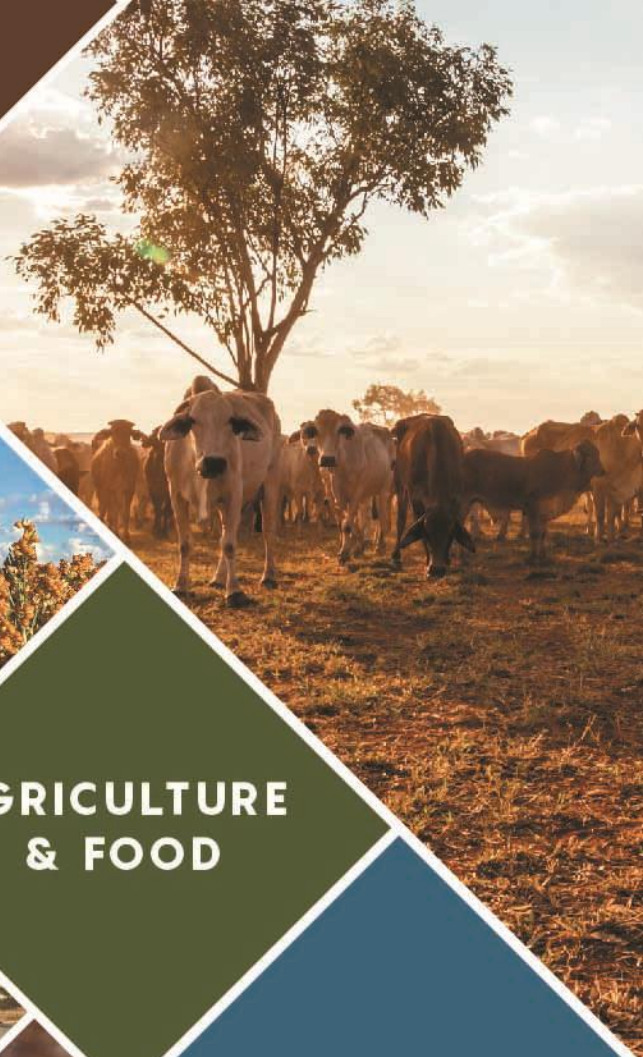
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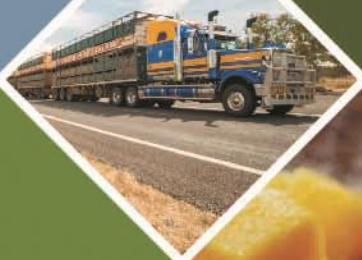






TRADITIONAL OWNER-LED DEVELOPMENT

AGRICULTURE & FOOD





PART E: KALIJIRI FINAL REPORT

Surya Bhattarai, Tieneke Trotter, Delwar Akbar, Azad Rahman and Michael Thomson

CRCNA
DEVELOPING NORTHERN AUSTRALIA

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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:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2018),

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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 five 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 participatory multilocation trials for initial evaluation of different spices crops including kalijiri, cumin, black sesame, fennel and kalonji 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. Market analysis for these selected five crops and gross margin analysis for sesame, fennel and kalonji was performed in the third year of the project.

This report presents performance evaluation of kalijiri varieties (two) across six locations in Queensland and the Northern Territory Australia planted during winter months of 2020. Kalijiri as winter season crop in the first year (initial varietal evaluation) trials showed highest seed yield potential of 1986 kg/ha for hand harvested yield for AVTKJ#1 at Ayr. The highest kalijiri seed yield (averaged for two varieties), was recorded for Ayr (1734kg/ha), followed by Biloela (1292kg/ha), Katherine (349kg/ha), Darwin (279kg/ha)) and lowest at Tully (86 kg/ha). The yield difference between the varieties was not significant in any of the trial locations, except for Ayr where the AVTKJ#1 produced 33% more seed yield than AVTKJ#2 . The crops at Rockhampton did not establish due to very poor growth and incidence of rot root, largely associated with wetter soils in heavy clay soil.

In spite of the encouraging yield recorded in Ayr and Biloela, the crop presented significant challenges for harvesting. The manual harvesting of the Kalijiri caused skin rash by the very light and dusty flower head attached to the seed, which was dispersed during harvesting/threshing operations. Combined with the unstable yields, this caused growers and industry to determine not to proceed with the verification and commercialisation trials.

High and stable-yielding varieties with better harvestability and plant type suitable for machine harvesting/threshing are required for kalijiri to be a viable option for production 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 kalijiri research were delivered:

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

This report have been published and are available via the CRCNA website.

The "Broadacre Cropping in Northern Australia - Newsletter 2021" presented the results of initial variety evaluation trials for five species crops, including kalijiri, cumin and kalonji as winter season, whereas sesame and fennel as summer season crops. These trials captured hand-harvested yield data to showcase the yield potentials of these selected spices crops in Northern Australia.

Market data for kalijiri are very scanty, therefore, the separate market analysis report has not been presented for Kailijiri.

The spicing up Northern Australia project outlined eight key deliverables for achieving the project objectives and purpose. The five key deliverables are related to crop production, quality assessment and economic analysis, and these are linked to this report (Part E: Kalijiri Final Report"). As the crop after initial evaluation trial did not progress through the verification and commercial crop trials, only the data from the initial varietal evaluation trials from 2020 season are presented in this report.

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

2. MARKET ASSESSMENT

The kalijiri price in Australia is largely influenced by the global market price. Market data for kalijiri are not readily available. The recent price listed by lead supplier of India, offers wholesale price of $3070/tonne (https://www.indiamart.com/proddetail/kali-jiri-15179831262.html). AgriVentis Technologies Ltd subscribe and access current information on the global market price for spice through their subscription of Tridge (https://www.tridge.com/intelligences/) and verification through the price on offer from the major importers/exporters in global spices markets (Hunter, 2023). The kalijiri is not currently listed in the Tridge as major spices commodity, hence the wholesale price from major suppliers has been referenced (Hunter, 2023).

Kalijiri is not currently produced in Australia in commercial scales. Australia's demand for kalijiri is not reported in formal literature , therefore, the import data for kalijiri could not be tracked. Grey literature suggests that India is by far the largest producer and consumer of kalijiri in the world (Ganga Baba, 2023), therefore, influence the supply and price for the kalijiri products.

3. CROP ASSESSMENT

3.1 Introduction

Kalijiri is also known as bitter cumin *(Centratherum anthelminticum* or *Vernonia anthelmintica*). It is a tall, sturdy leafy plant with wide distributions across the South Asian countries, and belongs to the Asteraceae family. Kalijiri is both a spice crop, as well as a medicinal plant with acceptance in traditional systems like *Ayurveda* and *Unani* for management of physiological conditions such as cough, diarrhoea, asthma, kidney troubles and inflammation.

Kalijiri grows well in tropical and subtropical regions. In India, the crop is grown in the tropical plains during the winter months and in the high-altitude area in the north during the summer months, as the crop prefer for a warm dry growing conditions. High humidity during flowering and seed setting is not desirable as such conditions favours the development fungal diseases on the leaves, flowers and seeds.

3.2 Kalijiri Initial Evaluation Trials (Year 1)

3.2.1 Materials and methods

Trial locations

Field trials were conducted to determine the suitability of two genotypes of AgriVentis kalijiri to the climate, soils and environmental conditions in Northern Australia. The trial locations included four sites in Queensland and two sites in the Northern Territory (Figure 1).

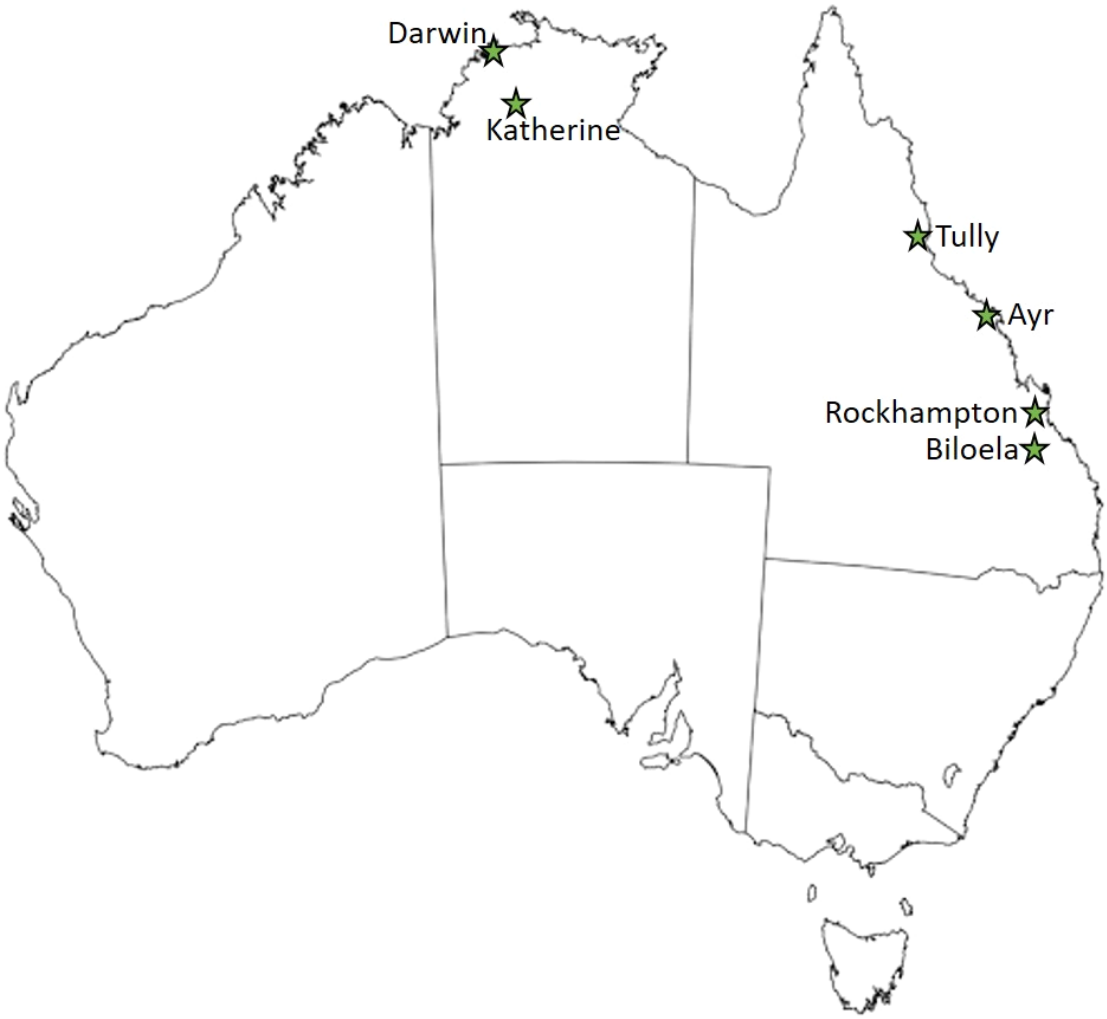


Figure 1. Kalijiri trial locations in northern Australia, including Biloela, Rockhampton, Ayr and Tully in Queensland, and Katherine and Darwin in the Northern Territory

Site descriptions

The kalijiri 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 locations, in-crop rainfall, soil types and cropping systems for the kalijiri trials

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

Planting season

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

Table 2. Kalijiri trial planting and harvest dates

Locations	Planting date	Harvest date	Crop duration (days after sowing)
Biloela, QLD	14 May 2020	16 October 2020	155
Rockhampton, QLD	27 May 2020	19 October 2020	145
Ayr, QLD	13 June 2020	13 October 2020	122
Tully, QLD		Not established	
Darwin, NT		Not established	
Katherine, NT	29 May 2020	9 October 2020	104

Site preparation

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

Raised beds 1.5m wide were prepared in Darwin and Katherine and the kalijiri 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 kailijiri per 2m length 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 production system, therefore, represent largely to the intensive horticultural crop production system in the open field rather than broadacre farming system adopted by grain growers.

Drip tape was installed in all sites for strategic irrigation. One drip line was installed along each of the guard and data rows. Irrigation was applied throughout the season to supplement soil moisture to refill point.

Varieties, trial design and planting densities and planting dates

Two varieties of kalijiri (AVTKJ#1, and AVTKJ#2) were grown for initial evaluation trials, following the paired comparison of the two lines, with multiple replications (seven) within the same farm in each location.

The between-row spacing was 50cm and the plant spacing within the row was approximately 5cm with an aim to achieve the target population of ~30 plants/m^2.

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 the NPK rate of 81:40:63kg Ha^{-1} at planting as a basal dose of fertilizer. No additional fertiliser was applied during the growing season. All sites received the same level of fertilizer. Soil samples pre-planting and post-harvest were collected and analysed.

Weed control at Katherine involved a pre-emergent herbicide Stomp (Pendimethalin A.I 440g/L) at the rate of 1.5L/ha, two days post-sowing for weed control (http://www.herbiguide.com.au/labels/pen33_61322-1209.pdf). In all other sites, hand weeding was carried out throughout the first month of growth to keep the weed competition low during the seedling establishment stage. Once the kalijiri canopy was well developed, minimal weeding was required as the plant canopy supressed weeds growth.

Once the kalijiri seeds had emerged and established, each of the rows was thinned to a target population of 30 plants/m^2. Thinning occurred at approximately 2-3 weeks after sowing. Thinning provided uniform spacing of approximately 5cm between the plants within the row.

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, 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 CQUniversity's Crop Science Seed 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 kalijiri 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 to 70^{o}C for 12 hours and the density of the seed was measured.

Data were analysed for individual sites following the procedure for paired t tests and mean separated using standard error of means using GenStat 2020 (VSN International, 2020) for assessing the effects of treatments.

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

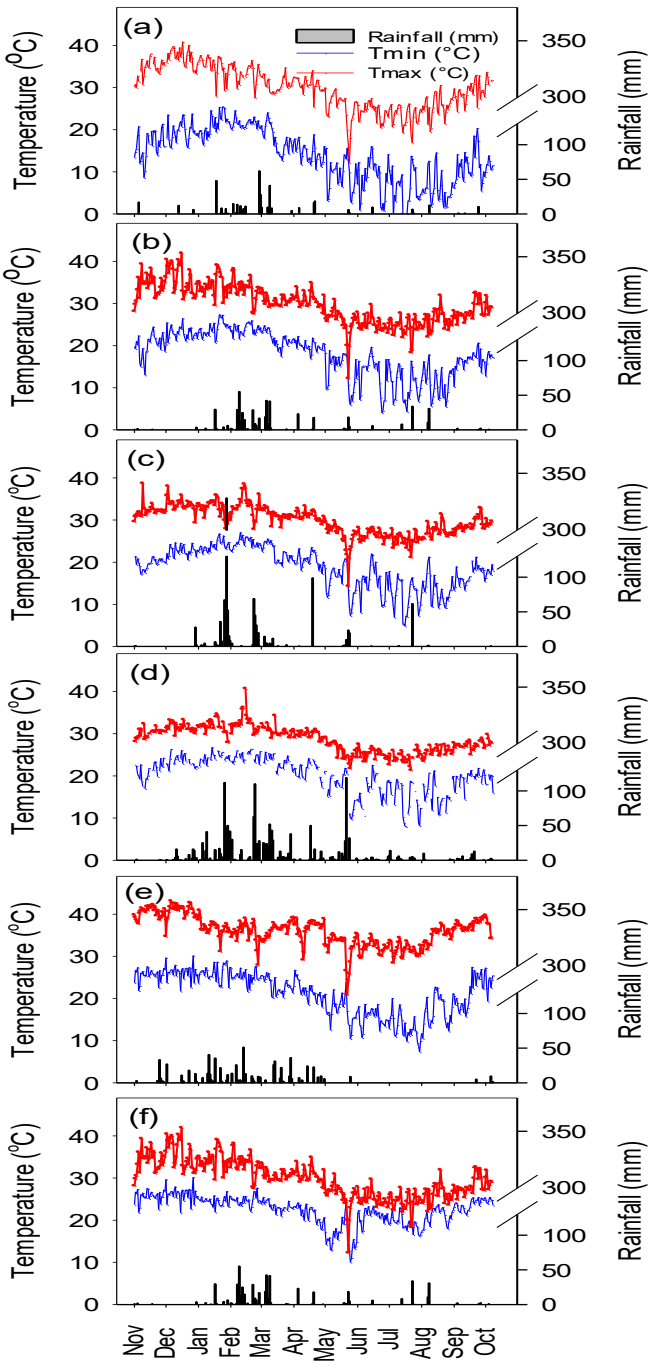


Figure 2. Daily minimum and maximum temperatures and rainfall over the kalijiri growing season at a) Biloela, b) Rockhampton, c) Ayr, d) Tully, e) Katherine and f) Darwin

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

Crop phenology

The kalijiri seeds were planted at varying dates during the winter season of 2020 (Figure 3). The emergence was as early as six days in Biloela and nine days in Ayr, up to 17 days in Katherine and 18 days at Rockhampton. The duration from emergence to flowering ranged from 35 days at Katherine to 72 days at

Biloela. The flowering to maturity commenced at 43 days in Ayr and Katherine, through to 55 days at Biloela. The crop maturity and harvest commenced 47-71 days after planting.

The sites were harvested manually after crop maturity all in a single day for each location.

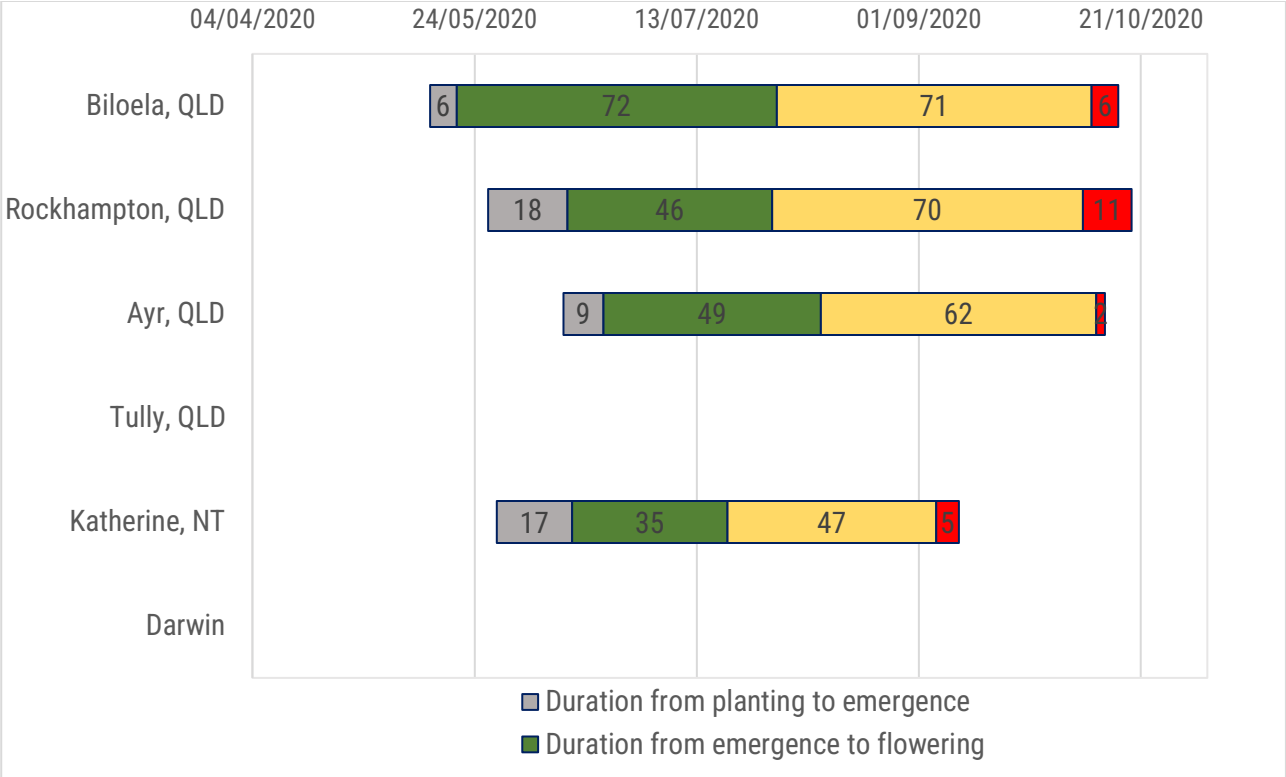


Figure 3. The kalijiri growing season (planting to harvest), and phenological development in the four trial locations

Seed Yield

Kalijiri as winter season crop in the first year (initial varietal evaluation) trials showed highest seed yield potential of 1986 kg/ha for hand harvested yield for AVTKJ#1 at Ayr (Table 3).

Table 3. Seed yield (kg/ha) of two Kalijiri varieties planted at different locations in QLD and NT in winter 2019-20.

Locations	AVTKJ#1	AVTKJ#2	Mean
Ayr	1986	1483	1734
Biloela	1230	1355	1292
Darwin	325	233	279
Katherine	344	354	349
Tully	73	99	86
Mean	**792**	**705**	**748**

The highest kalijiri seed yield (averaged for two varieties), was recorded for Ayr (1734 kg/ha), followed by Biloela (1292 kg/ha), Katherine (349kg/ha), Darwin (279kg/ha)) and lowest at Tully (86 kg/ha). The yield difference between the varieties was not significant in any of the trial locations, except for Ayr where the AVTKJ#1 produced 33% more seed yield than AVTKJ#2 (Figure 4) . The crops at Rockhampton did not establish due to very poor growth and incidence of rot root, largely associated with wetter soils in heavy clay soil.

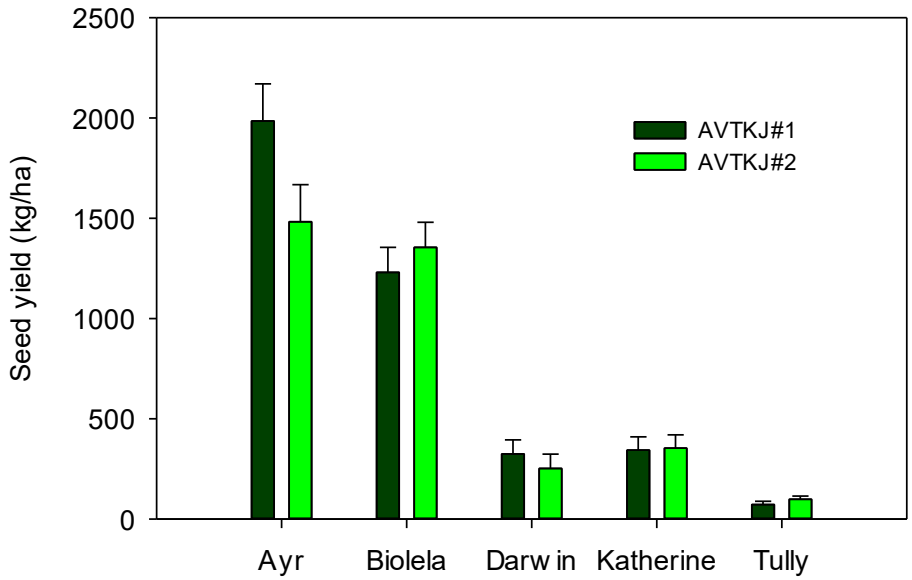


Figure 4. Seed yield of two kalijiri varieties in four locations for the winter season crop in 2020 (Data are mean yield ±Standard Errors of the mean (n=7)).

Yield Attributing Characteristics

1000 seed weight (g) - Test weight

The mean test weight (g) ranged from 3.23g to 3.30g (Table 3) between the sites. The 1000 seed weight was highest for Biloela (3.30g) and Ayr (3.29g), and was lowest for Katherine (3.23g). The varietal differences for 1000 seed weight was statistically not significant for two varieties (Table 4).

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

Locations	AVTKJ#1	AVTKJ#2	Mean
Ayr	3.36	3.23	3.29
Biloela	3.25	3.35	3.30
Darwin	3.23	3.31	3.28
Katherine	3.25	3.20	3.23
Tully	3.23	3.30	3.26
Mean	**3.26**	**3.27**	**3.27**

3.2.3 Discussions

There are very limited published work on Kalijiri in public domain. The publication are largely on the botanical descriptions of the crops (e.g. Berry et al., 1970). A trial crop evaluating different dates of sowing and plant geometry (row spacing) in 2010-2011 in Gujrat India reported a maximum yield up to 1978 kg/ha for October planting at spacing configuration of 45 cm between the rows (Patel et al., 2020). The seed yield recorded in Ayr are comparable to the yield reported from one of the large Kalijiri production region in India.

As the *kalijiri* yield under mulch where weed control and moisture management are strong, the yield response are very high compared to other nearby site, e.g. Tully. It suggest that *Kalijiri* yield could be significantly improved by optimising the crop husbandry practices. Further investigations are also required for nutrient management, and water management to substantiate such interpretation. Furthermore, k*alijiri* response to soil conditions could be a factor as the crop at Rockhampton planted in the heavy clay soil struggle to establish, hence further studies on crop response to edaphic conditions and other soil constraints will generate useful information for successful crop establishments.

The kalijiri crop presented major problems associated with harvesting challenges. The issue about excessive dust generation during harvesting and threshing, and associated with skin irritation, showed potential risks with the current method of harvest management. Therefore, the current harvest challenge is major impediments for a viability of commercial production of kalijiri seeds .

4. CONCLUSIONS AND RECOMMENDATIONS

The Kalijiri trial crop established in five out of six sites planted as the crop at Rockhampton did not establish to produce a harvestable yield, large associated with wet foot in heavy clay soil..

Future research on high and stable yielding variety suitable for machine harvest is suggested in order to extend the kalijiri innovation to commercial scale production. The presence of significant genetic diversity has been reported for kalijiri population. Assessment of new germplasm for more intact flower types that less disintegrates into dust during harvest, could provide alternative variety with less harvesting challenges. Suitable agronomic interventions to evaluate early harvest at physiological maturity that generates low dust and less harvesting challenges attract future studies for overcoming harvesting challenges.

Potentials of various alternative options for minimising harvesting challenges are also not the currently being evaluated in other production regions outside Australia, for the Australian industry to immediately follow. Therefore, the growers and industry realised significant amount of research work still required for large scale trial and commercial production, hence made an informed decision for not progressing to year two verification and year three commercialisation trials.

.



Image: Kalijiri varietal trial at Ayr ready for harvest (Source: S. Bhattarai)

REFERENCES

Berry, C.D. Lessman, K.J., White, G. A. and Earle, F. R. (1970). Genetic Diversity Inherent in *Vernonia anthelmintica* (L). Wild, Crop Science, 10 (2):178-180.

Ganga Baba (2023). Kalijiri (Centratherum anthelminticum)- Exporters in India. Accessed on 2 March 2023. https://gangababa.com/product/kalijiri-centratherum-anthelminticum-exporters-in-india-

Hunter, L. (2023). AgriVentis Technologies Ltd Australia. Personal Communication. 2023

Patel, J.R., Patel, D. H., Prajapati, K. N. (2020). Response of Different Dates of Sowing and Plant Geometry on Seed Yield, Quality and Economics of Vernonia (Vernonia anthelmintica L. Willd. Trends in Biosciences, 8(15) 3849-3854.

Rahman, A., Akbar, D., Timilsina, S., Trotter, T., Thomson, M., Bhattarai, S. (2020). Market analysis of caraway seed . CRCNA Report. Available at, https://crcna.com.au/resources/publications/market-analysis-caraway-seed

Tridge (2023). Agriculture and Food. Accessed on 2 March 2023.

https://www.tridge.com/categories/agriculture-foodories/agriculture-food

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