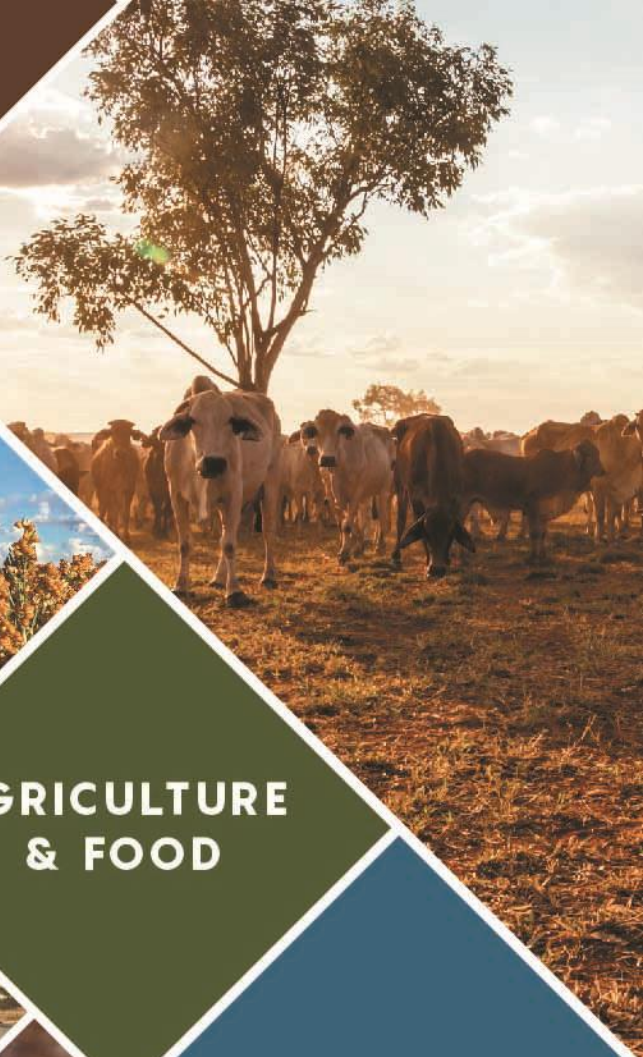
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PART D: CUMIN FINAL REPORT

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CRCNA

DEVELOPING NORTHERN AUSTRALIA

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The CRCNA recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

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- methodology
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EXECUTIVE SUMMARY

The Spicing Up Northern Australia Project research contributed knowledge to the development of a high-value broadacre spice and condiments industry in northern Australia. The research focused on the production of spices currently not commercially produced in Australia. The objectives were to identify suitable spice crop varieties and investigate agronomic practices underpinning production.

The project, conducted over three years involved farmers and business participating in multilocation trials for an initial evaluation of cumin, black sesame, fennel, kalonji, and kalijiri in the first year, followed by variety and agronomic verification trials in the second year and scaling up for commercial production trials in the third year. A market analysis was conducted for cumin, black sesame, fennel, kalonji and caraway (caraway did not progress to evaluation trials due to germination issues and was later replaced by kalijiri) and a gross margin analysis was conducted for sesame, fennel and kalonji in the third year of the project.

This report presents performance evaluation of three cumin varieties across six locations in Queensland and the Northern Territory Australia planted during winter of 2020. These initial varietal evaluations revealed a yield potential of 704 kilograms per hectare when hand-harvested for variety AVTCuS#3 at Rockhampton. The highest average cumin seed yield (averaged for three varieties), was recorded at Rockhampton QLD (688kg/ha), followed by Ayr QLD (460kg/ha), and lower yield at Biloela QLD (388kg/ha) and Katherine NT (343kg/ha). The yield difference between the varieties was not significant in any of the trial locations. The crops at Tully and Darwin did not establish due to very poor growth and incidence of rot root, largely associated with wetter soil.

The incidence of root rot disease at the early establishment stage and powdery mildew at the reproductive stage were two major disease challenges. The cumin crop in general displayed low growth resulting into short plant stature with most of the seed development near to the ground, making the crop unamenable for machine harvest.

The low yield, susceptibility to diseases and potential challenges for machine harvest associated with short plant stature, lead to the growers and industry participants deciding not to proceed with verification and commercialisation trials in years two and three. Therefore, high yielding, disease tolerant varieties, with a plant type suitable for machine harvesting, are suggested for cumin breeding programs if the crop is to have a future in Northern Australia.

1. INTRODUCTION

As a part of the CRCNA-funded project Spicing Up of Northern Australia (2019-2022), the following progress and technical reports related to cumin research were delivered:

- "Market Analysis of Cumin Seed" (2020) –

  https://crcna.com.au/resources/publications/market-analysis-cumin-seed

- "Broadacre Cropping in Northern Australia-Newsletter" 2021 - https://crcna.com.au/resources/publications/broadacre-cropping-northern-queensland

These reports have been published and are available via the CRCNA website.

The "Market Analysis of Cumin Seed 2020" revealed the current global cumin markets, and identified major global producers and importers of cumin seeds. The report also analyses current demand and forecasts future demand for cumin seed for Australia.

The "Broadacre Cropping in Northern Australia - Newsletter 2021" presented the results of initial variety evaluation trials for five species crops, including cumin, kalonji and kalijiri as winter options, and sesame and fennel as summer crops. These trial results presented hand-harvested yields to showcase the yield potential in different locations in Northern Australia.

The "Spicing up Northern Australia" project outlined eight key deliverables for achieving the project objectives and purpose. Five key deliverables are related to crop production, quality assessment and economic analysis, and these are addressed in this report. As the crop, after initial evaluation, did not progress through the verification and commercial trials, only the data from the year one varietal evaluations are presented in this report.

The common deliverables across the five crops, i.e., deliverable 6 - Extension; deliverable 7-Complementary Activities; and, deliverable 8 - Research Insights and Future Directions; are common for all five spices crops included in the project. Therefore, reporting for deliverables 6-8 is presented in the overarching Final Report to minimise the duplication of information and contents across the crop-specific reports.

2. MARKET ASSESSMENT

The market assessment undertaken in 2019-2020 investigated the current and future trends of the Australian and international cumin markets. The following extract from the report summarises the key findings. The full report is available at:

https://crcna.com.au/resources/publications/market-analysis-cumin-seed

The cumin market analysis report provides a baseline assessment of the global industry based on currently available information and identifies areas for further research to address the gaps in market information.

India is largest producer and exporter of cumin. In 2018, India exported about 187,000t of cumin at a net value of US$438 million. The average trade value of Indian cumin on the international market is US$2,344/ (Rahman et al., 2020). In the US, the domestic market price of cumin is approximately $3000/t (UN ComTrade, 2019, DASD, 2019, TurkStat, 2019).

The cumin price in Australia is largely influenced by the global market price. AgriVentis Technologies Ltd accessed information on the global market price for cumin through Tridge (https://www.tridge.com/intelligences/cumin-seed) and verified this through the price on offer by the key importers/exporters in global cumin markets (Hunter, 2023).

Cumin is not currently produced commercially in Australia. Australian demand for cumin is met solely by imports with 1,080 tonnes imported annually, largely form India (Rahman et al, 2020).

The demand trend line indicates that by 2025 Australian cumin demand will reach more than 1,800t/year. The trade price of cumin in Australia has been volatile over the last decade, with prices varying depending on the product origin and transport costs.

In 2018 the price was US$3,553/t (UN ComTrade, 2019). Australia typically pays a higher-than-average trading price for cumin on the international market for high-quality products (Hunter, 2023) which suggests there is an opportunity for a new local cumin industry to target the higher values on offer within Australia, before scaling up production for international markets.

3. CROP ASSESSMENT

3.1 Introduction

Cumin (*Cuminum cyminum* L.) is a small herb, belonging to the Apiaceae family. It produces aromatic dried fruit, which are marketed either whole or ground. Cumin seeds come in three colours: amber, white and black. Amber is the most widely available variety, but black cumin has the most intense flavour.

Cumin is widely used as seasoning in cooking, particularly in the cuisines of Mexico, India and the Middle East. Powder and oil are the most common value-added products of cumin. It is also used in perfumery and flavouring liquors, as well as in medicinal products.

Cumin is a good source of plant protein, monosaturated fats and dietary fibres, and the different biological and biomedical activities of cumin have been shown to assist in the treatment of indigestion and hypertension.

Currently about 91% of the world's cumin is produced in four countries: India, Syria, Turkey and the United Arab Emirates (UAE).

While limited global production data is available, India is estimated to produce about 70% of the world's cumin, with approximately 800,000ha under cultivation and yielding 500,000t.

Cumin grows well in tropical and subtropical climates under moderately cold dry climatic conditions. High humidity during flowering and seed setting is not desirable as such conditions favour the development of fungal diseases, such as root rot and powdery mildew, that cumin crop is susceptible to. The crop thrives in the temperature range from 9-26 °C for proper growth and development. Frost at the time of flowering and early fruit set cause adverse effects on the crop.

The Northern Australian climate is therefore suited to cumin production, particularly during winter. For Australian production to be competitive in international markets, variety development work for Australia needs to target yield and quality benchmarks comparable to the leading cumin producing countries of the world.

3.2 Cumin Initial Evaluation Trials (Year 1)

3.2.1 Materials and methods

Trial locations

Field trials were carried out in partnership with farmers and industry to determine the suitability of three genotypes of AgriVentis cumin to the climate, soils and environmental conditions in Northern Australia. The trial locations were four sites in Queensland and two sites in the Northern Territory (Figure 1).

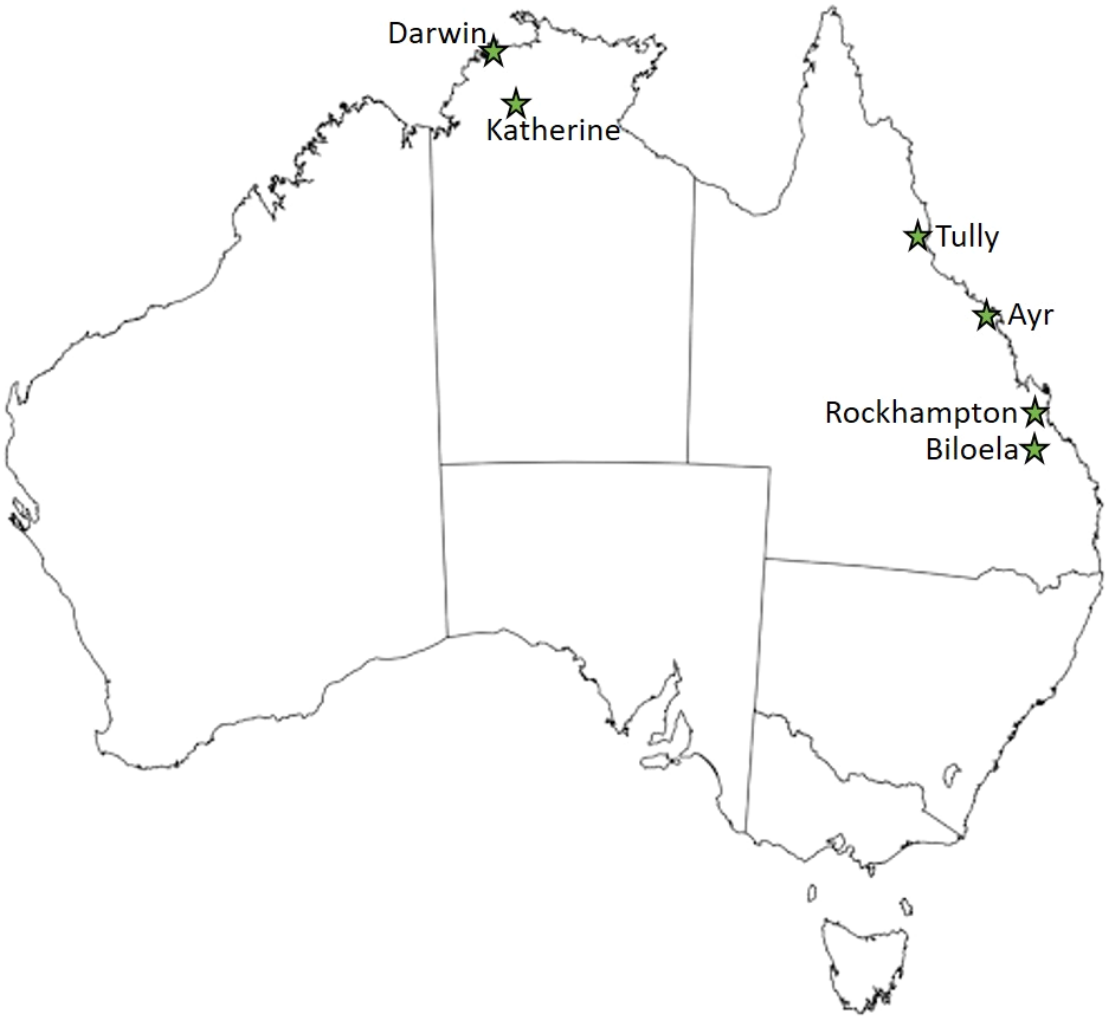


Figure 1. Cumin trial locations in Northern Australia: Biloela, Rockhampton, Ayr and Tully in Queensland, and Katherine and Darwin in the Northern Territory.

Site descriptions

The cumin varieties were planted as a winter crop (May-September). The soil types varied from alluvial and sandy loams (Biloela, Ayr and Tully) to vertisol (Rockhampton) and ferrosols (Katherine and Darwin NT). The trials sites also represented wider range of farming systems (Table 1).

Table 1. Geographic location, in-crop rainfall, soil types and cropping systems of the cumin trial locations.

Location	Latitude	Longitude	In-crop rainfall (mm)	Soils	Cropping system
Biloela, QLD	24º26'32S	150º31'53E	137	Alluvial loam	Hay crop-Cumin-hay crop
Rockhampton, QLD	23º18'24S	150º21'35E	145	Vertisol	Cotton-Cumin-Cotton
Ayr, QLD	19º37'8S	147º31'52E	85	Sandy loam	Melon-Cumin-Melon
Tully, QLD	18º7'23S	145º31'14E	195	Sandy loam	Sugarcane-Cumin- Sugarcane
Katherine, NT	14º28'12S	132º18'28E	70	Ferrosol	Sorghum-Cumin-Sorghum
Darwin, NT	12º35'38S	131º18'16E	203	Ferrosol	Sorghum-Cumin-Sorghum

Planting season

The planting window varied (Table 2) from mid-May to mid-June 2020 (Table 2).

Table 2. Cumin trial planting and harvest dates

Location	Date of sowing/planting	Date of harvest	Crop duration (days after sowing)
Biloela, QLD	14 May 2020	18 September 2020	127
Rockhampton, QLD	27 May 2020	28 September 2020	124
Ayr, QLD	13 June 2020	21 September 2020	100
Tully, QLD		Not established	
Darwin, NT		Not established	
Katherine, NT	29 May 2020	3 September 2020	97

Site preparation

At each site, the bed was prepared following the host grower's practice, and seeds were planted in well-tilled soils. At Biloela, Rockhampton and Tully, the cumin seed was planted in plots 1.5m wide and 2m long. Each plot had three rows of cumin planted 2m long. The two outside rows were guard rows and the one central row (data row) was used for data collection.

Raised beds of 1.5m wide were prepared in Darwin and Katherine and the cumin seeds were planted in four rows 2m in length. The outside two rows were guard rows, and the inside two rows were used for data rows.

In Ayr, 1.5m-wide raised beds covered with plastic mulch were prepared and three rows of cumin, in 2m lengths, were planted in the plastic mulch and one guard row was planted on either side of a single data row. At this site, the blocks of replicates were randomly stacked along one long bed, rather than in a square block pattern. The Ayr sites represents the intensive horticultural crop production systems in the open field, rather than the broadacre farming systems adopted by grain growers.

Drip tape was installed in all sites for supplementary irrigation. One drip line was installed along each of the guard and data rows. Irrigation was only applied to supplement rainfall so that soil moisture is maintained within refill point before reaching the wilting point.

Varieties, trial design and planting densities and planting dates

Three varieties of cumin (AVCuS#1, AVTCuS#2, and AVTCuS#3) were grown for the initial evaluation trials, following the randomised complete block design (RCBD), with multiple replications (five) within the same farm in each location.

The between-row spacing was 50cm and the plant spacing within the row was approximately 6cm with an aim to achieve the target population of ~30 plants/m^2. Thinning occurred at approximately 2-3 weeks after sowing.

Nutrient management

RICHGRO all-purpose complete garden fertiliser (NPKS 9-2-7-12) and RICHGROW High Phosphate–Super Phosphate fertiliser (NPK 0-9-0) was applied to the soil, for an NPK rate of 81:40:63kg Ha^{-1} at planting as a basal dose application. No additional fertiliser was applied during the growing season. All sites received the same level of fertiliser.

Weed control

Weed control at Katherine involved a pre-emergent herbicide Stomp (Pendimethalin A.I 440g/L) application at the rate of 1.5L/ha two days post-sowing for weed control (please see, http://www.herbiguide.com.au/labels/pen33_61322-1209.pdf).

At all other sites, hand weeding was carried out throughout the first month of crop growth to keep the weed competition low during the seedling establishment stage. Once the cumin canopy was well developed, minimal weeding was required as the plant canopy supressed weeds growth.

Data collection and analysis

Crop phenological, vegetative and reproductive data were collected throughout the growing season. The date of planting, emergence, emergence count, flowering, maturity and harvest, and plant stand at harvest were recorded. At maturity, the plant height, number of umbels per plant and height at the position of the first umbel were recorded on six randomly selected sample plants from each plot. The data rows were harvested, and the seeds were separated and cleaned, dried and weighted for determination of seed yield (kg/ha) and quality.

The quality assessments of the harvested seeds were undertaken in Central Queensland University's Crop Science Laboratory. For the quality assessment, a 100g sample of seed was cleaned from plant trash and dust, dried in an oven at 40^{o}C and weighed for determination of seed moisture content. The seed counter was used for the determination of 1000 seed weight from cleaned, dried cumin seeds (Wavwer, Model IC-VA, Japan). The weight for 1000 seeds was taken for each sample using a precision laboratory weighing balance. A subsample of 50g of seed was dried at 70^{o}C for 12 hours and the density of the seed was measured.

Data were analysed for individual sites following the procedure for analysis of variance (ANOVA) using GenStat 2020 (VSN International, 2020) for assessing the effects of treatments, and mean separated using Least Significant Difference (LSD).

3.2.2 Results

Climatic conditions

The weather data for each trial site was recorded using the closest BOM meteorological stations and data was sourced from the Climate Data Online (http://www.bom.gov.au/climate/data/) repository maintained by BOM. The web link for each of those sites for accessing weather data are listed below:

Biloela: Station number 039269.
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=039269

Rockhampton: Station number 039083.
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=039083

Ayr: Station number 033002.
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=033002

Tully: Station number 032167.
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=032167

Katherine: Station number 014902.
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=014902

Darwin: Station number 014183.
http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=136&p_display_type=dailyDataFile&p_startYear=&p_c=&p_stn_num=014183

The maximum temperatures during the early establishment stage were routinely about 20-30°C, whereas the minimum temperature often reached less than 10 °C for Biloela and Rockhampton. The crop vegetative growth coincided with cool and dry weather in all trial sites (Figure 2).

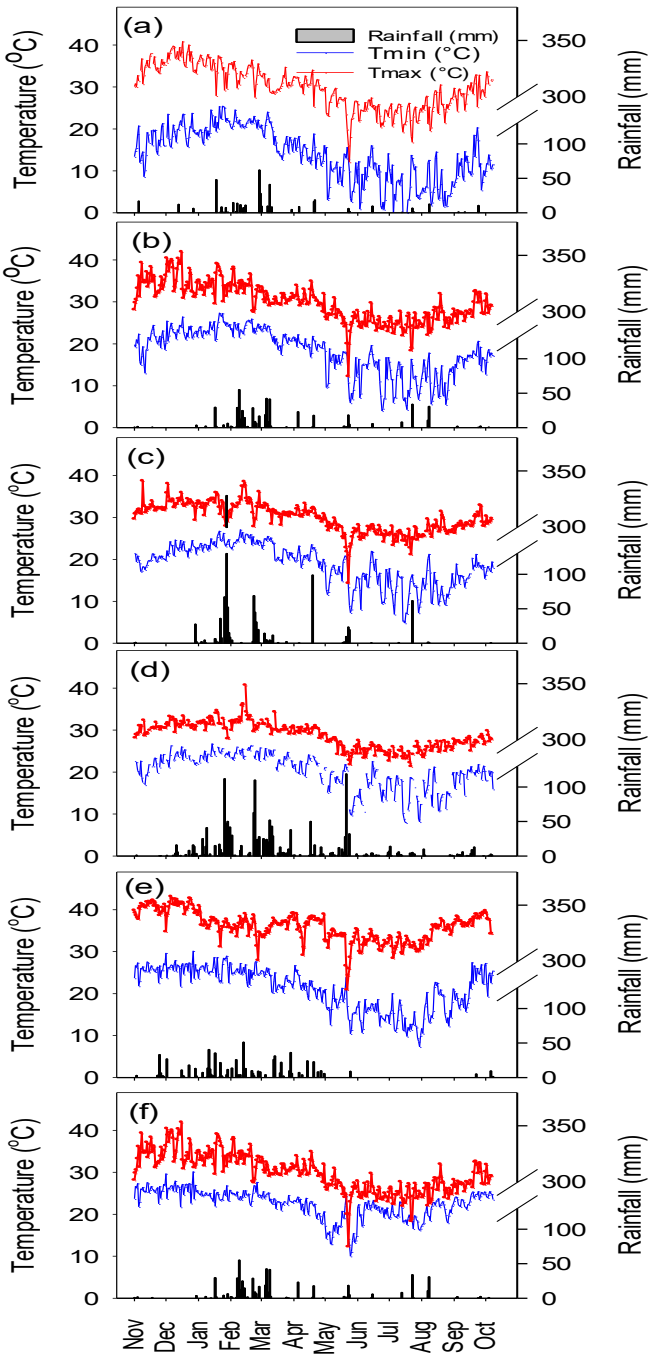


Figure 2. Daily minimum and maximum temperatures and rainfall over the cumin growing season at a) Biloela, b) Rockhampton, c) Ayr, d) Tully, e) Katherine and f) Darwin.

The soil moisture was also recorded at 0-20cm depths from the surface using the Campbell Scientific soil moisture sensors (Hydrosens) and irrigation commenced once the refill point for the soil was reached.

Crop phenology

The cumin seeds were planted at varying dates during the winter of 2020 (Figure 3). The emergence was as early as seven days in Ayr and eight days in Biloela, and out to 10 days for Rockhampton and Katherine. The duration from emergence to flowering ranged from 42 days (Katherine) to 56 days (Biloela). The

flowering-to-maturity stage commenced at 43 days at Ayr and Katherine, and was as late as 55 days at Biloela. The crop maturity and harvest commenced between 97 and 127 days after planting (Figure 3).

The sites were harvested manually after crop maturity, all in a single day at each site. The harvested crop was air dried for 7-14 days, threshed and cleaned manually, then oven dried at 40 °C for up to 12 hours to a constant weight and a moisture content of 6-8% in the dried seeds.

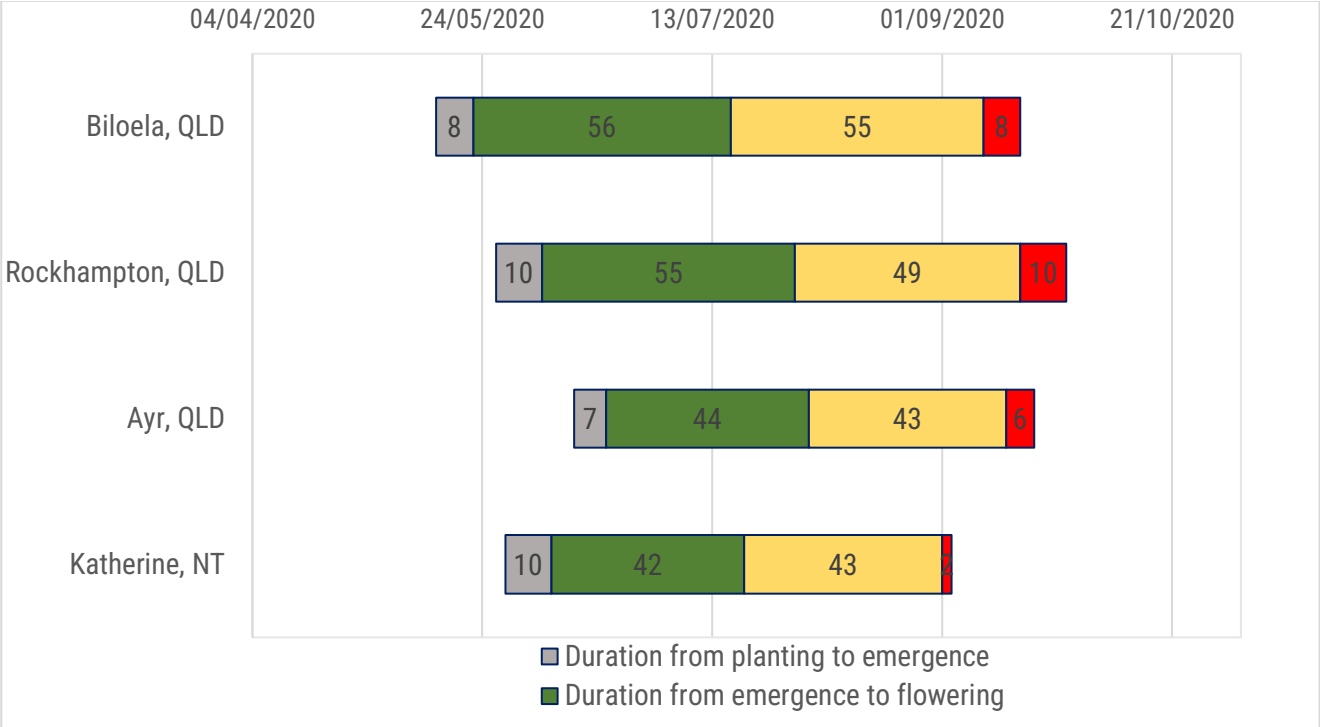


Figure 3. Cumin phenology from planting to harvest for winter cumin at the four trial locations in Northern Australia.

Seed yield

The highest cumin seed yield of 704kg/ha was recorded at Rockhampton for AVTCuS#3. The yield varied significantly between different locations but not between varieties (Table 3). The highest site mean seed yield, averaged across the three varieties, was recorded at Rockhampton at 688kg/ha, followed by Ayr with 460kg/ha, and lower yield at Biloela with 388kg/ha and Katherine with 343kg/ha. The crops at Tully and Darwin did not establish due to very poor growth and incidence of rot root, largely associated with wetter soil (Figure 4).

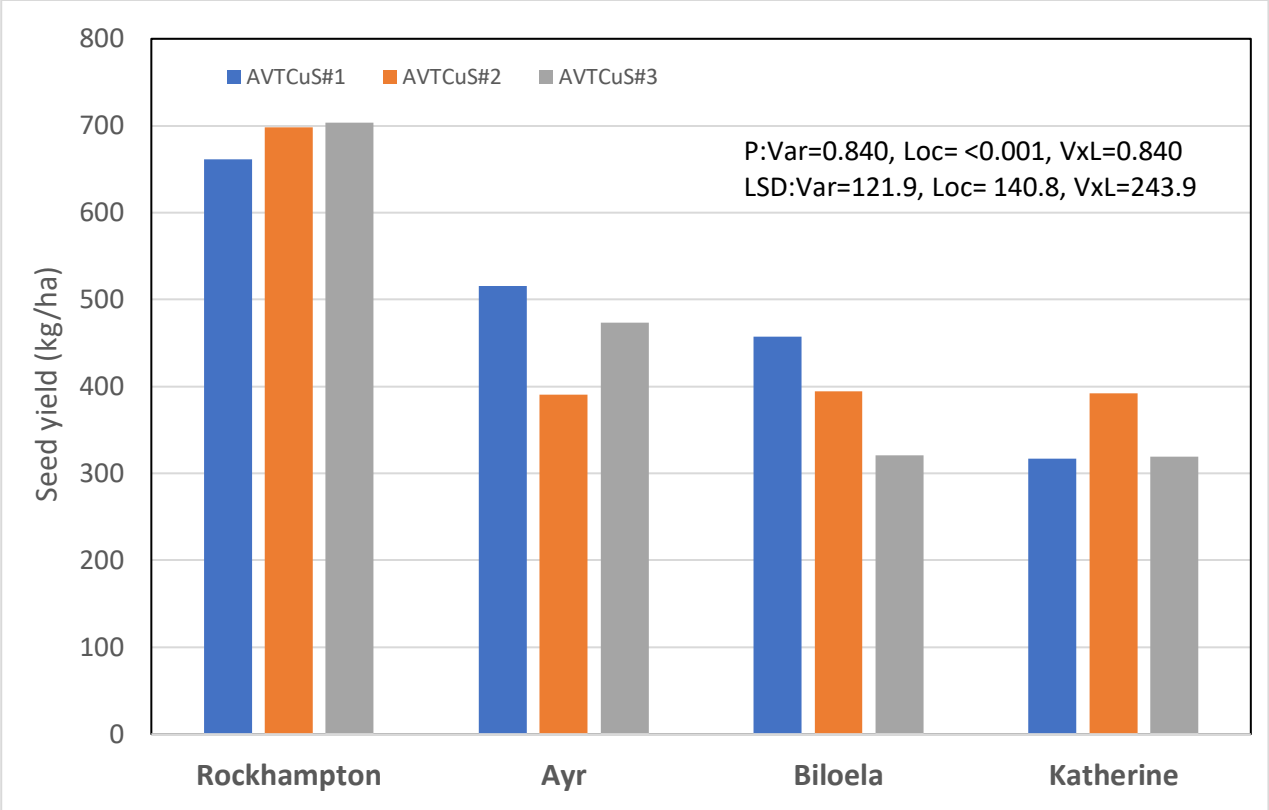


Figure 4. Cumin seed yield for three cumin varieties at four locations for winter 2020.

Table 3. Seed yield (kg/ha) of three cumin varieties planted at different locations in Qld and NT during winter 2020.

Locations	AVTCuS#1	AVTCuS#2	AVTCuS#3	Mean
Rockhampton	662	698	704	688
Ayr	516	391	474	460
Biloela	458	395	321	388
Katherine	317	392	319	343
Mean	489	469	454	471

Yield attributing characteristics

1000 seed weight (g) - Test weight

The mean test weight (g) ranged from 2.81g to 4.34g (Table 4) between the sites. The 1000-seed weight was higher for Katherine (4.34g) and Ayr (40 g), compared to Rockhampton (2.83g) and Biloela (2.81g). The varietal differences for 1000-seed weight were statistically significant only at Ayr (p=0.003), with the highest test weights of 1000 seeds recorded for AVTCuS#3, followed by AVTCuS#2 and lowest for AVTCuS#1 (Table 4).

Table 4. Test weight (g/1000 seeds) of the cumin seeds for different varieties.

Locations	AVTCuS#1	AVTCuS#2	AVTCuS#3	Mean
Rockhampton	2.7	2.8	2.9	2.8
Ayr	3.3	3.3	3.5	3.4
Biloela	2.6	2.3	2.6	2.5
Katherine	4.8	4.9	5.0	4.9
Mean	3.4	3.3	3.5	3.4

3.2.3 Discussion

The results from the first year of the multi-location field trials suggested that the seed yield did not differ between the varieties and only differed between the locations. The seed yield in general was consistently low across all sites. The yield recorded in this trial was lower than some of the recent yields reported in India (877kg/ha by Patel et al, 2022).

New varieties currently being developed and demonstrated in India show a quantum jump in yield. The average productivity obtained in frontline demonstration trials reported a yield potential for the GC-4 variety of between 1250kg/ha and 1875kg/ha, which is much higher than the previous record high yield of 877kg/ha (Kumar, 2017). Therefore, new varietal development is needed in Australia to achieve these new yield targets and thereby grow competitive commercial crops for domestic markets.

The traditional production regions of the world, (i.e., India, Syria and Turkey) is predominantly hand-harvested. For cumin to be successful in the Australian broadacre systems, the crop needs to be adapted for mechanised production. The short plant stature and the seed near the ground complicate the cumin harvest using combine harvesters currently used for other grains. These obstacles for mechanised harvesting, along with susceptibility to major diseases (root rot, leaf blight and powdery mildew) in the current varieties, warrants further variety development work for cumin to succeed in Australia.

4. CONCLUSIONS AND RECOMMENDATIONS

The cumin trial crop could establish only in four out of six sites planted as the crop at Tully and Darwin did not establish to produce a harvestable yield. The tested cumin varieties showed susceptibility to root rot, leaf blight and powdery mildew diseases, particularly in Tully and Darwin.

The trial recorded a highest seed yield of 704kg/ha for AVTCuS#3 at Rockhampton. The seed yield only varied significantly between locations and not between the varieties. Averaged over the three varieties in the trial, the highest cumin seed yield was recorded at Rockhampton (688kg/ha), followed by medium yield in Ayr (460kg/ha), and lower yields in Biloela (388kg/ha), and Katherine (343kg/ha). Some recent new varieties released for growers in the leading cumin-producing country, India, demonstrated on-farm yield potential of 1250-1875kg/ha and therefore, the yield received from the current varieties in these trials is far lower to be competitive in the global cumin markets.

Achieving higher cumin yield and yield stability is required for adoption by Australian growers. Introduction of high-yielding varieties, optimising the agronomy to maximise cumin production, the introduction of disease-tolerant elite varieties, and improved crop management practices are suggested. Further investigations are also required for nutrient management, control of diseases and weeds, and optimisation of density and time of planting.

The trial cumin crop also presented major problems associated with harvesting challenges.

Therefore, the current harvest challenges, susceptibility to diseases and low yield potentials are major impediments to the viability of commercial production of cumin seeds in Australia. Hence, the growers and industry participants determined not to progress the cumin trials to the year two verifications and year three commercial-scale evaluations.

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