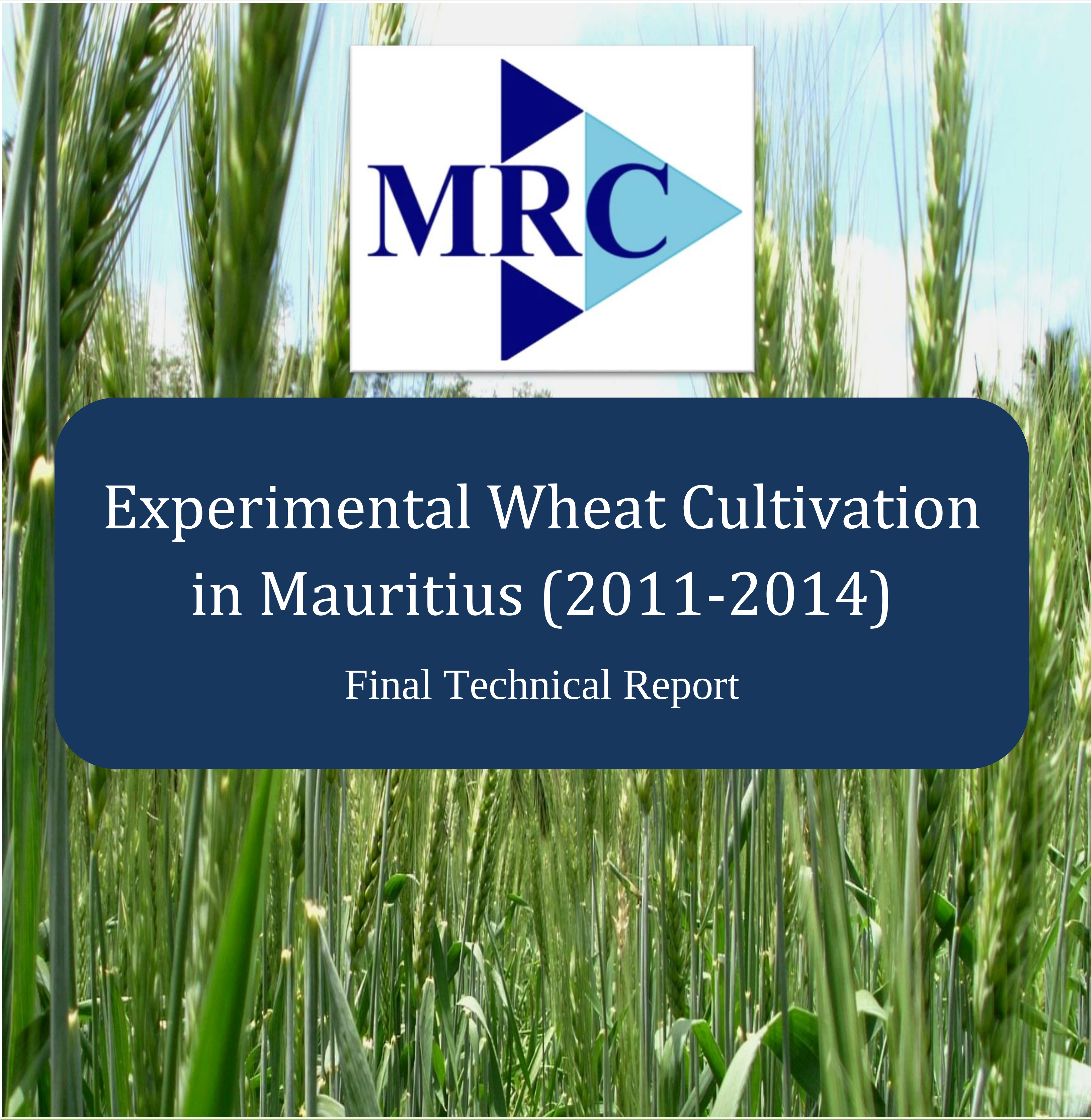

Experimental Wheat Cultivation in Mauritius (2011-2014)

Final Technical Report

May 2015

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EXECUTIVE SUMMARY

Mauritius is highly dependent on food imports and is currently importing 80% of its food requirements Wheat is the most important staple food, it is imported at the rate of around 170,000 tonnes annually and is priced 450 to 500 USD per tonne (FAO, 2012).

Therefore, the growing concerns over the food insecurity and the high dependence on imported foods have led to the initiation of research on wheat cultivation in Mauritius. The aim of this research program was to assess the potential of wheat cultivation in Mauritius.

The specific objectives were:

- To assess the adaptability of three wheat varieties under different agro-climatic conditions
- Evaluate specific variety of wheat suitable for local climate
- Evaluate the potential commercial application of the studied varieties.

Three tropical wheat varieties, were SC Nduna, SC Sky, and SC Stallion were procured from Seed Co Limited, Zimbabwe and evaluated in different agro climatic regions of Mauritius. The experiment was initiated in 2012 at Saint Antoine (20.02 °S, 57.39 °E) and upscaled in 2013 and 2014 at Petit Merlot (20.32 °S, 57.57 °E)and Cluny (Le Val) (20.40 °S, 57.61 °E) respectively.

Laboratory tests conducted for the three wheat varieties after first harvest revealed that all varieties had good milling characteristics, very high protein content, high moisture content and high falling number except for SC Stallion, and indicating high amylase activity in this variety. In addition, SC Stallion had the highest protein (19.6%) and gluten content while SC Sky had the highest moisture content.

An in-depth analysis was conducted in the last phase of the experiment in 2014 at Cluny, Le Val. The project was upscale on an area of 12 acres to evaluate the potential commercial application of the studied varieties.

1.0 INTRODUCTION

Wheat (*Triticum aestivum L*.) generally known as bread wheat, is the second most produced crop in the world, lagging behind only corn (Tiller, 2007) and is grown under both irrigated and rain fed conditions (IJACS, 2013). Despite being a temperate crop (C_3), wheat is a widely adapted crop. It is grown from temperate, irrigated to dry and high rain-fall areas and from warm, humid to dry, cold environments. It belongs to the grass family, namely Poaceae, also called gramineae family (Ali Khan, 2003). Wheat provides 21% of food calories and 20% of protein contents to more than 4.5 billion people in ninety-four developing countries (Goutam *et al.,* 2013). Globally, wheat is the leading source of vegetable protein in human food, having a higher protein content than other major cereals, maize (corn) or rice. In terms of total production tonnages used for food, it is currently second to rice as the main human food crop and ahead of maize, after allowing for maize's more extensive use in animal feeds.

Commercially, wheat is classified into distinct categories of grain hardness (soft, medium-hard and hard) and colour (red, white and amber). Based on growing habit, bread wheat is divided into two subclasses: spring and winter. There are quite large differences in grain composition and processing quality among wheat cultivars within a species: thus, one cultivar may be suitable to prepare one food type but unsuitable to prepare a different one. It is important to find the right cultivar for our requirements. One of the greatest developments in modern times has been the production of dwarf cultivars suited to the warmer countries by the International Maize and Wheat Improvement Center (CIMMYT). These dwarf varieties can support a heavier yield of grain without collapsing.

Mauritius is highly dependent on food imports and is currently importing 80% of its food requirements with rice and wheat (MAIF, 2008). Recent events pertaining to global food crisis, for example export ban on certain commodities by some countries have shown that financial resources alone can no longer guarantee procurement of food. Wheat being the most important staple food, it is imported at the rate of around 170,000 tonnes annually and is priced 450 to 500 USD per tonne (FAO, 2012). “Les Moulins de la Concorde” is a major importer of wheat in Mauritius and treats 165, 000 tonnes wheat into flour each year (LMLC, 2012). Hence there is a need to look into local production of some strategic crops for food sovereignty and national security.

Hence, research on these strategic crops must be carried out. These crops include ‘traditional crops’ such as potato, maize, pulses, etc. and ‘new crops’ such as rice and wheat. The production of these crops in Mauritius is deemed to be feasible, viable and sustainable. However, the main objective focus on producing as much crops as possible locally to reduce the dependency on imports, to decrease the food import bill, and to mitigate increases in prices to consumers. Therefore, the growing concerns over the food insecurity and the high dependence on imported foods have led to the initiation of research on wheat cultivation in Mauritius. Hence, the Mauritius Research Council (MRC) was mandated to conduct the study under the aegis of Ministry of Tertiary Education, Research, Science and Technology (MoTERST) in 2011.

1.1 AIMS AND OBJECTIVES

The aim of this research program was to assess the potential of wheat cultivation in Mauritius.

The specific objectives were:

- To assess the adaptability of three wheat varieties under different agro-climatic conditions
- Evaluate specific variety of wheat suitable for local climate
- Evaluate the potential commercial application of the studied varieties.

2.0 METHODOLOGY

The study was initiated in 2011 by developing a road map and setting up a technical committee.

2.1 TECHNICAL COMMITTEE

The technical committee was set up to drive the program and was spearheaded by MRC. The technical committee members were:

- Mauritius Sugar Industry Research Institute (MSIRI)
- Agricultural Research Extension Unit (AREU)
- Les Moulins de la Concorde (LMLC)
- Vita Rice Limited
- University of Mauritius (UOM)
- Flacq United Estates Limited (FUEL)
- Espitalier Noel Ltd/ Agri
- Compagnie Sucriere de Saint Antoine (CSSA)
- Rose Belle sugar Estates (RBSE)
- Mr Mukesh Rughoo, Agronomist recommended by MISRI

A three phase road map of wheat cultivation study was formulated below:

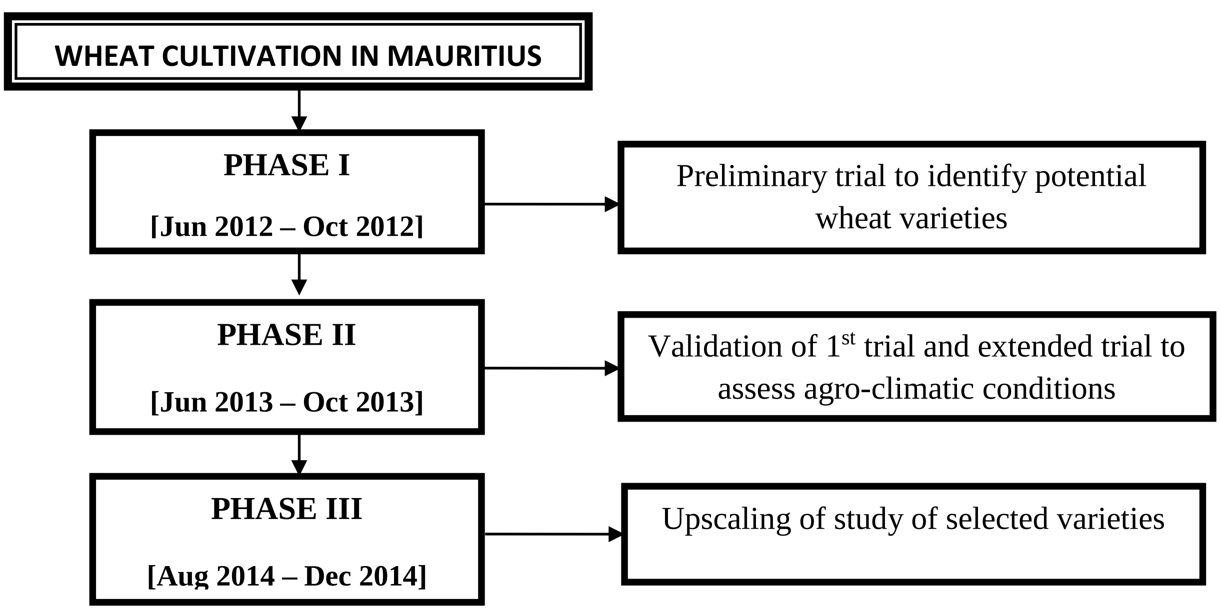


Figure 1: Road map of wheat cultivation study in Mauritius

2.2 CONSULTATIVE PROCESS

2.2.1 Consultative meeting

The decision-making on project activities was done in consultation with technical committee. Technical committee meetings were held regularly along this line.

Table 1: Consultative Process

CONSULTATIVE PROGRESS:	DATE	STAKEHOLDERS AND MEMBERS PRESENT	COMMENTS
Technical Committee Meeting	12th August 2011	MRC, AREU, MSIRI	-
	9th December 2011	MRC, AREU	-
	3rd January 2012	MRC, UOM, MSIRI, LMLC	-
	23rd February 2012	MRC, UOM, MSIRI	-
	16th April 2012	MRC, MSIRI, MoTERST	-
	6th September 2012	MoTESRT, MSIRI, UOM, ENL Agri Ltd, Compagnie Sucriere de Saint Antoine Ltd, Flacq United Estate Ltd	-
	15th May 2014	MRC, UOM	-
	11th June 2014	MRC, RBSE	-
	1st July 2014	MRC, RBSE, Vita Rice Ltd	-
	7th August 2014	MRC, MSIRI, UOM, Vita Rice Ltd	-
Half day Consultative Meeting	31st January 2013		❖ Result of feasibility studies ❖ Proposed way forward and roles of different stakeholders ❖ Brainstorming/ Interactive session
Harvest Training Programme at Petit-Merlot	18th November- 6th December 2013	MRC, National Women's Entrepreneur Council (NWEC)	❖ Encouraging women entrepreneurs and women in general to start up small–scale wheat cultivation as a

			means of empowerment. ❖ Imparting knowledge in wheat cultivation to fight against unemployment of women. ❖ Contributing in attaining food security
Wheat Harvest Ceremony (Public invited)	18th October 2012	-	❖ Saint Antoine
	24th October 2013	-	❖ Petit Merlot
	26th November 2014	-	❖ Le Val

2.3 SITE SELECTION

Experimental sites were established in different agro climatic regions including humid, super humid and sub-humid zones. **Table 2** illustrates the different regions where the trials were carried out with respect to their agro climatic conditions.

Table 2: Studies carried out at different agro-climatic regions

Year	**Super Humid*[1]**	**Sub-Humid*[3]**
2012	-	Saint Antoine
2013	Petit Merlot	-
2014	Le Val	-
Annual rainfall/mm	***[1] 3000 – 3500**	***[3] < 1250**

2.4 EXPERIMENTAL DESIGN

A completely randomized design was used for the cultivation of the three wheat varieties at the regions mentioned in **Figure 2**. The experiments were performed on different soil types under different acreage.

Saint Antoine
Soil Type: reddish brown silty clay loam

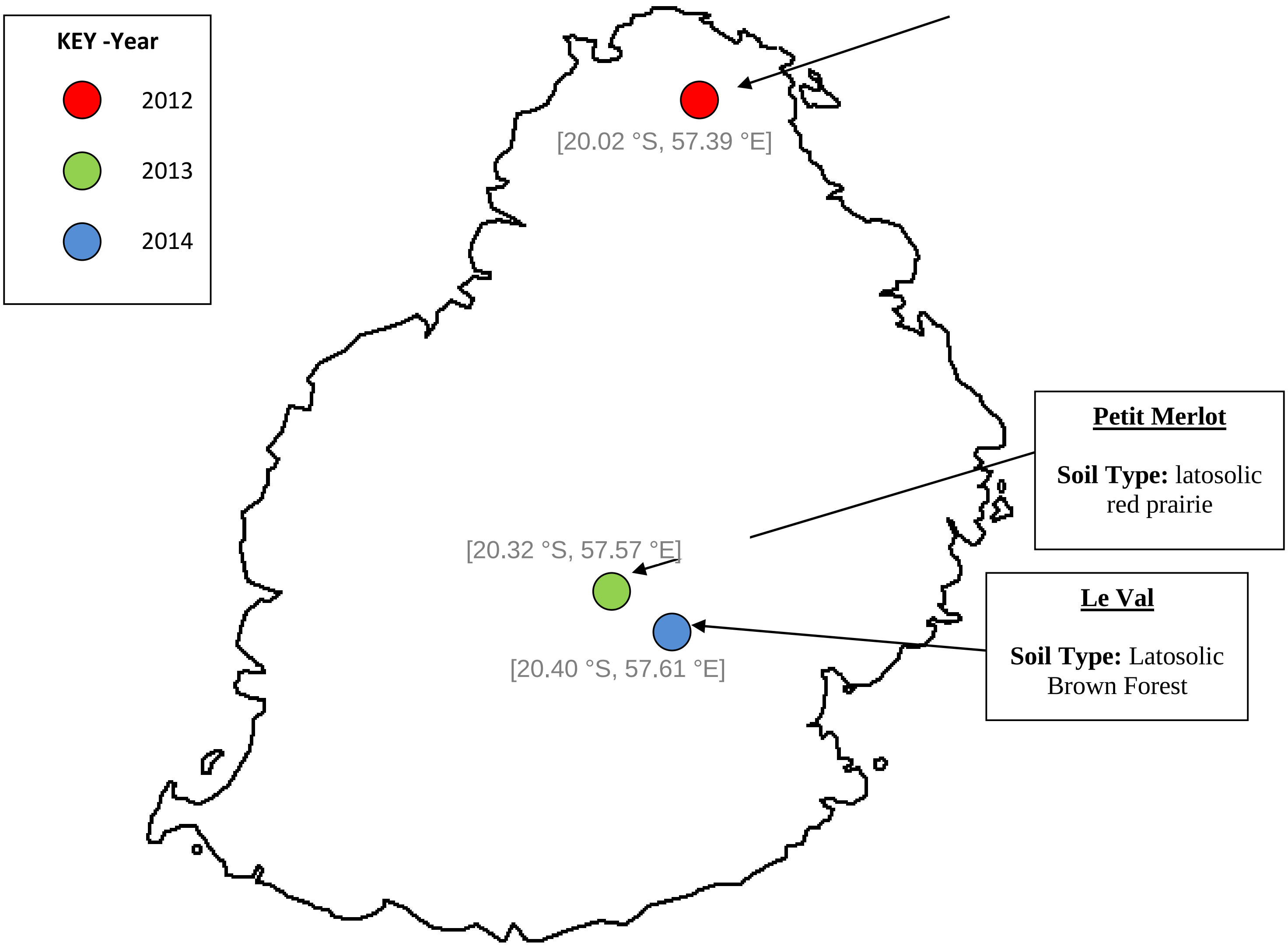


Figure 2: Experimental wheat cultivation in different agro-climatic regions

2.5 HISTORICAL BACKGROUND OF EXPERIMENTAL SITES

Table 3: Land use prior to wheat experiment

Year	Locations	Previous field conditions

2012	St Antoine	Sugarcane cultivation with shallow gravelly land
2013	Petit Merlot	Fallow land. The proliferation of *Pennistum purpureum* (also known as Napier grass or Elephant grass) was noted.
2014	Le Val	Rice cultivation

2.6 VARIETIES EVALUATED

Three open -pollinated winter wheat varieties were purchased from Seed Co Ltd, Zimbabwe. The three varieties were evaluated for their adaptability under different regions, yield potential and resistance to pests: Sc Stallion (Red), Sc Nduna (White) and Sc Sky (Red).

2.7 FIELD OPERATION AND CULTURAL PRACTICES

Land clearing was carried out at the different sites to remove boulders, cane setts and weeds. The lands were then tilled and leveled. Minor derocking (whenever required), pre emergence herbicide application and furrowing were done. Prior to planting, application of Urea was done at Le Val and seeds were also treated with fungicides Actara and Dithane M45 for all the wheat varieties planted.

Treated seeds of the three varieties were sown at a depth of 5 cm with 2.5 cm spacing at all the experimental sites and then covered. Cultivation was done on raised beds at some sites, while for others; furrows were dug at an interval distance of 20 cm. The seed rate was around 100 kg/ha.

Manual sowing was carried out for the different sites except for Le Val. Mechanized sowing was conducted using a Europard 1254 tractor including a disc plough and a variable grain seeder. The methods of sowing are illustrated in **Table 4.**

Table 4: Experimental sites: Acreage, previous use and sowing date

Site Location	Acreage	Sowing date	Method of cultivation
Saint Antoine	600 m^2	20.07.2012	Manual cultivation on raised beds
Petit Merlot	12660 m^2	02.017.2013	Manual cultivation in furrows

Le Val	50640 m²	18.08.2014	Mechanical sowing in furrows

Earthing up and top dressing was done using Calcium Ammonium Nitrate three to four weeks after plant emergence.

Manual Weeding was performed as required whenever there was weed infestation.

Table 5: Weeds present at the different agro-climatic regions

Saint Antoine	**Petit Merlot**	**Le Val**
Solarum nigrum (Brede Martin)	*Solarum nigrum* (Brede martin)	*Colocasia Esculenta* (Songe Blanc)
Plantago lanceolata (herbe plantain/ caroline)	*Amaranthus dibius* Mart. ex Thell. (Brede Malabar)	*Eleusine Indica*
Cardiospermum halicacabum (Liane poc poc)		*Cynodon dactylon*
Ageratum conyzoides Linn. (Herbe de bouc)		*Ageratum Conyzoides*
Kyllinga bulbosa P. Beauv. (Petit mota)		*Amaranthus dibius* Mart. ex Thell. (Brede Malabar)
Oxalis latifolia H.B.K. (Herbe trefle)		
Portulaca oleracea Linn.(Herbe pourpier)		

Application of fungicides and agro-chemicals were also done to control the prevalence of pest and diseases. Moreover, warning tapes, plastic bags fixed on bamboo poles and scare crows were placed on the fields to reduce bird attacks.

Table 6: Chemicals used during the wheat cultivation phases at the different sites

	Chemicals used	Dosage/ ha	Purpose	Mode
FERTILIZERS	Urea	100 – 150 kg	Increases the nitrogen content in soil	Prior to planting
	Calcium Ammonium Nitrate	180 – 270 kg	Improves the fertility of the soil, and therefore increases the growth and yield of the plants	Top dressing three weeks after planting
HERBICIDES (Whenever required)	2,4 D Amine	500 mL	Broadleaf weeds	Post emergence
	Glyphosate	3-3.6 L	Grasses, broadleaves & woody plants	Post emergence
	Metsulfuron	60 g + 240 mL/ Wetting agent	Broadleaf weeds & some annual grasses	Pre-emergence & post emergence
	Oxyfluorfen	2.4 L	Tough broadleaves & annual grasses	Pre-emergence & post emergence
FUNGICIDES (Whenever required)	Mancozeb	800 g -1.2 kg	Control of fungal disease such as rust, late blight and downy mildew	Post-emergence Insect/Disease
	Dithane M45 **Or** Ridomil	1.2 kg **Or** 1.8kg	Has curative and protective properties Controls soil and leaf diseases	Preventive
	Creoline	10mL/L water on boarder	Rodents repellent	Preventive
INSECTICIDES (Whenever required)	Steward 30 WC **Or** Karate Zeon	150 g **Or** 300 mL	Stem borer, ants & caterpillar	Preventive
	Actara	150 g	Sucking and some chewing pests	Preventive

Others	Meta pellet	-	Protect seedlings against snails and slugs	At emergence
	Push –Push	-	Used as a repellent to control hares	Preventive

2.8 DATA COLLECTION AND MONITORING

Weekly site visits were effected and growth stages as well as the health status of the plants were recorded. These include:

- **Evaluation of growth stages**

  Germination rate was visually assessed at emergence. Weekly phenological observations using the Feekes scale were made from sowing to harvest.

Table 7: Developmental stages as per Feekes' scale

Growth stages	Feekes Scale	Corresponding growth stage on field
Germination		
Seedling Growth	**1**	
Tillering	**2-3**	
Stem elongation	**4-9**	

Booting	**10**	
Anthesis	**10.51-10.53**	
Milk Development	**10.54-11.1**	
Ripening	**11.3-11.4**	

2.8.1 Quantitative data collection

Quantitative data collection was done by using quadrats assessment. Each experimental plot was randomly sampled on a weekly basis using a 1 m^2 quadrat. Four quadrats readings were taken for every 100 m^2 of cultivated plot.

The average plant height was recorded and yield data were evaluated based on grain yield after deshelling.

- **Damages observed**

  During weekly field monitoring, the damage caused by heavy rainfall, bird attack, hare attack, water logging, pest and diseases was visually evaluated and recorded.

- **Correlating climatic condition to crop developmental stages**

  Climatic data (weekly rainfall and temperature) was correlated with the crop developmental stages. The weekly average data of the experimental sites was estimated from daily data which was obtained from the closest stations of the Mauritius Meteorological Station. These stations were:

- Mon Loisir Rouillard for Saint Antoine
- Mon Bois for Petit Merlot
- Rose Belle for Le Val

2.9 SEED QUALITY TESTING

Wheat grain harvested from the wheat cultivation phase I (2012) and phase III (2014) was sent to Les Moulins de la Concorde for wheat testing (percentage Moisture, Ash, protein, wet gluten, gluten index and bug damaged). The quality of grains for bread making was hence evaluated.

2.10 TRANSFER OF TECHNOLOGY

A 3 week capacity building program was organized from 18 November 2013 to 6 December 2013 to provide the necessary knowledge to undertake small-scale wheat cultivation to potential women entrepreneurs. To this effect a group of 25 women from the women associations of the National Women's Council (NWC) were contacted in 2013.

An important objective of the program was to disseminate the results of the Experimental Wheat Cultivation Project spearheaded by the Council in view of:

1. Encouraging women entrepreneurs and women in general to start up a small-scale wheat plantation as a means of empowerment;
2. Imparting knowledge in wheat cultivation as a means to create potential revenue generating opportunities.

The 3 weeks work session was held between at Petit Merlot and this included lecture and practical sessions.

Table 8: Topics discussed during lecture and practical sessions

Topics discussed during the lecture sessions	Topics discussed during the Practical sessions

❖ Botanical description of wheat plant and wheat seeds.	❖ Land preparation
❖ Agro-climatic conditions required to grow wheat.	❖ Fertiliser application
❖ Pests and diseases that can attack wheat crops.	❖ Sowing of wheat seeds
❖ Fertiliser application	❖ Wheat harvest
❖ Weed control.	❖ Cultivation of wheat grass
❖ Grinding of wheat grains into flour.	❖ Artisanal grinding of wheat grains into whole wheat flour.
❖ Nutritional facts about wheat flour	

Visits were held at Les Moulins de La Concorde, where the participants had an overview of industrial wheat milling process and at the Agricultural Research and Extension Unit, where previously shelled wheat grains were milled using a machine suitable for grinding wheat on a small scale basis.

Following the 3 weeks harvest and training session an award ceremony was organized for the 25 participants by the Council. Each participant had the opportunity to display a product made from the wheat grains shelled during their practical sessions.

3.0 RESULTS AND DISCUSSION

3.1 MONITORING OF WHEAT DEVELOPMENTAL STAGES

3.1.1 Emergence

The seed germination rate was evaluated for each variety.

Table 9: Percentage of emergence for the 3 varieties

Varieties Cultivated	Sc Stallion	Sc Sky	Sc Nduna
% Emergence	99 %	97 %	97 %

Emergence was recorded 4-7 days after sowing and emergence rate was very high ranging from 97 to 99 % for the varieties.

3.1.2 Developmental stages

The growth and development of wheat are divided into different stages as depicted by Feeke's scale :germination (emergence), the first stage of plant growth leads to seedlings followed by tillering, booting, heading, flowering, ripening and harvest.

The number of days taken for each crop developmental stage of the three wheat varieties has been compiled for the three experimental sites. The average number of days taken to complete each phase of development is shown in **Figure 3**.

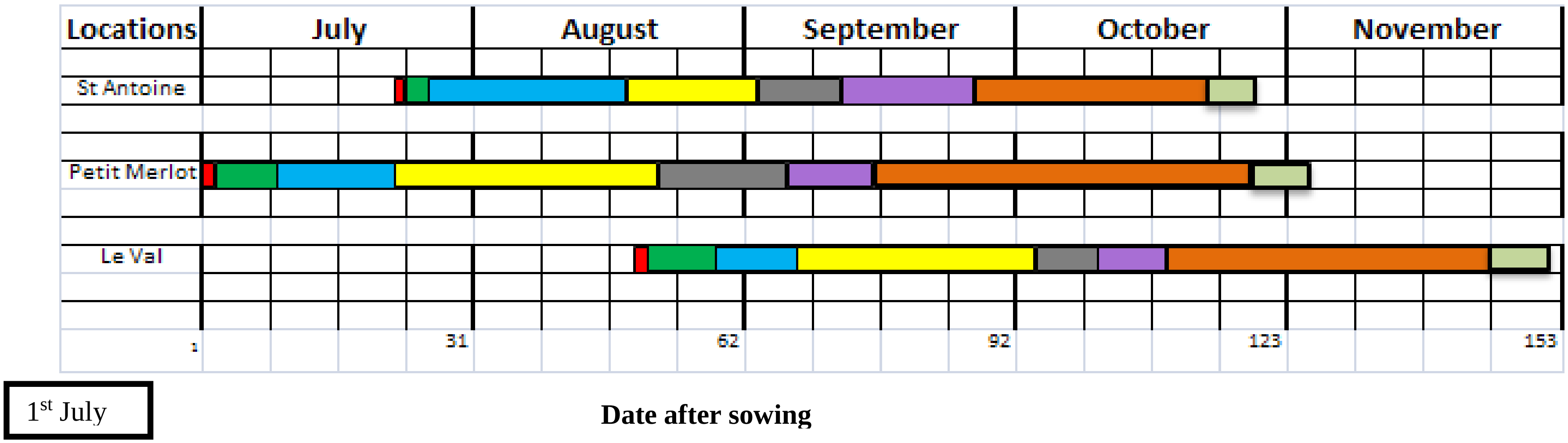


Figure 3: Phenology of different growth stages at different experimental sites

Day 0: 20th July 2012 for Saint Antoine; 2nd July 2013 Petit Merlot & 18th August 2014 for Le Val

An early emergence, 4 days after sowing was observed at Saint Antoine compared to Petit Merlot and Le Val where emergence was observed 7 days after sowing. However, the tillering phase was shorter at Le Val (18 Days After Sowing (DAS)) while at Saint Antoine and Petit Merlot it was at day 24 and 20 after sowing respectively.

Moreover, it was observed that at Petit Merlot, it took longer time for booting to occur (50 DAS) whereas at Saint Antoine and Le Val, booting occurred at the same time period (38 DAS).

The inflorescence emergence was longer at Saint Antoine as at Petit Merlot and Le Val it took about 7 to 9 days less to complete inflorescence emergence phase.

It could also be observed that wheat varieties grown at Petit Merlot took more time (75 days from sowing) to reach anthesis compared to the other two experimental sites (58 days for Le Val and 61 days for Saint Antoine).

Ripening was recorded earlier at Saint Antoine and Le Val (90 and 87 days after sowing respectively) while at Petit Merlot it occurred only 119 days after sowing.

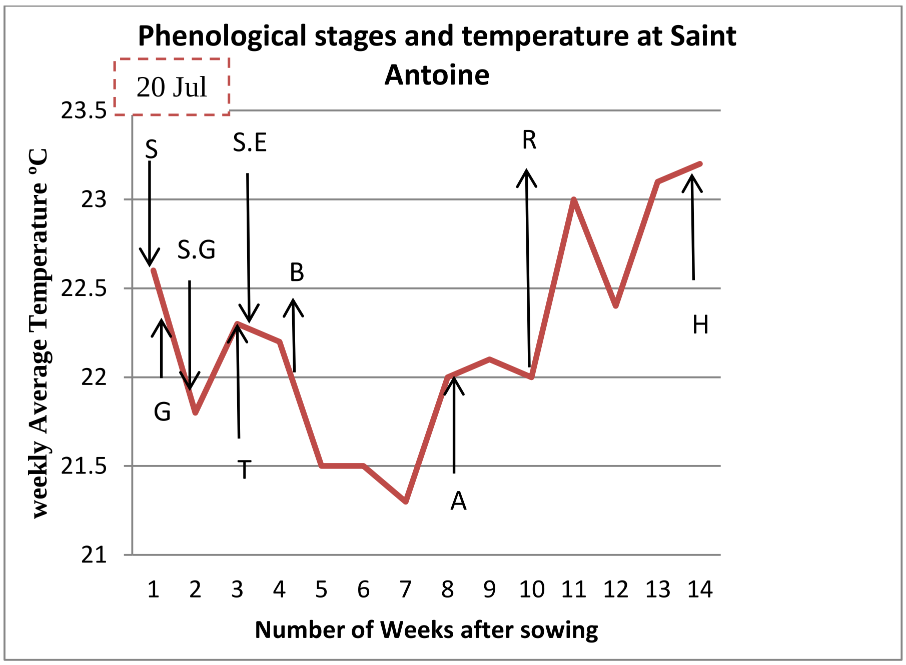
Lastly, harvesting was done approximately at the same time period at Saint Antoine and Le Val (95 and 93 DAS respectively). But it took a longer time at Petit Merlot for harvesting to be done.

3.2 CORRELATION BETWEEN PLANT GROWTH DEVELOPMENTAL STAGES AND CLIMATIC PARAMETERS

The time span of each developmental phase depends on genotype, temperature, day length and sowing date. Various environmental stresses, particularly heat, may shorten these growth phases in wheat (Acevedo *et al.*, 2002).

3.2.1 Phenological stages and temperature

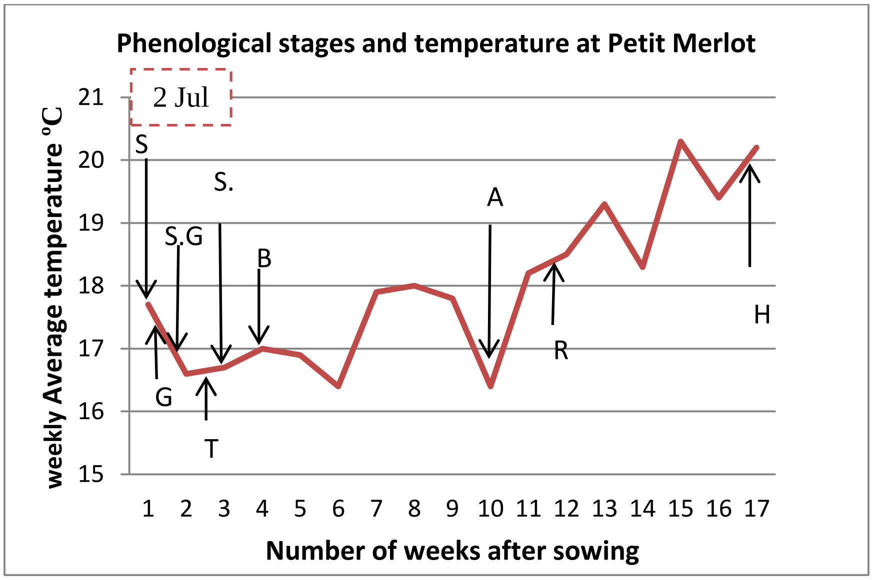
An attempt was made to correlate temperature to durations of the different phonological stages.



Note: ***S***- *Sowing,* ***G***- *Germination,* ***S.G***- *Seedling growth,* ***T***- *Tillering,* ***S.E***- *Stem Elongation,* ***B***- *Booting,* ***A***- *Anthesis,* ***R***- *Ripening,* ***H***- *Harvest*

Sowing Date: 20 July

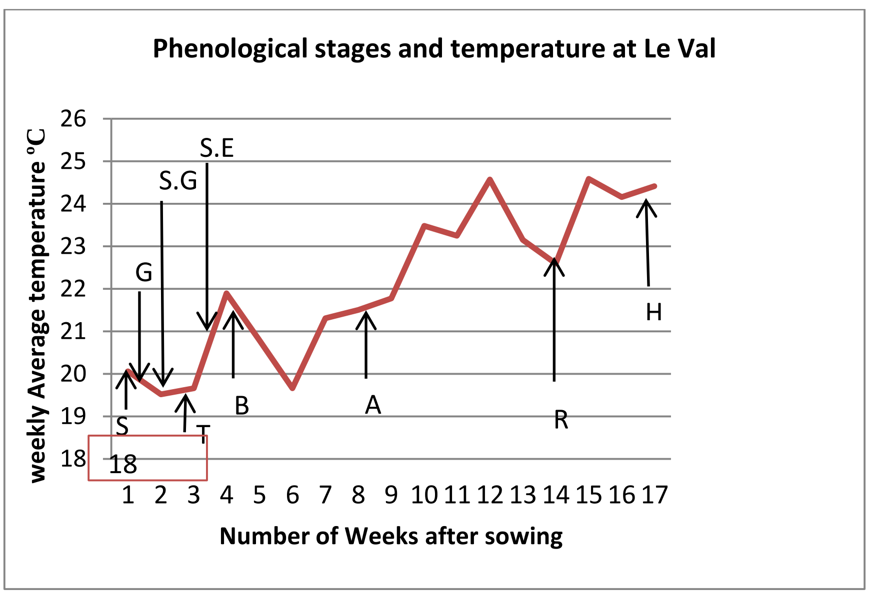
Figure 4: Phenological stages and temperature at Saint Antoine



Note: ***S***- *Sowing,* ***G***- *Germination,* ***S.G***- *Seedling growth,* ***T***- *Tillering,* ***S.E***- *Stem Elongation,* ***B***- *Booting,* ***A***- *Anthesis,* ***R***- *Ripening,* ***H***- *Harvest*

Sowing Date: 02 July

Figure 5: Phenological stages and temperature at Petit Merlot



Note: ***S***- *Sowing,* ***G***- *Germination,* ***S.G***- *Seedling growth,* ***T***- *Tillering,* ***S.E***- *Stem Elongation,* ***B***- *Booting,* ***A***- *Anthesis,* ***R***- *Ripening,* ***H***- *Harvest*
Sowing Date: 18th August

Figure 6: Phenological stages and temperature at Le Val

At the time that crop emergence occurs the seed embryo has three to four leaf primordia (Baker and Gallagher, 1983a, 1983b; Hay and Kirby, 1991). Normally, germination (emergence) may occur between 4 and 37°C being optimal from 12 to 25°C. In this present research, the duration of germination was observed 4-10 days after sowing at a temperature of 17- 23 ºC, but the emergence rate differed from site to site. Nahar *et al* (2010) reported that low temperature delays germination. This corresponds with present findings demonstrating emergence at 7 days at Petit Merlot and Le Val (17-20ºC) compared to 4 days at Saint Antoine (22-22.5ºC).

In Saint Antoine and Le Val, the temperature at sowing was 20 to 22.5ºC (Figure 4 and 6) compared 17.5ºC (Figure 5) at Petit Merlot. Consequently, the tillering, booting, inflorescence emergence, anthesis and ripening phases were shorter in Saint Antoine and Le Val (Figure 3). This resulted in harvest being conducted at 125 days after sowing in Petit Merlot and 95 and 93 days after sowing at Saint Antoine and Le Val (Figure 3).

With regard to specific development stages, according to FAO (2013), daily temperature for optimum growth and tillering is between 15 to 20ºC. Accordinglyto this study tillering occurred 18-24 days after sowing on the three sites and temperature varied from 16 to 22.5ºC during that stage.

Referring to the graphs (Figures 4-6), the time period from booting to anthesis at Saint Antoine and Le Val was 3 to 4 weeks and temperature varied from 21 to 22°C during that time.At Petit Merlot when the temperature was low (16 to 17°C), it took about 6 weeks to reach anthesis. Therefore, it was observed that low temperature lengthens the booting to anthesis phase, implying a longer developmental period.

Thee anthesis to ripening stage was longer at Le Val (6 weeks) compared to the other two sites (3-4 weeks). The temperature varied from18 to 19 °C in the latter regions while w at Saint Antoine temperature was in the range of 22 to 23 °C. This is an indication that low temperature delays harvest.

2.3 YIELD

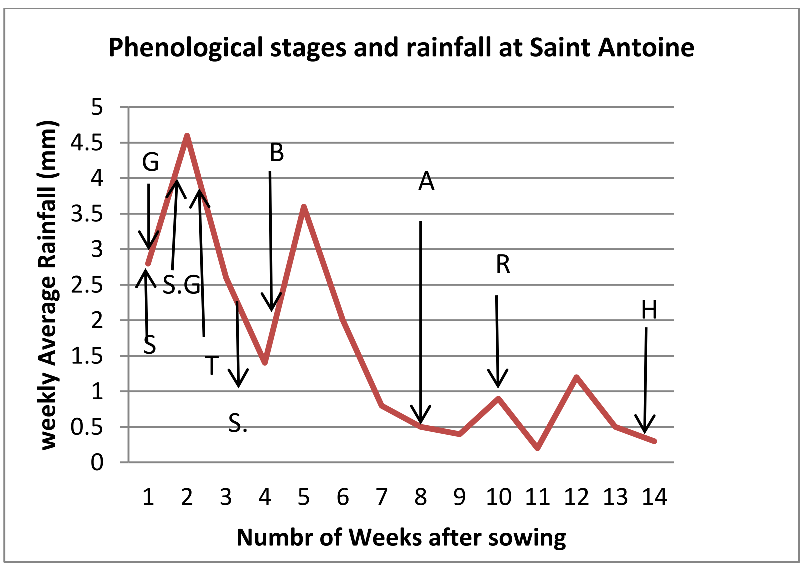
The yields from the three sites were compared. Given that there was no significant difference in yield among varieties, the average yield for each variety is presented in **Table 10**.

Table 10: Average yield calculated

Location	Average yield (t/ha)
Saint Antoine	3.4
Petit Merlot	7.62
Le Val	1.90

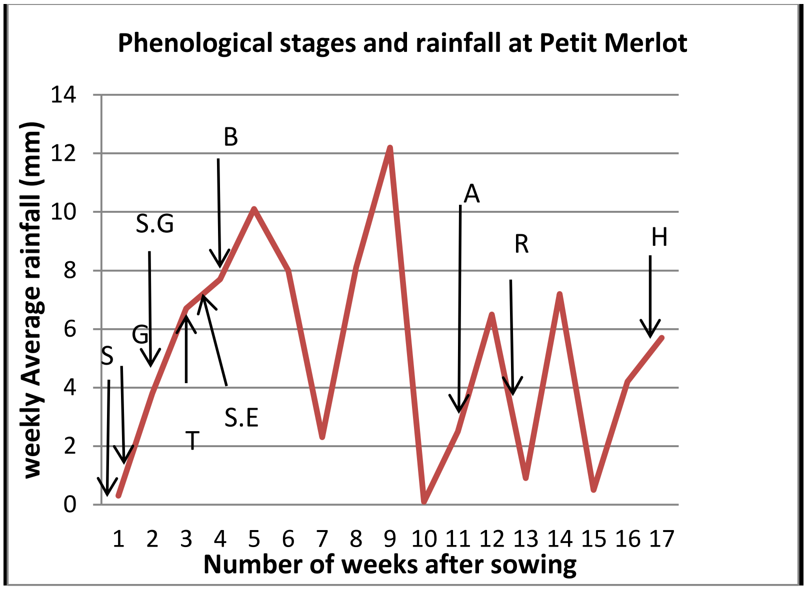
Yield varieties among sites were recorded the highest (7.62 t/ha) at Petit Merlot and lowest (1.90 t/ha) at Le Val.

Precipitation is an important factor affecting wheat yield during the vegetative stage, that is from germination to tillering. Hence, the correlation between rainfall pattern and phenological development was studied.



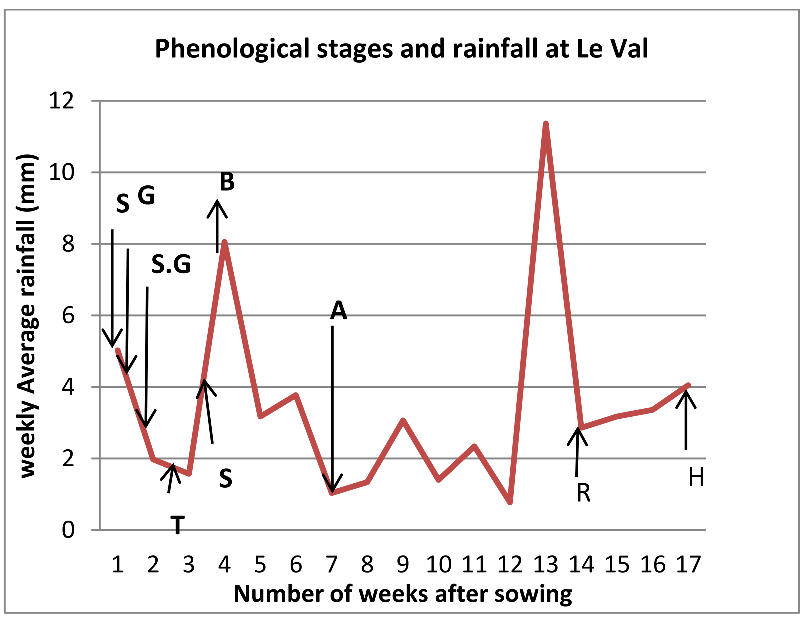
Note: ***S***- *Sowing*, ***G***- *Germination*, ***S.G***- *Seedling growth*, ***T***- *Tillering*, ***S.E***- *Stem Elongation*, ***B***- *Booting*, ***A***- *Anthesis*, ***R***- *Ripening*, ***H***- *Harvest*

Figure 7: Phenological stages and rainfall at Saint Antoine



Note: ***S***- *Sowing,* ***G***- *Germination,* ***S.G***- *Seedling growth,* ***T***- *Tillering,* ***S.E***- *Stem Elongation,* ***B***- *Booting,* ***A***- *Anthesis,* ***R***- *Ripening,* ***H***- *Harvest*

Figure 8: Phenological stages and rainfall at Petit Merlot



Note: ***S***- *Sowing,* ***G***- *Germination,* ***S.G***- *Seedling growth,* ***T***- *Tillering,* ***S.T***- *Stem Elongation,* ***B***- *Booting,* ***A***- *Anthesis,* ***R***- *Ripening,* ***H***- *Harvest*

Figure 9: Phenological stages and rainfall at Le Val

High temperature stress as well as water stress affects wheat crop productivity. Gibson & Pauslsen,(1994) reported that high temperature after anthesis coupled with drought generally decrease kernel number, reproductive duration and grain yield. Consistendly the weekly average temperature at anthesis at Saint Antoine and Le Val was 22.1 and 21.5^{o}C respectively and the average yield was lower than to Petit Merlot where temperature was 16 to 17 ^{0}C.

At the same time average weekly rainfall at Petit Merlot, Le Val and Saint Antoine at anthesis was 2.5 mm, 1.03 mm and 0.5 mm. Interestingly the yield was significantly higher at Petit Merlot (Figure 3) where there was high rainfall and lower temperature. This is consistent with the statement made by Gibson & Pauslsen (1994).

Ashraf (1998) further reported that water stress (mainly shortage of water) at anthesis reduces pollination and thus less number of grains is formed per spike which results in the reduction of grain yield. The graphs (Figure 6, 7, 8) indicate that the average weekly rainfall at anthesis was less than 1.5 mm of rainfall was recorded at Saint Antoine (0.5 mm) and Petit Merlot (1.03 mm) compared to Petit Merlot (2.5 mm). This might have affected the yield obtained at harvest.

Table 10 shows that the average yield obtained at Petit Merlot was 7.62 t/ha which is higher compared to Saint Antoine which was 3.4 t/ha and Le Val, 1.90 t/ha. These differences in the yield obtained might be due to anthesis at Petit Merlot (25 days) and the amount of rainfall obtained at each sites (anthesis). Moreover, the number of days from booting to anthesis at Le Val was less, hence average yield was low.

Spilde (1989) attributes higher number of tillers to higher grain yield. This could explain the low yield in Le Val and higher yield in Petit Merlot and Saint Antoine. Another factor affecting yield is ‘reproductive stage’ duration which includes booting, inflorescence emergence and flowering/ anthesis. From **Figure 3**, it is clear that the reproductive duration is higher in Petit Merlot and this corresponds to the increase in grain yield. Thus, this is in line with the finding with Gibson & Pauslsen (1994). From this exercise it is clear that the vegetative and reproductive duration of wheat are influence by temperature and rainfall and this have a direct effect on growth. Hence, all this needs to be considered when deciding on the optimal sowing date for wheat. From this study, the optimal sowing date would depend on the agro- climatic region.

3.4 GRAIN QUALITY FOR BREAD MAKING

The harvested grains from Saint Antoine and Le Val were evaluated for the use in bread making using standard methods. Wheat varieties were assessed for moisture content, wet gluten, ash, protein content (AOAC 2001.11) Ash (ISO 2171), Falling Number (AACC Method 56-81). Laboratory tests were conducted at Le Moulin de La Concorde which showed that all varieties had good milling characteristics based on the standard methodology.

Determining moisture content is an essential first step in analyzing wheat or flour quality since this data is used for other tests. The moisture content was high, with variety SC Sky having the highest percentage of moisture (14.8 % and 14.10 %). Wheat with high moisture content (greater than 14.5 %) attracts mold, bacteria, and insects, all of which cause deterioration during storage. Wheat with low moisture content is more stable during storage. Hence, it can be inferred that the cultivated wheat would have to go through a drying process to bring the moisture content to about 8-9% (as per STC Standard).

All varieties had very high (more than 15%) protein content; with variety SC Stallion having the highest protein content of 19.6% (Table 13) which displays high durum wheat characteristics.

Falling number was high in all varieties, except for SC Stallion, indicating minimal enzyme activity (α- amylase) and sound quality wheat or flour. However, for 2014 the failing number was low, indicating substantial enzyme activity and sprout damaged wheat or flour.

Table 11: Milling characteristics of investigated wheat varieties

	2012				2014		
Parameters	**SC Stallion**	**SC Sky**	**SC Nduna**		**SC Stallion**	**SC Sky**	**Desirable Range**
Moisture %	13.47	14.8	13.33		13.52	14.10	Low: <14
Ash % (Dry Basis)	1.82	1.95	1.62		1.64	1.59	0.3-1.5
Falling Number (s)	222	490	450		8154	126.15	High: >300
Protein % (Dry Basis)	19.6	18.52	16.96		15.15	16.76	High: 14-15
Wet Gluten %	42.0	38.5	34.5		34.50	32.20	Strong: 35
Gluten Index	60	79	80		62.03	45.65	90
Bug Damaged (per 30g)	13	6	5				Nil
Broken kernel (%)					3.70	2.40	

4.0 PROBLEMS ENCOUNTERED

Table 12: Problem encountered during the wheat cultivation phases

Problem encountered	Damage caused	Remedial measures
Hares	young shoots were nibbled	Physical barrier and repellent (creoline solution)
Snails and slugs	poor development of some plants	Application of meta pellets
Birds	Spike damage	Scarecrows made up with plastic bags and warning tape was placed all over the field
Stem borers	Damages of wheat plant	Application of Steward or Karate at recommended rates
Caterpillars	Failure of milk hardening, loss of yield	
Whiteflies	Leaves turns yellow (dry) and fall off plants	-
Fungus attack	Dark brown and purple lesions on the panicles	Application of Ridomilgold at recommended rate
Water logging	Seedling damage	-
Weed invasion	poor development of some plants	Application of Glyphosate prior to land preparation and manual weeding was performed

The problems encountered during the trials are tabulated in Table 12. Problems could be addressed successfully as per tabulated remedial measures except for bird attacks which were found to be a challenge despite the remedial measures.

5.0 CONCLUSION AND RECOMMENDATION

The three wheat varieties were found to be adaptable to the climatic conditions in Mauritius for cultivation.

The sowing season of the winter wheat varieties depend on agro-climatic regions. Since Petit Merlot and Le Val are situated in a cold region, it is best to sow between May to July whereas at Saint Antoine (hot region), it is recommended to sow between June to July.

Moreover, since the grain quality is promising in term of protein content conferring high durum wheat characteristics, the three varieties could potentially be used under local condition for making of flour and products such as pasta and spaghettis. Hence, women entrepreneurs and women in general can set up small scale wheat plantationsto produce flour rich in protein for their own consumption.

Pests and diseases were not a major problem and were easily controlled; except at Le Val where bird attack cause a major problem. The methods used to scare the birds were not effective at all. The birds ate all the panicles, leaving the plants without any seeds. Hence, another method of prevention should be identified to reduce the bird attack.

Moreover, for a complete insight into this activity the cultivation of summer varieties should be envisaged. This may clash with conventional Mauritian crops such as sugarcane or rice but conversely, dedicated land to cultivation of wheat plant may be considered where both a winter and summer cycle can be experimented.

Alternatively, wheat is found to be a suitable crop to be integrated in a rice-wheat or sugarcane-wheat crop cycle.

As future work it is recommended that the processing of the wheat varieties into different products should be evaluated. At the same time it is worthwhile conducting a study to evaluate the cost effectiveness of local wheat cultivation on a large scale.

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APPENDIX 1

T test was used to test statistically the difference among the growing stages for the 7 experimental sites at 95 % confidence interval

One-Sample T: em, t, B, In, An, Ri

Variable	N	Mean	StDev	SE Mean	95% CI
em	7	6.857	1.773	0.670	(5.218, 8.497)
t	7	20.43	4.86	1.84	(15.93, 24.92)
B	7	36.43	10.47	3.96	(26.75, 46.11)
In	7	53.00	7.12	2.69	(46.42, 59.58)
An	7	60.43	7.39	2.79	(53.59, 67.26)
Ri	5	108.40	15.71	7.03	(88.89, 127.91)

APPENDIX 2

Table 13: Growth and developmental stages for the different experimental sites

Growth Stages	Feeke's Scale	2012 Saint Antoine	2013 Petit Merlot	2014 Le Val	Mean	Standard deviation
Planting dates	**0**	**20-Jul**	**2-Jul**	**18-Aug**		
Emergence	**0**	**4**	**7**	**7**	**6**	**1.73**
Tillering	**2–3**	**24**	**20**	**18**	**20.67**	**3.06**
Booting	**8–10.1**	**38**	**50**	**38**	**42**	**6.93**
Inflorescence emergence	**10.2–11**	**45**	**66**	**46**	**52.33**	**11.85**
Flowering/ Anthesis	**11.4–11.6**	**61**	**75**	**53**	**63**	**11.14**
Ripening	**11.3–11.4**	**90**	**119**	**87**	**98.67**	**17.67**
Harvest	**-**	**95**	**125**	**93**	**104.33**	**17.93**

***DAS: Day After Sowing**

APPENDIX 3

Figure 10: Tractor with chisel plough and grain seeder

Figure 11: Emergence of wheat Varieties

Figure 12: Plant height and number of leaves

Some problems encountered:

Figure 13: Wheat plant being uprooted due to heavy rainfall

Figure 14: Damaged plants on SC Stallion plot caused by previous waterlog conditions

Figure 15: Continuous weed growth on the field

Figure 16: Presence of birds on field

Figure 17: Spikelet damage due to bird attacks

APPENDIX 4

Table 14: Summarizing the developmental stages as per Feekes' and Zadocks' scales

[redacted]				
Stage	**General Description**	**Feekes Scale**	**Zadoks Scale**	**Additional Comments**
Germination	Dry seed		00	
	Start of imbibition		01	
	Imbibition complete		03	Seed typically at 35 to 40% moisture.
	Radicle emerged from seed (caryopsis)		05	
	Coleoptile emerged from seed (caryopsis)		07	
	Leaf just at coleoptile tip		09	
Seedling Growth	First leaf through coleoptile	1	10	
	First leaf unfolded		11	
	2 leaves unfolded		12	
	3 leaves unfolded		13	
	4 leaves unfolded		14	
	5 leaves unfolded		15	
	6 leaves unfolded		16	
	7 leaves unfolded		17	
	8 leaves unfolded		18	
	9 or more leaves unfolded		19	
Tillering	Main shoot only		20	
	Main shoot and 1 tiller	2	21	
	Main shoot and 2 tillers		22	
	Main shoot and 3 tillers		23	Many plants will only have 2 or 3 tillers per plant at recommended populations.
	Main shoot and 4 tillers		24	
	Main shoot and 5 tillers		25	
	Main shoot and 6 tillers	3	26	Leaves often twisting spirally.
	Main shoot and 7 tillers		27	
	Main shoot and 8 tillers		28	
	Main shoot and 9 tillers		29	

[redacted]				
Stem Elongation	Pseudostem erection	4-5	30	
	1st detectable node	6	31	Jointing stage
	2nd detectable node	7	32	
	3rd detectable node		33	
	4th detectable node		34	Only 4 nodes may develop in modern varieties.
	5th detectable node		35	
	6th detectable node		36	
	Flag leaf visible	8	37	
	Flag leaf ligule and collar visible	9	39	
Booting	Flag leaf sheath extending		41	Early boot stage.
	Boot swollen	10	45	
	Flag leaf sheath opening		47	
	First visible awns		49	In awned varieties only.
Head (Inflorescence) Emergence	First spikelet of head visible	10.1	50	
	1/2 of head visible	10.2	52	
	1/2 of head visible	10.3	54	
	3/4 of head visible	10.4	56	
	Head completely emerged	10.5	58	
Pollination (Anthesis)	Beginning of flowering	10.51	60	Flowering usually begins in middle of head.
		10.52		Flowering completed at top of head.
		10.53		Flowering completed at bottom of head.
	1/2 of flowering complete		64	
	Flowering completed		68	
Milk Development	Kernel (caryopsis) watery ripe	10.54	71	
	Early milk		73	
	Medium Milk	11.1	75	Milky ripe.
	Late Milk		77	Noticeable increase in solids of liquid endosperm when crushing the kernel between fingers
Dough Development	Early dough		83	
	Soft dough	11.2	85	Mealy ripe: kernels soft but dry.

[redacted]				
	Hard dough		87	
Ripening	Kernel hard (hard to split by thumbnail)	11.3	91	Physiological maturity. No more dry matter accumulation.
	Kernel hard (cannot split by thumbnail)	11.4	92	Ripe for harvest. Straw dead.
	Kernel loosening in daytime		93	
	Overripe		94	
	Seed dormant		95	
	Viable seed has 50% germination		96	
	Seed not dormant		97	
	Secondary dormancy		98	
	Secondary dormancy lost		99	
Sources: Conley, et al. 2003. Management of Soft Red Winter Wheat. IPM1022. Univ. of Missouri. Alley, et al. 1993. Intensive Soft Red Winter Wheat Production: A Management Guide. Pub. 424-803. Virginia Coop. Extension. Johnson, Jr., et al. Arkansas Wheat Production and Management. MP404. Univ. of Arkansas. Coop. Ext. Serv.				