

Date	Submitted	Accepted	Published
	5 <sup>th</sup> June 2024	3 <sup>rd</sup> April 2025	11 <sup>th</sup> December 2025

## OPTIMISING CANOLA PRODUCTION (*Brasica napus* L.) THROUGH IRRIGATION: GLOBAL INSIGHTS AND SOUTH AFRICA APPLICATIONS

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## ABSTRACT

Canola (*Brassica napus L.*) is an herbaceous plant that produces small round seeds and is the most important source of edible oil in the world. The term “canola” is derived from Canadian oil-low acid since the crop is a rapeseed variety developed by Canadian plant breeders in the 1970s. It is a cool season crop that originates from Asia, where it is found growing in diversely cool temperate regions. Its oil contains less than 2% of the total fatty acid as erucic acid. Canola is used for production of the cooking oil, animal feed as well as clean and environmentally friendly biofuel. In most parts of the world, the crop is primarily produced under-dryland and it grows well in areas with above 300 mm annual rainfall. However, due to insufficient rainfall, during the growing season, plants tend to suffer from water stress resulting in yields decline. Therefore, this review provides an overview of the use of irrigation to increase canola productivity and manage water stress under different irrigation levels. The production of canola under irrigation is practiced in other countries such as Australia and Montana. Irrigation water increases seed emergence, biomass, yield, and oil content in canola. However, different types of irrigation system are being used to irrigate canola but sprinkler irrigation system gave the highest water productivity, yield and oil production. Irrigation scheduling and water use efficiency on canola production under deficit irrigation conditions is becoming increasingly important. Soil moisture probes are recommended to be installed to monitor moisture in the soil. This helps in irrigation scheduling which save water and avoiding under irrigating. Findings indicate that maintaining plant-available water at least depletion levels during flowering and pod development stages maximises yield and oil quality. This demonstrates that canola is a water thirsty crop, hence, the use of irrigation is necessary to mitigate the plant water stress, ensure good canola establishment, yield and oil content.

**Key words:** Canola, total fatty acid, dryland, irrigation, rainfall, water stress, oil content

**Citation:** Silwana S, Sindesi OA, Dumani A, Cutu A, Mulidzi R, Mhlontlo S, Mbangcolo M, Silwana TT and R Murovhi Optimising Canola Production (*Brasica napus L.*) Through Irrigation: Global Insights and South Africa Applications. *Afr. J. Food Agric. Nutr. Dev.* 2025; **25(10)**: 28240-28259. <https://doi.org/10.18697/ajfand.147.25015>



## INTRODUCTION

Canola (*Brassica napus L*) is a member of the *Brassicaceae* plant family, formerly known as *Cruciferaeae* [1]. Canola is a type of oilseed rape that produces seed oils and meals with low erucic acid and glucosinolate contents [1]. The crop is used as a source of edible oil, animal feed protein and a feedstock for biofuel production [2]. Canola seeds normally contain 40% or more oil and produce meals with 35 to 40% protein. Health-conscious consumers find it appealing given that it contains the lowest level of saturated fats, and the highest percentage of omega-3 fatty acids compared to other major edible vegetable oils. In human diets, canola is mostly used as cooking oil, salad oil, and in the production of margarine [1]. Its origin is traced to Asia where the plant grows in cool temperate regions [2]. It is also cultivated in other temperate regions such as North America, northern parts of Europe, Canada, China, India and some parts of South Africa (SA) [3]. It is considered the world's second-largest oil seed-producing crop after soya beans (*Glycine max L. Merr*) [4]. Canola is widely grown under dryland in many parts of the world but there is increasing interest in producing canola under irrigation due to its profitability. The cultivation of canola under irrigation is practiced by some countries including Australia and Montana as irrigation enhances seedling emergence, biomass, yield, and oil content [5].

In South Africa (SA), canola is cultivated in the Western Cape (WC) province, particularly in the Swartland and Southern Cape regions. These areas have a Mediterranean climate, with cool, wet winters and warm, dry summers, making them suitable for rainfed canola production. The WC mainly grows canola for its oil and as a rotational crop in the cereal-growing areas [6]. Generally, SA canola production is lower compared to other countries such as Australia, Canada, Denmark, USA and China. Nevertheless, the country's demand for plant oil is very high and consumes over 720 000 tons annually. In 2024. The area under canola production in SA increased from 127 000 ha to 145 000 ha, with an estimated national yield of 2t/ha [7]. Although the production of canola in SA is increasing there is still a deficit of around 430 000 tons. To meet the demand, SA is required to import large quantities of canola oil.

Due to the increasing world population and renewable energy policies, the current canola production may need to be doubled by the year 2050 [8]. Thus, expansion of canola production from relatively temperate areas where it is well adapted, into more marginal and drier areas is necessary in SA as the mineral oils are becoming limited. This review synthesises existing literature on global canola production, with a particular focus on its cultivation in SA. Additionally, it examines irrigation strategies for canola production in marginal areas.



## METHODOLOGY

A literature review on canola production, global trends, SA practices, and the role of irrigation in marginal lands was conducted using databases such as Web of Science, Scopus, ProQuest, Frontiers, ScienceDirect (Elsevier), Sabinet African Journals, PubMed, Springer, Wiley, and Google Scholar. Access to these databases was provided by the Cape Peninsula University of Technology, Agricultural Research Council SA and Dohne libraries. A range of keywords and search phrases were used to identify relevant eBooks and scientific publications. Publications that did not provide relevant information on canola production, the influence of reduced plant-water available water, or the impact of irrigation on marginal lands were excluded. Additionally, only publications written in English were considered. The selection process involved an initial screening of article titles, followed by an abstract review, and finally, a comprehensive reading of the full text. Duplicates across multiple databases were counted only once. Key findings related to global canola production trends, and irrigation strategies for marginal lands were extracted. The findings were synthesised to identify recurring themes, contradictions, and knowledge gaps. The information was then used to address the research objectives, outline recommendations for improving canola production in marginal lands, and highlight future research directions.

## CANOLA PRODUCTION

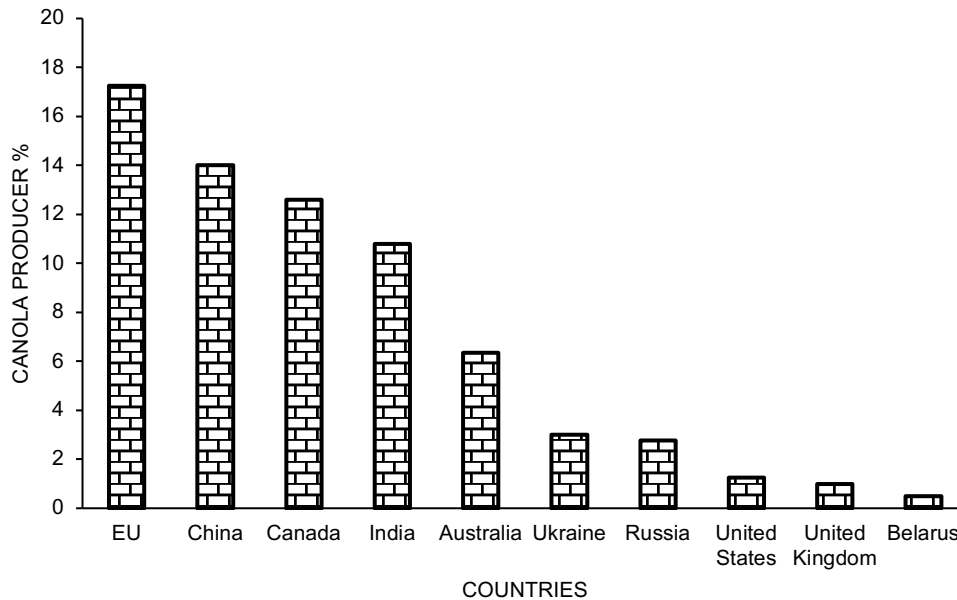
### Global Canola Production

There is currently a strong global demand for canola oil, this demand is expected to continue growing in the coming years. In 2024 the canola oil market was valued at USD 37.47 billion, and it is projected to grow to USD 51.10 billion by 2032 [2]. Rising health awareness, environmental sustainability, culinary versatility and industrial applications are some of the major factors driving canola oil demand. The primary industries driving demand for canola oil are the biofuel and food processing sectors. The versatility of canola oil and its renewable properties make it an excellent biodiesel source, which drives the global market's growth and expansion [9]. In addition, the demand for canola oil-derived biodiesel has grown due to the world's commitment to reducing greenhouse gas emissions and transitioning to cleaner energy sources [10]. More than 30% of canola is used to produce biodiesel in Canada and some European countries [10].

According to United States Department of Agriculture (2022), the European Union is the largest canola-producing region followed by China, Canada, India, Australia, Ukraine, Russia, United States, United Kingdom and Belarus (Figure 1). However, Canada is the largest canola exporter followed by the European Union, China, Australia and Ukraine; while on the market, the European Union countries are the



largest followed by China and Japan respectively [11]. These countries combined make up about 70% of the global canola production. Figure 1 below shows the top 10 canola-producing countries.



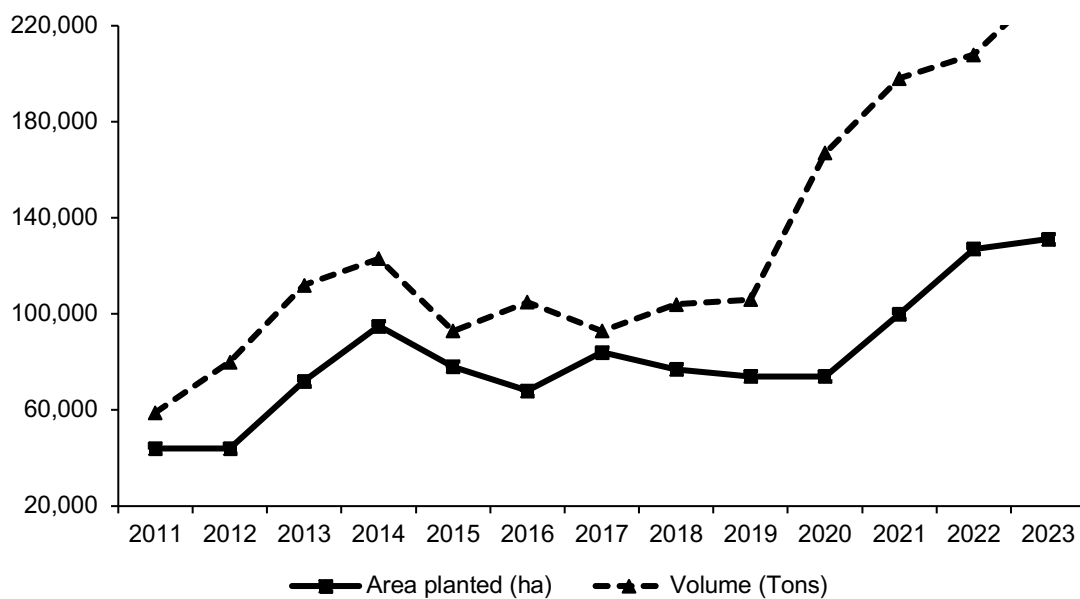
**Figure 1: The world's top ten canola-producing countries, adapted from USDA [11]**

### Canola Production in South Africa

In SA, canola is primarily produced under winter rainfall conditions in the Western Cape Province, particularly in the southern, Overberg and Swartland, regions [12]. This includes towns such as Swellendam, Malmesbury, Caledon, Riversdale, Riversonderend and Bot River [13]. The Overberg and Swartland regions of the Western Cape, SA, where canola is primarily grown, have a Mediterranean climate with cool, wet winters (May–September) and hot, dry summers (October–April). The regions have shallow, well-drained soil with moderate fertility, and strong seasonal winds, particularly in Swartland [14]. The Overberg and Swartland regions supply canola to various markets, including the domestic food industry, where it is used in cooking oils, margarine, and processed foods [8]. The livestock feed industry utilises canola meal as a high-protein supplement for dairy and livestock farming. The biofuel sector is an emerging market, driven by a call for sustainable fuel alternatives. While the country primarily imports canola oil, some raw seeds and by-products are exported, with trade opportunities in the Southern African Development Community (SADC countries). Additionally, canola oil is marketed for its health benefits, particularly its high omega-3 content, appealing to health-conscious consumers [15].

In the domestic market, canola competes primarily with sunflower seed and soya beans [7]. For cultivation, it is planted in rotation with wheat, which is an advantage for the suppression of diseases and pests [16]. It can also be planted as an alternate

crop under irrigation in summer rainfall areas such as Northwest, Free State and Limpopo Provinces [17]. There are currently no specific figures on the production of canola from these areas, however, the WC is the leading and ever-growing producer of canola in SA. A drastic increase in the production area and productivity of canola in the Western Cape (WC) has been observed in past years. Figure 2 shows the canola production area (ha) and production (ton) in the WC between 2011 and 2023. The production area increased from 44 000 ha in 2011 to approximately 127 000 ha in 2022, resulting in a production increase of more than 140000 tons. However, in the 2023 season, the country's canola planting area increased to above 130000 ha. This planting expansion and production is driven by an increase in local and global demand for canola oil, economic incentives, agronomic advantages, research and development efforts, government support and renewable energy policies promoting biodiesel in the country [18]. This makes canola a key crop for the country's agricultural sector, contributing to food security, economic growth, and sustainable farming practices.

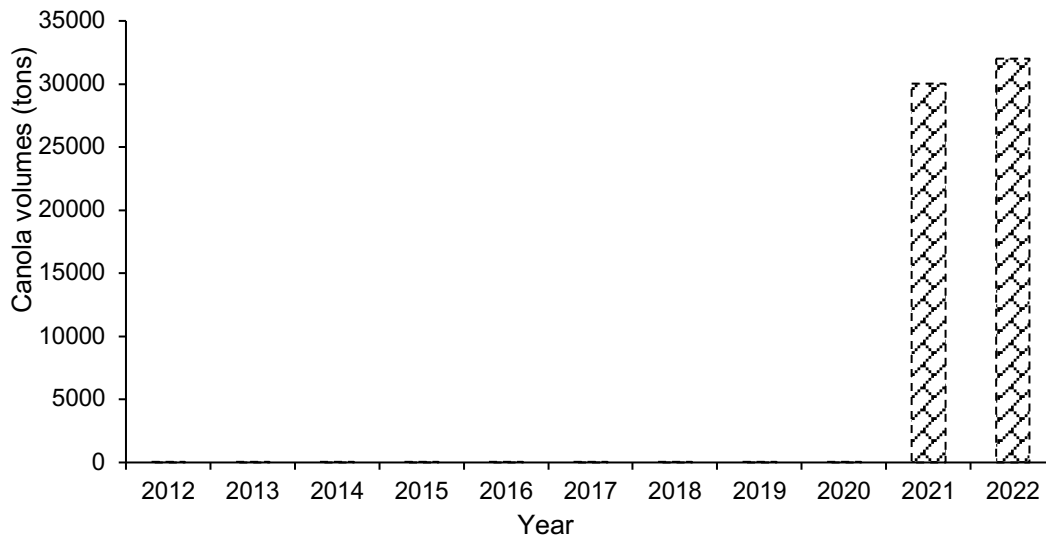


**Figure 2: Canola production area and production in the Western Cape of South Africa, adapted from DALRD [7]**

### South African canola exports

South Africa (SA) is a competitive country and can sell goods in the global market under fair conditions [7]. It exports its canola to several countries including the European Union, the United States of America, Lesotho, Botswana and Eswatini [7]. From 2012 to 2020, SA had low domestic canola production, resulting in low export volumes (Figure 3). However, the canola export volumes took a sharp increase from below 5000 tons to over 30,000 tons between 2021 and 2022, due to rising international demand (Figure 3).





**Figure 3: Canola exports volumes in SA adapted from DALRD [7]**

### South African domestic demand

In the local market, canola competes with other plant oils such as sunflower and soya oils. An estimated 720 000 tons of plant oils are consumed domestically each year while SA canola growers produce approximately 300 000 to 350 000 tons of plant oils [6], leading to SA importing more tons of canola. In 2020, SA mostly imported canola from Australia, Canada, Denmark, Poland, Hungary, and the United States. Australia was the biggest supplier of canola to SA in 2020. Australia supplied 163.4% of SA's entire canola imports in the same year, followed by Canada and Denmark with 32.8% and 1.7%, respectively. Between 2016 and 2020, SA's imports of canola from the rest of the globe climbed in value by 5% and volume by 23% [7]. This growing reliance on imports highlights a significant gap between domestic production and market demand. To reduce dependency on foreign suppliers and strengthen local agricultural sustainability, increasing canola production in SA is essential. Expanding canola cultivation could enhance food security, create economic opportunities for farmers, and support the local oil-processing industry, ultimately reducing the trade deficit associated with plant oil imports.

### The Role of Irrigation in Canola Production

#### Canola Production Under-Irrigation

Canola is widely grown under dryland conditions in most parts of the world [19]. Due to this, water stress has become the most targeted limiting factor to canola productivity around the world [20]. Water stress during the growing season results in lower crop yield, globally it is mainly due to insufficient rainfall which can be linked to climate change [21]. Water stress challenges were observed in other off-season canola-growing countries [22]. In general, canola seed yield characteristics increase

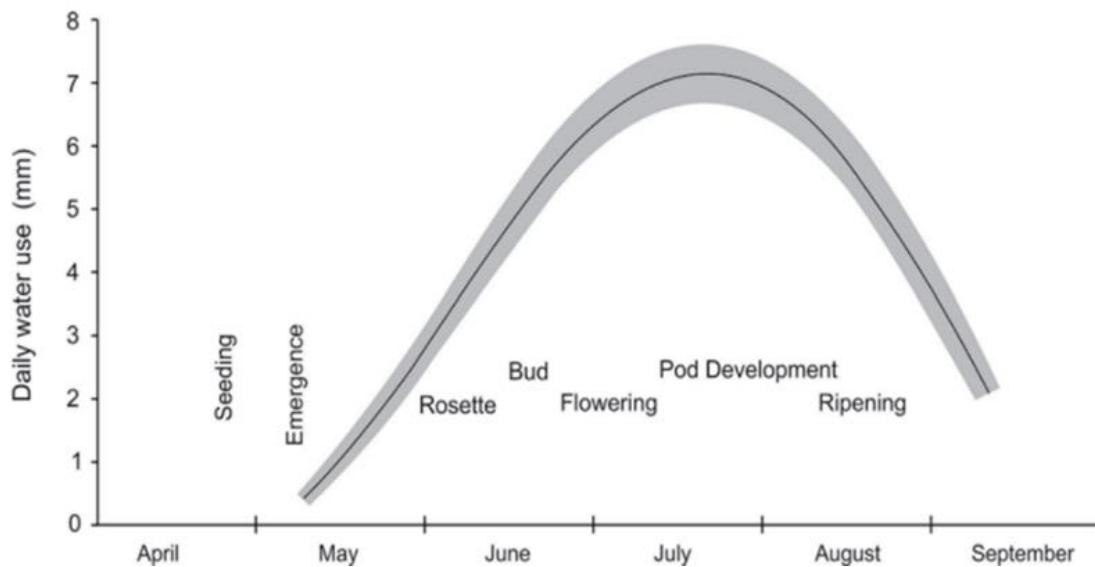
with increased irrigation. This was shown in the work by Tesfamariam *et al.* [23], the authors found that the well-irrigated canola plants gave the best seed yield of 3831 kg ha<sup>-1</sup>, and seed oil content of 398 g kg<sup>-1</sup> while the water-stressed plants gave a seed yield of 1361 kg ha<sup>-1</sup> and seed oil content of 340 g kg<sup>-1</sup>. This shows that canola producers can use irrigation to supplement rainfall and ensure good canola yields.

Canola seed and oil yield are most sensitive to water stress at flowering and less sensitive during the vegetative and seed-filling stages [23]. Irrigation provides opportunities to intensify production and increase productivity, mitigate water stress and increase dry matter, leaf area index, oil content, and yield [24]. As a result, water is required in greater amounts than any nutrient taken up from the soil by the plants. This indicates that the role of irrigation and irrigation scheduling in canola production is crucial for addressing water stress, improving yield stability, and maximising oil content. While irrigation has demonstrated significant benefits in multiple regions, its adoption must be tailored to local environmental and economic conditions. Table 1 shows some of the countries that plant canola under irrigation using different irrigation frequencies.

### **Water requirements and critical growing stages of canola**

Canola has a relatively high-water demand, with peak water use occurring during flowering and pod development. The crop also requires substantial irrigation during seed emergence and vegetative growth [25]. Studies have shown that irrigating canola at its critical stages significantly increases the yield. At the reproductive phase, water stress accelerates the process of flower drop and decreases seed yield [26]. Thus, flowering and pod development stages are the most crucial stages for irrigation. Water requirements during these stages range between 4 and 8 mm per day, depending on the soil type and cultivar (Figure 4). During seed emergence and flower bud development, the crop uses between 0.1 mm and 3 mm of water per day. Higher yields were obtained when sufficient irrigation water of 5- 7 mm day<sup>-1</sup> was applied at flowering and pod formation [27, 28]. However, in a different study, negative effects on pod formation and seed size were observed due to water stress during the flowering, which resulted in lower yield and oil content [29].





**Figure 4: Canola daily water use curve during growth stages under irrigation**

The shaded area shows variation in canola water use depending on cultivar, soil type and climatic conditions, adapted from Alberta Agriculture and Forestry Irrigation [25]

The most sensitive canola growth stage to water stress was evaluated in SA [23]. Canola exposed to water stress during flowering resulted in low seed yield and oil content. The work by Alberta Agriculture and Forestry Irrigation [25] suggests that most oil accumulation occurs from the pod stage up to maturation, therefore, irrigating during this time increases the oil content. In contrast [30] found no significant difference in seed oil concentration and yield between plants exposed to water stress from emergence and those stressed only after flowering. All water-stressed plants (stressed from emergence and stressed after flowering) showed a decrease in seed oil concentration, 1000 grain weights and yield when water stress was applied. Similar results were observed when the water stress was imposed from sowing to flowering [31] and the seed oil and protein contents were not significantly affected by different irrigation level applications [32]. This shows that irrigation timing and irrigation amount play a critical role in maximising canola productivity. In short, ensuring adequate water availability during flowering and pod development is essential for optimising both yield and oil content. However, variations in cultivar response, soil conditions, and regional climatic factors necessitate further research to establish location-specific irrigation strategies that enhance water use efficiency and overall crop performance.

### **Irrigation methods efficiency and yield responses**

Although canola is mainly grown under rain-fed farming systems, it is clear that some parts of the world successfully produce canola under irrigation [7]. The most common irrigation systems used for canola production include centre pivots, sprinklers and drip irrigation [33]. The centre pivot and sprinkler irrigation are overhead irrigation

systems, while drip irrigation is a low-flow trickle irrigation system providing water directly to the plant roots. The sprinkler irrigation and drip irrigation systems were compared in improving canola yield and water productivity [34]. In the study, the sprinkler irrigation system gave higher water productivity, yield and oil production than the drip irrigation system. The sprinkler irrigation system gave a 20% higher yield with 19% water use efficiency compared to basin irrigation [35]. Furthermore, a significant increase in plant population on overhead irrigation systems compared to surface irrigation when different irrigation systems were evaluated for canola production [36]. In contrast, drip irrigation system has major advantages over sprinkler systems as they irrigate with high efficiency and use less water pressure while having high yield and saving water [37].

The influence of different plant-water availability using four irrigation levels of 19%, 34%, 52%, 67% and full irrigation (0%) on canola water use was studied in Free State, SA [38]. The study found that the leaf area index and crop biomass significantly decreased at 19, 34, 52, and 67% compared to full irrigation (0% deficit). Additionally, canola yield and oil concentrations were observed to decrease when irrigation was applied at 37% of the full water requirement [39]. Another study on the effects of different allowable depletion levels of plant-available water on the yield, yield components, water, and irrigation water use efficiency of spring canola was done in Iran [40]. This study used three deficit irrigation levels of 20% (I2), 35% (I3), 50% (I4) and full irrigation (I1) and results showed the highest seasonal evapotranspiration occurred at full irrigation. This indicates that under full irrigation, canola plants utilised the maximum amount of irrigation water for transpiration and soil evaporation, supporting optimal growth and biomass production. However, it also suggests that water use efficiency should be carefully managed to avoid excessive water consumption while maintaining yield stability.

Canola yield and oil composition are crucial in canola production, high-yielding varieties with optimal oil quality ensure economic sustainability, market competitiveness, and canola health benefits. Table 2 lists studies that investigated the effect of different allowable depletion levels of plant-available water on canola yield and oil concentrations. Most of the results show that canola yield and oil content increased with increased irrigation. Most of the authors found that the plant's available water depletion level of 100% followed by 60% was the most effective for increasing canola yield and oil content. These findings highlight canola's status as a water-intensive crop, requiring strategic irrigation management for optimal growth and quality.

### **Monitoring Soil Moisture in Canola Production**

Water scarcity is the most limiting factor for crop production in arid and semi-arid regions [40]. As such, good irrigation management practices are required to ensure

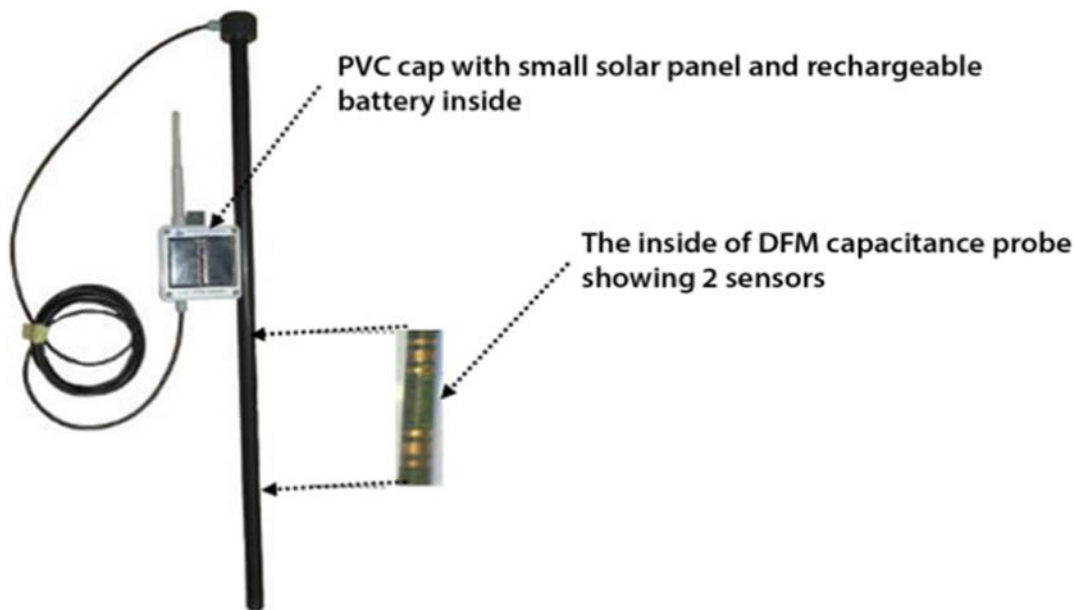


water use efficiency for improved and sustainable canola productivity [5]. There is a growing need to understand the effects of irrigation scheduling and water use efficiency on canola production under different irrigation conditions [40]. Integrating soil moisture monitoring technologies into irrigation scheduling can further enhance water use efficiency, ensuring optimal soil moisture levels for improved canola yield and oil composition. Soil moisture monitoring tools are required to accurately schedule irrigation, increase the water use efficiency of irrigated agriculture and significantly increase the crop yield [36]. Soil monitoring tools are suitable for water-saving. The common soil moisture monitoring equipment suitable for canola production includes tensiometers, TDR (Time-Domain Reflectometry) probes, neutron probes and capacitance probes buried below the planting depth or at the top 50 cm of the soil [25, 36].

The study by Gan *et al.* [26] used the Troxler instrument, model sentry 2000 (TDR) to ensure canola was produced under drought stress. The authors successfully assessed water use efficiency for grain yield, seed oil content, and protein content. Neutron and Dirk Friedhelm Mercker (DFM) capacitance probes were compared in measuring soil water content [41]. Both probes gave good soil water content measurements with good agreement with gravimetrically soil water content. However, the DFM capacitance probe was superior in providing accurate top-soil evaporation measurements than the neutron probe [41].

The DFM probes measure soil water content and temperatures with six (6) sensors placed at different depths and take measurements at hourly intervals (Figure 5). However, it was examined if DFM probes required field calibration for accurate soil moisture measurements using textural site-specific calibration and lumped site-specific equation [42]. The DFM probe readings were examined by plotting them against gravimetric and volumetric soil moisture readings. The gravimetric readings were obtained by collecting soil samples using soil augers and weighed before and after oven drying. The results indicated that the relationship between gravimetric and probe readings was reasonable, and the lumped site-specific calibration equation gave a lower accuracy compared to the textural site-specific calibration equation.





**Figure 5: DFM Probe for measuring soil water content [41, 42]**

The use of advanced soil moisture sensors, such as neutron and DFM capacitance probes, enhances irrigation scheduling by providing accurate, real-time data on soil water availability. While both probe types offer reliable measurements, the DFM capacitance probe proves superior in capturing topsoil evaporation, which is critical for managing water losses. Furthermore, site-specific calibration improves the accuracy of soil moisture readings, ensuring that irrigation decisions are well-informed. By integrating precise soil moisture monitoring with efficient irrigation practices, farmers can maximise water use efficiency, enhance crop yield and oil quality, and contribute to the sustainability of canola production in diverse agroecological conditions.

### **Limitations and Knowledge gaps**

Irrigation has been shown to enhance both yield and oil content in canola, with studies highlighting differences in its water stress tolerance across growth stages. Some research suggests that the pod development to maturation stage is relatively tolerant to water stress, while other findings indicate no significant impact on seed oil concentration when stress occurs at different stages. Additionally, various studies have used different soil moisture monitoring tools, such as DFM probes, neutron probes, and gravimetric methods. Irrigation has been done using irrigation systems like sprinklers and drip irrigation, to maintain relevant soil moisture in canola-irrigation research. However, there has not been any indication on the best moisture measuring tool for long-term field monitoring of canola fields.

Regarding irrigation systems, some studies identify sprinkler irrigation as the most efficient irrigation system, while others advocate for drip irrigation due to its water-

saving benefits. Regardless, these claims have not considered the economic feasibility of the various soil moisture monitoring tools as well as those of using different irrigation systems. Further research is needed to examine how irrigation timing influences oil quality and composition under varying levels of water stress. Additionally, location-specific studies comparing real-time soil moisture sensors are crucial to identifying the most accurate and cost-effective methods for canola irrigation management. Given the global production of canola across diverse soil types and climates, comprehensive studies are required to determine optimal irrigation strategies for different regions, particularly in SA which has a large canola oil demand with limited production and exports.

## CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The expansion of canola cultivation in SA presents an opportunity to meet rising domestic and global demands for plant oils. However, water stress remains a critical challenge in optimising yield and oil content. This review highlights the significance of irrigation in canola production, highlighting its role in improving seed emergence, biomass accumulation, and oil yield. It also looks at the different irrigation systems that have been studied under canola-irrigation research. Among these irrigation systems, sprinkler irrigation has demonstrated superior water productivity and yield advantages, while soil moisture monitoring tools such as capacitance probes aid in precise irrigation scheduling. In general, research indicates that applying full irrigation during critical growth stages particularly flowering and pod development results in optimal yields and oil content. Additionally, some deficit irrigation strategies have shown that they can enhance water use efficiency without compromising productivity. Regardless, future research should focus on location-specific irrigation models, cost-benefit analyses of different irrigation systems, and long-term soil moisture monitoring in canola fields. Ultimately by integrating advanced irrigation management practices, SA can strengthen its canola industry, reduce reliance on imports, and enhance the sustainability of oilseed production in marginal lands and in provinces where it is currently not grown.

## ACKNOWLEDGEMENTS

We acknowledge the support of Eastern Cape Department of Rural Development and Agrarian Reform and Agricultural Research Council for supporting the study.

## Declaration of Interests Statement

The authors declare no conflict of interest.



**Table 1: Canola irrigation frequency to obtain the highest yield**

Country	Soil type	Canola irrigation frequency to obtain the highest yield	Type of irrigation	Reference
Brazil	Red distroferric oxisol	Three times per week	Drip	[22]
Iran	Silt loam	Three times per season stem- elongation, flowering and seed-filling stages	Flood	[29]
Mexico	Unspecified	Frequency was depended on rainfall	Center-pivot	[43]
Pakistan	Clay loam	Three times per season- vegetative stage, flowering and seed formation	Sprinkler and Flood	[35]
Pakistan	Sandy clay loam	Three times per season – vegetative, flowering and seed formation stages	Unspecified	[32]

**Table 2: Effect of plant available water (PAW) levels on increasing canola yield**

Study site	Increase in canola yield or oil content	Suitable (PAW) level (%) to increase yield	References
Canada	Increase yield and oil content	60	[36]
University of Tabriz, Tabriz Uran	Increase yield	100	[40]
Harran University, Sanliurfa, Turkey	Increase in yield and oil content	100	[21]
Canada	Yield increase	60	[25]
Free State, SA	Highest seed yield	100	[38]
Griffith, Australia	Increase yield	60	[33]
Karaj, Iran	Increase yield	45	[44]
Brazil	Yield increase	80	[45]
Centre for Applied Biology, France	Increase in yield and oil concentration	100	[39]

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