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Issue Article

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EFFECT OF FORAGE PEA (Pisum sativum L.) CULTIVATION ON THE AGROPHYSICAL PROPERTIES OF SOILS

***Abstract**: The article presents the results of comprehensive field and laboratory studies aimed at assessing the effect of forage pea (Pisum sativum L.) cultivation under different sowing dates and planting schemes on the agrophysical properties of irrigated typical gray soils of the Kashkadarya region. Experimental studies were conducted in 2023–2025 on long-term irrigated typical gray soils of the Yakkabag district using forage pea cultivars Vostok-55, Osiyo 2001, and K-295.*

The results showed that the inclusion of forage pea as a green manure crop in crop rotation systems had a positive effect on soil structure by increasing the proportion of water-stable macroaggregates (>0.25 mm) and reducing the content of fine microaggregates. Planting schemes of 60×25 and 60×30 cm improved soil water-holding capacity, increased soil moisture in the plow layer by 1–3% compared with the control (60×20 cm), and reduced soil bulk density by 0.01–0.03 g/cm³.

The findings indicate the high agroecological efficiency of forage pea as a green manure crop, contributing to improved soil physical properties, enhanced soil fertility, and increased resistance to soil degradation processes. The results can be used in the development of resource-saving agrotechnologies for irrigated agriculture.

***Key words**: forage pea, Pisum sativum L., green manure crops, soil agrophysical properties, soil structure, soil moisture, bulk density, planting schemes, irrigated soils.*

***Language**: English*

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Introduction

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Pea (Pisum sativum L.) is one of the leading crops in global agriculture. Currently, the total cultivated area of peas worldwide amounts to 8,852.8 thousand hectares, with a gross production of 19,919 thousand tons and an average yield of 22.5 centners per hectare. The leading pea-producing countries include China (11.5 million tons), India (6.18 million tons), Pakistan (388 thousand tons), France (296 thousand tons), the USA (246 thousand tons), Kenya (204 thousand tons), Algeria (203 thousand tons), Egypt (166 thousand tons), the United Kingdom (161 thousand tons), and Peru (148 thousand tons).

In eleven countries - China, India, Pakistan, France, the USA, Kenya, Algeria, Egypt, the United Kingdom, Peru, and Russia—pea grain yields reach 25.0–40.0 centners per hectare or more, which clearly demonstrates the high agro-economic potential of this crop [1, 2, 4, 6, 12, 13, 14, 16, 17, 18, 19, 20]. This, in turn, necessitates the development of innovative agrotechnologies that ensure high and stable yields of high-quality grain from both food and forage pea varieties.

In addition, pea, as a leguminous crop, enhances soil fertility through biological nitrogen fixation mediated by rhizobacterial activity and plays a significant agroecological role in crop rotation systems. Improving pea cultivation technologies, scientifically substantiating optimal sowing dates and planting schemes, and developing effective agrotechnical measures to obtain high-quality seed yields represent pressing scientific and practical tasks.

Therefore, deepening scientific research on pea cultivation, developing and recommending innovative agrotechnologies aimed at increasing productivity, and substantiating their agroecological efficiency determine the relevance and necessity of the present research.

In short-term crop rotation systems, green manure leguminous crops are of great importance for maintaining, improving, and protecting the natural fertility of soils.

Purpose of the Study. The purpose of the study was to scientifically substantiate and improve the agrotechnology for cultivating forage pea varieties as a green manure and seed crop under different sowing dates and planting schemes in the irrigated typical gray soils of the Yakkabag district, Kashkadarya region, in order to ensure high-quality seed and grain yields.

Object of the Study. The object of the study was long-term irrigated typical gray soils of the Kashkadarya region and forage pea varieties *Vostok-55*, *Osiyo 2001*, and *K-295*.

Subject of the Study. The subject of the study included the growth and development of forage pea varieties under different sowing dates and planting schemes when grown as a green manure and seed crop, grain yield, leaf area, accumulation of biological dry matter, changes in agrophysical, agrochemical, water, and microbiological properties of the soil, as well as the effectiveness of agrotechnical measures on yield and seed quality indicators.

Research Conditions, Materials, and Methods

Field experiments were conducted for the first time during 2023–2025 on long-term irrigated typical gray soils of the “Uygur” and “Zafar” farms in the Yakkabag district of the Kashkadarya region. Groundwater occurred at a depth of 8–12 m, and the soil texture was medium loam.

In the plow layer (0–30 cm), the humus content was 1.0–1.8%, bulk density ranged from 1.27 to 1.30 g/cm³, particle density from 2.58 to 2.65 g/cm³, total nitrogen content was 0.094–0.095%, total phosphorus 0.144–0.163%, potassium 2.6–2.9%, nitrate nitrogen 5.14–6.51 mg/kg, available phosphorus 8–17 mg/kg, and exchangeable potassium 156–193 mg/kg. Soil reaction was slightly acidic (pH 5.9–6.7).

The experiments were carried out using forage pea varieties *Vostok-55*, *Osiyo 2001*, and *K-295*, registered in the State Register, sown in autumn (October) at planting schemes of 60×20 cm (control), 60×25 cm, and 60×30 cm. Each experimental plot covered 72 m², with three replications. Field and laboratory studies were conducted in accordance with standard methodologies, and statistical analysis was performed using the method of B.A. Dospekhov with Microsoft Excel.

For the first time, field experiments were conducted in 2023–2025 on long-term irrigated typical gray soils at the “Uyg‘ur” and “Zafar” farms of Yakkabog district, Qashqadarya region. These soils are characterized by a medium loam texture, with groundwater located at a depth of 8–12 m. In the plow layer (0–30 cm), soil properties were as follows: humus content 1.0–1.8%, bulk density 1.27–1.30 g/cm³, particle density 2.58–2.65 g/cm³, total nitrogen 0.094–0.095%, total phosphorus 0.144–0.163%, potassium 2.6–2.9%, nitrate nitrogen 5.14–6.51 mg/kg, available phosphorus 8–17 mg/kg, and exchangeable potassium 156–193 mg/kg. The soil reaction was weakly acidic (pH = 5.9–6.7). It was noted that the content of nutrient elements in the subsoil layer was slightly lower.

During 2023–2025, the field experiments used forage pea (*Pisum sativum L.*) cultivars “Vostok 55”, “Osiyo 2001”, and “K-295”, which are included in the State Register, sown in autumn (October) (see Table 2.3).

To achieve the objectives of the study, field experiments were carried out in the following directions (Tables 1 and 1.1A). The experiments were conducted on irrigated typical gray soils of the Yakkabog district at the “Uyg‘ur” and “Zafar” farms from 2023 to 2025. Considering the climatic conditions of the irrigated areas of Qashqadarya and the biological characteristics of forage pea, sowing dates of October 10, 20–21, and 30–31 and planting schemes of 60×30, 60×25, and 60×20 cm were selected to determine optimal sowing dates and schemes for cultivars Vostok 55, Osiyo 2001, and K-295.

In the field experiment, each plot occupied an area of 72 m² (length 20.0 m, width 3.6 m). There were 3 variants, 3 replications, and 8 subplots, with variants arranged in a single tier. The experiments were conducted according to the manuals: *Methods for Conducting Field Experiments* [Tashkent, UzPITI, 2007] and *Scientific Research in Plant Science* [Tashkent, ToshDAU, 2014].

Table 1. Experimental Design

Sowing Date	Planting Scheme (cm)	Cultivar	Sowing Date	Planting Scheme (cm)	Cultivar	Sowing Date	Planting Scheme (cm)	Cultivar
10.10	60x20 (control)	Osiyo 2001	20-21.10	60x25	Vostok 55	30-31.10	60x30	Vostok 55
		Vostok 55			Osiyo 2001			Osiyo 2001
		K-295			K-295			K-295

Sowing Dates and Norms. The sowing of forage pea (*Pisum sativum L.*) cultivars was carried out in the autumn period (October). The sowing was performed on October 10, 20–21, and 30–31. The number of plants per hectare, depending on the sowing scheme, was as follows: 83.3 thousand plants (60×20 cm), 66.6 thousand plants (60×25 cm), and 55.5 thousand plants (60×30 cm).

Forage pea is generally sown in narrow rows, while for seed production, wider rows are used. Sowing was conducted using SZ-3.6 and SZA-3.6 seed drills [R. Oripov, N. Khalilov, 2007, pp. 229–233].

Seeds of Vostok 55, Osiyo 2001, and K-295 were sown in each variant in two rows per cultivar. Before sowing, $N_{30}P_{100}K_{75}$ kg/ha was applied. Autumn-sown forage pea cultivars were additionally fertilized with N_{30} in early spring. Irrigation was carried out at a rate of 450–500 m^3/ha; and autumn-sown cultivars 4 times, with 2 irrigations in spring.

Research Methods

Scientific research included laboratory, field, and production trials; phenological observations; physiological and biometric analyses. Methods were applied according to: *Methods for Conducting Field Experiments*, *Scientific Research in Plant Science*, *State Methods for Crop Variety Testing*, *Photosynthetic Activity of Plants in Crops*, *Methods of Agrochemical, Agrophysical, and Microbiological Studies in Cotton Areas*, *Methods of Agrochemical Analysis of Soils and Plants of Central Asia*, and *Basic Provisions for Determining Economic Efficiency of R&D, New Technology, Inventions, and Rationalization Proposals in Agriculture*.

Mathematical-statistical analysis of field experiment data was performed using Microsoft Excel following the B.A. Dospexov method [3, 5, 7, 8, 9, 10, 15].

Table 1.1A. Sowing Dates and Planting Schemes of Forage Pea Cultivars in Autumn

No	Planting Scheme (cm)	Sowing Date (day, month)	Cultivars		
1.	60x20 (control)	10.10	Osiyo 2001	Vostok 55	K-295
			Osiyo 2001	Vostok 55	K-295
2	60x25	20-21.10	Osiyo 2001	Vostok 55	K-295
			Osiyo 2001	Vostok 55	K-295
3	60x30	30-31.10	Osiyo 2001	Vostok 55	K-295
			Osiyo 2001	Vostok 55	K-295

Research results

After the forage pea (*Pisum sativum L.*) cultivars were harvested for seed, soil samples were taken from the plow and sub-plow layers of the experimental plots. Laboratory analyses were conducted to study the effects on soil physical properties. The soil samples were placed in a phosphorus-containing container, wetted with water, fractionated, and the shares of mechanical particles were analyzed, i.e., macroaggregates larger than 0.25 mm and microaggregates ranging from 0.25 to 0.05 mm. The analysis revealed **positive changes in soil aggregates** after growing forage pea cultivars (Table 2).

Table 2. Changes in soil aggregate composition (%) in experimental plots after growing forage pea cultivars under different sowing dates and schemes (2024–2025)

No	Sowing Scheme (cm)	Macroaggregates >0.25 mm		Microaggregates 0.25–0.05 mm	
		Soil layers, cm		Soil layers, cm	
		0-10	10-30	0-10	10-30
1	60x20 (control)	16,8	19,5	25,2	26,4
2	60x25	17,1	20,7	24,9	25,9
3	60x30	18,4	21,5	24,7	25,5

In the various sowing dates and schemes, the share of macroaggregates (>0.25 mm) in the 0–10 cm plow layer and the 10–30 cm sub-plow layer increased compared to the control (60×20 cm) plots. The share of microaggregates (0.25–0.05 mm) in the plow layer was higher by 0.3–0.9% in the 60×25 and 60×30 cm sowing schemes compared to the control (60×20 cm).

In the 60×30 cm sowing scheme, the share of macroaggregates (>0.25 mm) in the plow layer increased to 18.4–21.5%, which is 1.6–2.0% higher than the control. In the 60×25 cm scheme, macroaggregates increased to 17.1–20.7%, which is 0.3–1.2% higher than the control.

In our study, each year, after harvesting the grain yield of forage pea (*Pisum sativum* L.) cultivars grown for seed, the plant and root residues were incorporated into the soil as biomass following field tillage. This process increased the proportion of decomposed organic matter in the arable layer, resulting in the aggregation of soil particles and an increase in macroaggregate content. Incorporation of the residues of forage pea into the soil promoted an increase in the proportion of 0.25 mm macroaggregates in the arable layer.

Thus, selecting intermediate and green manure crops that rapidly cover the soil surface with plant residues is of great importance. Leguminous green manure crops, which penetrate dense soil with extensive root systems, contribute to the formation and stabilization of soil aggregates and improve soil water-air permeability. Application of crop residues also maintains the natural fertility of the soil, and by protecting it with organic matter, promotes the formation of water-resistant large soil aggregates, thereby increasing resistance to water and wind erosion.

In our study, soil samples were collected from the arable layer to determine soil moisture during the growing period of different forage pea cultivars, sown according to various planting dates and schemes. The collected moist soil samples were dried in a thermostat for 3 hours under laboratory conditions. Under the conditions of traditionally irrigated typical gray soils, samples were taken from planting schemes of 60×20 (control), 60×25, and 60×30 cm of the forage pea cultivars Vostok 55, Osiyo 2001, and K-295 during the growing period, both before the first and the last irrigation. Soil moisture in the arable layer was analyzed under laboratory conditions. The results are presented in Table 3.

Table 3. Soil moisture changes (%) in experimental plots during the growing season of autumn forage pea cultivars (2024–2025)

No	Sowing Scheme (cm)	Before Sowing		During the growing period of forage pea (*Pisum sativum* L.) cultivars			
				First Irrigation		Last Irrigation	
		9-12.11		24-27.03		12-10.05	
		Soil layers, cm					
		0-20	20-30	0-20	20-30	0-20	20-30
1	60x20 (control)	22,5	23,4	28,7	26,8	26,8	27,1
2	60x25	23,3	23,5	29,2	27,9	28,1	27,8
3	60x30	23,4	25,9	31,4	28,8	29,0	28,6

When studying the winter-sown forage pea cultivars Vostok 55, Osiyo 2001, and K-295 grown for seed, soil moisture in the arable layer (0–20 and 20–30 cm) during the growing period before the first irrigation was 31.4–28.8% and 29.2–27.9% for the 60×30 cm and 60×25 cm planting schemes, respectively, which was 2.7–2.0% and 0.5–1.1% higher compared to the control (60×20 cm).

When studying winter-sown forage pea (*Pisum sativum* L.) cultivars Vostok 55, Osiyo 2001, and K-

295 for seed production under different sowing dates and schemes, it was found that during the growing period, before the last irrigation, soil moisture in the arable layer (0–20 and 20–30 cm) was higher in the 60×30 cm and 60×25 cm planting schemes compared to the cultivars, reaching 29.0–28.6% and 28.1–27.8%, respectively.

Thus, under various sowing dates and schemes, the soil moisture in the arable layer remained adequate before both the first and last irrigation, providing minimal moisture stress for the cultivation of Vostok 55, Osiyo 2001, and K-295 cultivars. It is recommended to promote and widely introduce forage pea cultivars as a prospective green manure crop for improving seed production and as a cover crop in cotton, vegetable, and potato cultivation.

During the years of research, under different sowing dates and schemes, changes in bulk density of the arable layer (0–30 cm) were determined in the field for the cultivars Vostok 55, Osiyo 2001, and K-295 grown for seed under 60×20 (control), 60×25, and 60×30 cm planting schemes. Soil bulk density in the arable layer was measured using a cylinder on undisturbed soil samples (Table 4).

Under the conditions of traditionally irrigated typical gray soils, the changes in soil bulk density in the arable layer during the growing period before the first and last irrigation for Vostok 55, Osiyo 2001, and K-295 cultivars are presented in Table 3. In 2024–2025, before the first irrigation, the average bulk density of the arable layer (0–20 and 20–30 cm) in the 60×30 cm and 60×25 cm planting schemes was 1.23–1.24 and 1.27–1.28 g/cm³, respectively, while in the control (60×20 cm), it was 1.25–1.29 g/cm³.

Before the last irrigation, the average bulk density in the arable layer (0–20 and 20–30 cm) under 60×30 cm and 60×25 cm schemes was 1.24–1.25 and 1.28–1.29 g/cm³, respectively. Compared to the control (60×20 cm), the arable layer's average bulk density decreased by 0.03–0.02 and 0.02–0.01 g/cm³, indicating that the selection of appropriate sowing dates and schemes for Vostok 55, Osiyo 2001, and K-295 is crucial for achieving high seed yields and maintaining optimal soil physical conditions.

Table 4. Changes in soil bulk density (g/cm³) in the plow layer during the growing season of autumn forage pea cultivars (2024–2025)

No	Sowing Scheme (cm)	During the growing period of forage pea (*Pisum sativum* L.) cultivars			
		First Irrigation		First Irrigation	
		Soil layers, cm			
		0-20	20-30	0-20	20-30
		24-27.03		12-10.05	
1	60x20 (control)	1,25	1,29	1,27	1,30
2	60x25	1,24	1,28	1,25	1,29
3	60x30	1,23	1,27	1,24	1,28

Conclusion, thus, selecting the appropriate sowing dates and schemes for winter-sown forage pea (*Pisum sativum* L.) cultivars Vostok 55, Osiyo 2001, and K-295 is crucial for achieving high seed yields from leguminous crops. The results indicate that cultivating forage pea under various sowing dates and schemes not only ensures a high and quality seed yield but also plays an important role in stabilizing the soil's agrophysical properties. As a legume crop, forage pea enhances soil microbiological activity and promotes biological nitrogen fixation through the activity of rhizobacteria, thereby creating a favorable nutrient environment for subsequent crops.

The experimental results showed that in wider row spacing schemes (60×25 and 60×30 cm), root systems developed more actively, improving soil porosity and water-air regime. Incorporating plant and root residues into the arable layer increased the amount of organic matter, which contributed to the strengthening of soil aggregates. As a result, the formation of water-stable large aggregates increased soil resistance to erosion processes.

Furthermore, maintaining optimal soil moisture throughout the growing period positively influenced plant physiological processes, accelerated photosynthesis, and promoted biomass accumulation. These findings scientifically justify the broad adoption of forage pea as a promising green manure crop for cotton, vegetable, and potato cultivation.

Key Findings:

1. Forage pea grown under different sowing dates and schemes significantly improved the soil's agrophysical properties by increasing the proportion of macroaggregates larger than 0.25 mm and reducing soil bulk density in the arable layer.

2. In the 60×25 and 60×30 cm planting schemes, soil moisture was 1–3% higher compared to the control, enhancing water retention capacity and the water-air regime, which provided favorable conditions for stable plant growth.

3. Introducing forage pea as a green manure in crop rotation systems plays an important agroecological role in maintaining and improving soil

fertility, increasing resistance to erosion, and ensuring higher yields of subsequent crops.

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