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Research Article

Cultivation of Garlic, Watermelon, and Table Tomatoes in Goiás: Evolution and Geographical Distribution of Production and Cultivated Areas

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Abstract

This study analyzes the geographical distribution of garlic, watermelon, and table tomato production in Goiás between 2000 and 2020, highlighting its evolution and economic importance in the region. The main objective was to investigate the production trends of these vegetables and the factors that influenced their performance over the studied period. The methodology included data analysis of harvested areas, productivity, and variations in cultivated regions using information from the Mauro Borges Institute of Statistics and Socioeconomic Studies (IMB) of Goiás. The main results revealed significant variations in production over the years, impacted by climatic conditions, technological adoption, and market demand. In 2020, production was driven by favorable climatic conditions and investments from producers, whereas in 2004, adverse weather and pest incidences affected watermelon production. These findings highlight the importance of adapting to environmental conditions and implementing management strategies for successful vegetable production in Goiás.

Keywords: Vegetable Production; Olericulture; Regional Economy

Introduction

Agricultural activities in Brazil have gained increasing importance due to the economic visibility of the sector in generating employment, income, and wealth, both directly and indirectly, reinforcing Brazil's agricultural propensity. The strength of the national agribusiness sector necessitates greater attention to various production chains to remain competitive in the global market [1]. In this context, olericulture, an important branch of agriculture, holds high socioeconomic importance due to the high consumption and nutritional value of these foods [2]. The state of Goiás, in addition to grain production, also stands out in the production of horticultural species.

One species with significant demand and production in the state is garlic (*Allium sativum* L.). It is one of the oldest plants used for human food, both as a spice and for its medicinal use [3]. Its reproduction is exclusively vegetative through bulbils, leading to a progressive increase in the incidence of viruses, which can significantly reduce crop yield and affect the viability of stored bulbils [4]. Due to the specific characteristics of the species, production in the cerrado was only possible with the development of refrigeration technology, allowing garlic cultivation in areas with higher temperatures and varied photoperiods [5].

Another horticultural crop cultivated in Goiás, nationally known, is watermelon (*Citrullus lanatus*). Belonging to the cucurbitaceae family, watermelon is a herbaceous, annual plant. Although it can be cultivated year-round in Brazil, the rainy season increases the likelihood of diseases, directly affecting fruit productivity and quality [6]. Warm days and nights result in fruits with higher soluble solid content, while high air and soil humidity reduce the biosynthesis of some compounds and pulp quality [7].

In addition to garlic and watermelon, tomatoes (*Solanum lycopersicum* L.) also play a significant role in Goiás' olericulture. Native to South America, tomatoes are one of the most economically important and widely propagated vegetables globally due to their acceptance and consumption [8]. They are considered nutritious and functional foods, easily incorporated into the processed fresh or processed human diet. The characteristics and destination of the fruit are criteria for differentiating cultivars, which can have indeterminate or determinate growth habits, forming diverse production chains [9].

Therefore, this study aimed to survey the geographical distribution, quantity produced (tons), productivity (tons per hectare), variation in cultivated areas (%), and geographical distribution in Goiás from 2000 to 2020 for garlic, watermelon, and table tomatoes.

Methodology

This research utilized data from the Mauro Borges Institute of Statistics and Socioeconomic Studies (IMB) to survey harvested areas (hectares) and production quantities (tons) from 2000 to 2020 for garlic, watermelon, and table tomatoes in Goiás, evaluating production across the state's 246 municipalities. The variation in harvested area was calculated by subtracting the area of one year from the previous year. Productivity was determined by the ratio of harvested area to production. The geographical distribution of garlic, watermelon, and table tomato production considered only the last five years of the study period (2016 to 2020), calculating the average harvested area due to the dynamic nature of the horticultural output compared to grain production, with areas increasingly being converted to soybean cultivation in Goiás' cerrado. Data were converted into tables and graphs for better visualization using SigmaPlot® and Microsoft Excel®.

Results and Discussion

Garlic

Due to genetic characteristics, garlic requires low temperatures for leaf sprouting since its propagation is asexual. Therefore, the development of agricultural technologies was crucial for the species' development in Goiás, characterized by high temperatures compared to southern Brazil, a former potential garlic-producing region [10]. The primary technology enabling the expansion of garlic cultivation in Brazil's cerrado, mainly in Goiás and Minas Gerais, was refrigeration, allowing significant progress in Goiás' garlic production [11].

Figure 1 shows garlic production distribution in Goiás. Despite its national significance, Goiás' garlic production is concentrated in the eastern and southern regions, primarily in the Federal District's surrounding micro-region. The garlic-producing municipalities in Goiás are limited to Água Fria de Goiás, Cabeceiras, Campo Alegre de Goiás, Catalão, Cristalina, Luziânia, Planaltina, and Ouvidor, with Cristalina having the largest production area, approximately 1,940 hectares.

Figure 1: Garlic Production Concentration in Goiás: Garlic-producing municipalities. UEG, 2024.
Source: Instituto Mauro Borges (2023).

Figure 2 depicts garlic production trends in Goiás from 2000 to 2020. In 2000, Goiás registered the lowest production in the period, around 10,206 tons. However, garlic production showed significant growth in subsequent years. In 2001, production increased by 33.1%, reaching 13,590 tons. This continuous growth extended into 2002, with a 43 per cent increase, resulting in 19,525 tons. The following decade, especially in 2010 and 2011, saw further increases in garlic production. After these growth years, production declined until 2014. From 2015, garlic production in Goiás began to rise again, following a linear growth pattern until 2020.

In 2020, garlic production peaked at 53,590 tons, representing a 52.6% increase compared to the previous year, driven by a 22.8% increase in cultivated area and a 23.8% rise in productivity. This production accounted for 34.4% of national garlic production. In 2000, a prolonged drought, high temperatures, and irregular rainfall distribution negatively affected garlic crops in Goiás. Elevated temperatures and irregular rainfall, coupled with higher incidences of pests and diseases like thrips and rust, reduced productivity. The lack of effective control measures aggravated these phytosanitary issues.

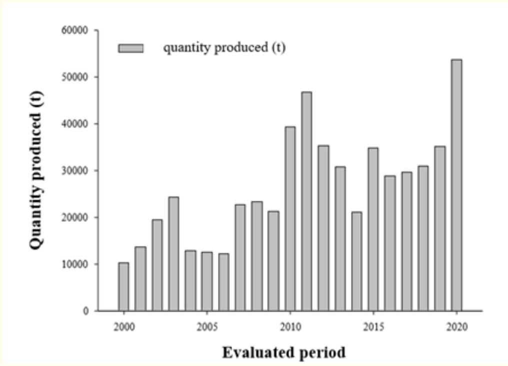

Figure 2: Evolution of Garlic Production (tons) in Goiás between 2000 and 2020. UEG, 2024.
Source: Instituto Mauro Borges (2023).

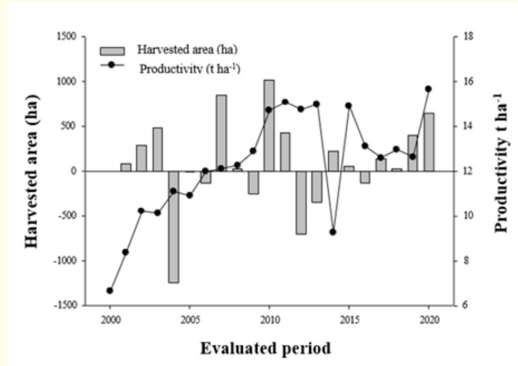

Figure 3: Variation in Harvested Area (hectares) and Productivity (tons per hectare) of Garlic in Goiás between 2000 and 2020. UEG, 2024.
Source: Instituto Mauro Borges (2023).

Garlic production in Goiás, as shown in figure 3, indicates an increasing trend in cultivated areas over the years, with specific periods of decline. In 2000, the harvested area was 1,536 hectares. Subsequent years, 2001, 2002, and 2003 saw growth in both area and productivity, reflecting a steady increase. However, 2004 witnessed a significant 51.7% drop in harvested area compared to the previous year, resulting in 1,156 hectares in 2005 and 1,024 hectares in 2006. These years marked a recovery phase. In 2007, the harvested area grew to 1,874 hectares, continuing to increase gradually until 2008. Nonetheless, 2009 saw another 13.1% reduction in harvested area. From 2010, garlic production in Goiás showed a growth trend again, with the harvested area rising to 2,666 hectares in 2010. In 2011, there was a 13.8% growth peak, indicating significant recovery and expansion in cultivated areas. Between 2012 and 2019, the harvested area remained relatively constant, reflecting stabilization after previous fluctuations. Finally, in 2020, Goiás recorded the largest increase in harvested area during the analyzed period, reaching 3,425 hectares.

Garlic productivity (Figure 3) in Goiás showed a growth trend from 2000 to 2013, with steady increases due to improvements in agricultural techniques and crop management. However, 2014 experienced a drastic productivity drop, breaking a decade-long positive trend. This decline could be attributed to various factors, including adverse climatic conditions and agronomic challenges affecting productivity levels. From 2015, productivity recovered rapidly and effectively from previous adversities. Subsequent years, from 2016 to 2019, saw productivity fluctuations, reflecting various influences from climate variability to agricultural management practices and external factors affecting production. In 2020, garlic productivity in Goiás peaked. This significant productivity change is mainly attributed to phytosanitary management issues and seed garlic refrigeration. Biotic stresses like thrips, leaf burn, and rust compromise the state's production.

Thrips (*Thrips tabaci*) hinder noble, semi-noble, or common garlic production nationwide [12]. The insect remains in its immature phase between central garlic leaf sheaths, which are more tender and have a smaller angle between leaves, providing shelter [13]. Chemical insecticides are the most common protection strategy against this pest, becoming economically unsustainable annually due to inefficiency and increasing acquisition costs regulated by US dollar exchange rate variations. Moreover, recommended insecticides for suppressing phytovirus transmitters negatively impact natural biological control in garlic agroecosystems, known for their natural enemy diversity [14], and induce insect resistance to chemical molecules [15].

Garlic plants are susceptible to rust at any development stage. The disease, caused by Puccinia porrii, is characterized by numerous small, elliptical pustules on the leaf blade, initially covered by the leaf cuticle. As the cuticle breaks, a yellow powdery mass of uredospores is exposed. In advanced stages, the pustule's powdery mass turns dark brown or black due to teliospore formation [16].

Due to unfavorable climatic and phytosanitary factors, some producers reduced the garlic cultivation area in Goiás that year, directly impacting total state production. Therefore, the combination of adverse climatic conditions, phytosanitary issues, and reduced planted area were the main factors influencing lower garlic production in Goiás in 2000 within the 2000-2020 analyzed period.

Evaluated period

Watermelon

Araguapaz, Caiapônia, Carmo do Rio Verde, Ceres, Cezarina, Guarani de Goiás, Heitoraí, Iaciara, Ipiranga de Goiás, Israelândia, Itaguari, Itaguaru, Itapuranga, Jaraguá, Jussara, Mara Rosa, Maurilândia, Mundo Novo, Nova Glória, Palmeiras de Goiás, Pontalina, Posse, Rialma, Rianápolis, Rio Verde, Santa Fé de Goiás, Santa Helena de Goiás, Santa Rosa de Goiás, Santo Antônio do Descoberto, Simolândia, Taquaral de Goiás, and Uruana. Among these municipalities, Uruana stands out as the main producer, known as the Watermelon Capital, with about 2,880 hectares dedicated to watermelon cultivation. Unlike garlic, watermelon production in Goiás is not region-specific due to the species' climatic requirements. Originating from the Equatorial Africa region, watermelon demands temperatures between 20 °C and 35 °C, coinciding with most seasons in Brazil, especially in the Central-West region [17]. However, the São Patrício Valley and Rio Vermelho regions excel in production.

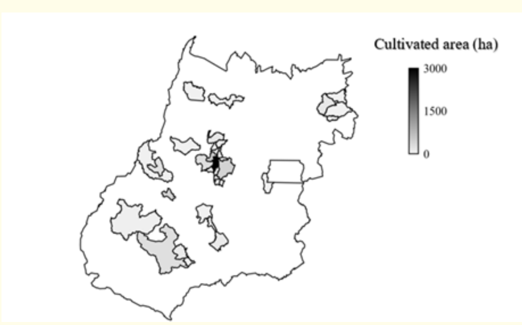

Figure 4: Watermelon Production Concentration in Goiás: Watermelon-producing municipalities. UEG, 2024. Source: Instituto Mauro Borges (2023).

Figure 5 Reveals watermelon production trends in Goiás over the analyzed period, showing overall growth with significant fluctuations over the years. From 2000 to 2002, watermelon production in the state increased continuously, peaking at 183,730 tons in 2002. However, 2003 saw a slight decline, with production dropping to 179,120 tons, and this downward trend continued in 2004 and 2005, likely representing a stabilization or specific challenges. In 2006, watermelon production significantly grew by 41.07% compared to the previous year, starting a consistent growth period extending through 2007, 2008, 2009, 2010, and 2011. However, 2012 experienced a significant decline, recording 272,949 tons. This decline initiated a negative trend that persisted until 2014. From 2015, there was a production recovery with a 3.7% increase. However, from 2015 to 2020, watermelon production in Goiás showed high and low variations annually, reflecting agriculture's volatile nature.

Watermelon production is a significant economic activity generating income and employment in Goiás. Despite its importance, producers often cite marketing issues as major obstacles to the culture's development [18]. Watermelon is a seasonal product with higher supply and consequent price drops during harvest months. This price variation throughout the year can affect producers' income and profitability, especially on a smaller scale.

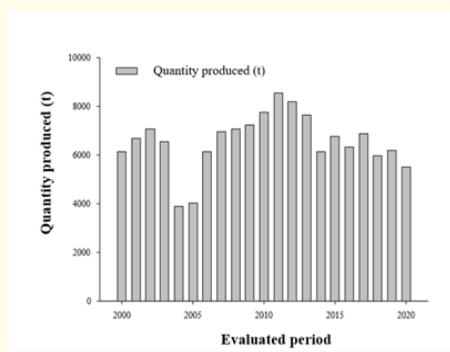

Figure 5: Evolution of Watermelon Production (tons) in Goiás between 2000 and 2020. Source: Instituto Mauro Borges (2023).

The harvested area of watermelon in Goiás, illustrated in Figure 6, shows fluctuations over the years, with specific periods of decline. In 2000, the harvested area was 6,120 hectares. The following two years saw a continuous increase, resulting in a 13.6 % growth from 2000. In 2003, the cultivated area reduced to 6,527 hectares, further decreasing to 3,74 hectares in 2004. This significant decline could be due to adverse factors like climatic issues and economic difficulties. In 2005, the cultivated area grew by 14.3 % from 2004, with additional growth in 2006, increasing the harvested area to 6,115 hectares. After this increase, the cultivated area stabilized, remaining relatively constant until 2011.

The years 2011 and 2012 marked the peak harvested area of watermelon in Goiás, reaching 8,532 hectares in 2011 and 8,183 hectares in 2012, likely due to favorable market conditions, technological advancements, and improved cultivation practices. In 2013, the cultivated area declined by 6.5 %, followed by a significant reduction in 2014 to 6,122 hectares. Post-2014, the watermelon cultivated area in Goiás showed few variations until 2020.

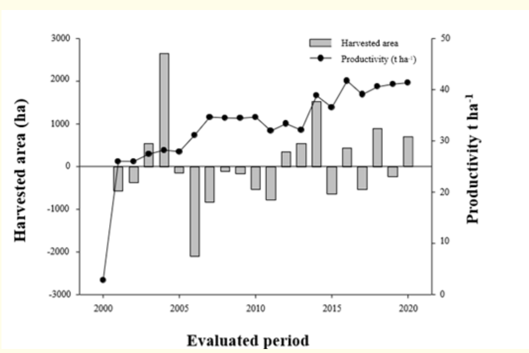

Figure 6: Variation in Harvested Area (hectares) and Productivity (tons per hectare) of Watermelon in Goiás between 2000 and 2020. UEG, 2024.

Source: Instituto Mauro Borges (2023).

The year 2004 was marked by irregular rainfall distribution in Goiás, with prolonged droughts in some producing regions, affecting watermelon plant development and productivity. Additionally, higher incidences of pests and diseases, such as whiteflies and fungal diseases like anthracnose, significantly damaged watermelon crops.

Whitefly (*Bemisia tabaci*) is one of the most important global agricultural pests, affecting a vast number of host plants, including watermelon, leading to substantial losses when present [19]. Thus, whitefly is a major agricultural pest in tropical and subtropical regions, causing significant production drops due to the damages it inflicts on crops [20].

Anthracnose (*Colletotrichum truncatum*) is a significant disease in various plant species, caused by Colletotrichum fungi, ranked as the eighth most important plant pathogenic fungus worldwide [21]. Initial symptoms appear as transparent yellow spots on leaves, which darken over time. Severe attacks result in leaves with a burnt appearance. Control recommendations include using certified seeds and seedlings free of the pathogen, crop rotation for three or more years, and maintaining well-ventilated plantations to avoid water accumulation on leaves and fruits. Inadequate pest and disease management, due to lack of technical assistance or limited access to inputs, exacerbated production losses.

Watermelon production in Goiás is influenced by a combination of factors, such as climatic conditions, technology availability, input and credit access, and market demand. These elements can vary annually, directly impacting production levels.

Table tomato

Table tomatoes are cultivated in all Brazilian states on different production scales, with Goiás, São Paulo, Minas Gerais, and Bahia being the largest producers for both processing and fresh consumption. Several factors contribute to Goiás producers' performance in terms of yield and productivity, including climate, topography, and genetic improvements providing precocity, environmental adaptability, and pest and disease resistance [22]. Tomatoes are the second most important vegetable in Brazil, cultivated in most states, with production divided between table and processed tomatoes [23].

Abadiânia, Água Fria de Goiás, Alexânia, Anápolis, Bela Vista de Goiás, Bonfinópolis, Buriti Alegre, Catalão, Cocalzinho de Goiás, Corumbá de Goiás, Cumari, Formosa, Gameleira de Goiás, Goianápolis, Goiânia, Itaberaí, Jaraguá, Leopoldo de Bulhões, Petrolina de

Goiás, Pirenópolis, Pires do Rio, Santa Rosa de Goiás, São Francisco de Goiás, São João d'Aliança, Silvânia, and Terezópolis de Goiás are table tomato-producing municipalities in Goiás. The geographical distribution of these municipalities is shown in figure 7, with production concentrated in the eastern, central, and southern regions of Goiás. Like watermelon, tomatoes also adapt well to Goiás' climate.

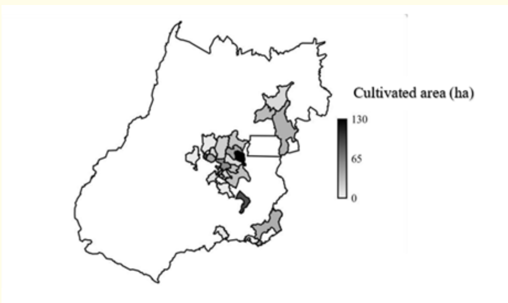

Figure 7: Table Tomato Production Concentration in Goiás: Table tomato-producing municipalities. UEG, 2024.
Source: Instituto Mauro Borges (2023).

Figure 8 shows that from 2000 to 2020, table tomato production in Goiás experienced significant variations influenced by various factors over the years. In 2000, Goiás recorded 114,418 tons of table tomatoes. Production remained relatively stable until 2002, with little variation. However, in 2003, production dropped to 94,710 tons, indicating a considerable decline that year. In 2004, production increased by 9.9 % compared to 2003. This growth continued in 2005, reaching 208,240 tons, marking a significant peak. However, 2006 saw a production decline to 121,230 tons, indicating annual production volatility.

Subsequent years continued to show production fluctuations. In 2007 and 2008, production declined to 108,208 and 100,830 tons, respectively. This decline period was followed by a recovery in 2009, with production rising to 125,133 tons. In 2010, production grew by 6.0% compared to the previous year, with Goiás registering a record 133,230 tons of table tomatoes due to favorable factors contributing to significant production increases during this period. From 2011 to 2018, Goiás experienced consecutive declines in table tomato production. This prolonged decline period may

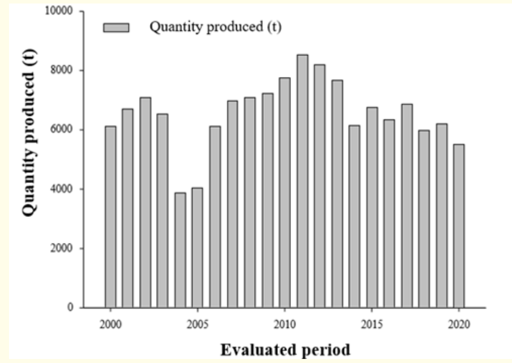

Figure 8: Evolution of Table Tomato Production (tons) in Goiás between 2000 and 2020.
Source: Instituto Mauro Borges (2023).

have been influenced by adverse climatic conditions, phytosanitary issues, market fluctuations, or changes in agricultural practices. In 2019, production increased significantly by 22.4%, reaching 70,880 tons. This growth marked a recovery after years of decline. In 2020, production remained similar to 2019, indicating stabilization after recovery.

In 2000, the harvested area was 2,092 hectares, remaining relatively constant until 2010. This initial stability period suggests consistent cultivated area maintenance over a decade. However, in 2011, there was a significant 24.2 % drop in harvested area, further decreasing in 2012 to 1,099 hectares. This decline trend continued steadily until 2018, when the harvested area dropped to 642 hectares. This prolonged decline could be due to economic difficulties, climatic changes, pests, diseases, or other challenges faced by producers.

In 2019, the harvested area increased by 19.8 % from the previous year, indicating a trend reversal, possibly due to improved market conditions, technological advancements, or favorable agricultural policies. In 2020, the harvested area remained similar to 2019, suggesting stabilization after recovery.

Figure 9 shows significant variations in table tomato productivity in Goiás over the analyzed period. The early period, from 2000 to 2001, saw a productivity decline, followed by a high in 2002. However, in 2003 experienced another drop, possibly due to unfavorable climatic conditions, diseases, or other negative factors. The year 2004 brought productivity increases, suggesting recovery after the 2003 decline. This growth period continued until 2009, indicating increased productivity. However, 2010 and 2011 saw consecutive productivity declines, likely due to changes in agricultural practices, management issues, or adverse climatic conditions.

Evaluated period

In contrast, 2012 showed significant productivity increases, followed by several declines in subsequent years until 2017. These fluctuations reflect the complex and variable nature of agriculture, with different years presenting unique challenges and opportunities for producers. In recent years, 2018, 2019, and 2020, productivity increased, indicating possible recovery or adaptation to market and climatic conditions. Goiás experienced very favorable climatic conditions for table tomato cultivation in 2010, with regular rainfall distribution and suitable temperatures during the crop cycle, contributing to healthy plant development and high productivity. There was a significant expansion in the area dedicated to table tomato cultivation in Goiás, incorporating new producing regions, contributing directly to increased total tomato production.

However, irregular rainfall regimes harmed tomato plant development, directly affecting production. Additionally, there was a high incidence of pests and diseases, such as black spots and whiteflies, causing significant crop damage. These phytosanitary pressures reduced fruit quality and quantity, negatively impacting production. Similar issues occurred in 2015 and 2016, possibly due to transportation and storage infrastructure problems, such as poor road conditions and insufficient warehouses. These logistical bottlenecks hindered production flow and fruit quality maintenance, affecting productivity.

Conclusion

Over the past two decades, the production of these vegetables has experienced growth, declines, and recoveries influenced by climatic conditions, agricultural practices, crop management, and infrastructure investments. Garlic production expanded significantly due to increasing demand and its adaptation to local climates, establishing Goiás as a key production area. Watermelon production fluctuated due to climatic variations and pest incidences. In contrast, table tomato production remained relatively stable, underscoring its economic importance and market acceptance.

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