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Article

Determining the Optimal Planting Scheme and Nutrient Area for High Yields from Cocktail-Type Tomato Hybrids

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Abstract: This article covers the determination of optimal planting schemes and nutrient areas for obtaining high-quality and abundant yields from cocktail-type tomato hybrids during the winter-spring growing season in unheated greenhouses. Applying a planting scheme and nutrient area that corresponds to the biological characteristics of cocktail-type tomato hybrids is one of the primary agrotechnical factors in achieving a high and superior-quality yield.

Keywords: cocktail-type, tomato, hybrid, planting scheme, nutrient area, growth, development, yield, clusters.

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Introduction

Tomato (Solanum lycopersicum L.) is one of the most widely cultivated and economically important vegetable crops in the world, with global production reaching nearly 187 million tonnes harvested from more than five million hectares in recent years [1]. Because the fresh fruit is highly perishable and sensitive to low temperature, wind, rainfall, and pest pressure, an increasing share of tomato production intended for year-round fresh-market supply has shifted from open fields into protected structures such as glasshouses, polytunnels, and unheated film greenhouses [2]. Protected cultivation buffers the crop against adverse weather, extends the growing season into the autumn–winter–spring period when open-field supply is limited, and, when combined with an appropriate cultivar and crop management program, can substantially raise both yield and fruit quality relative to open-field production [2], [3].

Within the wide diversity of tomato fruit types grown under protected conditions — ranging from classic round and plum tomatoes to beefsteak and vine (truss) types — cherry and cocktail-type hybrids form a small-fruited, indeterminate group that has expanded rapidly in the fresh and premium retail market because of its sweetness, attractive appearance, and convenience for direct consumption [4]. Because cocktail-type hybrids are indeterminate, they continue vegetative and generative growth simultaneously throughout the production cycle, forming successive flower clusters (trusses) along an ever-elongating main stem; consequently, their realized yield, the number of fruits set per cluster, and average fruit weight depend heavily on how well the grower manages plant architecture, cluster load and, in particular, the amount of growing space allotted to each plant [4], [5].

The influence of planting density and the resulting nutrient (feeding) area per plant on tomato yield and fruit quality has been documented across many countries and production systems. Classic studies on greenhouse tomato established that fruit yield per unit area rises with increasing plant density up to a threshold, beyond which competition among plants for light, water, and nutrients suppresses individual-plant productivity and reduces average fruit size [6]. Subsequent work on greenhouse-grown cultivars confirmed that wider in-row spacing consistently produces fewer but larger fruits per plant, whereas narrower spacing produces a greater number of smaller fruits and a higher total yield per unit area, up to the point at which excessive crowding triggers flower and fruit abortion [7]. More recent research using dynamic and stepwise plant-spacing regimes has shown that this yield–quality trade-off can be partially, though not completely, reconciled by adjusting plant density as the canopy develops [8]. Taken together, these findings show that no single planting scheme is universally optimal; the nutrient area must instead be matched to the specific hybrid's vigor, cluster-bearing habit, and fruit size class, which makes cultivar-specific field trials indispensable before a planting scheme can be recommended for commercial production.

In Uzbekistan, expanding greenhouse vegetable production has been identified as a national development priority. The Strategy for the Development of Agriculture of the Republic of Uzbekistan for 2020–2030 explicitly calls for increasing the area and productivity of protected-ground vegetable cultivation [9], while a dedicated presidential resolution has established additional conditions — including financing and infrastructure incentives — to stimulate the construction and modernization of greenhouse complexes throughout the country [10]. Domestic methodological literature has likewise addressed the general agrotechnics of vegetable production, including planting dates, schemes, and fertilization practices for a range of crops [11], and recent domestic studies have begun to evaluate greenhouse tomato variety selection and the associated agrotechnical measures required under local soil and climatic conditions [12]. International reference material maintained by the Food and Agriculture Organization of the United Nations provides further statistical and technical background on protected tomato cultivation worldwide [13].

Despite this growing body of work, most of the domestic and international literature available to date addresses either large-fruited greenhouse tomato varieties or the general biology and breeding of cherry-type tomatoes, without specifically examining cocktail-type hybrids under Uzbekistan's unheated (film) greenhouse conditions during the winter–spring cycle [14]–[16]. To our knowledge, the present study is the first to be conducted in the republic to select a cocktail-type tomato hybrid suited to local soil and climatic conditions and to determine, experimentally, the planting scheme and nutrient area that allow this hybrid type to realize its full productive potential in an unheated greenhouse. Establishing this optimum is of direct practical importance because, in protected cultivation, the material and infrastructure costs per unit of greenhouse area are considerably higher than in open-field production, so any planting scheme that under-utilizes the available area or over-crowds the plants translates directly into an economic loss for the grower. To supply the population with this valuable vegetable crop during the winter and spring seasons, tomatoes in Uzbekistan are therefore cultivated not only in open fields but increasingly also in protected ground structures.

Materials and Methods

When growing vegetables in a greenhouse, yield becomes an even more critical factor. This is because the material costs for cultivation in a greenhouse are considerably higher than in an open field. Therefore, we conducted a study to determine the optimal planting scheme and nutrient area for cocktail-type tomato hybrids to ensure the highest possible yield.

Results

This experiment was conducted on the Forte Roze F1 hybrid, which is distinguished by its excellent performance indicators. The planting date for the seedlings of this hybrid was March 10. To determine the planting scheme that ensures the highest and best quality yield, seedlings with 7-8 true leaves were planted according to the following experimental system: the control planting scheme was taken as 90+50/2 x 40 cm; followed by 80+60/2 x 20 cm; 80+60/2 x 30 cm; 80+60/2 x 40 cm; and 80+60/2 x 50 cm. 80+60/2 x 40 cm;

In our experiments, the variant planted with the highest density of plants per unit area—under the 80+60/2 x 20 cm scheme—stood out. Using this scheme, 71,428 plants are accommodated per hectare. This represents 35,714 more plants than the control variant (35,714 plants), which was planted under the 90+50/2 x 40 cm scheme. The lowest number of plants compared to the control was observed in the thinned-out variant, planted according to the 80+60/2 x 50 cm scheme. In this variant, the number of plants per hectare was 28,571, which was 7,143 fewer plants than the control.

The planting scheme and nutrient area also influenced the distance between the clusters that formed on the plants of the indeterminate cocktail-type tomato hybrid, Forte Roze F1. Our experimental observations showed a tendency for the distance between the formed clusters to decrease as the plants' nutrient area increased. Specifically, the experimental variant arranged in an 80+60/2x50 cm planting scheme, which had the largest nutrient area at 0.35 ^{m2} and the shortest average distance between clusters, was particularly noteworthy. In this variant, the distance between the clusters on the tomato plants was 19.4 cm, a figure 0.9 cm smaller than that of the control group. Meanwhile, in the control group—the experimental variant using a 90+50/2x40 cm planting scheme with a nutrient area of 0.28 m^2 this same indicator reached 20.3 cm.

The experimental variant using the 80+60/2x20 cm planting scheme, which had the smallest nutritional area of 0.14 m^2, was distinguished by the greatest distance between clusters on the tomato plants. In this variant, the distance between the formed clusters was 22.8 cm, a figure 2.5 cm greater than the control. In the remaining experimental variants, the average distance between clusters on a single plant occupied an intermediate position relative to the variants described above. The distance between successive clusters in these plants ranged from 19.4 to 22.8 cm, depending on their nutritional area.

Our observations show that the planting scheme and nutritional area also significantly influenced the average number of fruits formed per cluster. The highest number of fruits was recorded in the experimental variant with the largest nutritional area—0.35 ^{m2} which corresponded to the 80+60/2x50 cm planting scheme. In this variant, the number of fruits per cluster on the tomato plants reached up to 12, which was one fruit more than the control. In the control group, which utilized a 90+50/2x40 cm planting scheme with a nutritional area of 0.28 ^{m2,} the number of fruits formed per cluster was 11 (see Table 1).

Table 1.

Effect of Planting Scheme and Nutritional Area on the Development Indicators of the Indeterminate Cocktail-Type Tomato Hybrid Forte Roze F1 (2023–2025)

Planting scheme, cm	Nutritional area, m^2	Number of plants, plants/ha	Number of clusters per plant, pcs	Cluster spacing, cm	Number of fruits per cluster, pcs	Average weight of one fruit, g
×40, control	0.28	35714	10	20.3	11	51.2
×20	0.14	71428	8	22.8	10	40.3
30	0.21	47619	9	19.2	11	49.8
×40	0.28	35714	10	19.5	12	54.6
×50	0.35	35714	10	19.4	12	54.7
LSD_{05}	-	-	0.78	-	1.02	1.65
Sx	-	-	0.26	-	0.35	0.56

The plants in the experimental variant with the 80+60/2x20 cm planting scheme, which had the smallest nutritional area of 0.14 m^2, were distinguished by having the lowest number of fruits formed per cluster.

The planting scheme and nutritional area also affected the average weight of the cluster fruits in the plants of the indeterminate cocktail-type tomato hybrid Forte Roze F1. It was noted that the fruits were larger in plants with a wider nutritional area. Specifically, the plants in the experimental variant with the largest nutritional area—0.35 m^2, arranged in an 80+60/2x50 cm planting scheme—had the highest average fruit weight, at 54.7 g. In contrast, for the control variant, which was planted with a 90+50/2x40 cm scheme and had a nutritional area of 0.28 m^2, this indicator was 51.2 g. Therefore, the plants in this experimental variant formed fruits that were 3.5 g larger than those in the control group.

Discussion

The smallest fruits, weighing 40.3 g, were observed in the experimental variant where tomato plants were sown using a high-density planting scheme of 80+60/2x20 cm (nutrition area of 0.14 m2). The average weight of fruits formed on the plants in this experimental variant was 10.9 g lower than this indicator in the control variant. In the remaining experimental variants, the average weight of fruits formed on the plants held an intermediate position between the variants described above, with an average fruit weight ranging from 49.8 to 54.6 g, depending on the plants' nutrition area.

Conclusion

As cited in numerous scientific sources [6]–[8], the yield of indeterminate tomato hybrids is significantly influenced by the planting scheme and nutrient area. A hybrid can only fully realize its productive potential when the nutrient area occupied by a single plant meets its biological requirements. If this area is too small, i.e., when plants are planted too densely, their competition for soil nutrients and space increases, ultimately leading to a decrease in plant yield. The fruits on such plants may also be relatively smaller. Conversely, if the nutrient area is larger than the plant's biological needs, meaning the planting scheme is excessively wide, the utilization efficiency of the greenhouse area allocated per plant will decrease. Although plants grown under such a scheme may produce large fruits, the overall yield also decreases due to the lower number of plants per unit area. The results of the conducted research have established that the dynamics of leaf formation in the Forte Roze F1 indeterminate cocktail tomato hybrid are, to a certain extent, dependent on the planting scheme.

In the control variant, with a planting scheme of 90+50/2x40 cm, the formation periods for the 8th, 9th, 10th, 11th, and 12th leaves were 4, 3, 4, 3, and 4 days, respectively. In the 80+60/2x20 cm planting scheme, the formation of the 8th and 10th leaves was delayed by 1 day compared to the control variant, taking 5 days. A similar situation was observed in the 80+60/2x30 cm variant, where the formation period for the 8th and 10th leaves was also 5 days. In the 80+60/2x40 and 80+60/2x50 cm variants, the leaf formation period was the same as in the control variant.

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