# 120 YEARS OF SA AGRICULTURE: Highlights from research published in the *SAJS*

*Agriculture, an essential pillar of South Africa's economy, has evolved through a century of scientific advancements. In the recently published 120-year celebratory issue of the* South African Journal of Science *(SAJS), a special review highlighted the significant research contributions that have been made over the last 120 years to the improvement of agriculture in South Africa. The review examined historical challenges and emphasised ongoing issues such as climate change. Modern agricultural practices, including hybrid seeds, genetic modification and advanced irrigation techniques, have transformed crops, enabling increased productivity and global competitiveness. However, the sector faces persistent challenges, including food security concerns. The review also explored future prospects, underscoring the importance of technology adoption and sustainable practices. South Africa's agricultural research, although underfunded compared to developed nations, remains crucial for ensuring the sector's resilience and growth.*

The word 'agriculture' describes the multitude of ways that crops and livestock provide food and other products for the global human population. It is a practice of agroecosystem manipulation. Agricultural science is a multidisciplinary field that focuses on understanding and enhancing the productivity, sustainability and profitability of agriculture. In South Africa, agriculture not only includes the commercial sector but also smallholder and subsistence farmers, who have sustained rural communities and shaped the agricultural landscape for centuries. Agriculture has been, and still is, a pillar of South Africa's economy, contributing 2.83% to the Gross Domestic Product and providing 19.26% of total employment. Agricultural land covers approximately 80% of the country's total area of 1.22 million $km^2$ of which only 12% is regarded as arable. Agriculture has faced many challenges including, for example, the impact of climate change, pests and diseases, and the complexities of land reform and redistribution issues since 1994. Nonetheless, South African agriculture holds the promise of future growth and development, both locally and internationally, as there is an increasing global demand for food and its sustainable production.

In this review perspective, we present some highlights of the agricultural research that has been conducted over the past 120 years (1905–2023) – the lifespan of the *South African Journal of Science* (*SAJS*) from which most citations were taken. However, when subject-specific journals began to appear, for example, the *Agricultural*

*Journal of South Africa* in 1915, *Farming in South Africa* in 1927 and the *South African Journal of Agricultural Science* in 1957, authors preferred to publish in these journals, and fewer articles published on agricultural-related topics were published in the *SAJS*. For this reason, we included references from other journals. However, agriculture is such a broad and multidisciplinary topic that the focus of this review will be limited to research conducted on the production of citrus and maize and the challenges faced by these two sectors of the agricultural economy.

## Citrus history

Citrus trees, both oranges and lemons, were brought to the Cape from St Helena Island in 1654 and planted in the Cape Gardens. By 1661, 1000 trees had been established, and, for the next 200 years, citrus was grown by small-scale farmers in the Western Cape. At the beginning of the 19th century, early settlers in the Eastern Cape and KwaZulu-Natal provinces planted individual orange and soft citrus trees and, shortly after the Great Trek (1838), citrus trees were planted in the North West province.

As the era of the *SAJS* began at the end of the 19th century, the then Prime Minister of the Cape Colony, Cecil John Rhodes, hired horticulturists, HEV Pickstone and RE Davies from California, to develop the citrus industry in the Cape. Thereafter, citrus trees were grown on a commercial scale using the modern scientific methods known at that time. High-quality citrus fruit was exported to the United Kingdom for the first time in 1906 and "made their debut at the Show of the Royal Horticultural Society in London". The industry flourished thereafter, and between 1906 and 1921, a number of co-operative grower associations formed, the most important of which were the Fruit Growers' Co-operative Exchange (1922), the South African Co-operative Citrus Exchange (SACCE) (1925) and the Citrus Board (1939). Prior to 1941, the distribution and sale of citrus fruit were undertaken by individual producers, but in the year that the South African Citrus Scheme was introduced, sales increased as the fruit was sold in a "more profitable manner". By 1928, more than three million citrus trees had been planted in the Cape. Today, the area occupied by citrus trees of all species and varieties is over 100,000 ha, equating to approximately 55.5 million trees.

According to Fourie *et al.*, the first research officer posts were created by the SACCE in 1953 to undertake work on identified problem areas not adequately investigated by government and other research organisations. Between the 1960s and 1970s, three scientists, trained in California, were appointed by the SACCE in the fields of pre- and post-harvest pathology and horticulture. Their research was undertaken at the Citrus and Subtropical Fruit Institute in Nelspruit, which later became part of the Agricultural Research Council. The Citrus Improvement Programme was established in 1973 and later became known as the South African Citrus Improvement Scheme, managed by Citrus Research International. Scientists from this organisation conduct research on a range of topics relevant to their industry, including pathology, entomology and citriculture.

## Maize history

The introduction of maize into southern Africa is a matter of debate among archaeologists. Burtt-Davy suggested that maize seed was exchanged for water, meat or other commodities by the Portuguese *en route* to the East in the mid-1600s. In the latter part of the 19th century, maize was mainly cultivated for local subsistence needs. The market changed with the discovery of diamonds (1866) and gold (1886), and black and white farmers alike supplied maize to the rapidly expanding mining population. "Two agricultures" then emerged: the black smallholder farmers and the white commercial farmers; the production potential of the former was suppressed while the opposite was true for the latter farmers who were supported by substantial investment. Despite this initial division between the maize producers, which changed in the 1990s, South Africa increased its maize production from 328,000 tons in 1904 to 1.68 million tons in 1935 and 15.6 million tons in the 2022/2023 season. This significant increase can be attributed to factors such as the use of hybrid and genetically modified seed, and improved fertiliser programmes and farming practices. Our understanding of plant genetics and the use of biotechnological tools such as marker-assisted selection and genetic engineering, for example, have allowed the industry to produce superior-quality seed and plants resistant to pest infestations.

Maize is the most important crop in South Africa and is used both as animal feed and as a staple human food crop. Today the area planted to maize ranges from 2.5 to 2.8 million hectares annually. The cultivation of maize is restricted by climate. It is considered a dry-land crop, and is mainly grown in the summer rainfall areas such as the North West and Limpopo provinces. In 1923, the "maize triangle" as it became known with Mafikeng (North West), eNtokozweni (Machadodorp) (Mpumalanga) and Zastron (Free State) forming the apices, produced approximately 60% of the total amount (1.5 million tons) grown in the country. The remaining 40% was produced by other provinces (KwaZulu- Natal and the Cape) and subsistence farmers. Today, approximately 14 million tons are produced annually, mainly by commercial farmers, but small-scale farmers also produce a significant proportion of this amount. Approximately 3.2 million tons are exported, mainly to Zimbabwe, South Korea, Japan and Taiwan. The major producers are in the Free State, Mpumalanga and North West provinces.

Yellow and white maize, genetically modified with the Bt toxin, were commercially grown for the first time in the 1998/1999 and 2001/2002 seasons, respectively. South Africa then became the first genetically modified (GM) subsistence crop producer in the world. Food security benefits attributable to GM white maize in South Africa are substantial and "an average of 4.6 million additional white maize rations annually" have been suggested. Thus scientific research has played a pivotal role in the development and widespread adoption of using GM maize in the country.

## Challenges

### Water availability

Water is scarce in South Africa, and severe droughts have impacted agriculture. Water scarcity has been exacerbated in recent years by erratic rainfall patterns, the needs of industries and cities, and impending climate change. There have been several drought investigations in the past, with the first published in 1914 and the most recent report published in 2020, namely, the National Water Security Framework for South Africa. Over the years, drought-relief plans and management practices were proposed, which included better veld, stock and water management, and improved farm management.

Crop irrigation using flood and furrow methods, as opposed to dryland farming, was first proposed in 1905. Sources of water for irrigation purposes have been, and still are, from various aquifers, catchment areas and rivers. The benefits of irrigation were highlighted in the *SAJS* by van Reenen and Chunnett. Other methods of water delivery and applications such as drip irrigation, developed in the 1900s in Israel, or the use of microsprinklers, were shown to be more water efficient than flood and furrow methods. These more efficient methods are the generally preferred irrigation systems in citrus orchards, as water is directly placed in the root zone and can also be used for fertigation.

In maize, supplementing rainfall during the mid-season drought period positively impacted yield, and this method has been shown to improve and stabilise smallholder farmer maize yields in particular. Centre-pivot

irrigation was first introduced into South Africa in the 1970s to irrigate the farm Soetvelde near Vereeniging. This method enabled commercial farmers to increase the quantities of water applied, and is used in some areas for maize production.

## Soil quality

As early as 1923, soil erosion, by wind and/or rain, was recognised as a significant problem in South Africa. Policies were developed to prevent and mitigate erosion in the agricultural sector. In 1939, the Soil Erosion Advisory Council was formed, and the *Soil Conservation Act* was published in 1946. At that time, all these efforts led to the effective control of erosion in some areas of the country. Today, however, over 70% of South Africa is experiencing some form of soil erosion, with the extent of the problem varying by region.

Soil quality is multifaceted. Apart from soil erosion, South African soils have also been subjected to structural decay, subsoil compaction, acidification, salinisation, pollution, nutrient depletion and surface crusting, resulting in reduced water infiltration, increased run-off and erosion. A number of methods can improve and maintain soil quality, including the use of fertilisers. The low quantities of phosphorus in our soils were first recognised in the early 1900s and found to be the main limiting factor in crop production. This led to the development of the first phosphate plant in Durban in 1903. Fertilisers were also imported, with 19,000 tons of fertilisers imported in 1906. By 1962, this amount had grown to 1,385,000 tons, and, in 2023, 2,174,911 tons were imported. South African soils also have low organic matter levels, with about 58% of soils containing less than 0.5% organic carbon and only 4% containing more than 2% organic carbon.

## Pests and pathogens

The fields of entomology and plant pathology have a long history in South Africa that dates to the 17th century. Pests and pathogens were, and still are, responsible for significant losses in agriculture, not only during production but also during storage. Initially, the most common method of management was pesticide application. Locusts, for example, were controlled with arsenate of soda, while diseases of grapes were controlled using sulphur, with an amount of 264 tons used in 1916. After 1919, inorganic pesticides were used, including Bordeaux mixture used to prevent numerous fungal diseases. After 1945, numerous synthetic pesticides were developed, many of which are still used today. However, many were detrimental to the environment and to humans. In the 1980s, sustainable farming was encouraged in an attempt to revise the harmful practices of applying increasing amounts of chemicals. Today, management has moved from a reliance on pesticides to environmentally friendly options such as the use of biological control agents.

Crop losses due to pests and pathogens are becoming increasingly common. As pests and pathogens have the capacity to generate new variants containing key pathogenicity, fitness and aggressiveness traits, any new opportunity provided by climate change will be exploited by them. Fluctuations in rainfall, humidity, temperature and carbon dioxide levels may also result in the emergence of pests in the field, an increase in their reproductive rates, shifts in their life cycle and movement from one area to another.

## Citrus challenges

Doidge described numerous citrus diseases caused by bacteria and fungi occurring in South Africa between 1919 and 1929. Bacterial, fungal and viral pathogens were, and still are, problematic pre- and post-harvest. Citrus canker, first detected in the country in 1905/1906, was successfully eradicated by 1927, and was the first plant disease to be successfully eradicated in the world. Today, one of the most important citrus diseases is black spot (CBD), discovered in 1922 by Doidge. The disease is not present in the Western Cape, Northern Cape and Free State, and its presence on fruit from KwaZulu-Natal, North West, Mpumalanga and Limpopo has impacted on the export market. The European Union (EU) has strict regulations (zero tolerance) related to the import of fruit from South Africa, both with regard to CBD and the false codling moth, as neither occurs in Europe. To improve risk assessment and CBD management, spore release prediction models have been developed. The presence of viruses has also hampered citrus production. The earliest recorded evidence of a virus causing significant damage was the citrus tristeza virus in 1896, which led to the abandonment of sour orange as a rootstock in South Africa. The identification of the causal agent was, however, only confirmed in 1947.

Entomological problems of citrus described in 1934 included red scale, citrus aphid, fruit fly, mealy bugs and thrips. Today, many of these insects are still problematic. An additional problem with some pests is their ability to vector plant pathogens, for example, the citrus psyllid, which vectors the citrus greening pathogen. Although insecticides have been used for many years, an integrated pest management approach is more widely accepted today.

## Maize challenges

Maize has been plagued by many pests and pathogens over the past century. In 1911, cutworm, stalk borer, the striped earworm and a leaf disease of unknown cause were problematic. The number of new incursions of pests and pathogens steadily increased, with the fall armyworm making an appearance in 2017. Pathogens such as those causing cob and stalk rot and storage rot produce mycotoxins and threaten the health of humans and domestic stock. Leaf blight diseases include Northern and Southern leaf blights, grey leaf spot, common rust and maize streak virus, and may cause substantial losses each year.

The development of Bt maize, engineered to contain toxins from *Bacillus thuringiensis*, has provided resistance in South African maize to important insect pests such as the European corn borer and other lepidopteran species. In South Africa, Bt maize makes up more than 90% of the maize planted and has resulted in a significant reduction in pesticide usage, crop damage and attack by fungal pathogens.

## Climate change

A number of researchers have modelled climate change and the effects thereof on agriculture in southern Africa. 'According to the report of the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment Working Group II, climate change has increased the mean annual surface temperature of the Earth by 1.2°C, relative to 1850–1900, with the six hottest years ever recorded having occurred in the last decade. According to Blignaut *et al*., South Africa became 2% hotter and at least 6% drier in the period 1997 to 2006 compared to the 1970s. During the same period, the use of water also increased significantly, with irrigation agriculture using 60% of total consumption. An increase in temperature and a decrease in rainfall are not the only consequences of climate change; there are increases in extreme weather events, heatwave intensity and frequency, severe droughts and flooding after torrential rains. The average rainfall across South Africa has also decreased in all areas except the northwest and, despite an overall trend in aridity, the intensity and frequency of heavy rainfall events have also increased. In addition to these abiotic factors, biotic stresses, such as an increase in pest and pathogen populations, and increased weed growth have had negative impacts on agriculture.

Climate change will impact both citrus and maize production, leading to possible decreases in yield. In citrus, the effect will be physiological, resulting in a loss of productivity and fruit quality. Adaptation strategies such as canopy management, top netting, soil fertility management and water-saving approaches could be used. Maize production by both commercial and smallholder farming systems is predicted to decrease by between 10% and 16% because of the projected climatic impacts. One method of overcoming this challenge is to create new varieties, and in the case of citrus, new rootstocks, that can adapt to the predicted environmental conditions.

Johnston *et al.* – in a report entitled 'Climate change impacts in South Africa: what climate change means for a country and its people' – recorded that commercial, small-scale and subsistence farmers have implemented various climate change adaptation strategies. Conservation agriculture, which focuses on retaining soil carbon to enhance drought resilience, has become more important in dryland farming regions. Notably, improvements in irrigation efficiency, coupled with practical drought-tolerant crop and cultivar selection, have become standard practices. In addition, there has been a noticeable decrease in reliance on chemical inputs. Access to medium- and short-term weather forecasts has been enhanced, empowering farmers to proactively prepare for extreme weather events. This includes leveraging indigenous and local knowledge of weather and climate patterns, as well as implementing water resource management techniques. For instance, some farmers now harvest rainwater to sustain agricultural activities during dry periods, thereby prolonging the growing season. Due to these adaptations, the sector's economic sustainability has largely remained intact. Nevertheless, the escalating temperatures and the intensification of extreme weather phenomena pose difficult challenges to farmers' adaptive capacity. As such, ongoing efforts to innovate and implement resilient agricultural practices by both smallholder and commercial farmers will be essential in navigating the evolving climate landscape.

## Food security

The term 'food security' was coined in the 1970s. Food supplies are deemed secure when every member of the population has access to sufficient food for living an active, healthy life. There are four elements to the term: food availability, food access, food utilisation and stability.

Despite the constitutional right of every South African citizen to sufficient food and water, food provision is complex and determined by various environmental, health, economic, socio-political and agro-food-related issues. Over 20% of South Africans are food insecure, that is one in five members of the population, mostly from the lowest socio-economic groups, with about 55% of the population unable to pay for food and other basic needs. Widespread poverty, unemployment and inequality have exacerbated food insecurity. This has led to health issues such as obesity and hypertension. One in four children have stunted growth because of poor nutrition. There is an urgent need for significant investment in sustainable agriculture, the development of infrastructure, and poverty alleviation strategies to improve food security for all South Africans.

## Future perspectives

Despite all the challenges, agriculture remains a cornerstone of South Africa's economy, contributing 2.83% to the GDP. Over the past 120 years – the life of the *SAJS* – food production has increased due to genetic crop improvements, including the contentious use of genetically modified organisms (GMOs) and cropping practices, notably irrigation and fertilisers. Key issues that are likely to shape the agricultural future include the adaptation of technology; adaption to climate change; sustainable production strategies; production of less studied, locally adapted plant species used in rural communities as food; and education. Technology, such as the use of genetic methodologies like genome editing, artificial intelligence, precision agriculture, drones and satellite imaging for monitoring, and apps for decision-making, have the potential to increase both efficiency and productivity in agriculture. In the case of maize, there is a need to breed new varieties that are drought tolerant, and in citrus, rootstocks and scions that maintain production and fruit quality in the face of climate change. Integrated pest management strategies, including the sensible use of pesticides and the adoption of biological control strategies, will be crucial for managing pests and pathogens while at the same time minimising their environmental impact. Under-utilised agricultural crops, or orphan crops, such as moringa and *Plectranthus aeculentus*, can also contribute to food security. As agriculture will become more technology-intensive, at least in the commercial sector, skilled workers will need to be educated in fields such as data analysis and agricultural engineering. However, low capacity for adaptation, widespread poverty and low technology uptake might hamper agricultural productivity in South Africa.

In conclusion, South Africa's research focus areas are similar to those in the developed world, especially in terms of technology and infrastructure. The research conducted ranges from cutting-edge molecular studies to system modelling approaches. This is despite the fact that expenditure on research, estimated at 1.04% of the agriculture GDP, is significantly less than that of Europe (2.06%), the USA (3.7%) and Australia (4.02%). South Africa's expenditure is however, comparable to that of other developing countries. Since 2008, the government has recognised that South Africa needs to progress to a "developed state of agriculture and agroprocessing", especially in terms of technological innovation, so that wealth generation and socio-economic development within this sector can be achieved within the next 20 years.

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