

REPRODUCTIVE MANIFESTATIONS OF APPLES BY CONVENTIONAL FARMING

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Abstract

There are a number of innovative projects looking for techniques that can improve production while reducing resource input and impact on the environment. A study is made of growth and reproductive manifestations of apples (variety Florina) on the territory of the Plovdiv region, Bulgaria country. Conventional production is applied in two variants of area - on cultivated area and on grassplot area. The following parameters regarding the growth parameters of Florina apples are monitored: cross-sectional area of the stem, average weight of fruit, number of fruits per tree, productivity coefficient. The different indicators give a different reflection in the two variants of area, but in the same conventional production. The average weight of fruit, number of fruits per tree and the coefficient of productivity give better results on growing apples in a grassplot area. The indicator 'cross-sectional area of the stem' presents better values when growing apples on a cultivated area. The results are visualized by presentation in a digital technology, using Geographic Information Systems (GIS), with the aim of faster and rational use by modern farmers.

Key words: apple reproductive manifestations, conventional production, cultivated area, grassplot area, GIS.

INTRODUCTION

Due to the harmful effects of excessive pesticide use, increasing attention is being paid to maintaining a balanced nutrient composition in soils. One key factor in addressing this issue is the proper selection of a soil surface management system in orchards. The evolution of these systems is closely linked to the intensification of fruit production and the increasing adoption of environmentally friendly production methods.

Historically, two main soil management systems have been predominant - sod cover (grass swarding) and bare black fallow (Rubin, 1967; Spivakovsky, 1963; Trocme & Gras, 1964; Todorov, 1966). However, in recent decades, with scientific and technical advancements in countries with developed horticultural sectors, these traditional methods have been replaced by more modern systems. These include turf-mulch systems, herbicide fallows, and various hybrid approaches (Kotov, 1973; Otto & Winkler, 1975; Stamatov et al., 1982).

With the introduction of biological farming practices in orchards, the effects of chemical and organic herbicides have also been explored. Studies have shown that prolonged

use of chemical herbicides leads to soil erosion, a significant reduction in organic matter content, and an increase in nitrate concentrations in groundwater (Himmelsbach & Kleisinger, 1995).

In Bulgaria, Rusaliev and Rankova (2004) also emphasized the importance of minimizing soil surface tillage in orchards as a means to preserve soil structure and fertility.

Research has also focused on how different soil maintenance systems affect the physiology, productivity, and fruit quality of apple orchards (Hogue & Nielsen, 1987; Bugg & Waddington, 1994; Mika et al., 1998; Sanches et al., 2007; Zhang, 2008).

While many findings highlight the positive impacts of various systems, some negative effects - especially in the inter-row zones - have also been reported (Szewczuk, 2000).

In addition to plant response, the influence of soil maintenance systems on the physical and biological properties of soil has also been investigated. Grass coverage and swarding are particularly effective in reducing erosion and nutrient leaching, improving soil structure, water retention, microbial activity, and organic matter content, and in suppressing weed development (Mattern, 1989; Tzvetkova et al., 1995; Kabourakis, 1995; Glen, 1999; Higgins,

2001; Lang et al., 2001; Jordan & Jones, 2002; Loyd et al., 2002; Tasseva, 2003; Tanimu et al., 2007).

Nevertheless, the data collected in any experimental work is only valuable to producers if presented in an accessible and practical format. One of the most effective ways to achieve this is through the use of Geographic Information Systems (GIS), which offer a powerful tool for spatial analysis and visualization in precision agriculture.

Geographical Information Systems (GIS) have become indispensable tools in modern apple production, enabling the creation of thematic maps that facilitate various aspects of orchard management, site selection, and crop monitoring. By integrating spatial data with analytical techniques, GIS supports informed decision-making to enhance productivity and sustainability in apple cultivation.

GIS facilitates the monitoring of apple orchards by enabling the analysis of temporal and spatial data. A study in China developed a method to accurately identify the planting years of apple orchards using satellite remote sensing images. By analyzing phenological characteristics and employing spatiotemporal data fusion techniques, researchers could determine the age distribution of orchards, which is vital for predicting production and planning rejuvenation strategies (Zhang et al., 2020).

GIS is extensively employed to assess land suitability for apple orchards by analyzing multiple environmental factors such as climate, soil properties, topography, and water availability. For instance, a study in the central west of the southern Pyrenees utilized GIS combined with fuzzy logic and the Analytic Hierarchy Process (AHP) to identify optimal sites for apple orchards. This approach considered factors like reduced risk of late spring frosts and mild slopes, providing a modifiable tool for crop suitability assessment in mountainous regions (Casadó-Tortosa et al., 2023).

In apple orchards, GIS enables detailed spatial analysis of key factors such as soil properties, yield variability, and water distribution, which are crucial for implementing precision agriculture techniques. For instance, Aggelopoulou et al. (2011) demonstrated the effectiveness of GIS in mapping soil spatial

variability to support site-specific fertilization strategies, thus improving input efficiency and sustainability.

Yield estimation is another critical area where GIS has proven valuable by integrate image processing techniques and can facilitate predictive modeling of apple production (Aggelopoulou, Bochtis, Fountas, et al., 2011). Furthermore, GIS is used to assess the impact of varying irrigation regimes on spatial variability within orchards, allowing for targeted water management and improved fruit quality (Rud et al., 2018).

Recent advancements also include the use of unmanned aerial vehicles (UAVs) and deep learning within a GIS framework to produce high-resolution yield maps, offering a cloud-based solution for real-time decision-making in orchard management (Apolo-Apolo et al., 2020).

Collectively, these studies underscore the critical role of GIS in enhancing the precision, efficiency, and sustainability of apple orchard cultivation.

Conventional apple production remains a dominant and efficient agricultural system, but it also faces growing scrutiny due to its environmental footprint and potential health risks. As consumer awareness increases and regulations evolve, the industry may need to adopt more sustainable practices to balance productivity with ecological responsibility.

MATERIALS AND METHODS

The experiment was conducted in an apple orchard located at the Pomology Research and Training Station of the Agricultural University Plovdiv, Bulgaria, during the 2020-2021 period. The orchard consisted of trees of the Florina/MM106cultivar-rootstock combination. A conventional cultivation system was applied, including standard plant protection practices, mineral fertilization, drip irrigation, and mechanical soil management. The plant protection program included three preventive winter treatments targeting overwintering forms of economically significant pests and diseases, as well as additional applications during the growing season. Fertilization was carried out using mineral fertilizers, tailored to the specific nutritional needs of the orchard.

Irrigation was provided through a localized drip system, ensuring precise water delivery based on plant growth stages and prevailing weather conditions.

Soil cultivation was conducted using specialized equipment for both deep and shallow tillage suitable for orchard management (Stamatov et al., 1982; Todorov et al., 1974). Two different soil surface management systems were implemented in the inter-rows: (1) bare fallow (cultivated area) and (2) grass-covered (sodded area). The bare fallow method involved several shallow inter-row tillage operations to enhance nutrient availability, improve air and water exchange, and reduce weed infestation. Additionally, deep ploughing was performed in autumn at a depth of 18-20 cm.

The grass-covered system involved maintaining inter-rows with species such as *Poa pratensis* and *Trifolium repens*, which were periodically mowed. The root systems of these grasses contributed to natural soil loosening, enhancing aeration and water dynamics in the root zone. This system also stimulated microbial activity by increasing the organic matter content in the soil (Lichev et al., 2020; Stamatov et al., 1982). These two technological approaches represent distinct strategies for managing soil and plant protection resources under conventional apple production, each offering specific advantages and challenges related to sustainability, soil fertility, and long-term orchard productivity.

The experimental trees - Florina grafted onto MM106 - were at full fruit-bearing stage under both management systems and of equal age. Their crowns were trained to a free spindle form, planted in a rectangular pattern at 4.00 m × 1.80 m spacing.

Two experimental variants treatments were established:

- Treatment I: Maintenance of cultivated inter-rows (bare fallow);
- Treatment II: Maintenance of grassed inter-rows.

Each variant included four replications with three trees per replication.

The following parameters were monitored:

- Cross-sectional area of the trunk (cm²): Determined using the formula $S = \pi r^2$;
- Average fruit weight (kg): Based on 10 randomly sampled fruits from each replication;

- Number of fruits per tree;
- Productivity coefficient (kg/cm²): Calculated as the ratio of total fruit weight to trunk cross-sectional area;
- Instantaneous soil moisture (%): Measured at a soil depth of 0-60 cm during the key phenological phase of vigorous growth using a soil moisture meter. Three measurements were taken per replication.

All results were statistically processed using analysis of variance (ANOVA).

One of the most effective methods for presenting the collected data from the study area was through the implementation of Geographic Information Systems (GIS). GIS facilitates visualization and interpretation of how different soil surface management systems influence productivity, orchard health, and soil condition. It provides producers with highly useful visual and analytical insights through thematic maps, thus enabling data-driven decision-making and enhancing orchard management efficiency.

The GIS platform used for data visualization was QGIS 3.40.4, incorporating open-access datasets. Land boundaries were derived from the digital cadastral map and database of the Republic of Bulgaria. An interpolation method was applied for data visualization and thematic map generation.

RESULTS AND DISCUSSIONS

GIS offers a wide range of capabilities for data representation and analysis, with its most significant function being the ability to visually present research findings on maps. This approach facilitates easier interpretation of results, enables rapid and efficient analysis of large datasets, and allows for straightforward editing and modification. The system generates multilayered information that can be easily transformed into thematic maps, effectively illustrating the achieved outcomes.

In the study of various growth and reproduction indicators of the Florina apple variety under conventional observation on both cultivated and grassed areas, we used GIS to represent the studied area and its specific localization.

The studied area is located in the village of Brestnik, Burgas district, Bulgaria. The following Figure 1 is a thematic map.

The studied area is located in Brestnik village, Plovdiv region, Bulgaria country. The next Figure 1 presents it on the thematic map.

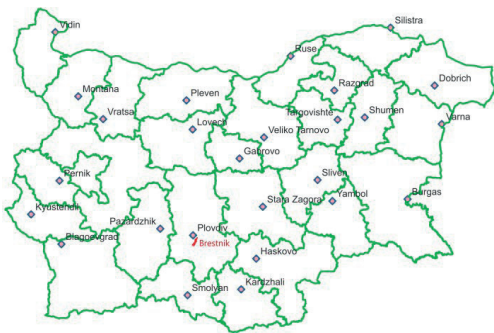


Figure 1. Localization of the studied area in Plovdiv region in border of Republic of Bulgaria

Brestnik village, located in Plovdiv Region, lies approximately 4 km south of the city of Plovdiv, at the beginning of the Rhodope ridge “Chernatitsa,” also known as the “Rhodope collar.”



Figure 2. Localization of Village Brestnik in Plovdiv region

This geographical position determines the specific relief, soil, and climatic characteristics of the area (Figure 2).

The village is situated on a slope with a distinct elevation difference between its northern and southern ends. The terrain has an inclination of 1% to 5%, typical of accumulative plains, covered with alluvial-deluvial deposits of relatively homogeneous composition.

The geological base of the area includes both carbonate and non-carbonate redeposited materials. The soils are represented by deluvial and proluvial deposits, typical for the Rhodope collar. The climate in the region is transitional-continental, characteristic of the Plovdiv plain in the Upper Thracian Lowland. The temperature regime is marked by hot summers and mild winters.

These natural conditions create a favorable environment for the development of agriculture and orchards in the territory of Brestnik village (Figure 3).

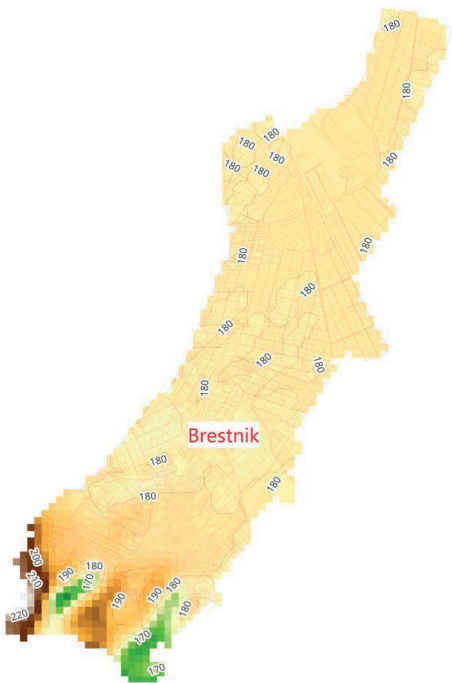


Figure 3. Topography map of studied area



Figure 4. Area of Florina apples orchard

The research includes two versions in conventional apple production - cultivated and grassed alleyways in orchard, located in Brestnik village.

A comparative analysis was conducted between cultivated and grassed inter-row management systems under conventional production of Florina apples (Figure 4). The results are presented in Table 1.

Table 1. Growth and reproductive manifestations of apples variety Florina in conventional production

Types of area Parameters	Florina apple conventional production		GD at		
	Cultivated	Grassed	5%	1%	0.1%
Cross-sectional area of the stem (cm ²)	162.58	157.08	23.08	57.63	179.69
Average weight of fruit (kg)	0.182	0.194	0.15	0.39	1.42
Number of fruits per tree	142.91	145.27	119.05	271.01	781.03
Productivity coefficient (kg/cm ²)	0.16	0.18	0.35	0.89	4.01

Regarding the cross-sectional area of the trunk in the experimental trees under the two inter-row soil surface management systems - cultivated (162.58 cm²) and grassed (157.08 cm²) - no statistically significant differences were observed. This parameter is one of several that contribute to determining tree productivity. However, in this experiment, the trees in both treatments were not affected by the soil surface management system applied.

Examining the fruit mass in both variants (0.182 kg for the cultivated area and 0.194 kg for the grassed area), a similar trend was observed. Although a slightly higher value was recorded for the fruits grown under the grassed system, the difference was too small to be statistically significant. Thus, fruit mass also appears to be unaffected by the type of inter-row soil surface management.

The difference in the number of fruits per tree between the two soil surface management systems was also minimal, and again, no statistically significant differences were detected between the treatments.

The most important indicator of fruit tree productivity is the productivity coefficient (kg/cm²), calculated as the ratio of fruit yield to the trunk cross-sectional area. As a natural outcome of the previously discussed results, this parameter also demonstrated minimal and statistically insignificant differences between the two treatments.

Table 2. Instantaneous soil moisture at 0-60 cm depth depending on inter-row soil surface management

Soil Surface Management	Soil Moisture (%)
Cultivated inter-rows	7.1
Grassed inter-rows	8.3

Table 2 presents the measured instantaneous soil moisture at a depth of 0-60 cm under two inter-row management systems in a conventional apple orchard. The results show that grassed inter-rows (sodded areas) maintained a higher soil moisture content (8.3%) compared to cultivated inter-rows (bare soil), which recorded 7.1%.

This difference, although numerically modest, highlights the positive effect of grass cover on soil water retention. The root system of grass species such as *Poa pratensis* and *Trifolium repens* contributes to improved soil structure and organic matter content, both of which enhance water-holding capacity.

Interpolate the results from apples study into GIS is presented by next thematic maps.

The baseline data include the boundaries of the area, markers of the studied plot, soil characteristics, and others.



Figure 5. Spatial distribution of different soil maintenance systems

Interpolate the results from apples study into GIS is presented by next thematic maps.

The baseline data include the boundaries of the area, markers of the studied plot, soil characteristics, and others.

The application of GIS in our study, through the creation of maps presents the spatial distribution of different soil management systems; a comparison between areas with varying soil surface conditions in terms of fruit yield; and zones with different current soil moisture levels depending on the implemented management system.

The two developed variants are presented in Figures 5 and 6. The cultivated and grassed areas are presented, including the corresponding repetitions.



Figure 6. Comparison between zones with different soil surface systems in terms of fruit production

The results of the conducted study on Florina apple variety regarding the productive parameters under the two surface soil treatment variants do not show significant or substantial differences (Figure 6).

However, the analysis of the samples taken for current soil moisture reveals notable differences between the treatments. In the grass-covered inter-rows, the soil moisture content is the higher compared to the tilled ones (Figure 7).



Figure 7. Zones with different soil moisture levels depending on the applied system

CONCLUSIONS

Based on the obtained results regarding the influence of two soil surface management systems in the inter-row space (cultivation and grassing) on the reproductive indicators of the apple cultivar-rootstock combination Florina/MM106, on the instantaneous soil moisture in the root zone, and on the visualization through the GIS system, the following conclusions can be drawn:

1. The type of soil surface management system did not have a statistically significant effect on the productivity of the Florina cultivar grafted onto MM106 rootstock. The absence of significant differences does not imply that further studies should be disregarded, particularly with other cultivar-rootstock combinations. This experiment may serve as a model system for such investigations.
2. Higher instantaneous soil moisture was recorded in the root zone when grassed inter-row management was applied.

3. GIS-based maps are developed to provide producers with spatial information regarding the distribution of different soil surface management systems and their associated effects - namely, the productivity of the Florina/MM106 apple cultivar-rootstock combination and the levels of instantaneous soil moisture in the orchard.

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