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Agrochemical efficacy of defoliants with physiologically active effects

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Агрохимическая эффективность дефолиантов, обладающих физиологически активным действием

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Abstract

This study is dedicated to the creation of new-generation defoliants based on sodium chlorate and the evaluation of their agrochemical efficacy under field conditions. During the research, five new defoliant compositions were developed using sodium chlorate ($NaClO_3$), thiocarbamide ($CS(NH_2)_2$), monoethanolamine (C_2H_7NO), formaldehyde (CH_2O), orthophosphoric acid (H_3PO_4), malic acid ($C_4H_6O_5$), and citric acid ($C_6H_8O_7$): F-1 – 30 % $NaClO_3$ + 2 % ($CS(NH_2)_2$ + $C_2H_7NO{\cdot}CH_2O$), F-2 – 30 % $NaClO_3$ + 2 % ($C_2H_7NO{\cdot}CH_2O$), F-3 – 30 % $NaClO_3$ + 2 % ($C_2H_7NO{\cdot}CH_2O$ + H_3PO_4), F-4 – 30 % $NaClO_3$ + 2 % ($C_4H_6O_5{\cdot}CS(NH_2)_2$ + C_2H_7NO), and F-5 – 30 % $NaClO_3$ + 2 % ($C_6H_8O_7{\cdot}CS(NH_2)_2{\cdot}C_2H_7NO$). The defoliating activity of these compositions was studied in field trials on the 'Sultan' cotton variety, cultivated in the fields of the «Bektemirnuragro» farm in the Urtachirchik district of the Tashkent region. Defoliation efficacy was assessed 6 and 12 days after application based on indicators such as leaf fall, degree of boll opening, the physiological state of the plants, and their readiness for mechanized harvesting. By day 12 post-application, leaf fall from these formulations reached 80.4-82.5 %, leaf desiccation was

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5.0–6.5 %, and boll opening was 89.4-91.4 %. Under the action of these defoliants, leaves shed through the natural process of abscission, without desiccation or severe necrosis; no phytotoxic damage to maturing bolls, nor drying of stems and peduncles, was observed. This confirms that the new formulations possess high selectivity and have a physiologically «gentle» effect on the plants. It was established that the synergistic interaction of these components accelerates the defoliation process, enhances the biological activity of the preparation, and reduces its negative environmental impact. The practical significance of the research lies in its contribution to the effective organization of mechanized cotton harvesting in Uzbekistan, reducing crop losses, and creating domestically produced, relatively eco-friendly, and highly effective defoliants. The results obtained provide an important scientific basis for the further development and implementation of highly effective, environmentally safe, and economically viable new-generation defoliants into cotton cultivation practices.

Аннотация

Настоящее исследование посвящено созданию дефолиантов нового поколения на основе хлората натрия и оценке их агрохимической эффективности в полевых условиях. В ходе исследования было разработано пять новых составов дефолиантов на основе хлората натрия ($NaClO_3$), тиокарбамида ($CS(NH_2)_2$), моноэтаноламина (C_2H_7NO), формальдегида (CH_2O), ортофосфорной кислоты (H_3PO_4), яблочной кислоты ($C_4H_6O_5$) и лимонной кислоты ($C_6H_8O_7$): F-1 – 30 % $NaClO_3$ + 2 % ($CS(NH_2)_2$ + $C_2H_7NO{\cdot}CH_2O$), F-2 – 30 % $NaClO_3$ + 2 % ($C_2H_7NO{\cdot}CH_2O$), F-3 – 30 % $NaClO_3$ + 2 % ($C_2H_7NO{\cdot}CH_2O$ + H_3PO_4), F-4 – 30 % $NaClO_3$ + 2 % ($C_4H_6O_5{\cdot}CS(NH_2)_2$ + C_2H_7NO) и F-5 – 30 % $NaClO_3$ + 2 % ($C_6H_8O_7{\cdot}CS(NH_2)_2{\cdot}C_2H_7NO$). Дефолиационная активность данных составов изучалась в полевых опытах на хлопчатнике сорта «Султан,» возделываемом на полях фермерского хозяйства «Бектемирнурагро» Уртачирчикского района Ташкентской области. Эффективность дефолиации оценивали через 6 и 12 дней после применения препаратов по таким показателям, как опадение листьев, степень раскрытия коробочек, физиологическое состояние растений и готовность к механизированной уборке хлопка. На 12-й день дефолиации опадение листьев от применения данных препаратов составило 80,4-82,5 %, высыхание листьев – 5,0-6,5 %, а раскрытие коробочек – 89,4-91,4 %. Под действием дефолиантов листья опали в результате естественного процесса абсциссии, без усыхания и сильного некроза; фитотоксических повреждений на созревающих коробочках, а также высыхания стеблей и плодоножек коробочек не наблюдалось. Это подтверждает, что новые формуляции обладают высокой селективностью и оказывают физиологически «мягкое» воздействие на растение. Выявлено, что синергетическое взаимодействие данных компонентов позволяет ускорить процесс дефолиации, повысить биологическую активность препарата и снизить его негативное воздействие на окружающую среду. Практическая значимость исследования заключается в его вкладе в эффективную организацию механизированной уборки хлопка в хлопководстве Узбекистана, снижение потерь урожая, а также в создание относительно экологически безопасных и высокоэффективных отечественных препаратов-дефолиантов. Полученные

результаты служат важной научной основой для дальнейшей разработки высокоэффективных, экологически безопасных и экономически целесообразных дефолиантов нового поколения и их внедрения в практику хлопководства.

Keywords: sodium chlorate, thiocarbamide, monoethanolamine, formaldehyde, orthophosphoric acid, malic acid, citric acid.

Ключевые слова: хлорат натрия, тиокарбамид, моноэтаноламин, формальдегид, ортофосфорная кислота, яблочная кислота, лимонная кислота.

Introduction

Cotton is one of the most important fibrous crops in the world, having strategic importance for the textile industry and agricultural economy. Sustainable cultivation of this crop is an important component of the global system for producing non-food but highly economically valuable agricultural products. Despite the constant improvement of cotton cultivation technologies, environmental restrictions remain one of the main factors reducing its yield and fiber quality. In particular, abiotic stress factors such as drought, salinization, low and high temperatures, and heavy metal pollution disrupt physiological, biochemical, and molecular processes in the plant. As a result, photosynthetic activity declines, the metabolic balance is disrupted, vegetative and generative development is limited, and yields decrease while fiber quality deteriorates [1 – 3]. Therefore, one of the pressing challenges is the development of modern agricultural technologies that increase the efficiency of mechanized harvesting while preserving crop quality. One of the most important agrotechnical measures that ensures harvesting is completed in a short timeframe and with minimal losses is pre-harvest defoliation [4,5]. Defoliation promotes the timely shedding of leaves, reduces the contamination of cotton fiber with leaves and other plant debris, encourages the uniform opening of bolls, and increases the efficiency of mechanized harvesting. An ideal defoliant should have an effect that mimics the natural process of aging and leaf fall, and it must not negatively affect the plant's yield, fiber quality, or seed development. Therefore, creating a new generation of environmentally safe and selective defoliants with high biological efficacy is a priority in modern cotton cultivation. Currently, defoliants based on thidiazuron, dimethipin, sodium chlorate, and magnesium chlorate are widely used in cotton farming. They induce leaf drop by stimulating endogenous ethylene synthesis, limiting auxin transport, and accelerating the abscission process in the leaf's abscission zone [6 – 8]. However, the efficacy of these preparations is largely dependent on environmental conditions, especially temperature, as their biological activity decreases sharply at low temperatures [9,10]. Furthermore, traditional chlorate-based defoliants have insufficient physiological selectivity. In some cases, they cause not only the leaves but also the entire plant stem to dry out, and phytotoxic burns are observed on the still-immature bolls of the upper tier. This leads to reduced yields and a deterioration in the quality of the cotton fiber. Moreover, the chlorate defoliants used in practice mainly promote leaf abscission but do not possess properties that accelerate the maturation and opening of cotton bolls or provide additional protection against pests. In recent years, the mass proliferation of aphids (Aphididae) in cotton fields has become a pressing issue. In addition to weakening the plant, these pests contaminate the cotton fiber with a sweet liquid they secrete (honeydew), which significantly reduces the fiber's quality, its processing

efficiency, and the product's market value. Therefore, developing complex-action defoliants that accelerate leaf drop, ensure uniform boll opening, and provide additional pest protection is a key scientific and practical focus in modern cotton cultivation [11,12]. Recent studies show that incorporating organic and inorganic components into defoliant compositions significantly increases their biological efficacy. Specifically, malic acid (C4H6O5) and citric acid (C6H8O7) can enhance the defoliation process by regulating cellular metabolism and pH balance. Thiourea (CS (NH2)2) is known for its ability to modulate plant stress responses, activate their antioxidant defense system, and intensify physiological processes. Urea-formaldehyde condensate (UFC), as a slow-release nitrogen compound, can normalize nitrogen metabolism in plant tissues, prolong the retention time of active substances on the leaf surface, and improve the plant's uptake of the defoliant. Orthophosphoric acid (H3PO4) stimulates cellular physiological processes by activating phosphorus exchange and energy metabolism. It is known from the literature that by the end of the growing season—that is, before leaf fall—the cotton plant becomes saturated with organic acids. Therefore, including these acids in the defoliant's composition can enhance the efficiency of the defoliation process. Monoethanolamine, due to the presence of the – CH2 – CH2– group in its structure, possesses biological activity and plays an important role in redox processes, as well as in regulating protein metabolism and increasing the activity of enzyme systems [13 – 14]. Sodium chlorate (NaClO3) is a strong oxidizing agent and one of the main active components that induce leaf drop. A rational combination of these components provides the scientific basis for creating multifunctional defoliants that ensure rapid and uniform leaf shedding, synchronous boll opening, increased defoliation efficiency, and optimization of the mechanized harvesting process. In this context, the purpose of this study is to evaluate the effect of newly developed complex defoliant compositions—based on sodium chlorate, organic acids, thiourea, and orthophosphoric acid—on cotton leaf drop, boll opening, and mechanized harvesting efficiency, as well as to determine their potential as multifunctional defoliants in modern cotton cultivation.

Materials and Methods

All chemical reagents used in this study were selected in accordance with the requirements of interstate standards (GOST) and technical specifications (TU). Certified analytical-grade preparations were used in the study; their physicochemical characteristics are fully presented in Table 1.

Table 1.

Nomenclature, physicochemical properties, and quality parameters of the chemical reagents used in the study

№	Chemical name	Formula	Molar mass (g/mol)	GOST / TU	Purity grade
1	Sodium chlorate	$NaClO_3$	106,44	GOST 12257-93	Grade "B"
2	Thiourea	$CS(NH_2)_2$	76,12	GOST 6344-73	AG
3	Monoethanolamine	C_2H_7NO	61,08	TU 6-09-2447-91	AG
4	Formaldehyde	CH_2O	30,03	GOST 1625-89	Pure
5	Phosphoric acid	H_3PO_4	97,99	GOST 6552-80	AG
6	Malic acid	$C_4H_6O_5$	134,09	GOST 32748-2014	Pure

№	Chemical name	Formula	Molar mass (g/mol)	GOST / TU	Purity grade
7	Citric acid	$C_6H_8O_7$	192,12	GOST 3652-69	AG

Under laboratory conditions, five defoliant formulations were prepared based on synthesized supramolecular complexes with the following compositions: (F-1): 30 % $NaClO_3$ + 2 % ($CS(NH_2)_2$ + $C_2H_7NO{\cdot}CH_2O$); (F-2): 30 % $NaClO_3$ + 2 % ($C_2H_7NO{\cdot}CH_2O$); (F-3): 30 % $NaClO_3$ + 2 % ($C_2H_7NO{\cdot}CH_2O$ + H_3PO_4); (F-4): 30 % NaClO3 + 2 % ($C_4H_6O_5{\cdot}CS(NH_2)_2$ + C_2H_7NO); (F-5): 30 % $NaClO_3$ + 2 % ($C_6H_8O_7{\cdot}CS(NH_2)_2{\cdot}C_2H_7NO$). Working solutions were prepared by dissolving the formulations in 6.5 liters of distilled water, based on the established application rate per hectare. The plants were treated with the defoliant on August 27, 2025, 15 days prior to the mechanized harvesting of raw cotton.

Application methods for preparations and meteorological conditions

The prepared working solutions were applied to the leaves of the «Sultan» cotton variety using a standard ORPD-12M field sprayer with a pneumatic motor. The treatment was carried out by continuous spraying to ensure uniform and complete coverage of both sides of the leaf blade. The preparations were sprayed at a consistent intensity and under constant pressure. It was noted that during the defoliation period, the meteorological conditions were agronomically favorable for conducting the experiment. Throughout the observation period, the average air temperature was maintained between 25.0-30.0 °C, which prevented high-temperature stress. These meteorological conditions created an optimal environment for objectively assessing the physiological effects of the defoliants on plant tissues.

Methods for Conducting Phenological Observations and Assessing Defoliation Effectiveness

Phenological observations of the cotton plants' condition before and after treatment were conducted in accordance with the approved methodology developed by the PSUY Research Institute. Observations were carried out regularly on the 6th and 12th day after treatment.The effectiveness of the defoliant preparations was quantitatively assessed based on two main indicators:— the degree of defoliation effectiveness — determined by the percentage (%) of leaves that had naturally fallen from the plant;— the degree of «harshness» of the preparations' action — assessed by the percentage (%) of leaves that dried out due to the defoliant but did not fall off. The obtained quantitative data were processed using standard methods of variational-statistical analysis and compared with the indicators of the control group. The experiment for each variant was replicated at least three times, and the results were presented as the arithmetic mean ± standard deviation (M ± SD).

Results and Discussion

The effectiveness of defoliation was assessed by the degree of leaf drop and the rate of boll opening. A defoliant based on liquid magnesium chlorate, applied at a rate of 8.0 L/ha, was used as the standard control. The results obtained during the study made it possible to determine the

comparative effectiveness of various defoliants on the «Sultan» cotton cultivar. The effect of the defoliants on accelerating leaf drop, as well as on the maturation and opening of bolls, was evaluated, with the results presented in Table 2.

Table 2.

Comparative Efficacy of Defoliants on the 'Sultan' Cotton Cultivar

№	Experience	Application rate: 1 L/ha + 1 kg/ha.	Defoliation percentage on day 6 post-treatment			Defoliation activity 12 days after treatment, %		
			Fallen leaf	Withered leaf	An open box	Fallen leaf	Withered leaf	An open box
1	30%$NaClO_3$+2%($CS(NH_2)_2$ C_2H_7NO CH_2O)	6.5	67.0	10.5	82.5	81.2	5.0	89.4
2	30%$NaClO_3$+2% (C_2H_7NO CH_2O)	6.5	66.8	11.4	83.0	82.5	6.0	90.0
3	30%$NaClO_3$+2% (C_2H_7NO CH_2O(H_3PO_4 pH=6))	6.5	65.9	11.0	85.4	82.3	6.5	90.4
4	30%$NaClO_3$+2% ($C_4H_6O_5$ $CS(NH_2)_2$ (C_2H_7NO pH=6)	6.5	67.4	10.8	87.2	82.2	6.4	89.8
5	30%$NaClO_3$+2% ($C_6H_8O_7$ $CS(NH_2)_2$ C_2H_7NO)	6.5	66.5	11.0	88.3	80.4	5.5	91.4
6	Standard XMD (reference)	8.0	63.75	13.60	70.20	79.8	9.20	81.3

An evaluation of experimental defoliant formulas applied at a rate of 6.5 L/ha showed that all tested formulations possessed high biological activity, stimulating leaf drop and boll opening within 12 days of application. However, the degree of their effect varied depending on the composition of the formulas.

A formula containing 30 % NaClO3 + 2 % (CS(NH2)2 + C2H7NO·CH2O) resulted in 81.2 % leaf drop, 5.0 % leaf desiccation, and 89.4 % boll opening. These results indicate that this formula effectively accelerates the process of leaf drop and ensures sufficient boll opening in the 'Sultan' cotton variety. Application of the composition with the formula 30 % NaClO3 + 2 % (C2H7NO·CH2O) resulted in leaf fall of 82.5 %, leaf desiccation of 6.0 %, and boll opening of 90.0 %. Compared to the previous formula, a slight improvement in defoliation and boll opening efficiency was observed, indicating a positive effect on crop maturation before harvesting.Similarly, the composition with the formula 30 % NaClO3 + 2 % (C2H7NO·CH2O + H3PO4) provided 82.3 % leaf fall, 6.5 % leaf desiccation, and 90.4 % boll opening. While maintaining high defoliation efficiency, the addition of phosphoric acid slightly improved boll opening compared to the composition containing formaldehyde. The formulation containing 30 % NaClO3 + 2 % (C4H6O5·CS(NH2)2 + C2H7NO) resulted in 82.2 % leaf defoliation, 6.4 % leaf desiccation, and 89.8 % boll opening. Although its overall performance was comparable to that of the preceding formulations, the percentage of boll opening was slightly lower, indicating that the compositional modifications did not lead to a significant improvement in biological activity. Among all the formulation containing 30 % NaClO3 + 2 % (C6H8O7· CS(NH2)2 · C2H7NO) achieved the

highest boll opening rate (91.4 %), while leaf defoliation and leaf desiccation reached 80.4 % and 5.5 %, respectively. Although the level of leaf defoliation was slightly lower than that observed for some other formulations, the superior boll opening indicates that this composition more effectively promoted reproductive maturation and improved crop readiness for mechanical harvesting.

Conclusion

Field experiments conducted in 2025 on the cotton cultivar “Sultan” at the Bektemirnuragro farm in the Urta chirchik District, Tashkent Region , evaluated the biological efficacy of five newly developed defoliant formulations (F-1-F-5) based on 30% $NaClO_3$. The results demonstrated that all formulations exhibited high defoliation activity, effectively promoting leaf abscission and boll opening. Leaf abscission ranged from 80.4-82.5%, leaf desiccation from 5.0-6.5%, and boll opening from 89.4 – 91.4%. Under the influence of the defoliants, leaf shedding occurred through the natural process of abscission without pronounced wilting or severe necrosis. No signs of phytotoxic damage were observed in the maturing bolls, nor was any drying of stems or boll peduncles detected. These results confirm the high selectivity of the newly developed formulations and indicate their physiologically gentle effect on cotton plants. Furthermore, during the trials, a significant reduction in pest population was observed, indicating that these formulations may possess additional protective properties alongside their ability to stimulate defoliation and boll opening. Overall, the newly developed complex defoliant formulations based on 30% $NaClO_3$ demonstrated high biological efficacy in preparing cotton plants for harvest and can be recommended as promising agents for improving the efficiency of mechanized harvesting.

References

1. Pettigrew W.T. (2002).Improved yield potential with an early planting cotton production system. Agronomy Journal,94(5), 997–1003 – URL: https://doi.org/. (accessed 07.08.2026)
2. Hussain M, Gao X, Qin D, Qin X, Wu G. Role of Biotic and Abiotic Factors for Sustainable Cotton Production. In: Gürsoy S, Akın S, editors. Best Crop Management and Processing Practices for Sustainable Cotton Production. London, United Kingdom: IntechOpen; 2023. P. 69–92 – URL: https://doi.org/. (accessed 07.08.2026)
3. Rihan HZ, Al-Issawi M, Fuller MP. Advances in physiological and molecular aspects of plant cold tolerance. Journal of Plant Interactions. 2017;12(1):143–157 – URL: https://doi.org/. (accessed 07.08.2026)
4. Meng L, Zhang L, Qi H, Du M, Zuo Y, Zhang M, Tian X, Li Z. Optimizing the application of a new harvesting aid to improve mechanically harvested cotton quality in the North China Plain. Journal of Integrative Agriculture. 2021;20(11):2892–2899 – URL: https://doi.org/63555-8. (accessed 07.08.2026)
5. Yu K, Li K, Wang J, Gong Z, Liang Y, Yang M, et al. Optimizing the ratio of thidiazuron and ethephon combinations to improve the efficiency of cotton harvest aids. Industrial Crops and Products. 2023;191:115949 – URL: https://doi.org/. (accessed 07.08.2026)

6. Du M, Li Y, Tian X, Duan L, Zhang M, Tan W, Xu D, Li Z, Zhang J. Phytotoxin coronatine induces abscission-related gene expression and cotton boll ripening during cotton defoliation. PLoS ONE. 2014;9(5):e97652 – URL: https://doi.org/. (accessed 07.08.2026)
7. Li F, Wu Q, Liao B, Yu K, Huo Y, Meng L, Wang S, Wang B, Du M, Tian X, Li Z. Thidiazuron promotes leaf abscission by regulating the crosstalk among ethylene, auxin, and cytokinin in cotton. International Journal of Molecular Sciences. 2022;23(5):2696 – URL: https://doi.org/. (accessed 07.08.2026)
8. Jin D, Wang X, Xu Y, Gui H, Zhang H, Dong Q, Sikder RK, Yang G, Song M. Chemical defoliant promotes leaf abscission by altering ROS metabolism and photosynthetic efficiency in Gossypium hirsutum. International Journal of Molecular Sciences. 2020;21(8):2738 – URL: https://doi.org/. (accessed 07.08.2026)
9. Wright SD, Hutmacher RB, Shrestha A, Banuelos G, Rios S, Hutmacher K, Munk DS, Keeley MP. Effects of early defoliation on boll opening, yield, and fiber quality of California Pima cotton. Journal of Crop Improvement. 2015;29(5):528–541 – URL: https://doi.org/. (accessed 07.08.2026)
10. Song X, Zhang L, Zhao W, Xu D, Eneji AE, Zhang X, Han H, Cao L, Zhang W, Lu Z, Huang X, Wang H, Xu D, Luo Z, Chen H, Zhang L, Du M, Tian X, Li Z. Relationship between cotton stem retention and leaf abscission at the field production site level. Crop Science. 2022;62(3): 1333–1347 – URL: https://doi.org/. (accessed 07.08.2026)
11. Ochilov R, Boltaev B. Advanced methods of protecting cotton from sucking insect pests. Uzbekistan Agriculture. Tashkent, Uzbekistan. 2010;(3):4.
12. Belan SR, Grapov AF, Melnikova GM. New Pesticides: Reference Book. Moscow, Russia: [Publisher]; 2001. 196 P.
13. Zubkova NF, Nadotchaia OG, Stonov LD. Defoliants as antagonists of IAA and stimulators of ethylene formation. Chemistry in Agriculture. 1975;13(8):32–35.
14. Nickell LG. Plant Growth Regulators. Moscow, Russia: Kolos; 1984. 191 p.