WEB OF SCIENTIST: INTERNATIONAL SCIENTIFIC RESEARCH JOURNAL
ISSN: 2776-0979, Volume 7, Issue 10, October- 2026

EFFECT OF MINERAL FERTILIZERS ON THE GROWTH AND DEVELOPMENT OF SOYBEAN CULTIVARS UNDER LIGHT SIEROZEM SOIL CONDITIONS OF THE FERGANA REGION: A NARRATIVE REVIEW

Mamanazirova Dilshoda Nematjon qizi
Mirzayeva Mutabar Azamovna
Fergana state university

Abstract
Soybean (Glycine max (L.) Merr.) is an increasingly important second crop in the irrigated Fergana Valley, where it is sown after winter wheat on soils that are low in humus and nitrogen. Mineral fertilizers are the main tool for improving its growth, development and seed yield, yet region-specific evidence for light sierozem (light gray) soils is scarce. This narrative review integrates verified evidence on (i) the agrochemical properties of light gray and meadow-gray soils of the Fergana region, (ii) the nitrogen, phosphorus and potassium requirements of soybean, and (iii) the interaction of mineral fertilizers with Bradyrhizobium/Rhizobium inoculation and micronutrients. The evidence indicates that biological nitrogen fixation supplies roughly half to 60% of soybean nitrogen demand, that fertilizer nitrogen rarely increases yield in the absence of a high yield potential, and that phosphorus and potassium stimulate nodulation and yield, with potassium often having the stronger effect. In the Fergana Valley, Rhizobium inoculation of the cultivar Orzu raised seed yield from 1.43–1.54 to up to 2.12 Mg/ha under irrigation. No published field trial that factorially tests N, P and K on soybean cultivars in the light sierozem soils of Fergana was identified. A hypothesis-driven experimental design is therefore proposed, and priorities for future research are outlined.

Keywords: Soybean; Glycine max; mineral fertilizers; light sierozem; Fergana Valley; nitrogen; phosphorus; potassium; Bradyrhizobium; growth and development.

1. Introduction

Soybean is a source of high-quality protein and oil and a nitrogen-fixing legume, which makes it attractive for diversifying irrigated cropping systems in Uzbekistan. After independence in 1991, the country reduced the irrigated cotton area and expanded winter wheat; wheat in turn allowed farmers to grow a second crop on the same land within the same season, and in the Ferghana Valley second crops became

an important source of farm income [1]. Soybean sown after winter wheat fits this niche, and recent work in the valley has treated it exactly as such a second crop [3]. Second-crop soybean has a short growing period and must establish, nodulate and fill seed within it, so its response to nutrient supply is time-limited. At the same time, the soils of the region are only moderately supplied with organic matter and nutrients. On light gray soils of southern Fergana, humus in the plough layer was about 1.3% and total nitrogen about 0.11% [4], and on irrigated meadow-gray soil of the Andijan area the topsoil contained 1.21% humus and 0.148% total N [3]. Such soils depend on mineral fertilizers, but the rates, ratios and timing that suit soybean on them have not been established on a sound experimental basis.

The aim of this review was to summarize verified evidence on the effect of mineral fertilizers on the growth, development and yield of soybean, to interpret it for the light sierozem conditions of the Fergana region, and to identify the knowledge gaps that a regional field experiment should address.

2. Materials and Methods

This is a narrative review. Sources were identified through targeted searches for soybean fertilization, nitrogen fixation, nodulation, inoculation, and the soils and cropping systems of Uzbekistan and the Fergana Valley. Priority was given to field studies, meta-analyses and reviews, and to work carried out in Uzbekistan. Each source cited here was checked against its publisher or repository record for authors, journal, year and, where available, DOI, and numerical results were taken from the abstracts and full pages of those records. The search was not exhaustive and did not follow a registered systematic-review protocol; the review should therefore be read as a structured synthesis and not as a complete census of the literature. Where no direct evidence for light sierozem soils was found, this is stated explicitly.

3. Soil conditions of the Fergana region

Light gray (light sierozem) soils of southern Fergana have a moderate level of humus and nutrients. According to agrochemical data, humus is about 1.3% in the plough layer and falls to about 0.3% in the lower horizons; total nitrogen is about 0.11% at the surface and 0.02–0.07% deeper; total phosphorus is relatively uniform at 0.19–0.20% through the profile; and total potassium declines from about 2.2% at the surface to about 1.6% at depth [4]. The author recommended regular organic fertilization, nutrient balance management based on agrochemical analysis and modern irrigation to preserve fertility [4].

Total contents do not show how much phosphorus and potassium is plant-available, and they say little about micronutrients. In the only recent soybean trial from the Fergana Valley identified in this review, the irrigated meadow-gray soil had 1.21% humus, 0.148% total N, 20.5 mg/kg nitrate and 220 mg/kg K2O in the 0–10 cm layer, with groundwater at 1.5–2.0 m [3]. These figures illustrate that soils of the valley combine low organic matter with a nitrogen reserve that is small for a high-protein crop, which raises the question of how much of soybean nitrogen demand can be met biologically and how much must be added.

4. Nitrogen: fixation versus fertilizer

A review of 637 site-year-treatment data sets from refereed field studies published between 1966 and 2006 showed that seed yield increased on average by 0.013 Mg per kg of nitrogen accumulated in aboveground biomass, and that biological N2 fixation met about 50–60% of soybean N demand [5]. Fixed nitrogen was usually not enough to replace the nitrogen removed in harvested seed: the partial N balance was negative in 80% of data sets, with a mean net soil N mining of –40 kg N/ha, although including an estimated below-ground N contribution brought the average close to neutral [5]. Yield responses to fertilizer N were more likely when yields exceeded 4.5 Mg/ha [5].

Recent field data are consistent with this. In a two-year experiment in Poland on four cultivars, 30 and 60 kg N/ha raised plant height and chlorophyll index (SPAD) but did not significantly increase seed yield; fertilized plots outyielded the control only in the first year, and the 30 and 60 kg N treatments did not differ [6]. The higher rate increased the number of pods and seeds per plant but lowered thousand-seed weight, which offset the gain [6]. The cultivar effect was larger than the nitrogen effect: the best cultivar averaged 5.06 t/ha and the lowest 4.25 t/ha [6].

For second-crop soybean in Fergana, where reported yields are around 1.4–2.1 Mg/ha [3], the yield level is far below the threshold at which nitrogen response becomes likely [5]. The practical implication is that nitrogen should be treated as a way to support early growth before nodules are active, and not as a substitute for fixation. This interpretation is an inference from the cited studies; it has not been tested on light sierozem.

5. Phosphorus and potassium

Phosphorus and potassium affect soybean through both plant nutrition and nodulation. In field experiments with P at 0–60 kg/ha and K at 0–112 kg/ha, each nutrient applied alone increased nodules per plant, potassium increased nodule

weight and pods per plant more than phosphorus did, and the largest gains occurred when both were applied [7]. Phosphorus above 15 kg/ha did not raise yield even though the soil was very low in available P, whereas yield increased with K up to 112 kg/ha when 60 kg P/ha was applied, although responses above 28 kg K/ha were not significant; the authors concluded that soybean requires more K than P [7]. In a four-year pot experiment in Yugoslavia, only phosphorus and phosphorus combined with a medium dose of nitrogen as calcium ammonium nitrate gave a significant average yield increase over the unfertilized control [10].

These results come from soils and climates that differ from Fergana, so they indicate mechanisms and the likely order of magnitude of response, not recommended rates for the valley. A further point specific to the region is that irrigated sierozem soils are typically carbonate-rich, which can reduce phosphorus availability (this was not measured in the sources reviewed here); it has to be verified by available-P and available-K analysis before any rate is set, and the available-nutrient status of the target fields is a necessary covariate in any trial.

6. Inoculation and micronutrients as modifiers of the fertilizer response

The strongest regional evidence concerns inoculation. In the Fergana Valley, on irrigated meadow-gray soil, soybean cv. Orzu sown after winter wheat was treated with a Rhizobium-based biofertilizer (Rhizotorphin, at least 1×10^8 CFU/g) under three irrigation regimes. Seed yield was 1.43–1.54 Mg/ha in non-inoculated treatments and up to 2.12 Mg/ha with inoculation under the 70–80–70% field-capacity regime; seed protein reached 46.3% and oil 25.5% against 38.4–43.6% and 22.3–23.2% in the controls, and nitrogen derived from the atmosphere was 62.9 kg N/ha, compared with none in non-inoculated plots [3]. The authors report a single site and two seasons, and some of their secondary claims, such as the size of the water saving, should be read cautiously [3].

Meta-analytic evidence shows that co-inoculation of Bradyrhizobium with plant growth-promoting rhizobacteria (PGPR) increased nodule number by 11.4% and root and shoot biomass, but did not significantly increase shoot nitrogen or grain yield, and that pot experiments showed larger effects than field experiments [8]. A trial on a low-fertility sandy Entisol in the Philippines found that Bradyrhizobium inoculation and foliar molybdenum (40 g Mo/ha) each raised seed yield, from 1.37 t/ha in the control to 1.74 and 1.90 t/ha, and the combination reached 2.06 t/ha [9]. Because the study was a single-season trial on a very different soil, it supports only the general idea that molybdenum and inoculation can complement fertilizer, not a specific recommendation for Fergana.

7. Cultivar differences and growth and development

Cultivar choice modifies the response to nutrients. A three-year evaluation of local and foreign soybean varieties in the Samarkand and Navoi regions found that Ustoz-MMAn-60 and Tomaris-MMAn-60 performed best in Samarkand, and Sparta and Oyjamol in Navoi, based on pods per plant, seeds per plant, thousand-seed weight and seed yield [2]. The report does not describe fertilizer treatments, so it indicates cultivar-by-environment variation that must be accounted for when fertilizer trials are designed.

Evidence on development is stage-specific. In the Fergana trial, nodules per plant increased from 13.1 at budding to 17.8 at flowering and 22.1 at pod formation in the best treatment [3], so the period from budding to pod formation is when nodulation and nitrogen fixation are being established. In the Polish trial, nitrogen fertilizer increased plant height and SPAD but also lowered photochemical efficiency parameters at higher rates [6]. These observations suggest that growth and development traits (plant height, leaf chlorophyll, nodule number, pods per plant, thousand-seed weight) should be recorded by phenological stage in any regional experiment.

8. Summary of evidence

Table 1. Main studies used in this review

Study	Setting	Treatments	Main finding
Nematov et al. [3]	Fergana Valley, irrigated meadow-gray soil, cv. Orzu, second crop	Irrigation regimes × Rhizobium inoculation	Seed yield 1.43–1.54 Mg/ha (controls) vs up to 2.12 Mg/ha (inoculated); protein up to 46.3%
Kholikova et al. [2]	Samarkand and Navoi, 2020–2022	Local and foreign varieties	Yield components differed between varieties and regions; no fertilizer data
Salvagiotti et al. [5]	Review of 637 data sets	Fertilizer N vs fixation	BNF supplies 50–60% of N; response to N more likely above 4.5 Mg/ha
Staniak et al. [6]	Poland, 2018–2019, rainfed	Four cultivars × 0, 30, 60 kg N/ha	N raised height and SPAD but not significantly seed yield
Jones et al. [7]	Field trials (P and K rates)	P 0–60, K 0–112 kg/ha	P and K increased nodulation; K response stronger than P
Zeffa et al. [8]	Meta-analysis, 42 articles	Co-inoculation with PGPR	Nodule number +11.4%; no significant yield effect
Guanzon and Rivera [9]	Philippines, sandy Entisol	Bradyrhizobium, foliar Mo	Seed yield 1.37 to 2.06 t/ha with the combination

9. Implications and a proposed experimental design

Taken together, the evidence supports four working hypotheses for soybean on light sierozem soils of the Fergana region. First, effective inoculation is a prerequisite for any nutrient response, because it determines whether nitrogen is supplied biologically. Second, phosphorus and potassium are more likely than nitrogen to raise yield, and potassium may have the larger effect. Third, a small starter dose of nitrogen is unlikely to harm and may improve early growth, but high rates will not pay. Fourth, the response will depend on the cultivar and on the available-nutrient status of each field. A factorial field experiment is the way to test these hypotheses. The treatments in Table 2 are illustrative and are meant to be adjusted after soil analysis; they are not recommended rates.

Table 2. Illustrative factorial design for a regional field experiment on light sierozem soil

Factor	Levels	Rationale
Nitrogen (kg N/ha)	0, 30, 60	Range tested in comparable work [6]; tests starter versus high N
Phosphorus (kg P2O5/ha)	0, 30, 60	Yield response to P often saturates at low rates [7]; set after available-P analysis
Potassium (kg K2O/ha)	0, 60, 120	K response was stronger than P and extended to higher rates [7]
Inoculation	With and without Rhizobium/Bradyrhizobium	Largest documented regional effect [3]
Cultivar	At least two locally adapted cultivars	Cultivar effect can exceed fertilizer effect [2,6]

Recommended measurements include soil available N, P and K and carbonate content before sowing; phenology; plant height, leaf chlorophyll, nodule number and mass at budding, flowering and pod formation; biomass; pods and seeds per plant; thousand-seed weight; seed yield, protein and oil; and water use, since irrigation interacts with the nutrient response [3]. At least two seasons and three replications are needed to separate fertilizer effects from year effects, as the Polish study showed [6].

10. Limitations

This review has several limitations. No factorial N-P-K field trial on soybean in light sierozem soils of the Fergana region was found, so the regional conclusions are inferences from studies in other conditions and from a small number of regional reports. Some sources are single-site and short-term [3,9], one is a pot experiment [10], and one regional soil source provides only total nutrient contents [4]. The literature search was targeted and not exhaustive, and unpublished or Russian- and Uzbek-language reports that may contain regional fertilizer data could have been missed.

11. Conclusion

Soybean grown as a second crop in the Fergana Valley depends on biological nitrogen fixation and on a balanced supply of phosphorus and potassium, while fertilizer nitrogen is likely to be of limited value at the yield levels currently reported. Rhizobium inoculation has the best-documented regional effect on yield and quality. Region-specific recommendations for light sierozem soils cannot yet be made, because the factorial field evidence is missing. A multi-season experiment combining N, P and K levels, inoculation and locally adapted cultivars, with measurements by growth stage, is the priority for future research.

References

[1] Platonov A, Wegerich K, Kazbekov J, Kabilov F. Beyond the state order? Second crop production in the Ferghana Valley, Uzbekistan. Int J Water Governance. 2014;2(2-3):83-104.

[2] Kholikova M, Babakhanova D, Rakhmatullayeva A, Khamrayev R, Abdrashitova E, Xojamkulova Y, et al. Evaluation of yield and yield attributes traits of soybean (Glycine max L. Merr.) varieties in Uzbekistan. J Wildlife Biodiversity. 2024;8(2):260-268. https://doi.org/10.5281/zenodo.11105572

[3] Nematov U, Shahmaliyeva S, Matyakubov B, Tursunov K, Yormatova D, Karabayev A, et al. Effects of biofertilizers under varying irrigation regimes on soybean productivity and soil fertility in arid agroecosystems. Front Soil Sci. 2026;6:1895897. https://doi.org/10.3389/fsoil.2026.1895897

[4] Nematov AA. Janubiy Farg'ona och tusli bo'z tuproqlarining agrokimyoviy xossalari va unumdorligi [Agrochemical properties and fertility of light gray soils of Southern Fergana]. FarDU ilmiy xabarlari. 2025;31(6):259.

[5] Salvagiotti F, Cassman KG, Specht JE, Walters DT, Weiss A, Dobermann A. Nitrogen uptake, fixation and response to fertilizer N in soybeans: a review. Field Crops Res. 2008;108(1):1-13. https://doi.org/10.1016/j.fcr.2008.03.001
[6] Staniak M, Baca E, Czopek K, Stępień-Warda A. Soybean [Glycine max (L.) Merrill] growth and yield responses to cultivar and nitrogen fertilization. Agronomy. 2025;15(12):2840. https://doi.org/10.3390/agronomy15122840
[7] Jones GD, Lutz JA, Smith TJ. Effects of phosphorus and potassium on soybean nodules and seed yield. Agron J. 1977;69(6). https://doi.org/10.2134/agronj1977.00021962006900060024x
[8] Zeffa DM, et al. Effects of plant growth-promoting rhizobacteria on co-inoculation with Bradyrhizobium in soybean crop: a meta-analysis of studies from 1987 to 2018. PeerJ. 2020;8:e7905. https://doi.org/10.7717/peerj.7905
[9] Guanzon IM, Rivera KJS. Enhancing biomass partitioning and yield traits in soybean (Glycine max L.) through Bradyrhizobium sp. and molybdenum fertilization. Discover Plants. 2025;2:305. https://doi.org/10.1007/s44372-025-00384-0
[10] Stojanovic J, Stojanovic S, Ognjanovic R. Investigation of fertilization influence on soybean yield. Zemljiste i biljka. 1994;43(1):67-75.