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MDMV INFLUENCE ON THE PRODUCTIVITY OF MAIZE (*ZEA MAYS* L.)

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SUMMARY

Currently, about 50 known phytopathogenic viruses infect maize worldwide; however, the maize dwarf mosaic virus (MDMV) is the most common. Studies on the effects of MDMV have progressed in the experimental fields of the Chirchik State Pedagogical University, Tashkent, Uzbekistan. In the latest research, seven different maize (*Zea mays* L.) cultivars received mechanical inoculation of viral sap. After infection, symptoms of a viral disease appeared 4–5 days later. A specific anti-serum, obtained by immunological method, served to diagnose the MDMV. The virus infection rate in 2020 was 47%, but in 2023, after using the developed control measures, it was 23%. Different maize genotypes, selected for the study, came from the genetic bank of the Scientific Research Institute of Plant Genetic Resources. According to the results, under the influence of MDMV, the number of cobs reduced by 50%, the length of cob decreased by 43.21%, the number of grains per cob decreased by 30.43%, and 1000-grain weight declined by 28.6%. In maize healthy genotypes, the average protein content was 3.5%, while in infected samples the said ratio was 2.5% and that decreased by 1.00%.

Keywords: Maize (*Zea mays* L.), cultivars, maize dwarf mosaic virus (MDMV), distribution, phytoviruses, yield-related traits, productivity, plant diseases

Key findings: The results revealed considerable effects of MDMV on yield-related traits and productivity of different maize (*Z. mays* L.) genotypes.

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INTRODUCTION

Maize (*Zea mays* L.) is a primary cereal crop and ranks third behind rice and wheat in production. Its production has an average of 380 million tons annually in 53 countries. Maize is the most widely grown crop, ranging from tropical areas with altitudes over 3000 m to temperate areas extending as far North as the 65th latitude. The maize crop is often prone to phytopathogenic viruses, causing massive damage to the biomass and affecting the quantity and quality of the maize. At present, more than 50 maize viruses have been prominent. However, the most common is the maize dwarf mosaic virus—maize dwarf mosaic potyvirus (Sobirova and Fayziev, 2020; Lukuyu *et al*., 2022).

In studying the effects of viruses on the plant photosynthetic apparatus, it was evident that chlorophyll a and b and carotenoid contents decreased by 50%, 40%, and 30%, respectively (Fayziev *et al*., 2020; Sobirova and Fayziev, 2021). The results also confirmed that in infected maize plants, the peroxidase associated with the cell membrane appeared more active than in control plants. It proves that contaminated maize plants were in a stressful situation due to the virus. The RT-PCR method is a widely used diagnostics tool to identify the virus species affiliation. The PCR proceeded based on the virus coat protein (CP) gene (Sobirova *et al*., 2023; Sobirova and Fayziev, 2023).

Phytopathogenic viruses reduce the productivity and quality of grain crops, including maize, and sometimes cause complete plant death (Sobirova *et al*., 2023). In most cases, the viral infection of maize slows down the growth, causing dwarfism of the plants, and eventually sharply decreasing productivity of green mass and grain yield (Sobirova *et al*., 2020). The MDMV infestation results in deformed leaves and stems, negatively affecting the production. With the viral infection, the crop damage occurs mostly at the growing points, impairing the photosynthesis and limiting the overall growth and development. Plants infection by viruses causes physiological disturbances responsible for managing plant diseases and agronomic traits in various crops (Nicaise, 2014).

Viral infections can lead to various variations in plant physiology and development. Infected maize plants may experience reduced growth and maturity, which may result in a decreased number of cobs per plant, including limited cob progress and improvement, formation of underdeveloped cobs, and even complete absence of cobs. It can lead to a significant variation in grain quantity and quality in infected plants. Viral infections could also possibly reduce the likelihood of grains fertilizing and cause grains to abort, reducing the total number of grains per plant. By integrating these various aspects, this study provides valuable insight into the complex mechanisms underlying virus-induced symptoms in plants and highlights the urgency of controlling viral diseases to achieve sustainable agriculture and food production (Jiang and Zhou, 2023).

Relevant to this problem, the authors conducted numerous studies and determined the effects of MDMV on the productivity and quality of various maize genotypes' yield structure (Sobirova and Fayziev, 2020, 2021, 2023; Sobirova *et al*., 2020, 2023). The effects of phytoviruses on maize cob length, grain quantity, and quality may vary depending on the specific maize genotype and virus type. However, in general, phytoviruses can negatively affect all aspects of maize yield formation. Almost all the viral diseases exhibited a decrease in the total carbohydrate content (Handford and Carr, 2007). As a result, plant wilting, a slowdown in the outflow of assimilates from the leaves, and the appearance of necrosis on the vegetative parts were visible (Gupta *et al*., 2021). Insufficient accumulation of energy and nutrient reserves due to viral infections can lead to decreased grain yield. It causes considerable variations in grain weight on infected plants, and some plants may produce seeds with insufficient size or even fail to produce seeds. Infected maize plants suffer from stunted growth, reducing yields by 7% to 43%.

The grain quality also affects the total yield structure. The quality of grains depends on its composition like protein and starch content. MDMV also modifies the maize grain quality, causing its deformation, size reduction, and variation in nutritional composition. For example, the maize plants infected with the virus have a decrease in the grain's starch and protein content, which, in turn, alter the maize quality as a food and feed product. Past studies determined the effects of the virus on grain quality by using the Lowry method, and the grain protein content in different maize cultivars appeared significantly reduced in infected samples compared to the control (Sobirova *et al*., 2023).

Such variations in crop plants can significantly change the maize yield and lead to unpredictability in the yield quantity and quality in infested areas. It highlights the importance of controlling viral infections and using the breeding of maize cultivars that hold higher resistance to viruses and maintain yield levels even when exposed to harmful phytoviruses. Currently, the available measures have shown to be effective in containing the spread of MDMV disease, as evidenced by the rare MDMV infection in field maize (Kannan *et al*., 2018). Control of MDMV in maize fields includes using treated seeds to protect against viruses, healthy seeds of plants without the virus infection, and management practices for pests that can spread viruses, such as insect vectors. Therefore, it is also vital to conduct regular surveys of fields for the presence of viral infections and take necessary measures to control the spread of viral diseases. The presented research sought to study the effects of MDMV on the seven maize cultivars (mechanically inoculated with viral sap) for growth and yield-related traits under field conditions at the Chirchik State Pedagogical University, Tashkent, Uzbekistan.

MATERIALS AND METHODS

The latest research comprised selected seven different maize cultivars, mechanically inoculated with viral sap and studied for the effects of MDMV on growth and yield-related traits under field conditions at the Chirchik State Pedagogical University, Tashkent, Uzbekistan. After infection, symptoms of the viral disease appeared 4–5 days later. The observations about the infection employed an immunological method. During the field experiment, monitoring the development of infected maize plants progressed. Infected maize plants developed the viral symptoms and were considerably different in growth and improvement from the genotypes' control group.

Determining the maize crop structure began before the harvest of plants fixed to observe the phases of their development. Harvesting continued during the period of ripeness of the cobs, with the following parameters determined: the number of cobs on each plant, the cob length, the number of grains per cob, and 1000-grain weight. The recording of data was on a single plant basis and then averaged for the productivity parameters in various maize genotypes.

The grains determined the crop structure by collecting maize samples in the waxy ripeness phase and beyond. In this case, the specific methods used determined plant density and the number of productive plants per 100 m^2. Then, the samples of 25 plants of various maize cultivars remained fixed for observations (five each per replication). From the plants' main stems, collection of all cobs ensued, having previously recording the number of productive cobs on the main stem of each plant. Separately bagging cobs from each replication continued, indicating the replication number. Later, cob threshing followed to obtain the grains' weight. After weighing, the grains from all replications reached mixing to determine the moisture content and 1000-grain weight. These all post-harvesting operations progressed equally for all the maize genotypes. Determining the ultimate results on crop structure and average productivity of a cob required the 1000-grain weight (Tseluiko and Medvedeva, 2015).

Additionally, detecting the effects of MDMV on the grain quality of various maize cultivars used the Lowry method (Evselyeva *et al*., 2012). The Lowry method determined the amount of protein in maize grain, which is an effective method for assessing grain quality and its variations under the influence of viral infections. The Lowry method is a classic protein analysis method based on the reaction of phenol with amino acids found in proteins (Sapan *et al*., 1999). By determining the protein content in maize grains in infected and control maize samples, the study obtained information about the virus' effects on grain quality. If a viral infection leads to a decrease in protein content, it may indicate a negative effect of the virus on the nutritional value of grains. In overcoming the biotic stress caused by virus infections, plants produce various types of secondary metabolites, which are crucial in protecting plants from virus infections (Mishra *et al*., 2020).

The research had the proteins isolated from the plant kernels belonging to seven different maize cultivars. The isolation of proteins from maize grains continued as follows: 1 g of grains of each maize cultivar ground to flour using a homogenizer and defatted with acetone in a ratio of 10:1 for an hour at room temperature; homogenate filtered and the remaining extract in the filter dried for 24 h; the dry defatted homogenate extracted in 0.2 M NaOH (10:1) at room temperature for 2 h with stirring; then, the extract centrifuged at 4500 rpm for 30 min, the sediment dialyzed with distilled water for 12 h; after dialysis, the total protein content of each maize cultivar determined using the Lowry method (Sapan *et al*., 1999).

Lowry's method employed staining aromatic amino acids in the detected protein with the Folin's reagent. Determining the content of proteins with the Lowry method required using 0.5 ml of the test solution. After adding the 2.5 ml of reagent into the solution, the mixture remained untouched for 10 min. Then, after pouring 0.25 ml of the reagent into the reaction mixture, it stood in the dark for 30 min with constant stirring. After the completed reaction, the mixture's color level determination engaged a spectrophotometer at a wavelength of 700 nm. The obtained results underwent calculations using a unique formula. The obtained data incurred statistical analysis to determine the significance of the differences between the infected and control samples. It further allows researchers to draw conclusions about the effect of viral infections on the yield parameters and grain protein content in maize genotypes with a high degree of confidence.

RESULTS

From the research results, it was clear that the productivity of maize cultivars infected with MDMV significantly lagged the control samples (Figure 1). The results of control samples showed each maize plant formed almost two cobs (1.97). Meanwhile, infected plant samples for each plant had 1.14 cobs, which was 1.72 times lesser than healthy maize plants (Table 1). In 50% of the infected plants, only created one cob on average. By comparing the length of the cob, on average in control plots, the cob length was 25.3 cm; however, the said length was shortest in infected plants (14.37 cm), revealing a decrease of 2.22 times.

Parameters' measurement, such as, the number of grains and grain weight per cob, ensued, which play a vital role in determining the productivity. On average, the number of grains per cob in the control samples was 370 grains, and in infected samples, the said value was 257 grains (Table 2). One can also see that, on average, the 1000-grain weight in the control maize sample was 359.28 g, while in infected samples, the said value was 249.85 g. It revealed the grain decrease by 1.44 times due to the virus' influence. By comparing the different maize cultivars, the control and infected plants of maize cultivars Sherzod and Hickax have slight differences in these parameters. However, the control and infected plants of the cultivars Osnova-209 and 205-2 have broad differences. The reason could be that cultivars Sherzod and Hickax were more resistant to viral infections as compared to the cultivars Osnova-209 and 205-2 (Table 2).

Additionally, acquiring the effects of MDMV on the number of grains per cob and the 1000-grain weight continued. The results showed that the MDMV infection significantly affected the number of grains per cob and the 1000-grain weight. Overall, the results provided a considerable decrease in the

Table 1. Definitions of the influence of MDMV on the maize productivity.

Cultivars' catalog number	Name of cultivars	Plants (#)	Number of cobs (pcs.), and cob length (cm)					
			Control	Average reading	Experimental	Average reading	Control	Experimental
NS13866	Osnova 209	25	45±0.02	1.8	24±0.002	0.96	24.6±0.05	12±0.002
NS16695	Extra Early Dightau209	25	49±0.01*	1.96	29±0.009	1.16	22±0.08	16.5±0.003
NS17641	San Pedro LATA	25	48±0.06	1.92	27±0.005	1.08	23.5±0.09	12.5±0.007
NS17646	Sherzod	25	58±0.08	2.32	38±0.006*	1.52	28±0.04	19±0.006
NS24935	Hickax	25	53±0.06	2.12	32±0.004	1.28	25.5±0.04	11.3±0.001
NS25033	205-2	25	44±0.04	1.76	22±0.005	0.88	27±0.06	10.8±0.004
NS25897	San Pedro2 IMTA	25	47±0.08	1.88	28±0.008	1.12	26.5±0.09	18.5±0.008
Average indication		25	49.14±0.06	1.99	28.57±0.04	1.04	25.3±0.06	14.37±0.003

*($P \leq 0.001$): Significant compared to control

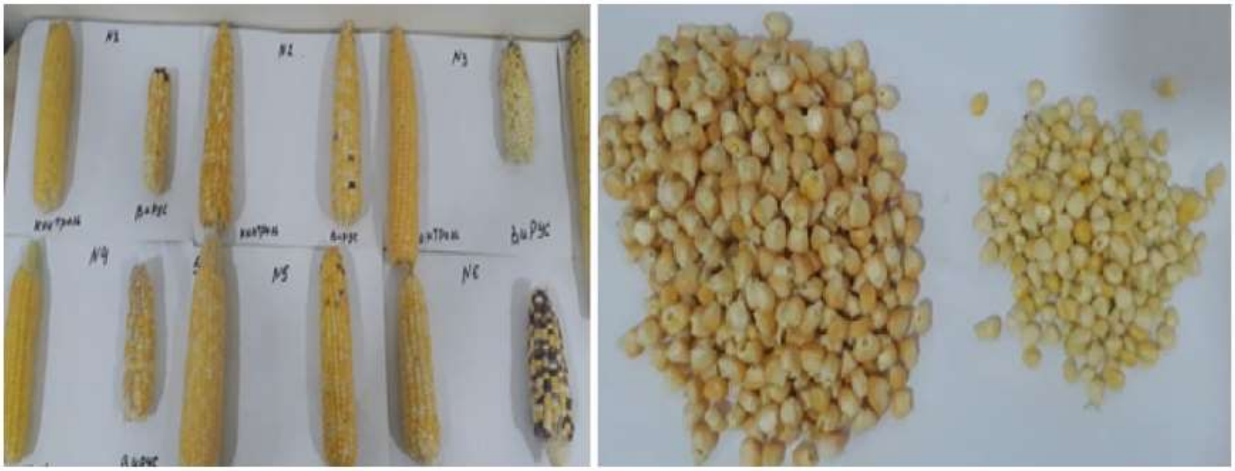
Table 2. Definitions of the influence of MDMV on the maize productivity.

Cultivars' catalog number	Name of cultivars	Plants (#)	Grains per cob (pcs)		1000-grain weight (g)	
			Control	Experimental	Control	Experimental
NS13866	Osnova 209	25	351±0.41	230±0.14	332±0.41	228.5±0.08
NS16695	Extra Early Dightau209	25	357±0.18	256±0.05	376±0.21	254.4±0.26
NS17641	San Pedro LATA	25	368±0.38	232±0.06	355±0.89	230±0.24
NS17646	Sherzod	25	432±0.19*	350±0.35	405±0.27	310±0.029
NS24935	Hickax	25	383±0.45	285±0.18	383±0.28	270±0.038
NS25033	205-2	25	328±0.11	206±0.27	302±0.14*	209±0.46
NS25897	San Pedro2 IMTA	25	374±0.09	245±0.08	362±0.18	248±0.16
Average indication		25	370±0.038	257±0.18	359.28±0.2	249.85±0.4

*($P \leq 0.001$): Significant compared with the control.

a b

Figure 1. Effect of MDMV on maize yield: a) infected with the virus, b) effect on grain yield.



a b

Figure 2. Effect of MDMV on maize yield: a) effect of the virus on cob length, (from left to right, infected maize cobs); b) effect on the weight of 1000-grain weight, (from left to right, infected maize grains).
Note: *(*P* ≤ 0.05): Significant in relation to the control.

Table 3. Determination of grain proteins in the composition of infected and control samples of maize cultivars.

Cultivars' catalog number	Name of cultivars	Proteins (%) in grain composition	
		Control	Experimental
NS13866	Osnova 209	3.14±0.002*	2.79±0.005
NS16695	Extra Early Dightau209	3.26±0.019	1.72±0.0009*
NS17641	San Pedro LATA	3.71±0.023	2.94±0.007
NS17646	Шерзод	4.58±0.019	3.08±0.018*
NS24935	Hickax	3.73±0.0057*	3.06±0.009
NS25033	205-2	2.75±0.002	2.03±0.0012*
NS25897	San Pedro2 IMTA	3.35±0.0026	1.98±0.001

Note: *P* ≤ 0.05 – significant in relation to the control, * - samples were taken from healthy plants as a control.

number of grains per cob in MDMV-infected maize plants. The explanation is plants infected with the virus could not accumulate a sufficient supply of nutrients, eventually reducing the cob length, the number of seeds per cob, and the grain weight (Figure 2).

The study determining the productivity of maize samples under the influence of MDMV provided the number of cobs of the studied maize samples reduced by 50%. The length of cob decreased by 43.21%, the number of grains per cob declined by 30.43%, and the 1000-grain weight lessened by 28.6% in the diseased maize plants.

The grain quality also influences the maize crop's yield structure. The quality of grains depends on the protein and starch content composition (Nazarov *et al*., 2020). Identifying the effect of the virus on grain quality used the Lowry method to determine the protein content in the grains of maize cultivars with infected and healthy samples. The results revealed that the infected samples of the maize cultivar Osnova 209 had the protein content -1.65% lesser than the same in the control samples (Table 3). For the cultivar Extra Early Dightau 209, this difference reaches 1.54%, for cultivar San Pedro LATA

(0.77%), Sherzod (1.5%), Hickax (0.8%), 205-2 (0.72%), and for cultivar San Pedro2 IMTA, the said difference was 1.37%. The cultivars San Pedro LATA, Hickax, and Sherzod have less protein content in the grain composition than other maize cultivars.

Based on the results, the effect of viral infection on the quality of maize grains was significant and much pronounced. The average amount of protein in healthy samples was 3.5%, and in infected samples, decreased to 2.5%, which indicates a significant reduction in the grain protein content under the virus influence. The proportion of grain protein content decreased by 1.00%. It means that the viral infection caused almost a one-third decrease in the protein content in maize grains. It further allowed researchers to conclude about the effects of viral infection on the grain protein in maize with a high degree of confidence.

DISCUSSION

Viruses cause epidemics in all major crops of agronomic importance, posing a serious threat to global food security (Nicaise, 2014). Phytoviruses affect the morphophysiological characteristics of crop plants and alter their productivity (Fayziev *et al*., 2020; Sobirova *et al*., 2023). Moreover, numerous studies have transpired on diagnosing phytopathogenic viruses using the molecular genetic method, including studies of viruses, such as, the plum mosaic virus, the barley yellow mosaic virus, the maize dwarf mosaic virus, and the potato L virus, reporting considerable effects on the crops' productivity (Ramazonov *et al*., 2020; Sattorov *et al*., 2020; Sobirova *et al*., 2023; Jovlieva *et al*., 2024; Makhmudov *et al*., 2023).

Based on symptoms of the diseases in the collected samples, helped determined and biologically identified the viral particles, with the timings of the disease contagiousness established. The same infected samples served as starting material for further virological studies. Additionally, the virus species determination used the PCR. The result of the PCR analysis established the sample isolated from a host plant with a yellow mosaic along with leaf veins, dwarf leaves, and characteristics of maize is a dwarf maize virus (MDMV), as confirmed by PCR diagnostics (Sobirova *et al*., 2023).

Furthermore, the MDMV effects on the morphophysiological properties of various maize genotypes were notable (Sobirova *et al*., 2020; Sobirova and Fayziev, 2020, 2021, 2023). Since maize is one of the main agricultural crops, determining the effect of MDMV on productivity was the main objective of the said research work. The study proceeded from 2019 to 2023, with different genotypes of sweet maize selected for the experiment. Authors also proposed the methods based on the involvement of farmers in becoming familiar with maize viral diseases, which would strengthen the capacity for virus detection and their assessment in local conditions.

This makes it possible to identify the genetic factors that may make certain maize genotypes more resistant to viruses. The presented results could also evaluate the effect of viral infections on grain yield, grain quality, and other agronomic characteristics of the maize crop. In reducing the damage caused by viruses and developing control strategies, it is critical to first identify viruses in crop plants through molecular studies (Ludmerszki *et al*., 2015; Akhmadaliyev *et al*., 2023; Akhmadaliyev *et al*., 2024; Kholmatova *et al*., 2024; Abduvaliev *et al*., 2024). In subsequent stages, the immunological method for diagnosing MDMV allowed for a quick and effective diagnosis of the virus in the maize fields of the Tashkent Region.

Such data highlight the serious impact of viral infections on the grain yield and quality of maize crops. A decrease in protein content can also modify the nutritional value of the grain for both humans and animals. It could also influence the profitability of maize production, as lower protein grains may have less value in the market (Lukuyu *et al*., 2020; Sobirova and Fayziev, 2023). Overall, the research in this area is essential for understanding the mechanisms by which the viruses affect the maize crop, as well as, for developing strategies for breeding and protecting maize crops from viral infections

(Nazarov *et al.*, 2020; Qureshi *et al*., 2023; Yigezu, 2023). One of the main strategies to combat such negative consequences is selecting maize cultivars with increased resistance to viral infections.

CONCLUSIONS

The results revealed that the MDMV influence significantly affected the yield-related traits and grain protein content of maize, and the infected plants showed reduced values for the said traits compared with healthy plants. The strategy for controlling viral diseases should focus on preventive measures, such as, using resistant cultivars, field isolation, controlling insect vectors, and detecting, identifying, and removing affected plants and seeds. Therefore, it is vital for the farming community and breeders to take these findings into account and develop strategies to combat viral infections and breed more resistant maize cultivars.

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