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The Influence Of Bentonite Clay Treatment Of Local Soybean Seeds On Germination Dynamics Under Light Chestnut Soil Conditions

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Abstract: The present study examines the impact of bentonite clay treatments on the germination dynamics of locally sourced soybean seeds cultivated under light chestnut soil conditions. Experimental variants included an unfertilized control, a mineral fertilizer background (N150P100K80), and the same background supplemented with bentonite at rates of 4 t/ha, 5 t/ha, and 6 t/ha. The findings provide empirical evidence regarding the effectiveness of bentonite application as an agro-resource, highlighting its potential role in enhancing seed germination performance through improved microelement availability and soil–seed interactions.

Keywords: Bentonite clays, resource-efficient technologies, agro-ore, microelements, germination dynamics.

Introduction: Ensuring sustained increases in crop productivity while maintaining or enhancing soil fertility represents one of the most critical challenges in contemporary agricultural science. Within the context of Uzbekistan, rational and efficient utilization of available natural and technological resources is essential for guaranteeing a stable supply of agricultural products to the population, improving overall productivity and economic efficiency, and strengthening the processing capacity of agricultural outputs. These priorities collectively underscore the need for innovative, resource-efficient approaches in crop production.

The integration of non-traditional agro-ores into soil management systems has emerged as a promising resource-saving technology. Numerous studies have demonstrated that such amendments contribute to improving the agro-physical and agrochemical properties of soils, accelerating biological processes within the soil environment, and enhancing the nutrient uptake efficiency of applied mineral fertilizers. Consequently, the combined effect of these improvements translates into increased crop yields alongside marked enhancements in product quality.

International experience with non-traditional agro-ores further confirms their agronomic value, indicating yield increases of 10–15%, improvements in crop quality, and the ability of these materials to assist in remediating soils contaminated with heavy metals, toxic compounds, and radioactive elements. Among these materials, bentonite clay is particularly noteworthy. In addition to supplying essential microelements required by plants and soils, bentonite plays a significant role in improving soil ameliorative conditions. Its capacity to retain soil moisture, bind surrounding sand particles, and increase the structural cohesion of sandy soils makes it an effective amendment for challenging soil environments. From a nutritional perspective, bentonite is also a valuable source of macro- and microelements, containing 0.3–4.7% carbon, 0.4–3.0% potassium, 0.3–1.5% phosphorus, and trace elements such as copper, zinc, boron, cobalt, molybdenum, manganese, and sulfur.

The development of new hybrid crop varieties that are optimally adapted to the soil and climatic conditions of Uzbekistan, their large-scale cultivation, and the production of high-yield harvests, followed by processing into diverse, high-quality, and value-added products, constitutes a critical contribution to the advancement of the national agricultural sector and the broader economy.[1]

In leading agricultural nations, the application of non-traditional agro-ores as supplementary nutrient sources alongside mineral fertilizers has been scientifically optimized and standardized for various soil conditions, ensuring both enhanced productivity and sustainable soil management.

METHODS

Currently, soybean accounts for approximately 40% of global vegetable oil production. Among leguminous crops, soybean leads the world in both total yield and cultivated area. In Uzbekistan, increasing soybean cultivation and fully satisfying the domestic demand for soybean oil have been prioritized by governmental policy initiatives.

In this context, Presidential Decree No. PD-2832, issued on 14 March 2017, “On Measures to Expand Soybean Cultivation and Increase Soybean Grain Production in the Republic in 2017–2021,” established a comprehensive program for the development of soybean cultivation. This program encompasses the creation of high-yielding soybean varieties, expansion of cultivation areas, and the systematic organization of soybean breeding and primary seed production for the period 2017–2021.[2]

Scientific investigations were conducted under controlled field and laboratory conditions. Field experiments were implemented in accordance with established methodological guidelines, including Methods of the State Variety Testing of Agricultural Crops (Moscow: Kolos, 1989)[3] and Methods for Conducting Field Experiments (Uzbek Scientific Research Institute of Plant Industry, Tashkent, 2007)[4]. Data analysis was performed using rigorous mathematical-statistical procedures as outlined in B.A. Dospekhov’s Methods of Field Experimentation.[5]

RESULTS AND DISCUSSION

The present study evaluated the influence of bentonite clay amendments on the germination dynamics of the soybean cultivar “Madad” under the light chestnut soils of the Kashkadarya region. Seeds were sown on 15 April at densities of 500,000, 600,000, and 700,000 seeds per hectare, across the following experimental treatments: control (no fertilizer), $N_{150}P_{100}K_{80}$ (background mineral fertilization, FON), FON supplemented with 4 t bentonite, FON + 5 t bentonite, and FON + 6 t bentonite. Seeds were sown at a depth of 3–4 cm, and germination was systematically monitored throughout the decadal periods of April.

The results indicate that germination dynamics were strongly influenced by the combined effects of seed density, fertilization regime, irrigation practices, and bentonite clay application. During the first decadal period of April, germination rates for the “Madad” cultivar were observed as follows:

500,000 seeds/ha: Control – 58%, FON – 59%, FON + 4 t – 59%, FON + 5 t – 64%, FON + 6 t – 62%, 600,000 seeds/ha: Control – 51%, FON – 54%, FON + 4 t – 52%, FON + 5 t – 58%, FON + 6 t – 57%, 700,000 seeds/ha: Control – 44%, FON – 48%, FON + 4 t – 56%, FON + 5 t – 63%, FON + 6 t – 65%.

During the second decadal period of April, a marked increase in germination was recorded:

500,000 seeds/ha: Control – 67%, FON – 64%, FON + 4 t – 64%, FON + 5 t – 72%, FON + 6 t – 70%, 600,000 seeds/ha: Control – 69%, FON – 64%, FON + 4 t – 66%, FON + 5 t – 70%, FON + 6 t – 69%, 700,000 seeds/ha: Control – 48%, FON – 50%, FON + 4 t – 60%, FON + 5 t – 79%, FON + 6 t – 81%.

Observations during the third decadal period of April demonstrated further progression in germination:

500,000 seeds/ha: Control – 78%, FON – 80%, FON + 4 t – 78%, FON + 5 t – 78%, FON + 6 t – 77%, 600,000 seeds/ha: Control – 69%, FON – 74%, FON + 4 t – 80%, FON + 5 t – 82%, FON + 6 t – 80%, 700,000 seeds/ha: Control – 50%, FON – 56%, FON + 4 t – 64%, FON + 5 t – 83%, FON + 6 t – 82%

These findings suggest that both bentonite clay amendments and seed density exert a statistically significant influence on germination dynamics. Notably, treatments incorporating FON with 5–6 t of bentonite consistently produced the highest germination rates across all sowing densities, indicating an optimal enhancement of seedling emergence under the tested soil and climatic conditions. The results underscore the potential of bentonite clay as a resource-efficient soil amendment capable of improving early soybean growth and overall crop establishment.

Table 1.

Effect of Bentonite Clay Treatment on the Germination Dynamics of Soybean Seeds

Cultivars	Option	Application Rates of Bentonite Clay for Seed Treatment	1. Germination Dynamics					
			April 15		April 17		April 19	
			Piece	%	Piece	%	Piece	%
Madad	Control	500 000	290	58	335	67	390	78

	(Unfertilized)	600 000	306	51	414	69	414	69
		700 000	308	44	336	48	350	50
	NPK 150:;100:80 (FON	500 000	295	59	320	64	400	80
		600 000	324	54	384	64	444	74
		700 000	336	48	350	50	392	56
	FON-4t bentonit	500 000	295	59	320	64	390	78
		600 000	312	52	396	66	480	80
		700 000	392	56	420	60	448	64
	FON-5t bentonit	500 000	320	64	360	72	390	78
		600 000	348	58	420	70	492	82
		700 000	441	63	553	79	581	83
	FON-6t bentonit	500 000	310	62	350	70	385	77
		600 000	342	57	414	69	480	80
		700 000	455	65	567	81	574	82

Based on the experimental results, no statistically significant differences were observed in the germination performance among the soybean cultivars themselves. Nevertheless, in comparison with the control (untreated) variant, the sowing and irrigation of seeds treated with bentonite clay—specifically N150P100K80 (FON), FON supplemented with 4 t, 5 t, and 6 t of bentonite—consistently exhibited superior germination dynamics. These findings indicate a positive effect of bentonite amendments on early seed development under the studied soil and climatic conditions.

CONCLUSION

The results of this study demonstrate that the application of bentonite clay to soybean seeds enhances seed moisture absorption, thereby increasing germination capacity (germination energy) and overall germination percentage. Moreover, bentonite treatment contributes to uniform seedling emergence, promoting the development of consistent and vigorous stands, which is critical for optimizing crop establishment and subsequent productivity.

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