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Project Code	
Project Type	

FINAL REPORT 2021

PROJECT CODE :	**GGG118**

PROJECT TITLE
Rapid development of innovative lentils for low rainfall regions

PROJECT DURATION

Project Start date	01/05/2018					
Project End date	30/06/2021					
SAGIT Funding Request	2018/19		2019/20		2020/21	

PROJECT SUPERVISOR CONTACT DETAILS

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PROJECT REPORT

Executive Summary (200 words maximum)

This is the first project that specifically targeted the breeding and evaluation of lentil lines in low rainfall environments (LRE) of SA. Key project outcomes include:

- summer plus growing season rainfall (Nov.-Oct.) is more important than summer or growing season rainfall alone to lentil production in LRE;
- a positive relationship between plant biomass pre-flowering and grain yield in lentils in LRE. Growers should place significant focus on achieving good establishment and early biomass production in lentil;
- PBA Jumbo2 was the highest yielding variety across all evaluations but had lower relative yields on heavier textured soils than on deeper sandier soils. IMI tolerant lines, PBA Highland and GIA Leader were similar yielding to PBA Jumbo2 in 2020, but IMI tolerant lines, GIA2003L and GIA2002L, were 7 and 6% higher yielding than PBA Jumbo2 respectively;
- Breeding lines, selected from a diverse population of PBA Jumbo2 directly in the mallee environment, were up to 12% higher yielding than PBA Jumbo2 across all 2020 trials;
- The traits of early vigour, multiple herbicide tolerances (Group B + C + soil residual I), improved plant biomass levels and higher harvest height were important to successful lentil production in LRE and are being incorporated into breeding lines.

Project Objectives

This project aims to develop innovative lentils with improved and unique traits for South Australia's low rainfall cropping regions (LRCR), through:

i) assessing the value of a novel high early vigour trait in lentil in the LRCR
ii) combining high early vigour trait with improved herbicide tolerance (Group B and Group C metabolism) in the elite, high yielding disease resistant background of PBA Jumbo2.
iii) the innovative development of lentil germplasm specifically adapted for the LRCR by selecting for morphological and phenological adaption in a LRCR environment from a large diverse population of M_2 PBA Jumbo.

Overall Performance

Achievement of project objectives

Lentil is currently the major pulse crop grown in South Australia (SA) and area continues to slowly expand in low rainfall regions. However, the lentil varieties grown in low rainfall environments (LRE) of SA are generally the same as those grown in more favourable regions, despite evidence that variety performance varies from sandy to heavier textured soils. Furthermore, there has been little or no specific breeding and evaluation of lentil in LRE of SA.

This project aimed to identify the key traits required for lentil production in low rainfall areas and develop innovative lentils with improved and unique traits for South Australia's low rainfall cropping regions.

SAGIT project GGG118 (Rapid development of innovative lentils for low-rainfall regions) successfully:

- identified a positive relationship between plant biomass pre-flowering and grain yield in lentils in LRE, this relationship has not been found in the favourable lentil growing regions of SA;
- identified IMI tolerant advanced breeding lentil lines with high yields in LRE (GIA2003L-I & GIA2002L-I were 7 and 6% higher yielding than PBA Jumbo 2 respectively, across all four SAGIT Stage 1 trials in 2020);
- developed and identified mutation derived PBA Jumbo2 lines with up to 12% higher yield than Jumbo2 across all low rainfall sites in 2020;
- developed lentil germplasm with specific traits (vigour, multiple herbicide tolerance, harvestability and pod retention) for LRE;
- developed novel screening tests for soil texture and Group C herbicides in lentil; and
- linked with relevant SAGIT projects (MSF115, TC116, TC119, MSF219) to provide project researchers with a unique and extensive understanding of lentil growth, response and performance in dune-swale LRE.

Project Personnel:
Dr Larn McMurray-10% FTE (In-kind)
Ms Mirella Butsch-5% FTE (In-kind)
Mr Jacob Materne-20% FTE
Dr Michael Materne-Advisor (In-kind)

Project Co-operators:
Wade & Chad Nickolls, Nickolls Partners, Pinnaroo
Bill, Max & Sam Trengove, Trengove Farms, Bute/Alford
Robin Schaefer & Andrew Biele, Bulla Burra Farms, Loxton
Kate & Grant Wilson, Hopetoun
Peter Blair, Blair Farms, Horsham
Michael Moodie, Frontier Agronomy
Sam Trengove, Trengove Consulting

Difficulties encountered:
The inherent nature and variability of the climate and soils in low rainfall regions, combined with limited adaptation of lentil to these environments, makes field evaluation challenging. Results are often difficult to interpret due to large error values and confounding effects of complex yield limiting factors. All trials were successfully harvested over the life of this project, but were not immune from these inherent difficulties in management and data interpretation. However, the planned use of multiple low rainfall sites and replication in time across years negated these effects and helped to understand the impact of seasonal production limiting factors. Furthermore, through a sound understanding of the genotype by environment by management interactions, in these trials, yield limiting factors such as variable establishment, drought and frost still provided valuable information to the project outcomes.

The UWA accelerated rapid generation technology (aRGT) process utilises complex combinations of nutrient/hormone solutions and controlled environment facilities to rapidly progress lentil plants through multiple generations in a year. Plant growth of metribuzin tolerant lentils, which have a mutation in the photosystem II (PSII) complex in the chloroplast, were severely affected in this artificial production system. This was likely to be due to inherent inefficiencies in electron transport though the PSII complex, exacerbated by the modified lighting conditions. Generation progression and seed return from the metribuzin tolerant plants were significantly reduced compared to those from metribuzin intolerant plants. Metribuzin tolerant lines have therefore largely come via the conventional breeding process and are subsequently delayed compared to material that was successfully multiplied in the aRGT process.

Key Performance Indicators (KPI)		
KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
Contract and provide seed to UWA for aRGT technology.	YES	F_2 seeds of targeted crosses was provided to UWA for aRGT technology in 2018 and 2019. F_4 to F_6 seeds returned from this process were sown in rows in 2019 and rows and plots in 2020.
Sow, manage and harvest first year of agronomic yield evaluation trials at three sites.	YES	Three field sites were successfully sown, managed and harvested at Alford (Yorke Pen.), Pinnaroo (SA mallee) and Hopetoun (Vic mallee) in 2018.
Sow and manage M_2 diverse PBA Jumbo2 field screen, and rescue and initiate summer multiplication of selected plants with LRCR traits	YES	Over 60 plants were identified, rescued and summer multiplied in 2018/19 from a 1 ha M_2 PBA Jumbo2 field screen comprising over 1 million individuals sown at Pinnaroo, SA in 2018.
Collate analyse and report first years research findings.	YES	All data was analysed and interpreted by the end of January 2019. Key results and outcomes were presented at a number of field days and research updates during 2019.
Sow, manage and harvest second year of agronomic yield evaluation trials at three sites	YES	Three field sites were successfully sown, managed and harvested at Alford (Yorke Pen.), Pinnaroo (SA mallee) and Hopetoun (Vic mallee) in 2019.
Sow, manage and harvest row multiplications of PBA Jumbo2 LRCR mutant selections, at least one site.	YES	A row seed multiplication trial of over 60 lines selected from the 2018 Pinnaroo M_2 field screen was successfully sown, managed and harvested at Horsham in 2019.
Sow, manage and harvest row multiplications of F_6-F7 high vigour lines, at least one site.	YES	Row multiplications of all F_4-F_6 lines (several hundred) from the 2018 UWA aRGT process were successfully sown, managed and harvested at Horsham in 2019. Small plot and row multiplication of several hundred breeding lines and F_3 and F_4 populations including those via the UWA aRGT process were successfully sown, managed and harvested at Horsham and Kadina (plots only) in 2020.
Collate analyse and report second years research findings.	YES	All data was analysed and interpreted by the end of January 2020. Key results and

		outcomes were presented at a number of field days, research updates and articles during 2020.
Sow, manage and harvest Stage 1 evaluation trials at four sites.	YES	Stage 1 low rainfall yield evaluation trials were successfully sown, managed and harvested at Bute, Loxton and Pinnaroo, and at a high rainfall, heavy textured contrast site at Horsham in 2020.
Collate analyse and report third years research findings.	YES	All data was analysed and interpreted by the end of January 2021. Key results and outcomes were presented at a number of field days and research updates during early 2021.
Submit final report.	YES	Final report submitted to SAGIT by August 31, 2021.

Technical Information

- Agronomic trials were conducted at three low rainfall sites and one favourable contrasting site (Horsham) in 2018 and 2019 to assess novel early vigour and herbicide traits (Table 1). In 2020, lentil breeding trials were held at similar locations to the agronomic trials (Table 1) and contained varieties and advanced breeding lines. The breeding lines were developed during the first two years of the project with specific adaptation to the low rainfall environment.

Table 1: Site characteristics from the low rainfall and contrast site lentil evaluation trials in SA and Victoria 2018-2020.

LOCATION	YEAR	SOIL TYPE	SOW DATE	TRIAL MEAN YIELD t/ha	RAINFALL TOTALS (mm) SR	GSR	AR
Pinnaroo	2020	SL/SC (flat)	14-May	3.3	108	266	370
	2019	SL/SC (flat)	30-May	0.7	52	178	212
	2018	SL/SC (flat)	16-May	0.56	76	134	210
Loxton	2020	SL/C (rise)	13-May	1.1	74	189	265
Hopetoun	2019	SL/C (flat)	17-May	1.8	209	186	246
	2018	SL/C (rise)	16-May	0.75	93	120	270
Bute	2020	SCL	18-May	1.6	73	301	390
Alford	2019	SL (hill)	23-May	1	65	207	234
	2018	SL (hill)	23-May	0.83	89	164	246
Horsham	2020	Grey C	9-Jun	1.9	103	287	399
	2019	Grey C	6-Jun	1.76	68	233	273
	2018	Grey C	28-May	0.63	88	180	256

SL=sandy loam, SC=sandy clay, C=clay, SCL=sandy clay loam; SR=summer rainfall (Nov-Mar), GSR=growing season rainfall (Apr-Oct), AR=annual rainfall (Jan-Dec).

- Mean grain yields across all low rainfall trials ranged from 0.6 t/ha to a very much above average 3.3 t/ha at Pinnaroo in 2020 (Table 1). The mean yield of two thirds of the trials was less than 1.2 t/ha and in a range considered typical for low rainfall areas. Trial mean grain yield correlated more strongly with an annual rainfall (Nov.-Oct.) total that included summer rainfall and growing season rainfall, than annual (Jan.-Dec.), growing season (Apr-Oct) or preceding summer (Nov. to Mar.) rainfall totals (Fig. 1). Importantly, this correlation improved (R^2 = 0.79) when only the more typical low rainfall sites, yielding less than 1.2 t/ha, were used in the regression, highlighting the importance of summer rainfall to low rainfall lentil production.

- Additional to rainfall, constraints to lentil yield and variety performance across the trials, included variable plant establishment, Group C herbicide damage, frost, soil induced poor and variable plant growth, low plant biomass production in winter and high temperatures and hot winds during the reproductive phase. This range and complexity of yield limiting factors highlights the numerous challenges facing lentil producers and plant breeders in low rainfall environments (LRE). Key traditional lentil breeding objectives for SA such as disease (botrytis grey mould and ascochyta blight) and the management of excessive biomass and lodging appeared to have no impact on lentil yields in these trials.

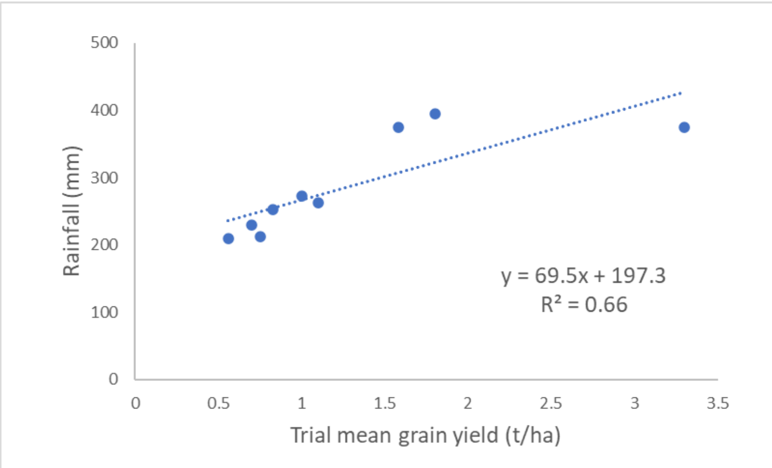

Fig. 1: Relationship between trial mean grain yield and location rainfall totals (annual rainfall (Nov. to Oct.)) at all low rainfall lentil evaluation sites in SA and Vic., 20018 to 2020.

- PBA Jumbo2 was the highest yielding variety across all years and trials but had lower relative yields on the heavier textured soils compared to the deeper sandier soils and is generally not favoured by growers in low rainfall environments. The newly released IMI tolerant lines, PBA Highland and GIA Leader were similar yielding to PBA Jumbo 2 in 2020 with the earlier maturing variety PBA Highland having slightly higher yields at most sites.
- A positive relationship was identified between grain yield and plant biomass (dry matter) at 10 weeks after sowing and at flowering in lentil grown in LRE (Table 2). This is a significant finding for growers and plant breeders and contrary to the understanding in more favorable lentil growing regions e.g. Wimmera and Yorke Peninsula. Thus, a focus on good quality seed, establishment, early biomass production, reducing weed competition and limiting plant stress (eg herbicide damage) will be important for successful lentil production in LRE.
- The "high vigour" breeding lines assessed in the first two years of the project exhibited improved levels of plant vigour, height and to a lesser extent biomass when

compared with commercial varieties. However, they were often poorly adapted due to increased levels of susceptibility to disease, herbicide, frost, lodging or shattering. Early vigour per se, had a lower positive correlation with grain yield than plant biomass at flowering. Improvements in plant vigour, while important in overcoming constraints such as reduced plant establishment and recovery from herbicide and wind erosion induced plant injury, should not come at the expense of plant biomass at flowering. The best adapted lines with high early vigour or high levels of biomass at flowering were used in crossing as part of this project.

- Novel GIA lines with multiple herbicide tolerance such as GIA2004L (metribuzin+IMI tolerant) and GIA1703L (IMI+pyridine (lontrel) soil residue tolerance), generally had lower plant vigour, height and grain yields than PBA Jumbo2 in LRE. However, observations throughout the project clearly showed the potential benefits of these novel herbicide tolerances in LRE. This project has developed breeding populations combining multiple herbicide tolerances with good early plant vigour, improved plant biomass and higher harvestable height for LRE. Several hundred breeding lines were successfully multiplied and evaluated at Horsham and Kadina in 2020.

Table 2: Relationship between mean grain yield and mean plant dry matter, 10 weeks after sowing and early flowering, in lentil at six LRE sites in SA and Vic. in 2018 and 2019.

Variety/line	Targeted grain Yield (t/ha)	Mean dry matter - 10 Weeks After Sowing (t/ha)	Mean dry matter - early flowering (t/ha)
R^2 (Grain yield)	-	0.52	0.85
F pr. (Grain yield)	-	0.03	<.001
Equation (Grain yield)	-	Y=0.212X+0.053	Y=1.215X+0.247
Estimated dry matter (t/ha) required for targeted grain yields (0.5, 1 & 2 t/ha)	0.5	0.16	0.82
	1	0.27	1.45
	2	0.48	2.73

- The LRE trials in 2020 identified two IMI tolerant GIA breeding lines with high yields in LRE. GIA2003L & GIA2002L were 28 and 13% higher yielding than PBA Jumbo2 respectively in the Loxton Stage 4 advanced trial (Table 3) and, 7 and 6% higher yielding than PBA Jumbo 2 respectively, across all four Stage 1 trials (Appendix 1). Both lines were also more than 10% higher yielding than all commercial lentil varieties and GRDC/VicDPI/PBA breeding lines across all NVT sites in Australia in 2020.
- A positive relationship between grain yield and NDVI was identified in the advanced evaluation trial at Loxton in 2020 (Table 3). Interestingly this relationship was strengthened when the highest yielding line, GIA2003L (15% higher yielding than the second highest yielding line, and 28% higher yielding than PBA Jumbo 2) was removed from the analysis. It is exciting that this finding suggests that, compared to other lentils, GIA2003L has a different mechanism(s) for attaining high grain yield in sandy low rainfall environments. Instead of rapid early growth to maximise grain

yield, GIA2003L either rapidly accumulates biomass during the reproductive phase or has some other adaptative trait(s) to sandy soils.

- A high level of variation for grain yield and key agronomic traits was observed in the breeding lines evaluated in the low rainfall Stage 1 trials in 2020 (Appendix 1). In particular, the set of 79 mutant Jumbo 2 lines derived from the Pinnaroo field screen in year one of the project, generally showed a normal distribution around the mean of PBA Jumbo2 for each trait measured. Within this set, lines were identified with improved levels of early vigour, plant biomass, height and response to soil and environmental stresses, along with variation in time to flower and maturity compared to PBA Jumbo2 (Appendix 1).
- A number of breeding lines were higher yielding than PBA Jumbo 2 across all four Stage 1 trials in 2020. This included 15PBAJUMBO2ML-18PP060 & 15PBAJUMBO2ML-18PP06044, 12 and 9% higher respectively (Appendix 1). These two lines and other promising lines are being further assessed in 2021. Conversely a number of lines were significantly lower yielding than PBA Jumbo2 across all sites. A few lines showed exceptional performance at some sites but average or poor performance at others. A subset of the PBA Jumbo 2 mutation lines, contrasting in grain yield performance and adaptational traits across sites, offers a valuable tool to further understand lentil adaptation across all growing areas of southern Australia.

Table 3: NDVI and grain yield of Stage 4 GIA lentils and commercial entries evaluated on a sandy soil at Loxton, 2020

LINE	NDVI_JULY		NDVI_AUGUST		GRAIN YIELD	
	NDVI	%JUMBO2	NDVI	%JUMBO2	t/ha	%JUMBO2
PBAJUMBO2	0.199	100	0.353	100	1.3	100
PBAHIGHLAND	0.185	93	0.357	101	1.37	106
PBAHALLMARK	0.179	90	0.32	91	1.26	97
GIALEADER	0.194	98	0.344	97	1.35	104
GIA1703L-LI	0.164	82	0.301	85	1.11	85
GIA1706L-LI	0.176	88	0.328	93	1.24	96
GIA2001L-I	0.187	94	0.333	94	1.27	98
GIA2002L-I	0.183	92	0.356	101	1.46	113
GIA2003L-I	0.177	89	0.319	90	1.66	128
GIA2004L-MI	0.171	86	0.284	81	1.18	91
GIA2005L-I	0.188	94	0.358	101	1.36	105
GIA2006L-L	0.183	92	0.357	101	1.31	101
MEAN	0.182	91	0.334	95	1.32	102
LSD(0.05)	0.015	8.4	0.024	7.4	0.17	13.8

- The Stage 1 lines, along with commercial checks, were screened for tolerance to soil texture (high sand content) in a novel poly house screen in 2020 (Appendix 1). Little variation for increased plant growth was observed in the commercial varieties and Jumbo2 mutant lines. However, a number of lines showed a reduction in plant growth compared to PBA Jumbo2, indicating that genetic variation in plant growth in sandy soils exists in lentil. Screening of a larger and more diverse set of lentils is required to identify lines with higher levels of tolerance to soils with a high sand content than exists in commercial lentil varieties.

Conclusions Reached &/or Discoveries Made

- Lentil trial mean grain yields in low rainfall environments (LRE) correlated with annual growing season rainfall totals (Nov. to Oct.) to a greater extent than with total annual, growing season or summer rainfall. This finding highlights the relative importance of summer rainfall, and its conservation, to lentil production in LRE. Furthermore, it will allow growers to consider summer rainfall when assessing the risk of growing lentil, prior to finalising sowing plans in April/May of each year.
- A positive relationship was identified between grain yield and plant biomass (dry matter) at 10 weeks after sowing and at flowering in lentil grown in LRE, contrasting with findings in more favourable lentil growing regions. Lentil growers in LRE should place a significant focus on good seed, establishment, early biomass production and limiting plant stress (eg herbicide damage) and weed competition to maximise yields. The use of early sowing to increase plant biomass production while likely to be beneficial will need to be managed with frost risk within these environments.
- The traits of early vigour, multiple herbicide tolerances (Group B + C + soil residual I), improved plant biomass levels and higher harvestable height were identified as important to successful lentil production in LRE.
- PBA Jumbo2 was the highest yielding variety across all years and trials but had lower relative yields on the heavier textured soils compared to the deeper sandier soils. The newly released IMI tolerant varieties, PBA Highland and GIA Leader were similar yielding to PBA Jumbo 2 in 2020. Two IMI tolerant advanced GIA breeding lines, GIA2003L & GIA2002L were 7 and 6% higher yielding than PBA Jumbo 2 respectively, across all four evaluation trials in 2020.
- A high level of variation for grain yield and key agronomic traits was observed in the set of 79 mutant Jumbo 2 lines, derived from the Pinnaroo field screen in year one of the project, in the Stage 1 trials in 2020. A number of these lines were higher yielding than PBA Jumbo 2 across all trials, including 15PBAJUMBO2ML-18PP060 & 15PBAJUMBO2ML-18PP06044, 12 and 9% higher respectively.
- Further evaluation of a strategic subset of the near isogenic mutant Jumbo 2 lines will help to provide new insights into understanding lentil growth, response and performance in sandy textured soils of the LRE of SA.
- Glass house screening tests for soil texture and Group C herbicides in lentil were developed in this project. Although no lines had improved growth in the sandy Mallee A horizon soil compared to Jumbo2, a number of lines showed a poorer performance than PBA Jumbo2, indicating that genetic variation in response to this stress exists in lentil.

Intellectual Property

GGG/GIA developed and signed off on an equity agreement with SAGIT in 2019/20 that covers the variety release of any germplasm developed in project GGG118.

This includes:

- approximately 80 mutant PBA Jumbo2 selections
- several hundred breeding lines, including those via the UWA aRGT process
- F_3 & F_4 populations
- F_2 lines from 2020 GGG118 crossing program

No line has been identified for commercial release however several promising and high yielding lines are in advanced GIA and collaborator evaluation trials in 2021. Furthermore, SAGIT has recently funded a new three-year project with GGG (GGG121) that aims to exploit the above listed germplasm and provide variety/ies that improve the reliability of lentil production in low rainfall environments (LRE).

Any line selected in GGG121 will be rapidly progressed and released to SA growers by GIA without the impediments or complexity of interacting with third parties. GIA plans to link with farming system groups and regional agronomists and facilitate the relevant agronomic research and communication needed to maximise variety adoption in LRE.

Application / Communication of Results

Main findings

- Summer plus growing season rainfall (Nov.-Oct.) is more important than summer or growing season rainfall alone to lentil production in low rainfall environments (LRE). Growers can use summer rainfall totals to guide lentil sowing plans and help to manage production risks of lentil in LRE.
- A positive relationship between plant biomass pre-flowering and grain yield in lentils in LRE. Lentil growers in LRE should place a significant focus on early sowing, good seed, establishment, early biomass production and limiting plant stress (eg herbicide damage) and weed competition to maximise yields.
- PBA Jumbo2 was the highest yielding variety across all years and trials but had lower relative yields on the heavier textured soils compared to the deeper sandier soils. PBA Highland and GIA Leader were similar yielding to PBA Jumbo2 in 2020. Two IMI tolerant advanced lines from Grains Innovation Australia (GIA), GIA2003L & GIA2002L, were 7 and 6% higher yielding than PBA Jumbo2 respectively across all trials in 2020, and more than 10% higher yielding than all commercial lentil varieties and PBA breeding lines in NVT in Australia in 2020.
- Lines derived from PBA Jumbo2 through direct selection in the SA mallee were up to 12% higher yielding than PBA Jumbo2 across four low rainfall evaluation trials in 2020. The best of these line will be identified in the SAGIT project (GGG121) with pure seed multiplication to be initiated in 2022.
- The traits of early vigour, multiple herbicide tolerances (Group B + C + soil residual I), increased plant biomass and higher harvestable height were identified as

important to successful lentil production in LRE and have been incorporated into breeding lines by GIA.
- The development of novel glass house screening tests for soil texture and Group C herbicides in lentil will allow the rapid incorporation of these traits into elite breeding lines.

Potential industry impact

- Lentil production in low rainfall areas of SA is in its infancy and has received little breeding effort. It is estimated that lentil occupies between 10 and 30,000 ha in low rainfall areas in any one year (PIRSA Crop Estimates) which is less than 1% of total cropped area in these environments.
- The identification and development of a variety with specific adaption to the LRE of SA from this project will have the potential to increase lentil area to at least 5% of the total low rainfall crop area, or approximately 100 to 150,000 ha. This represents a five-fold increase over the current area in LRE and a doubling of the total lentil area in SA. Additional rotational benefits of between 0.3and 0.5 t/ha would also be expected in the following cereal crop.
- The improved understanding of lentil growth and grain yield in dune-swale low rainfall environments have been extended to low rainfall growers, consultants and industry and will help to maximise lentil production with current varieties.

Publication and extension articles

- An article on the outcomes of the first two years of the project entitled "Development of innovative lentils for low rainfall regions" was published online in the MSF 2019 Research Compendium. Mallee Sustainable Farming | Development of innovative lentils for low rainfall regions (msfp.org.au)
- Numerous (greater than 20) field days, pulse check meetings, crop walks and group presentations on the results and broad outcomes of this project were presented by research personnel to growers, advisors, consultants and farming system groups of the LRE during the life of this project.

Suggested pathway to market

- GIA/GGG has expertise, capacity and capability across the whole breeding chain, (pre-breeding to commercialisation) enabling all aspects of lentil breeding and commercialisation to occur rapidly, timely and effectively.
- SAGIT has recently funded a new three-year project with GGG (GGG121) that aims to exploit all the germplasm developed in GGG118 and provide variety/ies that improve the reliability of lentil production in LRE.
- Any line selected in GGG121 will be rapidly progressed, and released, by GIA to SA growers without the impediments or complexity of interacting with third parties.
- GIA plans to link with farming system groups and regional agronomists and facilitate the relevant agronomic research and communication needed to maximise variety adoption in the LRE.
- Project outcomes have been shared with industry via field days, industry and grower meetings and articles.

POSSIBLE FUTURE WORK

- This project has identified several elite high yielding lines in low rainfall environments (LRE) and developed a large amount of germplasm with specific adaptive traits for LRE. Additionally, a unique and extensive understanding of lentil growth, response and performance on variable soils in LRE has been obtained by project researchers. SAGIT has recently funded a new three-year project with GGG (GGG121) that aims to exploit the germplasm from GGG118 and deliver variety/ies that improve the reliability of lentil production in LRE.
- Project GGG121 will also explore further traits that confer increased yield and yield stability in LRE including tolerance to adverse soil texture/sand content which was identified as a significant limitation to lentil production in LRE in GGG118.
- A unique opportunity exists for an industry body and/or chemical company(s) to partner with GIA in developing a novel use pattern label for the pyradine (Group I – lontrel) tolerant lentil, and also fieldpea and faba bean, varieties. A registered pyradine herbicide product will enable improved weed control in pulse rotations through the broader application opportunities in crops prior to, pulses but also in pulse crops, and thus expand the area of pulses in SA. This chemical package could include any novel solution, including a pre or post-emergent pyridine herbicide, or a unique Group B+pyridine herbicide supported by GIA and its varieties. GIA is currently assessing interest with chemical companies but to date there has been little interest due to lontrel being a generic herbicide and pulses being market failure crops.
- The ongoing development of collaborations with agronomic projects that aim to improve pulse reliability and profitability in LRE, such as the GRDC Southern Pulse Agronomy Project (SARDI/DEPI Vic) and lentil research projects led by Trengove Consulting, EPAG research, Frontier Farming and SA farming system groups, will be beneficial to both extending project outputs and evaluating potential variety releases from GGG118 and GGG121.

APPENDIX 1: **Grain yield (t/ha) and agronomic characteristics of selected Stage 1 commercial and breeding lines at four sites in 2020.**

	LINE	GRAIN YIELD % PBAJUMBO2 ALL SITES	HORSHAM	BUTE	PINNAROO	LOXTON	EARLY VIGOUR	RED PINNAROO	HERB. DAM. BUTE	NDVI JULY	NDVI AUGUST	DAYS TO FLOWER BUTE	DAYS TO FLOWER HORSHAM	PREMATURE WILT	MATURITY	LODGING MAT.	HEIGHT LOXTON	POD DROP HORSHAM	SHATTERING LOXTON	SOIL TEXTURE SCREEN	SALT SCREEN
CHECKS	**PBAJUMBO2**	**100**	**100**	**100**	**100**	**100**	**7.3**	**3**	**2**	**100**	**100**	**250**	**272**	**5**	**5.0**	**7.0**	**3**	**2**	**1**	**0.39**	**7.25**
	PBAHIGHLAND	**102**	**104**	**103**	**100**	**102**	**6.3**	**3**	**1**	**90**	**91**	**247**	**270**	**2**	**4.7**	**8.0**	**4**	**4**	**1**	**0.295**	**9.5**
	PBAHALLMARK	**94**	**98**	**97**	**93**	**89**	**6.8**	**1**	**1**	**97**	**94**	**246**	**270**	**1**	**5.3**	**7.5**	**4**	**4**	**1**	**0.245**	**1**
	GIALEADER	**98**	**96**	**106**	**96**	**94**	**6.0**	**4**	**1**	**102**	**90**	**251**	**279**	**1**	**6.7**	**7.8**	**4**	**3**	**1**	**0.315**	**3**
NOVEL TRAITS	GIA1703L-LI	92	95	101	110	61	5.3	3	1	92	89	252	280	2	5.0	7.5	2	3	1	0.165	4.25
	GIA1706L-LI	94	89	99	99	90	5.8	2	1	96	90	250	275	2	4.0	7.5	2	2	1		
	GIA1807L-I	100	90	104	95	109	7.3	1	1	98	94	247	269	4	3.7	7.8	5	3	1		
	GIA1901L-PI	91	90	100	88	85	6.5	4	1	98	90	249	275	3	4.0	7.5	4	4	1	0.245	19.5
	GIA1903L-P	97	103	103	97	83	7.3	1	1	97	96	250	271	3	4.7	6.8	4	3	1	0.22	4
	GIA2004L-MI	71	77	64	77	66	5.5	2	1	93	86	253	277	2	6.0	7.0	3	4	1	0.255	1
ELITE BREEDING	GGG1370-16P09	94	107	83	85	102	6.8	1	1	104	98	236	268	5	3.3	7.8	3	3	1	0.31	0.25
	GIA2001L-I	102	102	105	97	102	7.0	2	1	96	94	251	269	1	5.7	8.0	4	4	1	0.355	5
	GIA2002L-I	106	99	112	107	106	6.8	1	1	99	96	249	272	4	4.0	7.8	4	4	1	0.335	1
	GIA2003L-I	107	102	102	90	133	5.8	3	1	95	96	257	279	1	5.3	7.3	4	2	1	0.325	0
	GIA2005L-I	106	107	106	101	111	7.0	3	1	106	95	247	269	2	5.3	7.0	4	3	3	0.33	15.75
	GIA2006L-L	94	87	91	99	99	5.8	3	1	92	94	250	276	7	5.3	7.3	2	2	1	0.19	19
SUBSET OF JUMBO2 MUTANTS CONTRASTING IN TRAITS	15PBAJUMBO2ML-18PP004	94	107	105	88	77	6.5	3	2	94	97	253	278	3	5.7	7.3	2	2	2	0.26	19.25
	15PBAJUMBO2ML-18PP008	84	89	79	79	87	6.5	1	2	90	76	253	276	2	6.0	6.0	4	3	2	0.29	9.5
	15PBAJUMBO2ML-18PP011	93	115	91	81	86	7.8	1		100	100	251	272	5	5.0	6.5	4	2	1	0.235	35.25
	15PBAJUMBO2ML-18PP020	99	103	101	100	92	6.8	4	1	91	96	251	274	3	5.3	7.5	3	2	1	0.29	40.75
	15PBAJUMBO2ML-18PP036	93	88	103	119	61	6.0	3	1	96	94	253	273	4	4.7	7.3	2	2	2	0.21	51.25
	15PBAJUMBO2ML-18PP038	102	111	84	116	96	6.5	3	1	104	110	253	275	5	5.0	7.3	3	2	2	0.445	50
	15PBAJUMBO2ML-18PP039	99	94	99	81	120	6.5	4	2	100	88	257	274	3	5.7	7.0	4	2	1	0.375	37.5
	15PBAJUMBO2ML-18PP044	**109**	**109**	**102**	**100**	**125**	**7.3**	**2**	**1**	**96**	**97**	**250**	**275**	**2**	**5.0**	**7.3**	**3**	**2**	**1**	**0.305**	**40**
	15PBAJUMBO2ML-18PP047	100	99	113	96	93	6.8	3	1	97	97	257	274	1	5.0	7.3	2	1	2	0.17	57.5
	15PBAJUMBO2ML-18PP051	102	103	88	104	111	7.0	3	1	98	98	247	273	5	5.0	7.8	3	2	2	0.17	26.75
	15PBAJUMBO2ML-18PP052	105	110	104	108	99	7.3	3	2	95	102	251	273	3	5.0	7.3	2	2	1	0.32	18
	15PBAJUMBO2ML-18PP055	106	102	105	112	104	6.8	3	2	100	101	247	276	5	5.0	7.3	3	1	1	0.175	28
	15PBAJUMBO2ML-18PP056	100	106	106	95	93	8.0	1	1	103	103	247	271	4	4.3	7.3	4	2	1	0.285	11.25
	15PBAJUMBO2ML-18PP060	**112**	**108**	**104**	**113**	**122**	**7.5**	**4**	**1**	**97**	**105**	**249**	**273**	**3**	**5.3**	**7.5**	**3**	**1**	**3**	**0.245**	**34.25**
	15PBAJUMBO2ML-18PP063	106	111	98	108	106	7.3	3	4	97	103	252	277	2	5.3	7.3	4	3	1	0.33	37.5
	15PBAJUMBO2ML-18PP069	101	95	86	108	113	7.0	3	2	97	97	255	278	2	6.0	7.5	3	2	2	0.4	51.25
	15PBAJUMBO2ML-18PP071	105	106	101	113	101	7.0	3	2	97	103	251	271	3	5.3	7.5	3	1	1	0.32	46.25
	15PBAJUMBO2ML-18PP076	103	95	108	107	102	6.0	3	1	95	94	262	279	3	5.7	7.3	3	2	1	0.305	27.5
	15PBAJUMBO2ML-18PP089	100	106	88	104	101	6.8	3	1	96	101	252	271	4	4.7	7.3	3	3	2	0.35	51.25
	SITE MEAN (t/ha)	2.02	1.89	1.58	3.28	1.09															
	LSD(0.05) & (%)		0.42 (18)	0.31 (20)	0.63 (18)	0.39 (33)															

KEY: EARLY VIGOUR-Mean of all sites, 1=poor,9=high; RED PINNAROO-Mean seedling reddening score Pinnaroo, 1=none, 9=very high; HERB.DAM BUTE-Group C seedling plant herbicide damage score Bute, 1=none, 9=all plant death; NDVI-Mean NDVI score as % PBAJUMBO2 from Pinnaroo, Bute & Loxton; PREMATURE WILT BUTE-Score for premature plant death due to environmental conditions or potentially Stemphylium during pod fill at Bute, 1=none, 9=complete plot wilt; MATURITY-Mean of all sites, 1=Early,9=Late; LODGING-Mean of all sites, 1=flat,9=erect; Height-Plant height at maturity Loxton, 1=unacceptable machine harvest height, 5=excellent height; POD DROP HORSHAM-Pods on ground at maturity, 1=none, 9=all pods; SHATTERING-Seeds on ground at maturity, 1=none, 9=high; SOIL TEXTURE SCREEN-mean g/pot in poly house seedling sand texture screen; SALT SCREEN-mean % plant necrosis score in poly house seedling salt screen.