve oil content and yield.

10. Split N into basal and topdressing at 30 DAS to match crop uptake and reduce losses.

5. Water management

11. Niger is usually rainfed; adopt moisture conservation measures to make best use of seasonal_rain_mm.

12. In semi-rabi crops with supplemental irrigation, provide 1–2 irrigations at flowering and seed filling in case of dry spells.

6. Weed, pest and disease management

13. Keep field weed-free during first 30 DAS with two weedings at 15–20 and 30–35 DAS.

14. Manage niger caterpillar and other insect pests using bird perches, botanical extracts (e.g. NSKE) and need-based insecticides.

15. Use clean seed free from Cuscuta; remove parasitic weed infestations promptly where they appear.

7. Harvest and post-harvest

16. Harvest when heads turn brown and seeds are firm; delayed harvest causes shattering and quality loss.

17. Dry and thresh carefully to minimize mechanical damage; store seed at safe moisture to preserve oil quality.

SAFFLOWER

Yield classes for safflower
Low yield: 0.3 – 0.54 t/ha
Medium yield: > 0.54 – 0.83 t/ha
High yield: > 0.83 – 1.73 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	113.0 – 145.0	114.0 – 146.0	113.0 – 145.0
mean_temp_gs_C	13.59 – 30.38	14.13 – 29.95	14.35 – 29.35
temp_flowering_C	11.94 – 33.14	12.41 – 31.86	12.91 – 29.89
seasonal_rain_mm	320.35 – 900.7	317.2 – 872.45	315.61 – 845.79
rain_flowering_mm	22.35 – 227.85	25.55 – 226.75	26.5 – 209.08
humidity_mean_pct	41.0 – 84.4	41.1 – 85.4	40.87 – 83.63
soil_pH	4.91 – 8.15	4.94 – 8.17	4.96 – 8.0
clay_pct	9.1 – 50.7	9.0 – 52.55	9.67 – 50.2
soil_N_status_kg_ha	95.8 – 208.7	92.5 – 206.2	91.97 – 202.63
soil_P_status_kg_ha	8.25 – 36.35	9.2 – 36.2	8.17 – 36.2
soil_K_status_kg_ha	115.45 – 374.7	112.65 – 364.35	116.64 – 360.11
fert_N_kg_ha	68.5 – 243.95	62.45 – 239.65	56.0 – 232.05
fert_P_kg_ha	17.25 – 73.65	17.45 – 71.9	18.37 – 71.59
fert_K_kg_ha	12.0 – 107.85	10.3 – 106.0	12.7 – 106.93
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.37 – 0.8	0.41 – 0.89	0.46 – 0.9
ndvi_peak	0.5 – 0.85	0.58 – 0.9	0.64 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.3 – 0.5	0.57 – 0.8	0.86 – 1.28
soil_moisture_pct	18.0 – 20.21	20.89 – 23.41	24.13 – 28.72

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil management
1. Choose deep, well-drained soils with good water-holding capacity; safflower is suited to dryland rabi areas but cannot tolerate prolonged waterlogging.
2. Maintain soil_pH between 6.0 and 8.0; incorporate FYM to improve soil_moisture_pct and structure.
3. Use soil tests to adjust N, P, K and S fertilization for moving soils into medium fertility band.

2. Sowing time and seed rate
4. Sow safflower in recommended rabi window (often October–November) after cessation of monsoon rains, using residual soil moisture.
5. Use recommended seed rate (10–15 kg/ha) with row spacing of 45–60 cm and 15–20 cm between plants.
6. Treat seeds with fungicide to minimize seedling diseases.

3. Nutrient management

7. Apply 40–60 kg N, 40–60 kg P2O5 and 20–40 kg K2O/ha, depending on soil_test values.
8. Incorporate 20–40 kg S/ha in sulphur-deficient soils to improve oil content.
9. Apply all P, K and S and half N at sowing; topdress remaining N at 25–30 DAS to support branching and early flowering.

4. Water and moisture conservation

10. Safflower is largely rainfed; adopt moisture conservation practices such as broad-bed furrow or compartmental bunding.
11. In low rainfall years, provide one irrigation at branching and another at flowering if water is available.
12. Avoid heavy irrigations that cause lodging and disease.

5. Weed and pest management

13. Control weeds during first 30–40 DAS with intercultivation and, where recommended, pre-emergence herbicides.
14. Monitor for wilt and root rot; use tolerant varieties and rotation with non-host crops.
15. Manage insects like capsule borer and aphids using IPM and need-based insecticides.

6. Canopy and NDVI

16. Aim for uniform plant population and branching; this gives consistent NDVI across the field.
17. Use NDVI to detect moisture and nutrient stress early and respond with supplemental irrigation or topdressing where feasible.

7. Harvest

18. Harvest when most heads turn brown and spines are hard; delay leads to bird damage and shattering.
19. Dry heads thoroughly before threshing to ensure clean seed and good storability.

SESAME

Yield classes for sesame
Low yield: 0.3 – 0.46 t/ha
Medium yield: > 0.46 – 0.72 t/ha
High yield: > 0.72 – 1.56 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	113.0 – 146.0	114.0 – 146.7	114.0 – 146.0
mean_temp_gs_C	13.5 – 30.09	14.01 – 29.95	14.51 – 29.94
temp_flowering_C	11.98 – 33.45	12.32 – 32.36	13.19 – 30.63
seasonal_rain_mm	315.35 – 899.05	322.54 – 873.48	331.11 – 857.14
rain_flowering_mm	19.05 – 232.5	22.65 – 225.37	27.21 – 215.55
humidity_mean_pct	40.6 – 84.45	39.83 – 83.4	40.6 – 84.2
soil_pH	4.81 – 8.11	4.89 – 8.1	5.07 – 8.05
clay_pct	9.1 – 51.9	9.23 – 50.27	9.3 – 50.6
soil_N_status_kg_ha	97.1 – 206.7	93.7 – 203.0	91.6 – 202.61
soil_P_status_kg_ha	8.15 – 36.0	8.43 – 35.8	7.9 – 36.2
soil_K_status_kg_ha	108.75 – 372.95	112.96 – 368.04	115.96 – 359.61
fert_N_kg_ha	65.0 – 241.15	63.1 – 238.78	59.33 – 231.12
fert_P_kg_ha	18.05 – 73.65	17.63 – 74.27	16.59 – 72.6
fert_K_kg_ha	11.3 – 109.15	12.96 – 107.3	11.79 – 108.61
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.38 – 0.78	0.41 – 0.89	0.47 – 0.9
ndvi_peak	0.5 – 0.84	0.57 – 0.89	0.67 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.3 – 0.43	0.48 – 0.7	0.75 – 1.13
soil_moisture_pct	18.0 – 19.46	19.99 – 22.31	22.94 – 27.03

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil conditions
1. Choose light to medium textured, well-drained soils; sesame is highly sensitive to waterlogging.
2. Maintain soil_pH between 5.5 and 8.0; extreme acidity or alkalinity reduces nutrient availability and plant vigor.
3. Incorporate FYM or compost to improve soil_moisture_pct and resilience to short dry spells.

2. Sowing time and crop establishment
4. Sow sesame in recommended season (kharif, semi-rabi or summer) based on region so that flowering does not coincide with heavy continuous rains.
5. Use line sowing at 30–45 cm between rows and 10–15 cm between plants; adjust seed rate (~3–4 kg/ha) to ensure optimum population.
6. Treat seed with fungicide and bio-agents to control seedling diseases and improve early NDVI_veg_slope.

3. Nutrient management

7. Apply 40–60 kg N, 20–40 kg P2O5 and 20 kg K2O/ha based on soil_N/P/K_status_kg_ha.
8. Split N into basal and topdressing at 25–30 DAS to reduce lodging and increase nutrient use efficiency.
9. Apply 20 kg S/ha where sulphur is deficient, which improves oil content and yield.
10. Correct micronutrient deficiencies (Zn, B) through soil or foliar applications depending on soil test and crop response.

4. Water management

11. Sesame is often grown under rainfed conditions; conserve seasonal_rain_mm with contour farming, mulching and timely sowing.
12. In irrigated systems, provide 1–2 irrigations at flowering and capsule filling when seasonal_rain_mm is low.
13. Avoid any standing water; even short-term waterlogging can kill sesame plants and push fields into low-yield band.

5. Weed and pest management

14. Keep crop weed-free during first 30 DAS; weed competition at early stages leads to poor canopy and low NDVI.
15. Use pre-emergence herbicide where recommended, followed by one or two hand weedings.
16. Monitor for leaf spot, phyllody and other diseases; rogue and destroy infected plants promptly to avoid spread.
17. Manage insects like leaf roller, capsule borer and sucking pests using IPM and economic threshold-based sprays.

6. Canopy and NDVI monitoring

18. Sesame canopy is relatively open; maintain uniform plant stand for stable NDVI patterns.
19. Use NDVI to detect patches with poor establishment or nutrient deficiency and investigate causes (seed quality, soil constraints, pest damage).

7. Harvest and post-harvest

20. Harvest when majority of capsules turn yellow and begin to dry; delayed harvest leads to shattering and major yield loss.
21. Cut plants and stack them on tarpaulins to collect shed seeds; thresh gently and dry to safe moisture before storage.

SOYBEAN

Yield classes for soybean
Low yield: 0.42 – 0.42 t/ha
Medium yield: > 0.42 – 1.06 t/ha
High yield: > 1.06 – 2.5 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	97.0 – 121.0	97.0 – 121.0	98.0 – 122.0
mean_temp_gs_C	13.71 – 30.43	14.02 – 29.88	14.54 – 29.3
temp_flowering_C	12.13 – 33.43	12.47 – 32.07	12.96 – 30.23
seasonal_rain_mm	311.03 – 900.57	324.14 – 874.94	327.15 – 845.6
rain_flowering_mm	19.93 – 230.2	25.84 – 222.26	32.3 – 216.5
humidity_mean_pct	40.5 – 84.6	40.0 – 84.1	40.7 – 84.4
soil_pH	4.83 – 8.17	4.87 – 8.06	5.04 – 8.0
clay_pct	9.4 – 51.0	9.4 – 50.4	9.4 – 51.5
soil_N_status_kg_ha	96.3 – 208.0	94.24 – 206.1	91.9 – 204.0
soil_P_status_kg_ha	8.2 – 36.6	8.44 – 36.4	8.3 – 36.5
soil_K_status_kg_ha	110.83 – 372.8	109.74 – 370.1	111.75 – 361.7
fert_N_kg_ha	66.86 – 243.4	59.9 – 236.8	59.7 – 229.0
fert_P_kg_ha	16.5 – 73.9	16.7 – 72.6	17.3 – 72.1
fert_K_kg_ha	12.5 – 107.77	12.1 – 108.0	11.7 – 107.8
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.37 – 0.79	0.42 – 0.88	0.48 – 0.9
ndvi_peak	0.5 – 0.85	0.58 – 0.89	0.68 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.42 – 0.42	0.48 – 1.0	1.15 – 2.25
soil_moisture_pct	19.3 – 19.3	20.02 – 25.61	27.23 – 39.22

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil health
1. Prefer well-drained medium to deep black soils or loams with good structure; avoid fields prone to prolonged waterlogging which increase root and stem rot.
2. Maintain soil_pH between 6.0 and 7.5; in acidic soils apply lime based on soil test to improve nodulation and P availability.
3. Incorporate 5–10 t/ha FYM or compost to build soil organic matter, improve soil_moisture_pct and reduce surface sealing.
4. Use soil test reports to adjust fert_P_kg_ha and fert_K_kg_ha; soybean is moderately responsive to P and K, especially in low-testing soils.

2. Sowing window and varieties
5. Sow soybean at onset of monsoon (generally last week of June to first week of July) to ensure adequate seasonal_rain_mm and favorable temp_gs_C.
6. Use recommended varieties suitable for your region with appropriate maturity_days (early, medium or late) so that pod filling avoids terminal drought and heat.
7. Avoid too early sowing in dry soil which may lead to poor germination, crusting and patchy stands.

8. Avoid sowing beyond mid-July in most central Indian conditions; late sowing exposes crop to terminal moisture stress and higher incidence of pod blight.

3. Seed rate, inoculation and planting geometry

9. Use 65–80 kg seed/ha depending on seed size to achieve 4–4.5 lakh plants/ha; adjust when germination percentage differs.
10. Treat seeds with fungicide (e.g. carbendazim + thiram) to protect against seedling diseases.
11. After fungicide dries, inoculate seeds with specific Bradyrhizobium japonicum culture; keep inoculated seed away from direct sunlight and sow within 6–8 hours.
12. Maintain row spacing of 30–45 cm and plant spacing of 5–7 cm to ensure rapid canopy closure and high NDVI_veg_slope.

4. Nutrient management

13. Soybean can fix much of its N requirement; usually 20–30 kg N/ha as starter dose is sufficient where effective nodulation occurs.
14. Apply 40–60 kg P2O5/ha and 40–60 kg K2O/ha based on soil_P_status_kg_ha and soil_K_status_kg_ha.
15. Incorporate 20–40 kg S/ha (gypsum or elemental S) and required micronutrients (Zn, B, Mo) in deficient fields.
16. Avoid heavy basal N doses (>40 kg/ha) which can suppress nodulation and biological N fixation.
17. Where nodulation is poor (light green plants, low NDVI, few nodules), confirm inoculant quality and use effective culture in subsequent seasons.

5. Water management

18. Most soybean in India is rainfed; conserve seasonal_rain_mm using contour bunds, graded bunding and residue mulch.
19. Critical stages for water are flowering and pod filling; moisture stress during these stages reduces yield_t_ha sharply.
20. In irrigated or supplemental irrigation systems, provide 1–2 irrigations during long dry spells at critical stages.
21. Avoid waterlogging, especially in heavy soils; provide surface drains or raised beds where water stagnation is a risk.

6. Weed management

22. Soybean is highly sensitive to early weed competition; maintain weed-free conditions up to 40 DAS.
23. Use pre-emergence herbicides (e.g. pendimethalin, metribuzin) followed by one manual weeding or intercultivation at 20–25 DAS.
24. Where conservation tillage is practiced, use suitable post-emergence herbicides as per recommendations and weed spectrum.

7. Pest and disease management

25. Use disease-tolerant varieties where available; rotate soybean with cereals or other non-host crops to break disease cycles.
26. Treat seed with fungicides to manage seedling blights and root rots; in fields with history of stem rot or collar rot, avoid continuous soybean cultivation.
27. Monitor for stem fly, girdle beetle, defoliators and pod borers; apply insecticides only when population crosses economic threshold.
28. For foliar diseases such as rust and Cercospora leaf spot, use need-based fungicide sprays at the onset of disease symptoms.

8. Canopy health, NDVI and lodging

29. Healthy soybean canopy shows steady NDVI_veg_slope and NDVI_peak around full vegetative to early reproductive stage; sudden dips suggest stress or disease.
30. In excessively vigorous crops on high N soils, consider using slightly wider spacing to reduce lodging and disease risk.
31. Avoid traffic and animal movement in wet fields to reduce compaction and root damage, which can depress NDVI and yield.

9. Harvest and post-harvest

32. Harvest when 80–85% pods turn brown and seeds rattle; delay can cause shattering losses and weather damage.

33. If harvesting by combine, adjust drum speed and concave clearance to minimize seed breakage.

34. Dry grains to safe moisture (<9–10%) before storage and protect from storage pests; maintain cool, dry conditions to preserve viability and oil quality.

SUNFLOWER

Yield classes for sunflower
Low yield: 0.33 – 0.5 t/ha
Medium yield: > 0.5 – 0.99 t/ha
High yield: > 0.99 – 2.5 t/ha
(Based on terciles of yield_t_ha for this crop in the provided dataset.)

Feature ranges by yield class (10th–90th percentile within class)

Feature	Low yield range	Medium yield range	High yield range
maturity_days	98.0 – 126.0	98.0 – 126.0	98.0 – 126.0
mean_temp_gs_C	13.52 – 30.39	14.1 – 29.97	14.54 – 29.49
temp_flowering_C	12.16 – 33.56	12.39 – 32.13	13.03 – 30.06
seasonal_rain_mm	315.22 – 900.38	316.45 – 880.2	331.26 – 852.82
rain_flowering_mm	18.82 – 231.0	26.7 – 224.55	33.36 – 215.62
humidity_mean_pct	40.5 – 83.8	40.4 – 84.45	40.3 – 84.7
soil_pH	4.79 – 8.18	4.9 – 8.11	5.0 – 7.96
clay_pct	9.5 – 51.5	9.4 – 50.1	9.0 – 50.9
soil_N_status_kg_ha	96.4 – 208.6	94.2 – 205.6	91.8 – 203.1
soil_P_status_kg_ha	8.6 – 37.0	8.5 – 36.55	8.4 – 36.3
soil_K_status_kg_ha	115.62 – 374.68	112.45 – 368.4	114.68 – 359.52
fert_N_kg_ha	67.9 – 244.7	62.4 – 239.15	59.4 – 230.9
fert_P_kg_ha	16.7 – 73.6	16.9 – 73.3	17.2 – 71.2
fert_K_kg_ha	12.22 – 108.2	12.1 – 108.0	12.18 – 107.2
irrigation_events	0.0 – 5.0	0.0 – 5.0	0.0 – 5.0
ndvi_flowering	0.36 – 0.78	0.42 – 0.88	0.48 – 0.9
ndvi_peak	0.49 – 0.84	0.57 – 0.89	0.67 – 0.9
ndvi_veg_slope	0.0 – 0.01	0.0 – 0.01	0.0 – 0.01
yield_t_ha	0.33 – 0.45	0.55 – 0.94	1.05 – 1.75
soil_moisture_pct	18.36 – 19.67	20.77 – 24.99	26.2 – 33.81

Integrated management strategies to move the crop into the high-yield band

1. Land selection and soil health
1. Choose well-drained loam or sandy loam soils with moderate clay_pct; avoid fields with prolonged waterlogging which depresses NDVI and head size.
2. Incorporate 5–10 t/ha well-decomposed FYM or compost 2–3 weeks before sowing to improve soil_moisture_pct, structure and microbial activity.
3. Aim for soil_pH between 6.0 and 7.5; where pH is below 5.5, apply agricultural lime based on soil test; where pH > 8.0, use gypsum and more organic matter to improve nutrient availability.
4. Use soil tests to classify soil_N_status_kg_ha, soil_P_status_kg_ha and soil_K_status_kg_ha into low/medium/high; plan fert_N/P/K_kg_ha to lift low soils into at least medium status over 2–3 seasons.
5. Avoid hardpan formation by occasional deep tillage (chiseling) in compacted soils to enhance root penetration and water infiltration, improving seasonal_rain_mm use efficiency.

2. Sowing window, variety and maturity
6. Select hybrids recommended by ICAR/IIOR for your zone; choose maturity_days that fit your growing season so that

flowering and grain filling avoid extremes of temperature and rainfall.

7. In rainfed areas, sow soon after receiving reliable monsoon rains so that early NDVI_veg_slope is strong and soil_moisture_pct is sufficient for establishment.

8. In irrigated systems, sow in optimal window (often Jan–Feb for spring sunflower or June–July for kharif) as per local recommendations extracted from ICAR bulletins.

9. Avoid very late sowing that pushes flowering into periods with high temp_flowering_C (> 32–34°C) or heavy continuous rains, both of which reduce seed set and yield_t_ha.

10. Stagger sowing dates within a village to reduce synchronized peak for insect pests and allow better spray scheduling.

3. Seed quality, rate and planting geometry

11. Use certified seed with high germination; treat seeds with recommended fungicide + bio-agents (e.g., Trichoderma) against seed and soil-borne diseases.

12. Target plant population of 55,000–65,000 plants/ha using spacing of 60 × 30 cm or as per variety; adjust seed rate to achieve this based on expected field germination.

13. Use line sowing with seed drills to ensure uniform depth (3–5 cm) and spacing, which helps create an even NDVI pattern across the field.

14. Re-sow missing hills within 7–10 days to avoid large gaps that depress NDVI_peak and reduce effective plant population.

15. Avoid very high populations in high-fertility fields to prevent lodging and competition for light and nutrients.

4. Nutrient management (N, P, K, S and micronutrients)

16. For soils in medium fertility band, apply around 60–90 kg N, 60–80 kg P2O5 and 40–60 kg K2O/ha; adjust within this band using your soil_N/P/K_status_kg_ha values.

17. Apply full P and K and 50% of N as basal at sowing; split remaining N into 1–2 topdressings at 25–30 DAS and at bud initiation to maintain high NDVI_flowering.

18. Incorporate 20–40 kg S/ha (e.g. gypsum or elemental sulphur) in deficient soils; sulphur is critical for oil synthesis and high yield_t_ha in sunflower.

19. In Zn-deficient soils, apply 25 kg/ha zinc sulphate once in 2–3 years or use foliar sprays (0.5% ZnSO4 + lime) at vegetative stages.

20. Apply boron (0.2% borax foliar spray) at bud initiation and early flowering in deficient areas to improve seed set and head filling.

21. Monitor canopy color and NDVI; where NDVI_veg_slope is lower than expected, consider additional N topdressing if soil_moisture_pct is adequate.

5. Water management and rainfall use

22. In purely rainfed systems, conserve every mm of seasonal_rain_mm through contour farming, tied ridges, and residue mulch to lift soil_moisture_pct into the medium-to-high band.

23. In irrigated fields, schedule 4–5 irrigations at critical stages: establishment, bud initiation, flowering, and grain filling; avoid water stress at flowering which sharply reduces yield.

24. Maintain moderate soil moisture; avoid waterlogging by providing drainage, especially in heavy clay_pct soils that predispose to root and stem diseases.

25. Use mulching (straw, crop residues) between rows to reduce evaporation and buffer soil_moisture_pct during dry spells.

26. Where irrigation water is limited, prioritize bud initiation and flowering; skip non-critical irrigations to maximize yield per unit of water.

6. Weed management

27. Keep the field weed-free for the first 40–45 days; this period is most critical for competition for N, light and water and influences NDVI_veg_slope.

28. Use pre-emergence herbicide (e.g. pendimethalin) within 1–2 days of sowing followed by one intercultivation and one hand weeding at 30–35 DAS.

29. In minimum tillage systems, use stale seedbed technique by irrigating before sowing, letting weeds emerge and then killing them mechanically or chemically.

30. Monitor late-emerging weeds around flowering and control them if they exceed threshold, as they compete for post-flowering moisture and nutrients.

7. Pest and disease management

31. Follow ICAR-recommended IPM: use resistant or tolerant hybrids, seed treatment, crop rotation and need-based sprays for major diseases like Alternaria leaf spot, downy mildew and rust.

32. Scout weekly, especially around bud initiation and flowering, for capitulum borer, defoliators and sucking pests; use economic threshold-based insecticides rather than calendar sprays.

33. Encourage natural enemies through border crops and reduced broad-spectrum insecticide use; this indirectly maintains canopy health and NDVI_peak.

34. Implement crop rotation with cereals and pulses to reduce inoculum buildup of soil-borne pathogens and break pest cycles.

8. NDVI-based monitoring and correction

35. Track NDVI_veg_slope from emergence to 30–35 DAS; a slow rise may indicate poor emergence, low fertility or early pest damage.

36. Compare NDVI_flowering with known high-yield benchmarks for your region; values significantly below benchmark signal the need to examine N deficiency, disease, or plant stand.

37. Use NDVI_peak time and magnitude to assess whether canopy development was adequate; in low-yield fields NDVI_peak may be delayed or lower than in high-yield examples.

38. Use NDVI and field scouting together to map within-field variability and target variable-rate N or site-specific pest control where possible.

9. Climate risk and contingency planning

39. In areas with high temperature risk, choose slightly earlier-maturing hybrids and sow at the earliest safe date to escape terminal heat at grain filling.

40. When seasonal_rain_mm is forecast to be below normal, reduce plant population slightly and adjust fert_N_kg_ha downward to match water availability, avoiding wasted inputs.

41. For high rainfall zones, select hybrids tolerant to foliar diseases and ensure strong drainage to prevent root rot and Sclerotinia.

10. Harvest and post-harvest management

42. Harvest when the back of the heads turn lemon yellow, bracts are brown and seeds are hard; delaying harvest beyond this stage increases bird damage and shattering losses.

43. Dry heads on tarpaulins, not directly on soil, to maintain seed quality; thresh gently to avoid mechanical damage to seeds.

44. Store seed at <8–9% moisture in clean, dry bags on pallets to prevent fungal growth and oil quality deterioration.

45. Keep lots from different management practices separate and record yield_t_ha, NDVI patterns and input details to refine your advisory database over time.