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EFFECTIVENESS OF VERMICOMPOST AND CHLORELLA APPLICATION IN TOMATO CULTIVATION UNDER THE CONDITIONS OF KARAKALPAKSTAN

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Abstract. The effects of vermicompost and *Chlorella vulgaris*-based biological nutrition on fruit formation of the released tomato cultivar TMK-22 were evaluated under the soil and climatic conditions of the Republic of Karakalpakstan. Plants established by direct seeding and transplanting were compared in a field experiment with four treatments: chlorella, vermicompost, chlorella + vermicompost, and an unfertilized control, arranged in three replications. Fifteen sample plants per treatment were used to record phenological stages and the total, ripe, and unripe fruit number per plant. The transplanted vermicompost treatment produced 29 fruits per plant, 26.1% more than the control. The chlorella and combined treatments each produced 28 fruits per transplanted plant, compared with 23 fruits in the control. Organic and biological nutrition promoted continued fruit set; consequently, a proportion of newly formed fruit remained unripe at the final observation. The findings indicate that vermicompost application in transplanted TMK-22 tomato is a promising approach to increasing fruit number under Karakalpakstan conditions.

Keywords: tomato; *Solanum lycopersicum* L.; TMK-22; vermicompost; chlorella; organic fertilizer; transplanting; fruit set; Karakalpakstan.

Annotatsiya. Tadqiqotda Qoraqalpog'iston Respublikasining tuproq-iqlim sharoitida rayonlashtirilgan TMK-22 pomidor navini urug'dan va ko'chat usulida yetishtirishda biogumus hamda *Chlorella vulgaris* asosidagi biologik oziqlantirishning meva elementlari shakllanishiga ta'siri baholandi. Dala tajribasi to'rtta variantda: xlorella, biogumus, xlorella + biogumus va o'g'itsiz nazoratda, uch takrorlanishda olib borildi. Har bir variantda 15 tadan hisob o'simligi ajratilib, fenologik fazalar va bir tupdagi umumiy, pishgan hamda pishmagan mevalar soni aniqlandi. Biogumus qo'llanilgan ko'chat variantida bir tupdagi umumiy mevalar soni 29 donaga yetib, nazoratdan 26,1% yuqori bo'ldi. Xlorella qo'llanilganda ko'chat usulida 28 dona, xlorella va biogumus birgalikda qo'llanilganda 28 dona meva shakllandi; nazoratda esa 23 dona qayd etildi. Organik va biologik oziqlantirish meva tugish faolligini oshirgan, biroq kuzatuv yakunida yosh mevalarning bir qismi hali to'liq pishmaganligi sababli pishgan mevalar ulushi nazoratdagidan past bo'lgan. Natijalar TMK-22 navini ko'chat usulida yetishtirishda biogumudan foydalanish meva sonini oshirishning istiqbolli usuli ekanini ko'rsatdi.

Kalit so'zlar: pomidor; *Solanum lycopersicum* L.; TMK-22; biogumus; xlorella; organik o'g'it; ko'chat; meva tugishi; Qoraqalpog'iston.



Аннотация. В исследовании оценено влияние биогуруса и биологической подкормки на основе *Chlorella vulgaris* на формирование плодов районированного сорта томата ТМК-22 при выращивании из семян и рассадным способом в почвенно-климатических условиях Республики Каракалпакстан. Полевой опыт проводили в трех повторностях по четырем вариантам: хлорелла, биогурус, хлорелла + биогурус и контроль без удобрений. В каждом варианте выделяли 15 учетных растений и определяли фенологические фазы, общее количество, число созревших и незрелых плодов на растении. В рассадном варианте с биогурусом сформировалось 29 плодов на растение, что на 26,1% превышало контроль. При применении хлореллы и совместном применении хлореллы с биогурусом получено по 28 плодов, тогда как в контроле — 23. Органическое и биологическое питание усилило плодообразование, но к окончанию наблюдений часть молодых плодов еще не достигла полной зрелости. Результаты показывают перспективность применения биогуруса при рассадном выращивании сорта ТМК-22.

Ключевые слова: томат; *Solanum lycopersicum* L.; ТМК-22; биогурус; хлорелла; органическое удобрение; рассада; плодообразование; Каракалпакстан.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop for food security, the processing industry, and household incomes. Its productivity depends not only on the biological characteristics of the cultivar but also on soil fertility, temperature, irrigation regime, and plant nutrition. Under the sharply continental and arid climate of the Republic of Karakalpakstan, high temperatures, low air humidity, limited irrigation water, and soil salinity may adversely affect root activity, flowering, and fruit set in tomato.

Under these conditions, simply increasing the rate of mineral fertilizers cannot provide a sustainable solution. In soils with low organic-matter content, biologically active organic products can help improve soil physical properties and nutrient cycling. Vermicompost is regarded as a source of plant-available nutrients, humic compounds, and beneficial microorganisms. *Chlorella*-based products are used as biostimulants because they contain amino acids, pigments, and biologically active metabolites [1–4]. ТМК-22 is a locally released tomato cultivar grown in Karakalpakstan, and evaluating its response to organic and biological nutrition under field conditions is of practical importance. This study aimed to determine the effects of vermicompost, *chlorella*, and their combined application on phenological development and fruit formation in ТМК-22 tomato established by direct seeding and transplanting.

LITERATURE REVIEW

The effectiveness of vermicompost is attributed to its stable organic matter, macro- and micronutrients, humic acids, and microbial activity. In a greenhouse study, Wang et al. demonstrated that vermicompost improved tomato yield and quality as well as selected biochemical properties of the soil [1]. Subsequent studies have shown that the response to vermicompost depends on soil moisture, cropping history, and salinity level [2, 5, 6]. This relationship is particularly relevant to Karakalpakstan, where water scarcity and soil salinity often occur simultaneously.



Microalgae are used in agriculture as biofertilizers and biostimulants and may promote root development, nutrient uptake, and plant responses to abiotic stress. Renuka et al. reviewed the multifunctional potential of microalgal biomass for crop production [7]. Ronga et al. analyzed the effects of microalgae- and cyanobacteria-based products on plant growth and productivity [8]. Experiments involving *Chlorella vulgaris* in organic tomato production have also reported improvements in plant growth, yield, and selected fruit-quality traits [3, 9].

The effects of organic fertilizers and biostimulants vary with application rate and timing, soil conditions, cultivar, and water regime. Therefore, findings obtained elsewhere should be verified in replicated field experiments before being transferred directly to local production. In addition, an increase in total fruit number does not necessarily result in a higher percentage of ripe fruit at a particular observation date: if fruit set continues, the number of young fruit also increases. Total, ripe, and unripe fruit numbers should therefore be analyzed together to interpret biological responses correctly.

RESEARCH METHODOLOGY

The study was conducted in the open field at the Karakalpakstan Scientific Experimental Station using the released tomato cultivar TMK-22. The experiment comprised four treatments arranged in three replications: (1) chlorella, (2) vermicompost, (3) chlorella + vermicompost, and (4) an unfertilized control. Within each treatment, tomato establishment by direct seeding was compared with establishment using nursery-grown transplants. All treatments received the same agronomic operations at the same time and under comparable conditions.

Phenological observations were made on 15 sample plants in each treatment. The number of days to emergence, appearance of the first 1–2 true leaves, formation of lateral shoots, flowering, fruit set, and fruit ripening was recorded. To evaluate fruit formation, the total number of fruit per plant and the numbers of ripe and unripe fruit were counted. The percentage of each category was calculated by dividing the number of fruit in that category by the total fruit number and multiplying by 100.

The field experiment, observations, and synthesis of results followed established methodologies for vegetable and field experiments [10–12]. Values presented in the tables are means across three replications. Percentage differences relative to the control were calculated as $(\text{treatment} - \text{control}) / \text{control} \times 100$. Because the primary dataset did not include analysis of variance, standard errors, or LSD05 values, differences are interpreted in this paper as biological trends; no claim of statistical significance is made.

ANALYSIS AND RESULTS

Phenological development of tomato plants. Emergence occurred mainly 8 days after direct seeding and after 7 days in the transplant treatments. The first 1–2 true leaves appeared after 14 days in directly seeded plants and after approximately 12 days in transplanted plants. Depending on the treatment, flowering occurred after 50–52 days, fruit set after 65–73 days, and fruit ripening after 102–110 days. Field emergence of directly sown seed ranged from 75 to 85%.

Table 1. Duration of the phenological development stages of tomato plants, days



Establishment method	Emergence	First 1–2 true leaves	Lateral shoot formation	Flowering	Fruit set	Ripening
Direct seeding	8	14	35–37	50–52	70–73	102–110
Transplanting	7	12	35–36	50–52	65–68	104–108

Note: values are presented as the minimum–maximum range observed across the treatments.

The occurrence of the initial developmental stages 1–2 days earlier in the transplant treatments can be explained by the ability of plants with established roots and leaves to resume growth rapidly after field establishment. Differences in ripening time depended not only on the establishment method but also on the treatment and the development of individual plants. The phenological data provide the biological context required for interpreting fruit number.

Effects of organic fertilizers on fruit formation. The clearest difference among treatments was observed in the total number of fruit per plant. In the vermicompost treatment, directly seeded and transplanted plants produced 27 and 29 fruit per plant, respectively. The corresponding values in the control were 22 and 23 fruit per plant (Table 2).

Table 2. Effects of organic and biological nutrition on tomato fruit formation

Treatment	Establishment method	Total fruit, no.	Ripe fruit, no.	Ripe fruit, %	Unripe fruit, no.	Unripe fruit, %
Chlorella	Direct seeding	26	20	76.92	6	23.08
Chlorella	Transplanting	28	19	67.86	9	32.14
Vermicompost	Direct seeding	27	20	74.07	7	25.93
Vermicompost	Transplanting	29	21	72.41	8	27.59
Chlorella + vermicompost	Direct seeding	27	20	74.07	7	25.93
Chlorella + vermicompost	Transplanting	28	21	75.00	7	25.00
Control	Direct seeding	22	20	90.91	2	9.09
Control	Transplanting	23	19	82.61	4	17.39

In the chlorella treatment, the total fruit number exceeded the control by 18.2% in directly seeded plants and by 21.7% in transplanted plants. The corresponding advantages of the vermicompost treatment were 22.7 and 26.1%. When chlorella and vermicompost were applied together, fruit number exceeded the control by 22.7% under direct seeding and by 21.7% under transplanting. The highest numerical value was recorded in the transplanted vermicompost treatment.



The highest number of ripe fruit, 21 per plant, was recorded in the transplanted vermicompost and chlorella + vermicompost treatments. Nineteen ripe fruit per plant were observed in both the transplanted chlorella treatment and the transplanted control. The proportion of ripe fruit was higher in the control, reaching 90.91% under direct seeding and 82.61% under transplanting. In the fertilized treatments, this proportion ranged from 67.86 to 76.92%.

When interpreting these results, absolute fruit number must be distinguished from relative proportion. Organic nutrition increased the total number of fruit, but some newly formed fruit had not ripened by the final observation. Therefore, the lower proportion of ripe fruit may indicate continued generative activity rather than weak yield formation. Confirmation of this interpretation requires recording production over several harvests and determining total and marketable yield in t ha⁻¹.

The stronger numerical response to vermicompost in transplanted plants may be associated with two complementary factors. First, transplants already had established root systems and true leaves when they were planted in the field. Second, vermicompost may improve soil water-holding capacity, nutrient availability, and microbial activity [1, 2, 5]. Because these mechanisms were not measured directly in the present experiment, they should be regarded as literature-based interpretations rather than causal conclusions.

The combination of chlorella and vermicompost did not outperform vermicompost applied alone. This does not demonstrate that the combination was ineffective, because the experiment did not include separate gradients of application rate and timing. Plant responses to biostimulants depend on concentration, application method, developmental stage, and environmental conditions [7–9]. Future experiments should test several chlorella concentrations and vermicompost rates in a factorial design.

Study limitations. The primary dataset did not include fruit mass, marketable yield, mean fruit weight, soil chemical and salinity parameters, irrigation rate, or measures of experimental error. The results therefore demonstrate effects of vermicompost and chlorella on fruit number but do not conclusively establish that either treatment increased yield in t ha⁻¹. Future reports should provide analysis of variance, standard errors, LSD05, and p-values for each treatment.

SCIENTIFIC AND PRACTICAL SIGNIFICANCE OF THE RESULTS

The findings provide initial scientific evidence for comparing organic and biological nutrition products on a locally grown tomato cultivar under the challenging soil and climatic conditions of Karakalpakstan. Simultaneous comparison of establishment methods and nutrition treatments made it possible to identify the combined response of transplanting and vermicompost. The highest total fruit number in the transplanted vermicompost treatment indicates that this treatment should be prioritized for evaluation in the next stage of research.

From a practical perspective, vermicompost should not be regarded as a complete replacement for mineral nutrition but as a component that supports soil organic matter and biological activity. If the application rate is not aligned with soil-test results, crop nutrient requirements, and water availability, costs may increase or



plants may develop excessive vegetative growth. A production recommendation should therefore address the economic efficiency of vermicompost, fruit quality, and its balance with mineral fertilizers.

When *Chlorella*-based products are used, viable-cell concentration, shelf life, and application method should be standardized. Future experiments should evaluate foliar spraying and soil drenching separately and compare application at different phenological stages. These measures would distinguish the independent effect of *chlorella* from its effect on a vermicompost background and support development of a reproducible production protocol.

CONCLUSION AND RECOMMENDATIONS

1. Under Karakalpakstan conditions, differences associated with the establishment method were observed in the phenological development of TMK-22 tomato: emergence occurred after 8 days under direct seeding and after 7 days under transplanting, whereas the first 1–2 true leaves appeared after 14 and 12 days, respectively.
2. The transplanted vermicompost treatment produced 29 fruit per plant, the highest value recorded in the experiment and 26.1% more than the control.
3. In the transplanted *chlorella* and *chlorella* + vermicompost treatments, 28 fruit per plant were formed, representing a 21.7% increase over the 23 fruit recorded in the control.
4. The relatively low proportion of ripe fruit in the fertilized treatments may be associated with continued fruit set and the presence of young fruit at the final observation.
5. Before recommendations are made for commercial production, the experiment should be repeated for at least two growing seasons; yield should be measured in t ha⁻¹ together with mean fruit weight, marketability, and quality, and the data should be evaluated using ANOVA and LSD05.
6. Future research should evaluate vermicompost rates, *chlorella* concentrations, and application timing in a factorial experiment and should regularly record soil EC and pH as well as irrigation-water inputs.

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