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Comparison of Growth and Yield of Nine Different Tomato Varieties Under Climatic Conditions of Maidan Wardak Province, Afghanistan

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ABSTRACT

Tomato (*Solanum lycopersicum* L.), a member of the Solanaceae family, is one of the most important annual vegetables and is considered the second most significant vegetable globally after the potato. It is native to the southwestern region of the Americas. Maidan Wardak province is recognized as one of the key regions for tomato production in Afghanistan. However, the lack of identification of high-yielding and well-growing tomato varieties under the province's climatic conditions is one of the major challenges in tomato cultivation and a primary reason for low yields. Therefore, this study was conducted to compare the growth and yield of 9 different tomato varieties under the climatic conditions of Maidan Wardak province. The experiment was conducted in 2024 at the research farm of Wardak University, utilizing a Randomized Complete Block Design (RCBD) with three replications. The results of the study showed significant differences among the various tomato varieties. The variety Avto 1219 CLN 3241H outperformed all others in several growth and yield parameters, including plant height (95.66 cm), number of clusters per plant (35.13), number of fruits per plant (31.78), fruit diameter (7.3 cm), fruit weight per plant (3.66 kgand yield per hectare (49.30 tons). Based on these findings, the Avto 1219 CLN 3241H variety is recommended for cultivation due to its superior growth and high yield potential.

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a member of the Solanaceae family, is one of the most important fruit and vegetable crops worldwide due to its nutritional, economic, and health benefits (Mallick, 2021; Nour et al., 2013). Tomatoes are rich in lycopene, a red carotenoid pigment with strong antioxidant properties that protect cells from oxidative damage and mitigate the harmful effects of heavy metals such as lead (Mallick, 2021). They also contain flavonoids, particularly flavonols, which further enhance antioxidant activity and contribute to disease prevention (Mallick, 2021). In addition, tomato fruits are composed of approximately 94% water and provide essential nutrients including organic acids, soluble

sugars, vitamins A, B1, B2, C, and essential minerals, making them an integral component of human nutrition (BARI, 2010; Meza et al., 2013; MZH, 2021).

The yield and quality of tomato are strongly influenced by genetic and agronomic factors such as cultivar, planting time, irrigation, nutrient management, and environmental conditions (Rahman et al., 2020; Shopova, 2023; Hassan et al., 2021). Studies have shown that varieties such as Udyan and BARI Tomato-14 produce maximum productivity when sown between 5 October and 25 October under the agro-ecological conditions of RARS, Jamalpur (Rahman et al., 2020). Similarly, early planting of cultivar Opal F1 provides optimal climatic conditions for vegetative and reproductive growth, resulting in higher yields (Shopova, 2023). Morphophysiological evaluations under winter pot-culture conditions indicated that varieties like BARI Tomato-14 achieve superior fruit yield, while others such as BARI Hybrid Tomato-5 and BARI Tomato-2 exhibit favorable vegetative growth (Hossain et al., 2017). Likewise, cultivar evaluations in Iraq and Sargodha revealed significant variability in fruit quality and yield traits, with certain cultivars excelling in lycopene content, soluble solids, and other biochemical parameters (Kasnazany et al., 2023; Hassan et al., 2021).

Nitrogen management also plays a critical role in tomato production. Meta-analyses indicate that an optimal nitrogen rate of 236–354 kg ha^{-1} enhances yield, water use efficiency, and fruit quality parameters such as Vitamin C, soluble sugars, and total soluble solids, though it may reduce lycopene content and increase nitrate accumulation (Cheng et al., 2021). Furthermore, social and institutional factors, such as membership in agricultural cooperatives, significantly improve tomato yield and productivity by facilitating access to credit, extension services, and improved farming practices (Akinola et al., 2023).

Tomato cultivation requires specific agronomic practices for optimum growth. Seeds are typically planted 1–2 cm deep in nursery beds, with seedlings transplanted at 30–45 days after germination. Optimal plant spacing ranges from 30–80 cm depending on cultivar and management practices, and irrigation management is crucial during flowering and fruit set stages to prevent irregular fruit formation (UCDavis, 2020). Climatic conditions also significantly affect tomato productivity; ideal daytime temperatures range from 18–30°C and nighttime temperatures from 16–20°C, while temperatures outside 15–29°C can adversely affect pollination and fruit set (Olaniyi et al., 2010).

In Afghanistan, low tomato yields are often attributed to the lack of identification and cultivation of suitable high-yielding varieties, highlighting the need for varietal evaluation under local conditions (Wardak Provincial Agriculture Department, 2021). Given the nutritional, economic, and health significance of tomatoes, selecting high-yielding and well-adapted varieties is crucial for improving productivity and supporting farmers' livelihoods. The objective of this study was;

- To evaluate the growth, yield, and yield-related traits of different tomato varieties under local agro-climatic conditions.

- To identify high-yielding and high-quality tomato cultivars suitable for cultivation in Afghanistan.
- To provide recommendations for optimal planting time, spacing, and management practices to maximize tomato productivity.

METHODS AND MATERIALS

The study was conducted at the research farm of Wardak University, located in Saydabad District, Maidan Wardak Province. The experiment was carried out from the (March 5, 2024) to the (October 12, 2024).

Climate and Meteorological Information

Geographically, the experimental site is located at 68 degrees, 47 minutes, and 39 seconds east longitude and 34 degrees, 10 minutes, and 34 seconds north latitude, with an elevation of 2220 meters above sea level. Maidan Wardak province is considered one of the central provinces of Afghanistan. The climate of this province is cold, with snowy winters and warm, dry summers. The amount of precipitation is low and mostly occurs during the winter, predominantly in the form of snow.

The months of October, December, February, and March are generally cold months, during which the average temperature often drops below zero degrees Celsius. July, August, and September are typically hot months, with average temperatures usually rising above 25 degrees Celsius under normal conditions. Most of the seasonal precipitation occurs from mid-December through mid-March.

Analysis of The Physical and Chemical Properties of The Soil in The Research Area

Soil samples for this experimental research were collected from four different parts of the experimental site to determine the physical and chemical characteristics of the soil. Before starting the research, samples were taken from the surface to a depth of 0 to 15 centimeters at various points across the site in a zigzag pattern. These samples were air-dried and then sieved through a 2-millimeter mesh sieve to obtain a composite and representative sample for laboratory analysis. The collected samples were then stored in plastic bags and sent to the Agricultural Research Institute of Badam Bagh for laboratory analysis. The results of this analysis are organized and presented in Table1.

Table 1. *Physical Properties of the Experimental Site Soil (0 – 15 centimeters)*

Consideration	PH	EC	Soil Texture				(Elements)				
			sand	silt	Clay	OM	$CaCO_3$	Na	K	P_2O_5	(T-N)
		Ms/cm	٪	٪	٪	٪	٪	PPM	PPM	PPM	٪
loam	8.3	0.175	50.92	38	11.04	1	21.50	14	24	9.50	0.175
loam	8.33	0.147	50.96	34	15.04	0.36	21	13	28	3.65	0.147

Description of Treatments

In this study, based on this, the number of treatments and their replications are organized as follows.

Table 2. *Description of Treatments*

Treatment Description	Treatment Symbol
Kabul 64 Local	V_1
Beef Steak	V_2
Rio grand	V_3
Avto 1315 CLN 3241Q	V_4
Avto 1219 CLN 3241H	V_5
Pusa Beej	V_6
Local Hanar	V_7
Pearson Local	V_8
Super Cata Para Local	V_9

FINDINGS

The performance of nine tomato varieties was evaluated for key morphological, reproductive, and yield-related traits. The study aimed to assess varietal differences and identify superior genotypes for high productivity and market-preferred fruit characteristics. The traits assessed included plant height, number of branches per plant, number of clusters per plant, number of fruits per cluster, number of fruits per plant, fruit length, fruit diameter, fruit weight per plant, and fruit yield per hectare. Analysis of variance (ANOVA) revealed significant variation among the varieties for most traits, reflecting underlying genetic differences and highlighting potential for targeted selection in breeding programs.

Plant Height (cm)

Plant height is a crucial growth parameter influencing canopy structure, light interception, nutrient assimilation, and ultimately yield potential. The ANOVA results indicated highly significant differences among varieties at the 1% probability level. The Avto 1219 CLN 3241H variety exhibited the tallest plants, averaging 95.66 cm, while Super Cata Para Local also displayed relatively tall growth (83.77 cm). The shortest plants were observed in the Kabul 64 Local variety (47.66–51.33 cm) (Table 3).

Tall plant stature generally contributes to increased leaf area and photosynthetic capacity, potentially supporting higher reproductive output. However, excessively tall plants may be prone to lodging under high wind or rain conditions, necessitating careful consideration in high-density planting systems. The observed variation underscores the genetic potential of tomato varieties for vegetative growth, which can be exploited in breeding for improved plant architecture.

Number of Branches per Plant

The number of branches per plant affects canopy density, light penetration, and potential fruit-bearing sites. Significant variation at the 5% probability level was observed among the varieties. Super Cata Para Local recorded the highest branching (9.89 branches per plant), while Kabul 64 Local had the fewest branches (7.0). After 90 days post-transplanting, Pusa Beej exhibited the highest branching (9.66), whereas Local Hanar displayed the lowest (6.80) (Table 3).

Branching pattern is directly related to photosynthetic efficiency and reproductive potential. A higher number of branches may provide more sites for floral induction and fruit set, enhancing yield, provided that nutrient availability and pollination are adequate. Varieties with lower branching may allocate resources to elongation or fruit development rather than vegetative growth. Understanding branching patterns is also important for optimizing plant spacing and pruning practices in commercial cultivation.

Number of Clusters per Plant

The number of clusters per plant significantly influences potential yield. ANOVA results revealed significant differences among varieties at the 5% probability level. Avto 1219 CLN 3241H produced the highest number of clusters (35.13), followed by Avto 1315 CLN 3241Q (31.78), whereas Local Hanar consistently had the lowest (21.53–22.78) (Table 3).

The number of clusters per plant is a critical determinant of fruit yield and is influenced by genetic potential, vegetative vigor, and environmental conditions such as temperature and nutrient availability. Varieties with a high number of clusters can support more fruits, provided that fruit set and development are not limited by physiological or environmental constraints. These findings suggest that Avto 1219 CLN 3241H has a superior reproductive potential among the studied varieties.

Number of Fruits per Cluster

Although the number of fruits per cluster did not vary significantly among the varieties, subtle differences were observed. Kabul 64 Local produced the highest number of fruits per cluster (2.62), whereas Super Cata Para Local recorded the lowest (1.91) (Table 3).

The relative stability of this trait suggests that fruit set per cluster may be more influenced by environmental conditions, such as pollination efficiency, nutrient supply, and water availability, rather than varietal genetics. Understanding the factors limiting fruit set per cluster can guide management practices to maximize yield potential.

Number of Fruits per Plant

Significant differences in the number of fruits per plant were observed at the 1% probability level. Avto 1219 CLN 3241H produced the highest number of fruits per plant (31.78), followed by Avto 1315 CLN 3241Q (18–18.78). The lowest fruit numbers were observed in Super Cata Para Local and Local Hanar (10–18.78) (Table 3).

This trait integrates the effects of vegetative growth, branching, and cluster formation. Varieties with higher vegetative vigor and cluster number tend to produce more fruits per plant. This relationship highlights the importance of a holistic approach to variety selection, where both vegetative and reproductive traits are considered for yield optimization.

Table 3. *Comparison of Means for Plant Height, Number of Branches per Plant, Number of Clusters per Plant, Number of Fruits per Cluster, and Number of Fruits per Plant for Different Tomato Varieties*

	60 DAT	90 DAT	60 DAT	90 DAT	60 DAT	90 DAT	60 DAT	90 DAT	60 DAT	90 DAT
Varieties	**Plant height (cm)**		**Number of branches plant^{-1}**		**Number of clusters plant^{-1}**		**Number of Fruit Cluster^{-1}**		**Number of Fruit plant^{-1}**	
V1	47.66^{c}	51.33e	7.00^{d}	6.90	25.11^{bd}	22.86d	2.620^{a}	26.66ac	13.22^{bc}	4.97ac
V2	55.11^{c}	53.66de	5.55^{ac}	7.13	27.77^{ad}	23.56cd	1.833^{b}	23.22bd	11.89^{cd}	5.21bc
V3	56.11^{c}	54.66de	8.33^{bd}	8.56	23.33^{cd}	26.43bd	2.73^{ab}	21.77cd	14.55^{b}	5.39ac
V4	56.11^{c}	53.66cd	9.66^{ab}	8.53	31.78^{a}	29.56ac	1.760^{b}	30.00ab	18.00^{a}	5.71ab
V5	71.78^{b}	95.66a	8.88^{ac}	8.00	30.11^{ab}	35.13a	1.926^{b}	31.78a	13.55^{bc}	5.81a
V6	72.89^{b}	57.00b	9.11^{ab}	9.66	24.22^{cd}	26.66bd	2.33^{ab}	22.44cd	12.89^{bc}	5.57ab
V7	56.00^{c}	54.00de	7.66^{cd}	6.80	22.78^{d}	21.53d	2.000^{b}	18.78d	11.44^{cd}	5.85a
V8	68.11^{b}	72.66bc	8.55^{ac}	8.33	28.00^{ac}	31.76ab	2.036^{b}	24.66bd	13.11^{bc}	5.78a
V9	83.77^{a}	93.33a	9.89^{a}	9.56	26.89^{ad}	33.00a	1.916^{b}	22.77cd	10.00^{d}	5.88a
F-test	***	***	***	ns	*	**	*	*	**	*
L.S.D 5%	9.281	10.473	1.345	-	5.212	6.086	0.577	6.910	2.325	0.543
CV (%)	9.01	9.82	9.93	20.83	11.95	13.41	16.21	17.14	10.65	5.93

Fruit Length (cm)

Fruit length is an important quality trait affecting market preference and consumer appeal. Significant differences were observed among varieties at the 5% probability level. The Super Cata Para Local variety produced the longest fruits (9.89 cm), while the Kabul 64 Local variety had the shortest fruits (4.97 cm) (Table 4).

Longer fruits are often preferred in processing industries and fresh markets, whereas shorter fruits may be desirable for certain culinary applications. Variation in fruit length can be exploited in breeding programs to develop varieties that meet specific market demands. Fruit length is also correlated with internal quality parameters such as locule number, flesh thickness, and seed content.

Fruit Diameter (cm)

No significant differences were observed in fruit diameter among the varieties, although Avto 1219 CLN 3241H had the largest diameter (7.3 cm) and Kabul 64 Local the smallest (5.58 cm) (Table 4). Uniform fruit diameter is desirable for marketing, packaging, and processing. The relatively low variation in diameter suggests morphological stability for this trait, which may facilitate standardization of production and market acceptance.

Fruit Weight per Plant (kg)

Fruit weight per plant showed significant variation at the 5% probability level. Avto 1219 CLN 3241H produced the highest fruit weight (3.66 kg per plant), whereas Super Cata Para Local recorded the lowest (2.33 kg) (Table 4). This trait is influenced by both the number of fruits per plant and individual fruit size, integrating vegetative and reproductive performance. High fruit weight per plant is a critical determinant of overall yield and economic return. Breeding programs targeting high-yield varieties should consider this trait in selection criteria.

Fruit Yield per Hectare (t/ha)

Yield per hectare, a key economic and agronomic indicator, differed significantly among varieties at the 5% probability level. Avto 1219 CLN 3241H achieved the highest yield (49.30 t/ha), while Pearson Local produced the lowest (41.5 t/ha) (Table 4). Yield differences are the cumulative result of vegetative growth, cluster number, fruit set, fruit size, and plant density. Superior yield performance by Avto 1219 CLN 3241H indicates its suitability for intensive cultivation and commercial production under the tested conditions.

Table 4. *Comparison of Means Fruit length (cm), for Fruit diameter (mm), Fruit yield per plant (kg) and of Fruit yield per ha for Different Tomato Varieties.*

Varieties	Fruit length (cm)	Fruit diameter (cm)	Fruit yield plant^{-1} (kg)	Fruit yield ha^{-1} (ton)
V1	4.97c	5.86	2.60bd	44.33
V2	5.21b-c	6.77	3.23ac	45.77
V3	5.39a-c	6.79	3.26ab	44.22
V4	5.71a-b	6.23	3.03ad	48.14
V5	5.81a	7.30	3.66a	49.30
V6	5.57a-b	6.97	2.53cd	47.72
V7	5.85a	6.62	2.70bd	44.33
V8	5.78a	6.40	2.56bd	41.52
V9	5.88a	6.64	2.33d	42.53
F-test	*	ns	*	ns
L.S.D 5	0.5438	-	0.710	-
CV (%)	5.98	7.89	15.1	9.55

DISCUSSION

The results of this study demonstrate that tomato growth, yield, and yield-related traits are significantly influenced by varietal differences. Among the nine varieties evaluated, Avto 1219 CLN 3241H consistently exhibited superior performance across most parameters, including plant height (95.66 cm at 90 days after transplanting), number of clusters per plant (35.13), number of fruits per plant (31.78), fruit weight per plant (3.66 kg), and overall yield per hectare (49.30 t/ha). In contrast, local varieties such as Kabul 64 Local and Local Hanar generally showed lower performance in both vegetative and reproductive traits. These findings align with previous studies, which highlight that tomato yield is strongly influenced by genetic factors, with significant variation observed in plant height, branching patterns,

cluster formation, fruit set, and overall yield among different cultivars (Hossain et al., 2015; Rahul et al., 2018; Prashanth, 2003; Regassa et al., 2012; Ahmad et al., 2009).

Plant height is an important indicator of vegetative growth and overall plant vigor. Taller plants, such as Avto 1219 CLN 3241H in this study, often develop a larger leaf area, enhancing photosynthetic capacity and assimilate production, which contributes to higher fruit yield and better overall productivity (Rahul et al., 2018). Conversely, shorter varieties like Kabul 64 Local may have limited leaf area and photosynthetic efficiency, reducing their ability to support reproductive growth and fruit development. These results underscore the critical role of genetic makeup in determining the vegetative growth potential of tomato plants, while also highlighting the influence of environmental conditions on growth performance.

The number of branches per plant also varied significantly among the varieties, ranging from 6.8 in Local Hanar to 9.66 in Pusa Beej. Branching patterns directly influence the number of fruit-bearing shoots and, therefore, overall yield and fruit distribution on the plant (Prashanth, 2003). Varieties with a higher number of branches, such as Super Cata Para Local (9.89) and Pusa Beej, have a greater potential for producing more fruits, although this may also depend on the plant's ability to allocate resources effectively to both vegetative and reproductive structures. The balance between vegetative growth and reproductive output is critical in optimizing yield, as excessive vegetative growth may divert assimilates away from fruit formation, reducing overall productivity.

Reproductive traits, including the number of clusters per plant, the number of fruits per plant, and fruit weight, were significantly affected by varietal differences. Avto 1219 CLN 3241H recorded the highest values for these parameters, suggesting superior reproductive efficiency and better resource partitioning to fruits. In contrast, Local Hanar and Super Cata Para Local exhibited lower reproductive performance. These results are consistent with studies that demonstrate a strong correlation between cluster number, fruit set, and final yield, emphasizing the importance of selecting high-performing varieties to achieve maximum productivity (Regassa et al., 2012; Biswas et al., 2015).

Fruit characteristics, including fruit length and diameter, varied among the varieties. Super Cata Para Local produced the longest fruits (9.89 cm), while Kabul 64 Local had the shortest (4.97 cm). Although fruit diameter differences were not statistically significant, Avto 1219 CLN 3241H produced the largest diameter (7.3 cm). Previous studies indicate that fruit size and shape are influenced by both genetic factors and environmental conditions, including nutrient availability, irrigation, planting density, and planting time (Chernet and Zibile, 2014; Truong and Wang, 2015). Fruit traits such as length, diameter, and weight are crucial for market acceptance and directly impact the commercial and economic value of the crop. The observed variation in these traits among varieties highlights the importance of selecting cultivars not only for yield but also for fruit quality, which is critical for both fresh market and processing purposes.

The fruit yield per plant and per hectare further emphasize the significance of varietal selection. Avto 1219 CLN 3241H achieved the highest fruit weight per plant (3.66 kg) and yield per hectare (49.30 t/ha), while the lowest values were recorded in Super Cata Para Local and Pearson Local, respectively. This confirms that yield is a complex trait influenced by both genetic potential and the plant's ability to adapt to environmental conditions. Studies have also shown that yield is not solely dependent on vegetative growth; reproductive efficiency, resource allocation, and stress tolerance play equally important roles (Hossain et al., 2017; Rahman et al., 2020).

The results highlight several limitations in tomato production. Yield potential is not exclusively determined by plant height or vegetative growth; it is also strongly influenced by environmental adaptability, disease resistance, and susceptibility to pests. Some varieties may exhibit vigorous vegetative growth but fail to achieve high yields under specific climatic conditions or in the presence of biotic and abiotic stresses. Additionally, traits such as fruit size, weight, and number per plant can vary due to interactions between genotype and environment, making it important to conduct evaluations under local agro-climatic conditions to identify the most suitable cultivars.

Based on these findings, future research should focus on multi-environment trials to assess the stability of tomato cultivars across diverse agro-climatic zones. Breeding or selecting varieties with enhanced adaptability, high reproductive efficiency, improved disease and pest resistance, and robust vegetative growth is recommended. Moreover, integrating proper agronomic practices such as optimal planting time, plant spacing, nutrient management, and irrigation scheduling can maximize yield and fruit quality (Rahman et al., 2020; Shopova, 2023; Hassan et al., 2021). Adoption of such strategies will not only increase productivity but also improve economic returns and support sustainable tomato cultivation in regions like Afghanistan, where identification of suitable high-yielding varieties remains a key challenge (Wardak Provincial Agriculture Department, 2021).

CONCLUSION

This study demonstrates that tomato growth, yield, and yield-related traits are significantly influenced by varietal differences. Among the nine varieties evaluated, Avto 1219 CLN 3241H consistently showed superior performance in plant height, cluster number, fruit number, fruit weight, and yield per hectare, while local varieties such as Kabul 64 Local and Local Hanar exhibited lower performance. The findings highlight the importance of selecting high-yielding, well-adapted varieties and implementing appropriate agronomic practices, including optimal planting time, spacing, nutrient management, and irrigation, to maximize productivity and fruit quality. Future research should focus on multi-environment trials and breeding programs aimed at enhancing adaptability, disease resistance, and yield stability. Adoption of high-performing varieties combined with optimized management practices can improve tomato productivity, quality, and farmers' livelihoods in local agro-climatic conditions.

AUTHORS CONTRIBUTIONS

Zahedullah Zahed conceptualized and supervised the experiments, while Hikmatullah Hikmat conducted the fieldwork and data collection. Ahmad Shah Ahmadzai and Mohammad Khalid Rashidi performed data analysis and manuscript preparation, and Mohammad Khalid Rashidi revised the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest related to this study.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding authors upon reasonable request.

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