



Soybean: A Versatile Legume Crop for Mixed Farming

*Souhardya Adhikari¹, Dr. Gurpreet Singh², Shaheen Naz³ and Dr. Anand Kumar Jain⁴

¹M.Sc. Agronomy, Lovely Professional University, Phagwara, Punjab, India

²Assistant Professor, Department of Agronomy, Lovely Professional University, Phagwara, Punjab, India

³Assistant Professor cum Junior Scientist, Department of Agronomy, Veer Kunwar Singh College of Agriculture, Dumraon, Buxar, Bihar-802136, India

⁴Associate Professor cum Senior Scientist (Agronomy), Pulses Research Centre, Mokama Patna-803302, Bihar, India

*Corresponding Author's email: souhardyaadhikari@gmail.com

Soybean (*Glycine max* L. Merrill) is an economically significant leguminous crop that plays a crucial role in global agriculture due to its dual value as a rich source of protein and oil. Although commonly grouped under oilseeds, soybean is also classified as a pulse because of its high protein content and ability to fix atmospheric nitrogen. Its unique composition—approximately 40% protein and 20% oil—makes it an essential component in human diets, animal feed, and industrial products. In mixed farming—where crop production is integrated with livestock rearing—soybean provides multiple advantages. It serves as a nutritious feed, improves soil structure, and diversifies farm income. As climate change and resource constraints challenge conventional farming practices, soybean presents a resilient, eco-friendly, and economically viable alternative for small and marginal farmers. This review explores the multifaceted role of soybean in mixed farming, highlighting its agronomic, ecological, and economic benefits.

Botanical Characteristics

Soybean (*Glycine max* L. Merrill) is an annual herbaceous legume belonging to the family Fabaceae (Leguminosae) and subfamily Papilionoideae. It is a short-day plant, meaning it requires specific photoperiod conditions for flowering and seed development. The plant exhibits considerable morphological variation depending on the cultivar, environmental conditions, and cultivation practices.

1. Growth Habit—Soybean plants can have either a **determinate** or **indeterminate** growth habit:

- **Determinate types:** These stop vegetative growth after flowering begins, suitable for mechanical harvesting.
- **Indeterminate types:** These continue vegetative growth even after flowering, providing a longer harvest window.

2. Root System

- Taproot system with profuse lateral branching.
- Nodules form on roots due to symbiosis with *Rhizobium japonicum*, facilitating biological nitrogen fixation.
- Enhances soil fertility by adding organic nitrogen.

3. Stem

- Erect, bushy, and moderately branched.
- Covered with fine hairs (pubescent).
- Varies in height from 30 cm to over 1 meter depending on variety and environment.

4. Leaves

- **Pinnately trifoliate**, with three oval to lanceolate leaflets.
- Leaflets are green, pubescent, and sensitive to photoperiod changes.
- Leaves senesce before maturity.

5. Inflorescence and Flowers

- Inflorescence is an **axillary raceme**.
- Flowers are **papilionaceous** (typical of legumes), small, and white to purple in color.
- Mostly **self-pollinated**, although cross-pollination can occur occasionally.

6. Fruit and Seeds

- Fruit is a **pubescent pod**, typically 3–8 cm long, containing 2–4 seeds.
- Seeds are round to oval and vary in color (yellow, black, brown, green).
- Seed coat may be smooth or wrinkled depending on the variety.

7. Chromosome Number

- $2n = 40$

8. Climate and Soil Requirements

- Requires warm climate (20°C–30°C) and well-distributed rainfall (500–800 mm).
- Grows best on **well-drained loamy soils** with a pH range of **6.0–7.5**.
- Sensitive to waterlogging but moderately tolerant to drought.

Nutritional Composition of Soybean (per 100g raw seeds)

Component	Approximate Value
Protein	36–40 g
Fat	18–20 g
Carbohydrates	20–30 g
Dietary Fiber	9–11 g
Calcium	200 mg
Iron	15 mg
Isoflavones	100–300 mg

Agro-Ecological Benefits

1. Biological Nitrogen Fixation (BNF)

Soybean forms a symbiotic relationship with **Rhizobium japonicum**, a nitrogen-fixing bacterium that colonizes root nodules. Through this process:

- It can fix **50–150 kg of nitrogen per hectare** per season.
- This reduces dependence on synthetic nitrogen fertilizers.
- Enhances the productivity of subsequent crops like wheat, maize, or sorghum in crop rotation.

2. Improvement of Soil Fertility and Structure

- Soybean contributes to **organic matter** through leaf fall and root residues.
- It **improves soil texture** and promotes microbial activity in the rhizosphere.
- Helps in the **reclamation of degraded soils** when cultivated regularly in rotation.

3. Breaks Pest and Disease Cycles

- When used in **crop rotation**, soybean helps **interrupt life cycles** of pests and pathogens affecting cereals.
- Reduces incidence of soil-borne diseases and pests like nematodes and grubs.
- Enhances biodiversity in soil microbiota, leading to healthier crop environments.

4. Water Efficiency and Drought Resilience

- Compared to other legumes and oilseeds, soybean is **relatively water-efficient**.
- Short growth cycle (90–110 days) reduces the total water requirement.
- Some varieties show **moderate drought tolerance**, making them suitable for rainfed conditions.

5. Weed Suppression

- When intercropped or densely planted, soybean exhibits **good canopy coverage**.

- This helps in **natural suppression of weeds** by limiting light and space.
- Reduces the need for herbicides, contributing to environmentally friendly farming.

Mixed Farming Systems

Mixed farming is an integrated agricultural system in which crops are grown in combination with livestock, poultry, or other farming enterprises. It enhances farm productivity, diversifies income sources, and makes more efficient use of land, labor, and resources. Soybean, with its versatile uses and agronomic compatibility, plays a vital role in mixed farming systems across rainfed and irrigated regions.

1. Intercropping with Cereals and Millets

Soybean is highly suitable for **intercropping**, especially with cereals like maize, sorghum, pearl millet, and pigeon pea. Its shorter stature and complementary root structure allow efficient resource use without significant competition.

Benefits:

- Enhances total biomass and yield per unit area.
- Improves soil nitrogen availability for the main crop.
- Reduces pest incidence and promotes system stability.
- Economically viable, especially under rainfed conditions.

Examples:

- Soybean + Maize
- Soybean + Pigeon pea
- Soybean + Sorghum

2. Integration with Livestock Enterprises

Soybean serves multiple roles in **integrated crop-livestock farming systems**:

- **Soybean meal** is a high-protein feed for poultry, pigs, and dairy animals.
- **Soybean fodder** (haulms and leaves) can be used as green or dry fodder.
- The residual straw improves feed quality when mixed with cereal stubble.

This integration helps in:

- Reducing the cost of external feed.
- Improving animal nutrition and productivity.
- Recycling of nutrients through manure back to fields.

3. Use in Agroforestry Systems

Soybean is compatible with **agroforestry** and **horti-agri systems**, especially during the initial years of plantation crops. It utilizes available sunlight and nutrients efficiently before tree canopies close.

- Suitable for **alley cropping** with trees like *Leucaena*, *Gliricidia*, and *Neem*.
- Improves soil organic matter and fertility around plantation bases.
- Serves as a temporary cash crop during orchard establishment.

4. Crop Rotation and Diversification

Soybean fits well in crop rotations and helps maintain **soil health and economic sustainability** of the farm. Typical rotations include:

- Soybean – Wheat
- Soybean – Chickpea
- Soybean – Mustard

Benefits of rotation:

- Improves nutrient cycling.
- Reduces pest and disease buildup.
- Enhances long-term productivity of the farm.

5. Role in Organic and Natural Farming Systems

Soybean is gaining popularity in **organic farming systems** as:

- It naturally enhances soil fertility through nitrogen fixation.
- Requires minimal chemical inputs.
- Offers market opportunities for organic soy-based products like soy milk and tofu.

6. Nutritional Security at the Farm Level

With high protein and oil content, soybean contributes to **household food security** in mixed farming setups. Farmers can use part of their produce for:

- Home consumption (soy flour, soymilk, tofu).
- Feeding livestock and poultry.
- Selling value-added products for extra income.

Challenges in Soybean Cultivation

1. Climatic Sensitivity

- **Dependence on monsoon** makes soybean vulnerable to erratic rainfall patterns.
- **Excess moisture** or **waterlogging** during early stages leads to root rot and poor nodulation.
- **Drought stress** during flowering and pod filling stages significantly reduces yield.

2. Pest and Disease Pressure

Soybean is affected by several pests and diseases, especially under monoculture or continuous cropping:

- **Insect pests:** Stem fly (*Melanagromyza sojae*), girdle beetle (*Oberea brevis*), leaf-eating caterpillars, whiteflies, aphids, and pod borers.
- **Diseases:**
 - ✓ **Rust** (*Phakopsora pachyrhizi*)
 - ✓ **Yellow Mosaic Virus (YMV)**
 - ✓ **Cercospora leaf spot**
 - ✓ **Bacterial pustule**
 - ✓ **Collar rot** and **charcoal rot**

These biotic stresses can cause up to **30–70% yield losses** if not managed in time.

3. Short Sowing Window

- In India, soybean is mainly cultivated during the **kharif season**, with a short optimal sowing window (last week of June to mid-July).
- **Delayed sowing** due to late rains or labor shortage leads to poor plant establishment and low yields.
- Early sowing also affects seedling emergence due to high soil temperatures.

4. Soil Constraints

- **Soil acidity** or **salinity** reduces nodulation and nitrogen fixation.
- Poor soil drainage leads to **anaerobic conditions**, affecting root health.
- Micronutrient deficiencies, especially **zinc** and **molybdenum**, affect crop performance.

5. Lack of Quality Seeds and Inputs

- Many farmers use **farm-saved seeds** with poor germination and genetic purity.
- Limited access to **certified seeds**, **biofertilizers** (e.g., *Rhizobium*, *PSB*), and crop protection inputs hampers yield potential.
- Seed inoculation practices are often neglected.

6. Harvest and Post-Harvest Issues

- **Lodging** and **shattering** are common problems near maturity, especially in indeterminate varieties.
- **Manual harvesting** is labor-intensive and time-bound, leading to losses during peak season.
- Inadequate **storage infrastructure** results in fungal contamination and reduced market value.

7. Market Fluctuations and Price Instability

- Global soybean prices are influenced by international trade policies, making farmers vulnerable to **price crashes**.
- Lack of **local processing** and **market linkages** limits the profitability of smallholders.
- Often, farmers are forced to sell at lower prices due to the absence of storage and collective marketing systems.

8. Limited Mechanization

- In many rainfed regions, small landholdings and uneven terrains hinder the use of **machinery for sowing and harvesting**.
- Mechanization is either unavailable or unaffordable, reducing operational efficiency.

Management Practices for Success

1. Selection of High-Yielding and Climate-Resilient Varieties

- Choose region-specific, **short-duration, high-yielding, and disease-resistant varieties**.
- Examples in India include:
 - ✓ **JS 95-60, JS 20-29, RKS 24, NRC 37, and MACS 1410.**
- Preference should be given to varieties resistant to **Yellow Mosaic Virus, rust, and pod shattering**.

2. Optimum Time of Sowing

- Ideal sowing time: **last week of June to second week of July** (Kharif season).
- Early or late sowing reduces yield due to mismatched rainfall and temperature patterns.
- Sowing should be done when **soil moisture is adequate**.

3. Proper Seed Rate and Sowing Method

- Seed rate: **70–80 kg/ha** (depending on seed size and spacing).
- Spacing: **30–45 cm between rows** and **5–7 cm between plants**.
- Depth: **3–5 cm**.
- **Line sowing with seed drill** is recommended for uniform plant population and ease of intercultural operations.

4. Seed Treatment and Inoculation

- Treat seeds with fungicide (**Carbendazim + Thiram**) to protect against seed and soil-borne diseases.
- **Inoculate seeds with *Rhizobium japonicum* and Phosphate Solubilizing Bacteria (PSB)** to enhance nitrogen fixation and phosphorus availability.

5. Integrated Nutrient Management (INM)

- Apply **20–25 kg N/ha, 60–80 kg P₂O₅/ha, and 40 kg K₂O/ha** depending on soil test.
- Use **organic manures** (FYM, compost, vermicompost) to improve soil health.
- **Micronutrients:** Apply **ZnSO₄** (25 kg/ha) and **Molybdenum** (1–2 g/kg seed) where deficiency is known.

6. Irrigation Management

- Though soybean is mostly rainfed, **life-saving irrigations** during flowering and pod filling stages can significantly boost yields.
- Avoid **water stagnation**, as soybean is sensitive to waterlogging.

7. Weed Management

- First **30–40 days** after sowing are critical for weed competition.
- Practices:
 - ✓ **Pre-emergence herbicide:** Pendimethalin (1.0–1.2 kg a.i./ha)
 - ✓ **Post-emergence:** Imazethapyr (75 g a.i./ha) at 20–25 DAS
 - ✓ Two manual weeding (20 and 40 DAS) if herbicides are not used

8. Integrated Pest and Disease Management (IPM)

- Monitor regularly for insect pests and diseases.
- Use **Neem-based bio-pesticides, light traps, and pheromone traps**.
- Apply **chemical pesticides** only when economic threshold level (ETL) is crossed.
- Cultivate **resistant varieties** and practice **crop rotation** to break pest cycles.

9. Harvesting and Post-Harvest Handling

- Harvest when **80–85% of pods turn brown** and leaves start shedding.
- **Delay in harvesting** leads to pod shattering and seed loss.
- After harvest:
 - ✓ Dry the seeds to **8–10% moisture**
 - ✓ Store in **cool, dry, insect-free conditions**
 - ✓ Use **fumigation or botanical protectants** if storing for longer periods

10. Use of Mechanization and ICT Tools

- **Seed drills, multi-crop planters, and axial-flow threshers** reduce labor costs.
- Mobile apps and farmer advisories (e.g., Kisan Suvidha, eNAM) provide real-time data on:
 - ✓ Weather alerts
 - ✓ Pest diagnosis
 - ✓ Market prices
 - ✓ Government schemes

Recent Innovations

To overcome production challenges and enhance the economic potential of soybean, numerous technological innovations and research breakthroughs have emerged in recent years. These advancements focus on increasing yield, improving resilience, promoting sustainability, and adding value to the soybean value chain—from farm to consumer.

1. Development of High-Yielding and Stress-Tolerant Varieties

- Indian research institutes like **ICAR-IISR (Indore)** and **IARI** have released improved varieties such as:
 - ✓ **JS 20-29, NRC 142, MACS 1407, and RVS 2001-4.**
- Traits include:
 - ✓ Resistance to **yellow mosaic virus, rust, and stem fly.**
 - ✓ **Short-duration cultivars** for rainfed and late sowing conditions.
 - ✓ **Shatter-resistant pods** for mechanized harvesting.

2. Precision Farming and ICT Tools

- Use of **GIS, remote sensing, and drones** for:
 - ✓ Monitoring crop health and pest outbreaks.
 - ✓ Estimating crop yield and mapping soil nutrient status.
- **Mobile apps** like *SoyApp India*, *IFFCO Kisan*, and *Kisan Suvidha* provide:
 - ✓ Real-time weather alerts.
 - ✓ Fertilizer and pesticide recommendations.
 - ✓ Market price updates.

3. Biofertilizers and Biopesticides

- Advanced strains of **Rhizobium japonicum** and **Phosphate-Solubilizing Bacteria (PSB)** enhance nitrogen fixation and nutrient uptake.
- Use of **Trichoderma spp., Bacillus subtilis, and Neem-based formulations** for managing soil-borne and foliar diseases.

4. Mechanization in Cultivation and Harvesting

- Introduction of **multi-crop seed drill, ridge-furrow planters, and axial-flow threshers** for small and medium farms.
- Use of **mechanical pod threshers and harvesters** reduces drudgery and harvest losses, especially in large-scale operations.

5. Soy-Based Value Addition Technologies

- Processing units now produce a range of soy products such as:
 - ✓ **Soy milk, tofu (soy paneer), soy flour, soy nuts, textured soy protein (TSP), and biscuits.**
- Development of **extruded soy products** and **ready-to-eat snacks** enhances market appeal and shelf life.
- Introduction of **low anti-nutrient processing** techniques improves digestibility and nutritional value.

6. Organic and Natural Farming Inputs

- Soybean fits well in **organic farming** due to its nitrogen-fixing ability and low pesticide requirement.
- Use of **natural farming preparations** like *Jeevamrut*, *Beejamrut*, and *Neemastra* is being promoted under **Bhartiya Prakritik Krishi Paddhati (BPKP)**.

7. Climate-Smart Agriculture Practices

- Promotion of **contingency cropping plans** and **drought-tolerant varieties** to adapt to climate risks.
- Use of **mulching**, **drip irrigation**, and **soil moisture sensors** improves water-use efficiency.

8. Promotion of Farmer Producer Organizations (FPOs)

- Government and NGOs are encouraging formation of **FPOs** and **cooperatives** to:
 - ✓ Facilitate collective input purchase and market linkage.
 - ✓ Set up local processing and value-addition units.
 - ✓ Reduce dependence on middlemen and increase farmers' share in consumer price.

Conclusion

Soybean has emerged as a multipurpose and environmentally sustainable crop with significant relevance in modern agriculture, especially within mixed farming systems. Its high protein and oil content, nitrogen-fixing ability, and compatibility with intercropping, rotation, and livestock integration make it a key driver of agricultural diversification, nutritional security, and ecological balance. Despite challenges such as climatic variability, pest pressures, and post-harvest constraints, recent advancements in varieties, mechanization, and agro-advisory tools have strengthened soybean's role in climate-resilient and profitable farming models. The crop not only contributes to farm income and livestock nutrition, but also supports soil fertility, biodiversity, and low-emission agriculture. For smallholder farmers, especially in rainfed areas, soybean offers a pathway to sustainable livelihoods, risk reduction, and value addition. Strategic support through extension services, infrastructure, and market access will be crucial in unlocking its full potential. Thus, integrating soybean into mixed farming is not only a practical agronomic choice but also a visionary step toward sustainable agriculture, food security, and rural empowerment