Soybean *(Glycine max [L.] Merr.)*

French: Soya; Spanish: Soja; Italian: Soja; German: Sojabohne

Crop data

Annual. Harvested part: seeds.

Sown February-August (Northern hemisphere).

Flowers 1-3 months after sowing.

Harvested 3-5 months after sowing.

Plant density:

Planting date	**Row width**		
	Wide > 75 cm	**Medium 30-75 cm**	**Narrow <30 cm**
	'000 plants/ha		
Early spring	150-300	200-450	250-700
Spring	150-300	200-450	250-600
Summer	150-200	150-300	200-450
Autumn	200-300	200-450	250-700

The crop is adapted to a wide range of climatic conditions. It is most susceptible to drought damage during flowering and grain filling. It is not generally irrigated.

Availability of essential nutrients is influenced by soil pH through its effects on Al saturation percentage and on nutrient fixation and release mechanisms. Highest soybean yields are usually produced when soil pH is between 6.2 and 7.0. In this range, adequate Ca and Mg are normally available. Soybeans grown on naturally acid oxisols and ultisols will generally produce to their potential at soil pH between 5.5 and 6.5. However, liming of these soils should also reflect the importance of exchangeable aluminum. Soils with low exchangeable Al with no soil solution Al generally will not benefit from lime application. This usually occurs at a soil pH of 5.5 or greater.

Nutrient demand/uptake/removal

Nutrient demand/uptake/removal - Macronutrients							
Part	**Source**	**kg/t grain**					
		N	**P2O5**	**K2O**	**MgO**	**CaO**	**S**
Grain only	(1)	65	14	23	5	4	2
Grain only	(2)	100	16	21	21	4	4
Grain only	(3)	65	11	20	4	4	2
Total		81	14	33	18	24	3
Grain only	(4)	64	11	20	4	4	2
Total		77	14	39	7	18	8
Grain only	(5)	38	8	16	19	9	n.a.

Nutrient demand/uptake/removal - Micronutrients							
Part	**Source**	**g/t grain**					
		Fe	**Mn**	**Zn**	**Cu**	**B**	**Mo**
Grain only	(1)	n.a.	20	17	16	n.a.	n.a.

Grain only	(3)	110	33	43	16	16	6
Total		366	90	61	25	39	7
Grain only	(5)	n.a.	n.a.	24	n.a.	n.a.	n.a.
(1) Adapted from "The Fertilizer Handbook", TFI, 1982 (2) Bataglia et al., 1977 (3) Bataglia & Mascarenhas, 1978 (4) Cordeio et al., 1979 (5) Guo Qingyuan, 1991 (personal communication)							

Plant analysis data

Sufficiency range for upper fully developed leaf at initial flowering stage - Macronutrients				
% of dry matter				
N	**P**	**K**	**Mg**	**Ca**
4.62-5.50	0.26-0.50	1.71-2.50	0.26-1.00	0.36-2.00
Source: Small & Ohlrogge, 1978				

Sufficiency range for upper fully developed leaf at initial flowering stage - Micronutrients					
ppm dry matter					
Fe	**Mn**	**Cu**	**Zn**	**B**	**Mo**
51-350	21-100	10-30	21-50	21-55	1-5
Source: Small & Ohlrogge, 1978					

Fertilizer recommendations

Available organic manures should be applied and incorporated well before primary tillage. If necessary soil pH corrections should be made prior to doing primary tillage. Mineral fertilizers may be split into two or more applications on highighly leachable soils or soils which fix large amounts of nutrients. Most non-sandy soils are soils in which fixation is low; usually one application of fertilizer is satisfactory. On soils low in nutrients it is often more efficient to apply fertilizers in a band near the row at seeding.

N: Soybeans, being a legume fix adequate atmospheric N to produce yields of 3 000-4 000 kg/ha, if well nodulated. Johnson et al. (1975) found that adding N to well nodulated soybeans produced no yield increase. Fertilizer N added at planting will delay nodulation. Gascho et al. (1989) suggested that N applications during the vegetative stages result in decreases in nodulation in proportion to the rates applied. Adding N is recommended only when adequate nodulation is not expected.
N deficiency results in reduced chlorophyll development and a pale-green leaf colour. Growth, development and yield are reduced.

P: taken up througout the growing season. The period of greatest demand starts just before the pods begin to form and continues until about 10 days before the seeds are fully developed. Much P used in seed development is taken up early, stored temporarily in leaves, stems and petioles, and then translocated into the seed.
Stunted growth is usually the only symptom of P deficiency, though some leaf cupping and discolouration are possible.

K: Relatively large amounts of K are required. Hanway & Weber (1971) reported that the rate of uptake is highest during rapid vegetative growth and slows as seed formation begins. Uptake continues until two to three weeks before the seed is mature; it can be depressed by poor soil condition including compaction, excess moisture and poor aeration. Most K taken up moves to the roots by diffusion through moisture films around soil particles. As the water

content of a soil decreases, moisture films around the soil particles become thinner and the path length of ion movement increases and the movement of K to roots decreases.
Lawton (1945) reported that K uptake decreases if the oxygen content of the soil is low, therefore poor aeration would require higher available K.
Cold soils reduce the rate and extent of root growth and this can limit K uptake. When farmers plant earlier or adopt tillage practices that result in lower soil temperatures early in the growing season, such as no-till, higher levels of available K in the soil are likely to be needed for optimum growth.
K deficiency is easily recognized; chlorosis starts along the outside edges of leaves, especially the older leaves.

Mg and Ca: In most cases Mg and Ca needs are met when a suitable soil pH is maintained. Acid soils are often deficient in Mg; dolomite is therefore the preferred lime source.

S: Substantial amounts of S are taken up, but few research trials have shown responses to added sulphur. In the past, S was a component of several fertilizers applied as sources of other nutrients; and additional S from emissions from burning of fossil fuels may have been enough to make up the remaining requirements. Today, most fertilizers contain little sulphur, and emissions from fossil fuels are being reduced, so it may become more limiting in the future.
Deficiency is most likely to occur during cool, wet weather on highly leachable soils low in organic matter.

Micronutrients: Some of the first growers to experience micronutrient deficiencies are those who have supplied plenty of N, P and K and raised yields to the point where stress is put on the micronutrient-supplying capacity of soil.
Deficiencies of micronutrients are more common than on most other field crops. Shortages of Fe, Mn, Mo and Zn have been observed. Deficiencies are limited to rather specific soil situations, viz:

- Strongly weathered soils. These soils are old in terms of the extent of chemical and physical changes that have occurred. Many have lost nutrients within the soybean rooting zone through leaching.

- Coarse-textured soils. These soils were formed from rock materials low in micronutrients. Furthermore, rainfall penetrates much more rapidly and to a greater depth, thus causing more leaching of nutrients from sandy and gravelly soils than from loams, silt loams, and silty clay loams.

- Alkaline soils. The solubility, though not total supply, of several nutrients diminishes as pH rises; it is not feasible, however, to lower the pH to correct micronutrient deficiencies.

- Organic soils. These soils have a low mineral content.

Soil tests have not been nearly as satisfactory for determining micronutrient deficiencies as have plant analyses. Differential responses have been found between varieties to both Fe and Mn.

Where a micronutrient deficiency is acute, the visual response to small, corrective applications may be striking, but often the yield response, if any, is negligible and there is no visible change in plant growth. Carefully controlled research trials are usually needed for precise evaluation. The margin between too little, just enough, and too much of a micronutrient is very often narrow.

Fe and Mn: Deficiencies of both occur on soils with high pH. Symptoms are very similar: stunted plants with pale yellow to nearly white leaves, but with green veins, over the whole plant. Fe deficiency is accentuated by very dry soil conditions. Mn deficiency is most pronounced in cool wheather.
If soybeans are planted in rows wider than 50 cm and the planter can apply row fertilizer, then the use of an acid-forming row fertilizer will usually prevent Mn deficiency. The alternative method is foliar application of 5-10 kg/ha manganese sulphate when the plants have two or three trifoliate leaves.

B: Results with boron additions where soil tests indicate low supplies have been inconsistent. Conditions conducive to B shortage are: high pH (7.0-8.0); coarse-textured soil from which nutrients leach readily; low organic matter; and drought. Because of the scarcity and variability of results and the extreme susceptibility of soybeans to boron toxicity, growers should consult their agronomist for guidance.

Cu: seldom deficient, except on soils high in organic matter (mucks) with pH > 6.0.

Mo: Differs from other micronutrients in that availability increases with rising soil pH. It is seldom lacking for soybeans at pH 6.0 or above. Legumes need Mo for N fixation. The deficiency symptom is pale green or yellow plants indicating a nitrogen shortage in the leaf tissue. Not surprisingly, this usually does not occur on any soil that is high enough in N to make up for the lack of nodule fixation.
Sodium molybdate (30 % Mo) and ammonium molybdate (48 % Mo) are used as seed treatments to supply 30-40 g/ha Mo; soil treatment is 60-120 g/ha Mo, but the first step is always to establish the correct soil pH.

Zn: Deficiency is most likely on soils with a high pH, high P and low organic matter. Soybeans on sandy soils are more susceptible than those on finer-textured soils. The deficiency can be caused by heavy P fertilization, especially near the row, or by very high soil test levels for P. Deficient plants are stunted. The leaves are yellow or light green. The lower leaves may turn brown and drop. Flowers are scarce. The few pods that do set are abnormal and slow-maturing. In mild deficiencies, early growth is stunted and plants are very light green or chlorotic. Soil tests are available, but plant analysis is usually recommended for additional confirmation.
Zinc sulphate is the most widely applied inorganic source. A single broadcast application is normally adequate for 2-4 years, if soils do not have high pH or high P level. When chelated zinc is used, manufacturers' directions should be carefully followed. Application of organic manure often corrects Zn deficiency.

Preferred nutrient forms

All fertilizers applied should provide easily plant-available forms. On soils which are highly leachable and low in organic matter, K2O should be applied preferredly in the sulphate form.

Present fertilizer practices

USA:

Only P and K are routinely used. Primary and secondary nutrients are added when there is a predicted need from either plant or soil analysis. Common basal fertilizer rates are incorporated into the soil prior to seeding.

The three dominant soil tests used for P analysis are Bray P1, Mehlich and Olson; the numerical value for sufficiency differs for each extractant. Most soil tests for K use an extractant which indicates amounts of exchangeable K in the soil. The clay content is sometimes used along with exchangeable K values to determine sufficiency levels for potassium. The Cation Exchange Capacity is used to indicate soil high in clay. Basal fertilizer rates are:

Soil test level	**Fertilizer nutrients recommended kg/ha**		
	P2O5	**K2O**	
		Low or normal clay content	**High clay content**
Low	40-60	100-150	120-180
Medium	30-40	50-100	70-100
Adequate	0-30	0- 50	0- 70
High	0	0	0
For expected yield of 2 500-2 700 kg/ha; for each additional 1 000 kg add an extra 10-15 kg/ha P2O5 and 20-30 kg/ha K2O.			

Brazil:

- Rio Grande do Sul and Santa Catarina

P: 10-140 kg/ha P2O5 (average about 50 kg/ha P2O5) on basis of soil analysis, % clay, number of successive soybean crops and expected yield.

K: <40-120 kg/ha K2O on basis of soil analysis, number of successive soybean crops and expected yield.

Liming: to pH 6.0

Micronutrients: When the pH is low, 8-10 g/ha Mo should be applied to the seeds.

- Paraná

P: 90-100 kg/ha P2O5 on soils used less than 3 years, or 20-50 kg/ha P2O5 on soils used 3 or more years, on basis of soil analysis and number of years of cropping.

K: up to 45 kg/ha K2O on soils used less than 3 years, or up to 60 kg/ha K2O on soils used 3 or more years, on basis of soil analysis and number of years of cropping.

Liming: on basis of formula:
NC = ((70 - V1) x T) / 100 x f
where :

NC - lime requirement
V1 - base saturation, before liming
T - CEC
f lime reactivity, usually 1.5

- Sao Paulo

P: 20-80 kg/ha P2O5 on basis of soil analysis.

K: up to 60 kg/ha K20 on basis of soil analysis.

S: 20 kg/ha S.

Liming: using same formula as in Paraná.

- Minas Gerais

P: 40-120 kg/ha P2O5 on basis of soil analysis.

K: 20-60 kg/ha K2O on basis of soil analysis.

Liming: using same formula as in Paraná.

- Cerrado Region

P: 60-100 kg/ha P2O5 on basis of soil analysis and % clay. Yields over 3 t/ha on soils with medium to good P supply require an additional 20 kg/ha P2O5 for each additional ton grain. A corrective application of partially acidulated phosphate or thermophosphate, broadcast and incorporated into the soil, is recommended at 50-120 kg/ha P2O5 for soils low in P (or 100-240 kg/ha P2O5 for soils very low in P).

K: 20 kg/ha K2O for each ton of grain expected. A corrective application of up to 100 kg/ha K20 is recommended for soils low in K. Where CEC is < 4 meq/100 cm3, half of the K may be applied at sowing and half 30 days after plant emergence.
Zn: 4 kg/ha Zn.

Liming: using same formula as in Paraná

China:

Sowing time	Province	Yield level	Basal fertilization kg/ha					Remarks
		t/ha	N	P2O5	K2O	ZnSO4	H2BO3	
Spring	Heilong-jiang	2-2.25	45	45	-	-	-	30-45 kg/ha N topdressed 2 months after sowing
Spring	Hunan	3	-	45	120	-	6	60 kg/ha N topdressed 2 months after sowing
Summer	Henan	2-2.25	45	60	-	15	-	
		3	60	60	60	15	-	
Autumn	Hubei,Hunan	2.25	60	45	80	-	-	

The basal fertilization is banded in the seedrow and incorporated into the upper 15 cm of soil.

Further reading

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