Local hybrids have the potential to increase South Africa's sunflower yield

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Sunflower is one of the most important oilseed crops in the world. Global production grew steadily over the last 25 years and the Food and Agriculture Organization of the United Nations (FAO) estimates that global sunflower production will approach 60 million tons by 2050.

The four largest producers (Russian Federation, Ukraine, European Union and Argentina) account for 70% of global volume, with an exponential growth of production in the Black Sea region during the last decade, due to increased acreage and higher yields achieved by replacing old varieties with certified and higher yielding hybrids.

Global sunflower seed production for 2021/22 is estimated at 57,19 million tons, planted on 28,75 million hectares, with an average yield of 1,99 tons per hectare, sunflower oil at 21,11 million tons, and sunflower meal at 22,57 million tons.

Sunflower production in SA

In South Africa, sunflower seed is the fourth largest grain crop produced after maize, wheat and soya bean. Between 2010/11 and 2020/21, an average of 734 253 tons of sunflower seed were produced annually on an average area of 565 896ha, with an average yield of 1,3t/ha.

Until the early 2000s, South African sunflower seed yields were comfortably on par with the average yields obtained by the four largest producers and exporters of sunflower in the world. Since 2004, however, the area under production has declined and South African yields have not followed the same increasing trend as the rest of the world. In fact, the ten-year world average yield (2011 to 2021) of 1,75t/ha was 35% higher than the ten-year average of 1,3t/ha in South Africa.

In the sunflower national cultivar trials conducted by the Agricultural Research Council's ARC-Grain Crops, a ten-year average yield of 2,24t/ha was achieved, which is 28% higher than the world average and 72% higher than the national sunflower average for the same period. This is a clear indication that local sunflower hybrids do have the genetic potential to produce yields that are in line with or even higher than the global trend.

Under-utilisation of good farming principles such as optimal planting dates, planting density, field selection (soil pH), fertilisation, introduction of advanced sunflower hybrids, environmental factors, and the fact that sunflower is often not the first-choice crop on South African farms are likely contributing factors to this yield gap.

ARC trial results from 2018-2021

To investigate the performance potential of commercially available sunflower hybrids from different seed companies, 16 hybrids were evaluated for seed yield, oil content and oil yield in 21 different environments (sites and years), in the Free State and North West provinces during the 2018/19, 2019/20 and 2020/21 growing seasons.

A randomised, complete block design with three replicates was executed for each site. Seed yield was recorded for each site individually and an analysis of variance (ANOVA) was performed on the yield data of each individual site. Combined analyses of variance were also performed on the pooled annual data. Seed samples were sent to the Southern African Grain Laboratory (SAGL) for oil content analyses. Seed oil yield was calculated by multiplying oil content (%) with seed yield (t/ha).

Results: Seed yield

Seed yield is a complex trait that is influenced by genotype, environmental factors and management practices. Both additive and non-additive genetic effects play a role in the inheritance of seed yield.

Results of this research showed that the average seed yield recorded across the tested hybrids and growing seasons was 2,49t/ha, with 100% of tested hybrids yielding more than 2t/ha. During the 2018/19 growing season, 94% of tested hybrids yielded more than 2t/ha, with an average yield of 2,25t/ha, which varied from 1,98 (SY 3970 CL) to 2,44t/ha (PAN 7080).

During the 2019/20 and 2020/21 growing seasons, 100% of the hybrids again produced more than 2t/ha. During 2019/20, an average yield of 2,55t/ha was achieved, which varied between 2,34 (SY 3970 CL) and 2,68t/ha (PAN 7080). In 2020/22, an average yield of 2,66t/ha was recorded, which ranged between 2,3 (SY 3970 CL) and 2,84t/ha (PAN 7100) (*Figure 1*).

Results: Oil content

Oil content (OC) was predominantly influenced by the hybrid, followed by environmental factors and agricultural practices. Producing sunflower hybrids with a high OC might contribute to enhanced sunflower production in South Africa.

Significant differences in OC (%) were observed between tested hybrids as well as across different environments and growing seasons, with an average moisture-free OC of 42,38%. The highest OC of 51,53% (SY 3970 CL) was recorded during the 2018/19 growing season and the lowest (37,61%) (AGSUN 5106 CLP) in 2019/20.

During the 2018/19 growing season and across hybrids, the moisture-free OC varied from 40,65 to 51,53%, with 50% of the hybrids recording more than 42% OC and 44% recording an OC of more than 44%. In 2019/20, the lowest OC was 37,61% and the highest 50,61%, with 44% of the hybrids having an OC of more than 42% and 19% having an OC of more than 44%.

During 2020/21, the lowest OC was 37,93% and the highest 49,37%, with 50% of the hybrids recording more than 42% OC and 19% more than 44%. Across the three growing seasons, 50% of the tested hybrids produced an OC of more or equal to 42%, and 25% had an OC of more than 44% (*Figure 2*).

These results demonstrate that

Figure 1: Seed yield for 16 sunflower hybrids tested from 2018/19 until 2020/21.

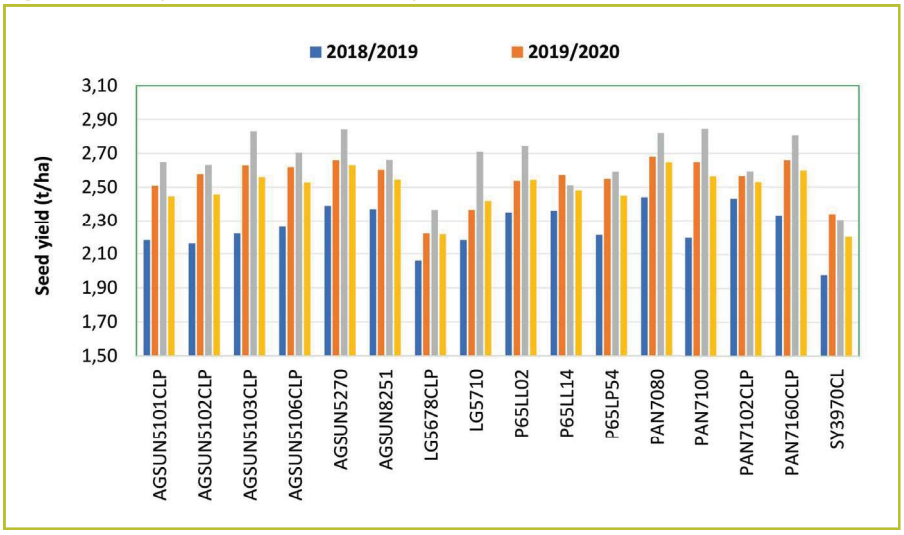


Figure 2: Oil content for 16 sunflower hybrids tested from 2018/19 until 2020/21.

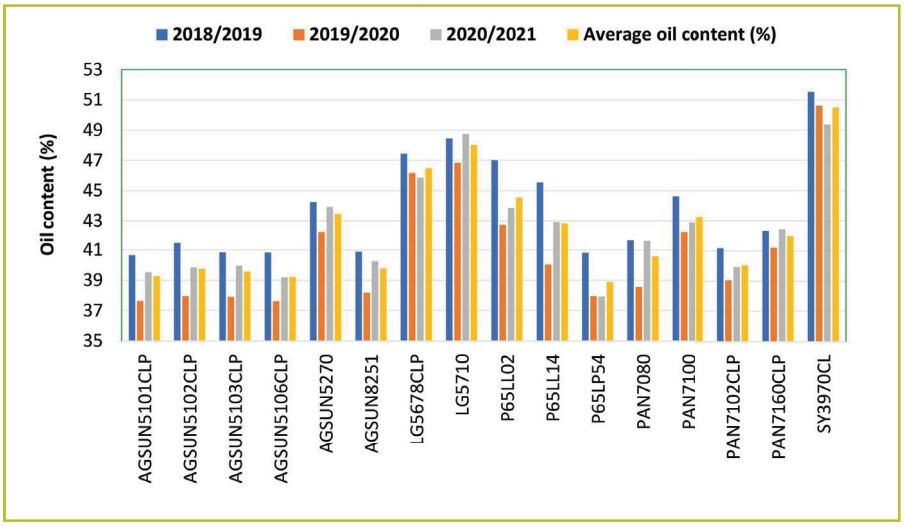
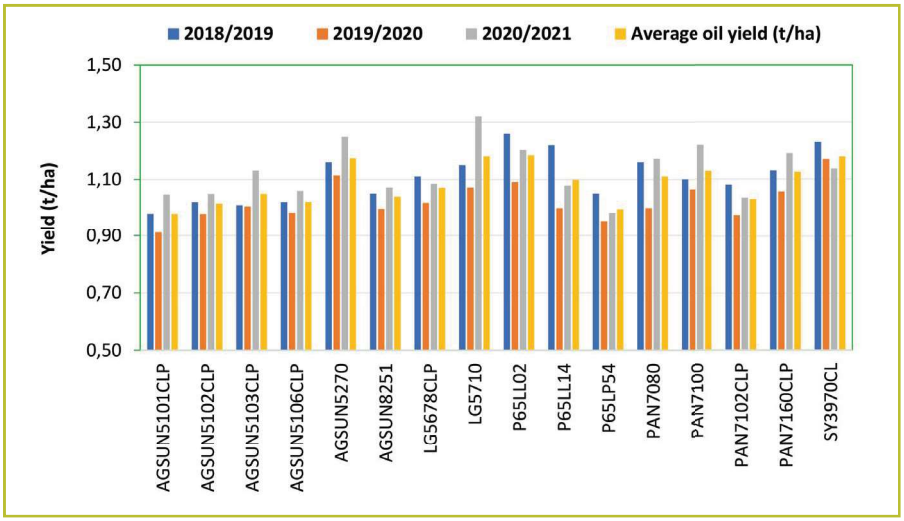


Figure 3: Oil yield for 16 sunflower hybrids tested from 2018/19 until 2020/21.



sunflower OC is not affected only by cultivar selection, but also (often more importantly) by environmental variables and agronomic management practices.

Results: Oil yield

The oil yield per plant is the result of the number of seeds per capitulum, weight per seed, and oil content. These components are determined by genetic factors, although they can be modified by environmental and growth conditions.

Significant differences were recorded among the sunflower hybrids across different localities and during the three growing seasons, with 94% of hybrids having an oil yield of more than 1t/ha. In the 2018/19 growing season, the oil yield ranged from 0,98 (AGSUN 5101 CLP) to 1,26t/ha (P 65 LL 02), with an overall mean of 1,11t/ha.

A total of 94% of hybrids produced an oil yield of more than 1t/ha. During the 2019/20 growing season, the oil yield varied between 0,91 (AGSUN 5101 CLP) and 1,17t/ha (SY 3970 CL), with an overall mean of 1,02t/ha and a total of 69% of hybrids yielding more than 1t/ha.

In 2020/21, the average oil yield was 1,13t/ha, which ranged from 0,98 (P 65 LP 54) to 1,32t/ha (LG 5710), with 94% of hybrids producing more than 1t/ha across environments (*Figure 3*).

Concluding remarks

Cultivar choice and technologies, together with agronomical practices and environmental factors are all important drivers for oil content in sunflower seed. Research conducted by ARC-Grain Crops demonstrated that local sunflower hybrids have the potential to produce moderately higher seed yields with high oil contents, and more importantly, greater than 1t/ha oil yields in the North West and Free State production areas.

The sunflower hybrids that are currently available in the South African market therefore do have the genetic potential to produce higher yields that are more in line with international trends, but producers are yet to tap into their potential.

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Yield targets varied from 2 800 to 3 900kg per hectare at different sites. Most fertiliser was side-banded 2cm beside and 3 to 4cm below the seed row, with small amounts of nitrogen and phosphorus also placed with crop seeds.

The experimental design was a randomised complete block design with four replications. A factorial arrangement of treatments (5x2) was imposed with four canola seed size treatments (average 1 000 seed weights: 3,96; 4,6; 4,8; 5,7g) and one unsized treatment (4,4g) seeded at 75 or 150 seeds/m. The seed was treated prior to seed size segregation.

One or two in-crop applications of glyphosate at 450g of acid equivalent (ae) per hectare were applied as required to control local weed populations. Fungicides and insecticides were applied as needed, according to local disease and pest insect infestations. Data collection included crop emergence density, crop biomass at the six-leaf stage, days to start and end of flowering, days to maturity, canola yield and productive plant stubble density.

Seeding rate effects

Seeding rate did not interact with seed size for any dependent variable ($P \geq 0,2031$) (*Table 1*). Canola seeding rate influenced most dependent variables (*Table 2*). Similar to the results of Kutcher *et al*. (2013), a higher seeding rate did not increase canola yield ($P = 0,1360$).

Despite significant site x seeding rate interactions for both variables, all individual site data were in complete compliance with the all-site means. Emergence percentage was 55% for both seeding rates. In a previous study, canola seeded at a depth of 1cm had 45% emergence (Harker *et al.*, 2012a).

Canola biomass at the six-leaf stage increased with the higher seeding rate (150 seeds/m) (*Table 2*). Results from seven of nine sites supported the seeding rate effect on biomass. The two remaining sites were not statistically significant. Seeding rates leading to higher crop biomass help to rapidly close the crop canopy and facilitate integrated weed management strategies (Blackshaw *et al.*, 2008) that delay weed resistance to herbicides (O'Donovan *et al.*, 2007).

The higher canola seeding rate (150 seeds/m) also increased 1 000-seed weight and seed oil content. The latter seeding rate effects were not significant at most individual sites, but no sites demonstrated a contrary effect. Seed weight is an important yield component for canola productivity. Greater crop biomass from the higher seeding rate probably reduced compensatory growth (McGregor 1987; Angadi *et al.*, 2003), and the number of smaller, less mature seeds. Similarly, oil content is increased in larger, more mature seeds.

The higher canola seeding rate reduced days to the start of flowering and days to maturity, with a trend ($P = 0,0514$) to reduce days to the end of flowering (*Table 2*). Greater plant biomass and intraspecific competition from the high seeding rate probably reduced compensatory growth and hastened flowering and maturity. Although the differences in flowering and maturity were small, they could have large impacts on canola yield and quality.

Earlier flowering and maturity increase the probability that canola will avoid relatively high temperatures that reduce canola yield potential. Similarly, earlier maturity can reduce the likelihood of frost damage and subsequent yield and green seed-related quality reductions.

Seed size effects

Yield is usually the most important response variable in agronomic experiments. Even though there were no significant regression contrasts for canola yield versus seed size with sites treated as a random effect ($P \geq 0,2249$), it remains useful to observe individual site effects and variability.

Site-to-site yield variability was dramatic. Yields at the highest yielding site were approximately threefold greater than the lowest yielding site. The site-by-seed size interaction for yield was highly significant ($P = 0,0010$). Excluding only one site, there were no significant

Table 1: The statistical significance of treatment and site sources of variation, including regression contrasts for dependent variables.

Source	Dependent variables										
	Emergence density (nr m^{-2})	Crop biomass (kg per ha^{-1})	Start of flowering (days)	End of flowering (days)	Crop maturity (days)	Yield (kg per ha^{-1})	Stubble density (nr m^{-2})	1 000-seed weight (g)	Green seed (%)	Oil content (%)	Protein content (%)
Seed rate (R)	<0,0001	0,0019	0,0398	0,0514	0,0094	0,1360	<0,0001	0,0405	0,3577	0,0001	0,0006
Seed size (S)	0,4656	0,0005	0,0038	0,0828	0,5727	0,4491	0,1942	0,0561	0,3244	0,9454	0,9527
R x S	0,6462	0,4434	0,5074	0,4350	0,2031	0,8650	0,6456	0,5756	0,4777	0,7417	0,6189
Site	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001
Site x R	0,0230	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	0,0430	0,0935	<0,0001	0,9449	0,9672
Site x S	0,0006	<0,0001	0,9130	0,0003	0,0957	0,0001	0,7779	0,8475	0,0843	0,9939	0,9872
Site x R x S	0,9408	0,9841	1,000	0,0014	0,1454	0,9895	0,7687	0,9621	0,0085	0,9863	0,9979
Regression contrasts for seed size (S)											
Linear	0,6588	0,0003	0,0003	0,0171	0,2463	0,2249	0,1799	0,0089	0,1775	0,6589	0,7135
Quadratic	0,3567	0,1381	0,7770	0,4303	0,8163	0,6833	0,5295	0,5555	0,7269	0,9086	0,7381
Cubic	0,6479	0,1740	0,9651	0,8062	0,7145	0,4062	0,7029	0,6541	0,5225	0,8370	0,8409