Agronomy to promote resilience for indigenous students and farmers in Fiji

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Abstract

"Nai takele ni kai viti na vuli – Ratu Sukua"

Agriculture is acknowledged as one of the significant contributors to the Fijian economy (United Nations Pacific, 2021). The United Nations and the Secretariat of the Pacific Community have identified Fiji as a country with a vulnerable agriculture sector and high food security risks. This conclusion is owed to Fiji's seasonal cyclones, inadequate extension programmes, lack of technical knowledge, and primitive farmer mindset (Asian Development Bank, 2011).

Research suggests that indigenous Fijian people learn primarily through observation and practical application. Similarly, the transfer of knowledge is through stories, songs and dances, making them practical people. A change in the pedagogical approach in agricultural universities by including field trials and linking them with the theoretical experience will promote learning for our indigenous students. Moreover, there is space to explore teaching approaches that may be effective in training indigenous students.

Opening training pathways that lead to a better understanding of developing critical thinking for indigenous students is imperative. Farm trials (applied in the appropriate context) can enhance understanding and improve outcomes to bridge the gap between theory, indigeneity, and practice in agronomy. These attributes help address current agricultural problems in Fiji, such as climate change and food security, which farmers can adopt to develop adaptive, resilient and robust approaches to improve production.

The results generated through this paper reflected a positive outcome in terms of pedagogical approaches in tertiary level in Fiji. The incorporation of field trials in practical activities with the guide of assessments is proven to develop awareness and critical thinking in indigenous Fijian students. The formulated templates are a key component in undertaking field trials as they can be utilised to adapt to any crop.

***Key Words**: indigenous pedagogy, agronomy, field trials, Climate Change, Food Security, sustainability, resilience.*

Dedication

To all the indigenous Fijian Farmers, who try to make ends meet.

To my parents (Joeli Koroikata Savou and Esita Soromasi Tabua)

I am who I am today because of you, and for this, I am forever in your debt.

Malo sara vaka levu na vei vaka vulici kei na vei tuberi cecere.

Tamaqu – Thank you for the life lessons and the sense of understanding.

Tinaqu - For your struggles away from home, this thesis is the result of your bravery, perseverance and consistency.

To my small unit (Margaret, Esita and Matai)

Thank you for your unceasing love, support and passion, for your loyalty, patience, understanding and being there for me despite my many shortfalls.

You are and always will be the drive of this vessel to the unknown ahead.

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At this point, I would like to acknowledge my God for his guidance and protection over my life.

"Ask, and it shall be given; seek, and ye shall find; knock, and it shall be opened unto you." Matthew 7:7

This thesis will identify that I am the sole author of this paper. However, several individuals must be acknowledged for their unrelenting support and inspiration, which led to the completion of this thesis. It is at this time that I realised the strength in bonding relationships.

"The most important thing one could ever give you is their time, as time is the only thing one cannot get back in this world"

Firstly, I would like to acknowledge Professor Nick Roskruge for being a great supervisor, friend, guardian, counsellor, and most importantly, for believing in me. I am privileged to have shared time and knowledge with you from when this master's idea was conceived to its completion.

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To the Palmy squad, thank you for the unforgettable memories… "Faya Na Marau"

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Chapter 1

Introduction

This chapter elaborates the background of this study covering Fiji's geographical location, the agricultural sector, along with the factors that contribute to Fiji's vulnerable agricultural sector and a comparison of roles played by indigenous Fijians in agriculture and its kinship with nature in the early days with contemporary agriculture in Fiji. The issue is approached through a pedagogical method that is intended to cater for the future leaders of agriculture in the Pacific.

1.1 Background

The Republic of the Fiji Islands extends over 18 376 km^2, consists of two main islands (Viti Levu and Vanua Levu) and 330 inhabited islands that includes the island of Rotuma. These form Fiji's archipelago (Walsh, 2006), geographically located between 17.7134° South, 178.0650° East. Nearby countries include New Zealand, Australia, Tonga, Vanuatu, Samoa, New Caledonia, Tuvalu and Wallis and Futuna (Shane, 2021) (see Figure 1.1). According to the 2017 census, Fiji's total population increased to 884,887 from 837,271 in 2007, projecting a 5.7% addition within ten years (Fiji Bureau of Statistics, 2017). As a developing country, the main contributors to the Fijian economy are agriculture and tourism (Gounder, 2001).

Figure 1. 1 A Cross Section Map of Fiji, presenting the position of Fiji on the globe, the Pacific Islands and Fiji's archipelago[1,2,3]

The United Nations, together with the Secretariat of the Pacific Community, have identified Fiji as a country with a vulnerable agriculture sector and high food security risks (Taylor, McGregor, & Andrew, 2016). Fiji relies heavily on imports such as prepared foodstuffs, meat, dairy, vegetables, and fruits (Fiji Bureau of Statistics, 2020). Factors contributing to Fiji's vulnerable agricultural sector include seasonal cyclones, lack of technical knowledge, inadequate extension programs, and the traditional agricultural mindset of many farmers (Taylor et al., 2016).

Fiji's agriculture sector's vulnerability highlights the need for an adaptive, resilient climate-smart agriculture approach to achieve sustainability to cater to the country's ever-growing population and support the tourism industry along with other dependent sectors.

[1] https://www.met.gov.fj/
[2] https://en.wikipedia.org/wiki/Fiji
[3] https://en.wikipedia.org/wiki/Geography_of_Fiji

Nowadays, climate change and food security are issues for Fiji, negatively affecting the local food systems, agricultural sector, and rural dwellers livelihoods as their survival depends on agriculture. Early explorers and settlers have little documentation of traditional agriculture in Fiji (Williams, 1860). However, despite the lack of records, it is evident that early Fijians could systematically produce a variety of crops throughout Fiji (Donnelly, Terence, Kerr, Gavin, & Max, 1994). These crops mainly included crops such as yams (*Dioscorea bulbifera*), giant taro (*Alocasia macrorrhizos*), plantain (*Musa bulbisiana*), ferns (*Diplazium esculantum*) duruka (*Saccharum edule*), sweetpotatoes (*Ipomoea batatas*), banana (*Musa acuminata*) and other vegetables (Veitayaki, 2004).

There is recognition of subsistence farming, crop rotation and a shifting cultivation approach in villages throughout Fiji and its archipelago (Ward, 1964). These farming systems preserved soil fertility by cultivating sufficient crops for a small group, where cultivation is practiced on a different area after harvest. Similarly, crop rotation practices the planting of different crops sequentially on the same area (Donnelly *et al.*, 1994). These systems safeguarded a reliable food source providing food security for early Fijians.

Most indigenous people depend on agriculture (including horticulture) for survival, and, thus, it plays a vital role in the community (Roskruge, 2007). Horticulture was a part of the daily life of early indigenous people, accompanied by food gathering, hunting, and fishing. All these activities had time in various indigenous calendars; a similar concept is observed in the *Vula Vaka Viti* (Fijian lunar calendar). This calendar provides information on the seasonally available food sources and the type of activity to be practised throughout the year (Movono, Dahles, & Becken, 2018; Tokaimalo and Ra Province, 1992).

However, the activities have indicators and observations such as the flowering and spawning of certain land and sea-dwelling creatures. These phenomena only occur when climatic conditions are favourable for spawning and flowering species (Borchert, 1983; Caspers, 1984) and many are fluctuating with climate change. Early indigenous people's kinship with nature aided their broader understanding of climate impacts and cultivation needs, where fruiting behaviour of plants or an abundance of particular fisheries indicated a change in climatic conditions (Singh & Singh, 2017).

The kinship between early Fijians and nature is influenced by their relationships with specific animals both on land and water along with plants, acting as totems (Movono *et* *al*., 2018). These totems serve as an emblem of a specific village or area, which act as a reminder of their ancestry. This kinship benefits both indigenous Fijians and the ecosystem that surrounds them, mutually supporting one another.

One of the first crops ever documented to be trialed for commercialisation in Fiji was sugarcane in 1862 at Wakaya Island (Ali & Narayan, 2019). Since theses trials, agricultural practice in Fiji has rapidly transitioned from traditional subsistence farming to a capital-focused monocultural farming system (Shah, Moroca, & Bhat, 2018). Influencing factors such as; declining soil fertility, inadequate investment in agriculture, population growth, loss of biodiversity, urbanisation and labour migration, improper extension work, shortage of technical skills add to Fiji’s vulnerable agriculture sector (Taylor et al., 2016). Fijian farmers are caught between their traditional and modern agricultural practices that have established globally (Taylor et al., 2016).

Furthermore, this transition has forced many Fijian farmers to partially abandon traditional Fijian agriculture, which will ultimately lead to the loss of traditional agricultural knowledge. Simultaneously, the lack of modern agricultural skills and practical education for young students and farmers contributes to the agricultural sector's transition. The lack of technical knowledge taught to students and its dissemination to farmers is a barricade to the transition. Research has proven the positive effects of combining traditional and modern agricultural practices (Schusky, 1989; Xu & Jeffrey, 1998), and this could very well work in Fiji's case.

In Fiji, the lack of modern agricultural techical skills and education does not necessarily mean that Fijians are illiterate or that agriculture is not taught in schools. Compared to earlier decades, the most recent decade has offered students a higher opportunity to attend schools, leading to a 99.7% literacy rate in 2017 (United Nations Educational Scientific and Cultural Organisation, 2021; Wynn, 1996). The increase in students attending tertiary education is owed to the free education policy and the high uptake of student loans (Pratibha, 2019; Radio New Zealand, 2013; Reddy, 2019). This loan policy was formulated to alleviate students burden from fees and transportation costs, followed by political factors in the past (Glavin, 2021).

The Fijian education system includes primary, secondary, and tertiary education, where the English language is the mode of instruction. Primary consists of the first eight school years within these three groups, covering the ages 6 to 14 (Study country, 2020). The secondary school covers four years, which offer students various disciplines including agriculture as a career path for the future. Finally, tertiary education offers a higher-level understanding of significant concepts of respective disciplines.

Fiji comprises two major universities that are ranked as the best in terms of agriculture in the South Pacific; the University of the South Pacific (USP) and Fiji National University (FNU) (Scimago Institution Ranking, 2021). These two universities cater to the South Pacific in higher education and are recognised for their credibility throughout the Pacific. With a cohort of students drawn from both Pacific and international origins, these universities contribute to the Pacific's future leaders.

Twelve countries jointly own USP: Samoa, Tuvalu, Tokelau, Niue, Marshall Islands, Fiji, Vanuatu, Tonga, Solomon Islands, Nauru and Kiribati (World University Ranking, 2021), with its main campus situated in Suva, the capital of Fiji. On the other hand, FNU contains Fiji's oldest agriculture college that has been the backbone of producing students with several key positions in the agricultural sector today (Fiji National University, 2021). With the changing practices and technology, formulating a sound pedagogical approach to promote learning of agriculture for indigenous Fijian students is essential.

Today's youth are the leaders of tomorrow, and effective practices through the education system will lead to a better future for Fiji. However, some concerning factors acknowledged in tertiary education throughout the Pacific are; under-qualified staff, class effectiveness, and a theory-heavy approach (Minogue, 1990). A lack of conceptual clarity can lead to the development of a confusing collection of learning objectives. Finding a solution to these issues will improve indigenous Fijian students understanding of agriculture and horticulture and boost the extension delivery to farmers.

1.2 Problem Statement

The lack of indigenous Fijian students' critical thinking and technical knowledge, followed by farmers' traditional mindset, contributes significantly to an increased food security risk in Fiji.

1.3 Research Questions

- What impact does the current pedagogy applied in Fiji have on agricultural (agronomy) indigenous student development?

- Can a change in the pedagogy approach for agronomy at the tertiary level improve students understanding of addressing climate change and food security? If so, which approach is most suitable to impact technical knowledge and create students critical thinking.

- Will this newly designed pedagogy approach positively impact indigenous Fiji farmers and the agriculture sector as a whole? If so, how will these be regulated.

1.4 Aim

To address Fiji's food security, resilience, and climate-smart agriculture by empowering practical pedagogies at the tertiary level to improve indigenous Fijian student experiences, develop critical thinking and support local farmer development.

1.5 Objectives

- To understand the current agriculture trends (agronomy) in Fiji, including limitations addressed through the education system.

- To compare the effectiveness of Fijian pedagogy for agriculture approaches with international examples.

- Design a pedagogy approach for practical training suitable for the South Pacific, focussing on Fiji.

- Undertake, assess and review a range of agronomy trials for future application in an indigenous Fijian context.

Chapter 2

Literature Review

2.1 Introduction

This chapter reviews the relationship between incorporating field trials into the education system at the tertiary level and its potential to promote learning for indigenous Fijians. A full review of information aligned to this study is summarised in this chapter, beginning from agronomy, where field trials would fit, to the concepts of field trials, their benefits, types, and an overview of the adopted trials serving as examples. A brief explanation of the different pedagogical theories followed by how traditional knowledge is obtained and how early traditional Fijian learned. Simultaneously, the key features of how assessments play a vital role in grasping the required knowledge intended for indigenous Fijian students.

2.2 Agronomy

Agronomy is a branch of agriculture considered an art, science, and business for field crops under field conditions (Terminology, 2021); art as the knowledge to perform the operations does not necessarily involve understanding the principles behind the cultural practice (Ministry of Agriculture, 2021; Panda, 2005). Mental and physical skills are critical for positive crop production. it is a science, as the scientific principles are adopted to improve agricultural productivity and quality while understanding the synthesis of its knowledge (Pinto, 2007; Roy et al., 2021) and it is business, as it contributes to small and marginal scale farmers, production on a sustainable level, with progressive and large-scale farmers maximising for-profit production purposes (Drucker, 1984; Lichtfouse et al., 2009. The primary principles of agronomy involve planning, programming, and maximising land utilisation, labourer, capital, and production (Azam-Ali & Squire, 2002).

The term agronomy originates from the Greek words *agros* and *nomos,* which translates to field management (Maliwal and Mundra, 2007). Agronomy deals with management practices that contribute to the production of field crops. Agronomy practices include tillage, seeds, sowing, nutrient, water, weed management, harvest, storage, and marketing. Over the decades, the definition of agronomy has evolved rapidly. Researchers have various definitions of agronomy; however, they all lead to soil and crop production management. The broader definition includes:

- The branch of agriculture deals with soil management theory and the production of field crops (Day, 1954).
- Agronomy is the study of field crops with relation to the environment (McCormick, 1982).
- Agronomy applies various soil and plant science that improves soil management and crop production (Sumberg, Thompson, & Woodhouse, 2013).
- Agronomy integrates scientific disciplines, which involve crop calendar, cultivars, plant population, manures, and fertilisers, followed by the justification of cropping and farming systems (Rana & Kumar, 2014).
- Agronomy is the applied science and technology from various subjects such as biology, pest management, and genetics to enhancing and managing significant world crops (University of California, 2021a).

At first, agronomy was merely the science of crop production (Lichtfouse et al., 2009). Recently, traditional knowledge in the science field has proven its usefulness in agronomy with the potential to optimise outputs (Roskruge, 2007). Agricultural systems such as mixed planting, crop rotation and shifting agriculture play a vital role in maintaining soil health (Veitayaki, 2004). Traditional knowledge offers modern breeders traditional varieties that are potentially resistant or tolerant to current pest and diseases (Thrupp, 2000). Similarly, the selection of traditional varieties as a climate smart approach to address the current climate impacts is evident (Swiderska et al., 2011).

Today, agronomy concentrates on the associations between climate, soil, cultural practices, crop quality and yield, and their impact on the plants, environment and food security (Ingram, Gregory, & Izac, 2008). Therefore, agronomy is most applicable to global issues as it integrates a holistic perspective from several sciences such as ecology, biology, soil science, chemistry, and genetics at various spatial scales (Lichtfouse et al., 2009)

Agronomist is the term given to scientists specialising in specific areas such as crop husbandry, soil classification, fertility, and pest control (Dhyani, Newaj, & Sharma, 2009). In this situation, the main objective of agronomy is to optimise yield in a given area, considering the effects on the surrounding environment. Agronomists incorporate complex sciences and cultural knowledge that regulate farming systems at various spatial and temporal scales at high environmental variability (Pan et al., 2017; Roskruge, 2007). The results obtained from an experimental field may not be replicated in another field due to possible variations in soil and climate conditions (Mackay et al., 2011). Therefore, critical points of agronomical investigations are used to define the validity domain of each outcome.

According to agronomists, they all have their preferences as to who is the father of agronomy. Some of the most favourable options of the father of agronomy are:

- Columella, in the first century, calculated areas of the fields with various geometrical patterns. Found the basic formula of square feet (Lévy-Leblond, 2003).
- Pietro DeCrescenzi revitalised European agriculture in 1304, where he focused significantly on soil conservation. Crescenzi elaborated on soil erosion progress with vegetative and mechanical measures as recommendations to control soil erosion (Olson, 1944).
- Jethro Tull introduced the pulverisation of the soil with a horse-driven seed drill (Sayre, 2010). This invention brought about Britain's agricultural revolution in 1700 (British Broadcasting Corporation, 2014).

No doubt, these contributions significantly impacted agronomy and agriculture on a global scale. Over the past decades, research in agronomy and its practices has developed significantly and transformed fundamentally. Often labelled as soft science or side science, agronomy has rapidly gained popularity as a central science due to food being the current global problem (Sparks, 2012; Sumberg et al., 2013). However, in Latin America, agronomy is widely used for the science of agriculture and horticulture.

Climate smart agriculture transforms and reorients the current agricultural systems to address food security under the new realities of climate change. Widespread changes in rainfall and temperature patterns threaten agriculture and developing countries for their livelihoods which includes the whole of the Pacific (Lipper et al., 2014). These changes in climate negatively impacting food markets, which poses risks to food supply. Climate smart agriculture is a positive response to contemporary issues, where threats can be reduced through the adaptive ability of agriculturists as well as increasing resilience and resource use efficiency in agricultural production systems (Rosenstock et al., 2016).

2.3 Field Trials

Agronomists in developed countries have broadened their approach to the farmer level and those, who perform the cultural practices, while simultaneously considering its impact on biodiversity changes, water pollution, and soil erosion (Makowski, Nesme, Papy, & Doré, 2014; Philibert, Loyce, & Makowski, 2012). Such studies are termed field research and are adopted rapidly due to the growing interest among farmers, agronomists, and the research community (Kyveryga, 2019). Field trials were adopted to test and evaluate research findings at the farmer's field, analysed, and modified to obtain optimum yields and sustainability (J. A. Ashby, 1987). Field trials are the most straightforward approach for students to learn how products, practices, and equipment will work in their cropping system (Licht & Witt, 2019).

The concept behind field trials has been used for decades, where the primary focus is to compare and evaluate different practices, production, and technology under realistic growing conditions (Laurent, Makowski, Aveline, Dupin, & Miguez, 2021). The objectives of any field trial are to forecast how various management practices will achieve outcomes compared to each other under a particular environment and cropping system, simultaneously focusing on optimising outputs and getting the best outputs concentrating on returns rather than yields alone.

Due to statistical considerations, a few researchers are still uncertain of results from field trials; it is often insufficient to be accepted by scientific journals (Food and Agriculture Organisation of the United Nations, 2021). However, other researchers have proven that the procedure of examining a hypothesis and applying the information gained has been highly successful in providing viable options for making decisions on the farm (Gopal & Kumar, 2010; Jansonius, 2008). Various studies have confirmed that data collection and analyses from field trials enhance farmers experience and satisfaction by providing knowledge for future decisions (Elias, Nohmi, Yasunobu, & Ishida, 2016; Tanaka, 2021).

This enhancement is through learning through participating and witnessing improved productivity and economic performance and simultaneously increasing their adaptation of conservation practices (Kyveryga, 2019).

The involvement of farmers in an field trial is crucial mainly for two reasons; (1) The need to improve information feedback regarding grassroots level constraints and the potential acceptability of new practices, methods and technology, (2) The need to develop methodologies for adaptive and robust research which take into account the diversity and micro-environment that characterise farming conditions (Secretariat of the Pacific Community, 2015). However, although farmer participation is essential in farming systems programs, farmers participation is typically restricted to managing the field trials, and little information exists on alternative approaches (J. A. Ashby, 1987).

Today, farm trials are easier to conduct as formalised field trial programs aligned to analytic software, and technology such as global positioning system (GPS) and precision technologies assistance (De Roo, Andersson, & Krupnik, 2019; Hildebrand, 1984). New technologies, tools, and analytic approaches have (and continue to) rapidly evolved to enhance field research in developed countries (Miller, Herman, Jahn, & Bradford, 2010). Field trials in developing countries are predicted to contribute significantly in the future as they have considerable potential to improve farming, research and agriculture as a whole (Kyveryga, 2019).

There are various ways of classifying field trials performed at research stations, farmer's fields, or both. Generally, there are two significant categories of field trials (i) performance (replicated) trials and (ii) strip (non-replicated) trials (Yan, Hunt, Johnson, Stewart, & Lu, 2002).

The performance trial attempts to account for the variability between repeated comparisons. These trial types are adopted by institutions, where results from the trial aid in recommendations to farmers (Yan et al., 2002). These trials are often regarded as the most authentic system. It consists of equilateral tests of the same crop or cultivar at specific locations with different treatments and managed by trained personnel (Noordergraaf et al., 2006). Performance trials provide balanced and replicated data, which is required for calculating the statistical difference (*ibid.*).

This type of trial however is more technical than field trials and requires trained personnel supervision at the farmers level for a robust outcome (Noordergraaf et al., 2006). The replicated field trials provide information on a narrow range of conditions within the sampling area (Pioneer Hi-Breed International, 2010). These conditions may not wholly represent the climate, soil, and other variables specific to the production's environment. There is still uncertainty of whether small plots are sufficient to represent large-scale farming conditions (Fleury, 2021).

Strip trials are the most straightforward design for farmers and generally focus on yield contests, yield claims, demonstration trials, and farmer observation and experience (Yan et al., 2002). Regularly adopted by seed companies, seed growers, and farmers to provide a head-to-head comparison between treatments. In this type of trial, cultivars or treatments are planted in sectioned or strips of the field to compare the best management practices (Krueger, 2018). The comparisons are made on the field among different strips aid farmers to determine which cultivar or practice would be most effective and profitable.

Field-sized trials add precision to the testing process as they closely represent the crop's growing environment and crop production methods (Pioneer Hi-Breed International, 2010). Strip trials are non-replicated and practised large-scale compared to performance trials plots (Leggett et al., 2015). Numerous strip trials are conducted yearly, while only a few plants are evaluated in a trial, which is insufficient to represent the whole field, often resulting in an unbalanced data set. However, the development of replicated strip trials has proven to be more reliable compared to the traditional strip trial (Kandel, Hunt, Kyveryga, Mueller, & Mueller, 2018).

The current limited knowledge on conducting research and generating new knowledge by agricultural graduates is a concerning issue in Fiji (Secrateriate Pacific Comission, 2021). The reason promoted is that conventional research methods are not appropriate for new graduates to impact the agricultural workforce by improving the livelihood of farming communities (Xing, 2015). However, donor-funded projects involving extension officers to carry out field research is increasing, and its accomplishment will depend on the officers’ capacity to conduct and record valid data from the trials (Jarvis, Myer, & Klemick, 2000). Therefore, it is paramount to train students on research design and methods that shape their ability to construct research to create reliable data and evidence to solve farmers' farming problems.

Field research trials are particularly appropriate for Fiji as a developing country, where agricultural production systems are often more diverse and understudied (Thaman, Meleisea, & Makasiale, 2002). In addition, Fiji has fewer resources typically to distribute to agricultural research (Kate, 16/07/2021). While field research trials are increasing, it remains an uncommon method in Fiji and there is limited capacity building for graduates from agricultural universities and extension officers. Future graduates need to be equipped with critical thinking and appropriate knowledge on research design, methods, data recording, analysis and reporting to impact the agricultural workforce, which ultimately improves the livelihood of farmers.

Any adopted strategies should address two crucial limitations on formal agricultural research systems in developing countries:

1. Resource-poor farmers occasionally have access to institutionalised channels, such as producer associations, for communicating with technology designers about their experience with recommended technologies (Braun, Jiggins, Röling, van den Berg, & Snijders, 2006). Farmer participation is required for institutionalised feedback channels to researchers and extension officers regarding farmer constraints and the acceptability of the new practice, method, or technology.
2. The uncertainty created by technical innovations targeted at very diverse, location-specific regions (Merrill-Sands & Collion, 1994). The micro-environment diversity enforces server constraints on the capacity of formal research systems to screen new technology for its suitability to farm conditions. As a result, farmers must bear some of the risks of screening new technologies for their specific farming by experimenting themselves.

2.4 Adopted Trials for Learning

The selection of field trials for this thesis aligns with the current teaching approach in Fiji’s agricultural universities. The crops selected act as vehicles that drive the experiment; there is no issue with the type of crop being adopted. The principal concepts such as the effect of photosynthesis, crop variety and fertiliser, and other topics are the required knowledge that needs to be transferred to the students so they understand how and why these phenomena occur.

2.4.1 Photosynthesis Trial

The photosynthesis phenomenon is addressed and widely understood throughout Fiji's education system (Muralidhar, 1991). The foundations are laid from the primary school level to more detailed information in secondary school, followed by a deep understanding at the tertiary level. However, at the tertiary level, indigenous students often encounter this deep understanding of photosynthesis and its relationship with yield through a purely theory-based approach. This practice alone is insufficient to transfer knowledge as complex as photosynthesis to indigenous students who often find it challenging to grasp scientific learning objectives (Lagi, 2021). Knowledge disseminated theoretically is easily diluted in students' consciousness as they rarely engage in problem-solving practical activities to demonstrate the phenomenon and mechanics of photosynthesis for proper knowledge registration (*ibid.*).

Photosynthesis is long known as the foundation of agriculture (Daniels, 1951). This phenomenon is recognised globally by botanists and biologists to create energy for plants with the sun to help produce their food with oxygen as a by-product (Rabinowitch, 1951; Stirbet, Lazár, Guo, & Govindjee, 2020). The agriculturist relates photosynthesis with yield, proven by much research (Mae, 1997; Makino, 2011). However, the challenges for photosynthesis research remain and can further contribute with further understanding (Murchie, Pinto, & Horton, 2009; Ryu, Berry, & Baldocchi, 2019).

Agricultural practices in Fiji universities provide students with the knowledge of photosynthesis; however, the concentration of this study lies in the theoretical aspects and less emphasis on the practical aspects of learning. Topics including photoreaction, photoperiodism, types of photosynthesis are taught in classes as a base of photosynthesis. Students need to be aware of how these mentioned topics work in different ways and how the mechanics inside the plants play a vital role in the link between photosynthesis and yield.

This trial encourages students to investigate the technical aspects of photosynthesis and develop critical thinking to understand how and why photosynthesis happen. By understanding the mechanisms of photosynthesis, students can identify the rate of photosynthesis in different conditions. Furthermore, they can manipulate the photosynthesis rate to encourage plant growth and boost yield.

2.4.2 The Variety Trial

Indigenous Fijians had long practised variety trials before the dawn of modern civilisation, which led to area-based adaptive agricultural techniques (Veitayaki, 2002). Early Fijians focused more on the crops that would thrive in their environmental conditions, and different varieties of these crops were used as gifts to areas where crops did not prosper.

One of Fiji's first documented variety trials was with an introduced crop, sugarcane's (*Saccharum officinarum*) initial production in Wakaya in 1862, introducing commercial production (Reddy, 2009). Experiments in Suva in 1872 by Brewer and Jsoske in search of favourable yields were undertaken under different environmental conditions. This experiment concluded that sugarcane thrives well in hot and dry conditions, concentrated in the western part of Fiji (Moynagh, 2017). Thus, its commercialisation in the dry (western) areas of Fiji such as Lautoka, Nadi, Ba, Rakiraki, and Labasa.

Modern cultivars of a wide range of crops are available in the market are selected for yield, resistance to pests and diseases, broad adaptation to high input agriculture systems, and shelf life (Ordiales et al., 2017). Unfortunately, farmer uncertainty often clouds their decision to adopt and cultivate particular crops and/or varieties (Ministry of Agriculture, 2020). The Ministry of Agriculture conducts germination, growth and yield trials of imported seeds to determine their quality and stability in Fiji’s climatic conditions.

The current farmer understanding and adoption of new crops relies on Fiji's Ministry of Agriculture, where the ministry conducts the trials, and the farmers are convinced to adopt the most favourable result (Ketewai, 2021). However, most traditional farmers are not easily persuaded to adopt new crops and varieties, as the production of the current cultivated crop is enough to sustain them (Nowak, 1992). This drawback forces farmers to be prone to risks such as the impact of climate factors, cyclones and other external factors that will ultimately reduce the yield when venturing into new crops.

Farming at times may feel like one gamble after the other, but successful farmers have identified that promising risk management approaches increase farm stability and profitability (Danso-Abbeam, Bosiako, Ehiakpor, & Mabe, 2017). Since farmers have started to engage in variety trials, experiments have been undertaken to explore new cultivation techniques and inputs, alternative and diversified markets, and pest and disease management practices (Colley & Myers, 2007b). The complexity of operating a farm and its market demands can be overwhelming. However, engaging in variety trials aids in refining production practices which keeps innovation alive and fosters the sense of wonder that draws many farmers to farming.

Variety trials are often overlooked as a tool for managing risks in agriculture (Colley & Myers, 2007b). Selecting suitable crops and varieties for the local climate, field conditions, available resources and market can significantly minimise loss and increase agricultural success while avoiding the expense of investing in poorly adapted or poorly performing varieties. Conducting variety trials aids in identifying varieties that can:

- Optimise crop yields.
- Reduce crop losses to pests and diseases.
- Fill market and production niches.
- Identify the best sources to purchase healthy planting material.

Adopting basic scientific methods when conducting agronomy trials brings a level of assurance to the results, whereas simply trying a new variety without an experimental design can give misleading and even invalid information.

This experiment will teach students the importance of risk management approaches in crop production, where a crops morphological characteristics are assessed to make the necessary crop selections. Similarly, quality components of crops are identified and utilised to compare between varieties to determine their differences. This way, students can distinguish one variety from the other by the slightest morphological or physiological variations and match varieties with given climatic and environmental conditions.

2.4.3 The Fertiliser Trial

According to research, limited crop yields in the Pacific Islands are often due to soil fertility factors (Hunter, Eaqub, & Aiono, 2009). Plant nutrient supply from fertilisers is widely known as the key to increasing agricultural production by enhancing agricultural productivity (Jaga & Patel, 2012). Fertiliser demand and use in Fiji fluctuates due to cost and farmer uncertainty. Indigenous farmers produce sizable yields with traditional practices and have limited knowledge of fertiliser applications and rates; therefore, they are slow in its adoption (Ketewai, 2021; (Lal, 2021). There is a need for education of the indigenous farmer community to implement and regulate the sustainable use of fertiliser to optimise crop yield, which ultimately will address food security (DeFries, Foley, & Asner, 2004).

Despite the beneficial impacts of fertiliser on agricultural production, past research has also claimed its harmful impacts that can have a long-term effect on the quality of the environment (Ruhl, 2000; Savci, 2012) due to excessive use of fertiliser and the lack of technical knowledge of fertiliser application (Lal, 2021; Zhu & Jin, 2013). However, negative impacts of fertiliser can be managed with timely applications of appropriate doses required by the crop (Prasad, 2009).

Fijian students are well resourced with information regarding which fertiliser plan is suitable for a particular crop from farmers, industries, institutes, and the Ministry of Agriculture. There is a range of views on fertiliser selection and application rates for crops, followed by suggestions on how and when to apply them (Stone, 2003). These views do not justify that some opinions are correct, and others are less so. When dealing with fertiliser, different plans are required for different farms on different soil types as the optimum rate, type, and application method may vary with climate, season, crop and soil type, method of cultivation, sowing time, and a host of other factors (Zhenbang, 2003).

The purpose of this fertiliser experiment is to transfer knowledge to students regarding the importance of soil knowledge and fertilisers in crop production, identifying critical nutrients required by crops, time of application followed by the application dose suitable for crops. The manipulation of fertiliser inputs requires skills and critical thinking to attain accurate information to suit the requirement of any particular crop (Hunter et al., 2009). However, students will require a template to guide them through achieving a standard level of information.

2.5 Traditional Indigenous Knowledge and Learning

Early indigenous peoples were nomadic hunters and gathers that depended on nature for their survival (Lee & DeVore, 2017). Learning for indigenous communities was a daily activity accumulated to aid in decision-making in the future (McGregor, 2004). These rich knowledge systems and experiences are known as indigenous knowledge. Western science refers to indigenous knowledge as traditional indigenous knowledge (Simpson, 2004). However, indigenous knowledge could be characterised as science on its own, as it is a foundation of knowledge developed primarily through the same principles of western knowledge: observations, experimentation, and analysis (Herman, 2016; Living Knowledge, 2008; Snively, 2016).

Traditional indigenous knowledge is a complex intergenerational, symbiotic relationship between indigenous people and nature that inter-twines with local myths and legends imbibed in their culture (Roskruge, 2007). This knowledge includes language, attachment to place, spirituality, and world views. Traditional indigenous knowledge is a controversial term currently debated among academics. However, there have been various definitions of the term over the decades that all come to the same conclusions.

- Traditional knowledge is a holistic and inclusive form of knowledge that is a product of the direct experience and relationship of the indigenous people with nature, which includes cultural traditions, values, beliefs and worldviews of local people in a community (Dei, 1993).
- Traditional knowledge is the living body of knowledge developed, maintained and passed on for generations within a group of people of the same interest and often forms part of its cultural or spiritual identity (World Intellectual Property Organisation, 2000).
- Traditional knowledge plays a vital role in the culture and history of a local community, which evolves over years of observations and trials of the resources surrounded by the community (Ghosh & Sahoo, 2011).
- Traditional knowledge refers to the innovations and practices of indigenous people, which are developed from experience over centuries and are adapted by local communities (United Nations, 2019b).

‘Western’ science has primarily disregarded traditional indigenous knowledge around protecting biodiversity in the past century; however, this is starting to change. Global histories of ongoing colonisation, westernisation, racism, exploitation, and dispossessions of indigenous peoples have led to structural and societal exclusion and vulnerability (United Nations, 2019b). Indigenous knowledge has value and worth. Most importantly, indigenous knowledge can offer answers and solutions to contemporary problems.

The inclusion of traditional indigenous knowledge in modern agriculture has been under the spotlight for the past decades (Kremen, Iles, & Bacon, 2012). This attention is due to the impacts of methods once seen as solutions to the agricultural industry to address food security (Boutin & Jobin, 1998; Qiguo, 1997). Several methods, such as forest clearing, monoculture, adoption of chemicals and machinery are driven by capitalism and considered as generally harmful to the environment.

Traditional knowledge about land and plant conservation and management and revitalisation of biological resources is established in indigenous peoples daily lives and practices and their intimate understanding of their environments cultivated over thousands of years (United Nations, 2019b). Traditional indigenous knowledge can play a crucial role in sustainable development and in addressing the current agricultural global problems, such as climate change, land management, land conservation, and strengthening scientific and technological knowledge. Furthermore, traditional knowledge can present promising opportunities for sustainability, food sovereignty and food security (Ibnouf, 2012; Nalau et al., 2018). Many indigenous lands and environmental management practices have been proven to enhance and promote biodiversity at the local level and maintain the ecosystem.

The traditional practices adopted by early indigenous communities are passed down from generation to generation through conversations, stories, songs, dances, observations and experimentations through trial and error, making them practical people (Lagi, 2021). These methods of transmitting rich indigenous knowledge are intimate and require attention as it is shared with a small circle (Movono, 2021).

Certain aspects of traditional indigenous knowledge have been modified and imbibed into agricultural universities in Fiji, such as subsistence cropping, mixed cropping, mulching, agroforestry, fallowing, and many more. However, there is less emphasis given to indigenous knowledge being the main contributor to the evolution of these methods. The inclusion of this approach into education will improve learning by increasing student interest towards an intimate connection of the topic.

The most basic form of indigenous Fijian agriculture that explains the sustainability of early Fijians is the *Vula Vakaviti* (Traditional Fijian Calendar). Based on the cultivation of yams (*Dioscoria* sp.), this calendar does not resemble the English calendar, where the start of a new year begins after 365 days (Movono et al., 2018). The *Vula Vakaviti* begins around June and July, known as *Vula I Werewere:* clearing the land for cultivation (Tokaimalo and Ra Province, 1992). *Vula I Werewere* is identified through the ripening of local fruits like kavika and dawa. Similarly, the spawning of water, land animals and ripening of plants indicates the transitions of months.

The *Vula Vakaviti* is a constructive approach to addressing climate change as the spawning of water and land animals and plants depend on favourable climatic conditions. Furthermore, addressing food security with the *Vula Vakaviti* is a viable option, and it indicates the climatic conditions suitable for the type and time of fish and crops to be avoided or planted and harvested.

This phenomenon demonstrates how practical indigenous Fijians are and their positive relationship with mother nature. As the saying goes, "practice makes perfect" the *Vula Vaka Viti* is demonstrated to the young generations in the early days, and this knowledge is absorbed by observation and practising. Learning through the natural indigenous ways has the potential to develop indigenous students' intelligence.

2.6 Pedagogy and the Learning Theories

Pedagogy is the theory, method, and philosophy of teaching (Watkins & Mortimore, 1999). The word pedagogy is drawn from the Greek word *paidagogos* which translates to children's leader. The word pedagogy thrived during the 1900s, emphasising the science behind learning; however, in the past dacade, the use of pedagogy has been declining (Darling-Hammond & Hammerness, 2002). While the precise reason is still to be determined, a hypothetical description leads to increased teacher workload and underqualified teachers. The teacher's workload survey discovers that workload continuously rises annually (Higton et al., 2017). This teacher's workload could be why teachers have limited time in the academic field to study their approaches.

Four main learning theories act as pillars in the pedagogical space and are adopted worldwide: behaviourism, liberationism, social constructivism, and connectivism (Ouadoud, Nejjari, Chkouri, & El-Kadiri, 2017). These fundamental ideas of pedagogy have their uniqueness followed by their merits and demerits. However, time plays a crucial role in adopting new and improved approaches in the following order: behaviourism, liberationism, social constructivism, and connectivism (Levin and Barbara, 2003).

Behaviourism facilitates the idea that teachers control the classroom, and reiteration is the best way to absorb knowledge (Graham, 2000). Edward Thorndike discovered behaviourism in 1898 with a cat and stated the first attempt at pedagogy (Thorndike & Bruce, 2017). An experiment on this learning theory surfaced from a cat in a puzzle box, where the cat is rewarded every time it escapes. Thorndike determined that the cat associated receiving a treat with escaping and escaped quicker every time it was put in the box. This behaviour is termed operant conditioning and forms the core of behaviourism.

BF Skinner adopted the same concept in the education system and stated that for students to obtain optimum knowledge, teachers need complete control of the lesson followed by incentives (Thorndike & Bruce, 2017). Skinners approach believes praising students encourages them and structures their learning towards the instructor's goal (Catania & Harnad and Stevan, 1988). However, this approach deprives students of individual thinking and independence, which results in a lack of critical thinking and self-expression.

Liberationism is the idea that is more student focused rather than the teachers (Elias, 1994). Paulo Freire suggested this learning theory in 1964, where he believed students are originators of knowledge instead of an empty vessel that requires filling from teachers, and education can liberate those in poverty (Shor & Freire, 1987). However, it was the education system at that time that prevented it. Liberation allows students to decide how they learn best and which topics they need more focus on and encourage critical thinking and independent learners outside the classroom (Freire, 1972).

Liberationism is a pedagogy that rejects the idea that education is simply about learning things and targets the way we learn (Fenstermacher, Gary, Soltis, Jonas, & Matthew, 2015). This core idea allocates students front and centre of the learning platform, where teachers act as a guide rather than taking control of the class. Breaking away from the traditional learning structure in a classroom to cluster student groups is proven to capture more learning styles (McInerney, 2009). In addition, liberationism allows students to decide which task addresses their learning gaps.

Social constructivism is a pedagogy method that seeks whether students communication in the classroom enhances learning (Kim, 2001). The impression is that social interactions provides a key component in the learning experience. The term social constructivism was coined by Lev Vygotsky, where he believed that children learn more when communicating with themselves to solve a problem (peer learning) (Amineh & Asl, 2015). This idea was built on an existing theory of cognitive constructivism, which states that students capacity for learning increases as their academic ability grows (Liu & Chen, 2010). Cognitive constructivism deals with learning as an internal process that occurs in the minds of students. However, social constructivism states that learning is an external process that occurs when students solve problems through discussions (Young, 2007).

Social constructivism is practical when time is given for students to discuss the problems in their groups and then with the teacher (Amineh & Asl, 2015). Students in mixed ability groups attempt on solving problems together, enabling them to communicate and learn from one another's experiences. This learning theory offers students ahead to solidify the information for their peers, and the students who are behindhand will have a chance to progress to the groups level (Liu & Chen, 2010).

Connectivism is the latest approach to the learning theories coined in 2005 by George Siemens, where it considers the impact of technology in education and how teachers can adapt to it (Siemens, 2017). This idea describes learning via technology and developing skills to navigate vast network information such as the internet (Goldie, 2016). It applies modern technology to all these ideas to create a learning theory for the future.

This learning theory connects the teacher and the students by creating a diverse learning environment contained within the internet (Duke, Harper, & Johnston, 2013). However, connectivism offers more than just online learning, as it also assists learners in the digital age (Goldie, 2016). This learning theory allows students to learn wherever and whenever they want. Teachers in this platform facilitate students search for knowledge by displaying various ways of recording or saving knowledge. Once comfortable navigating this world of information, students can broaden their learning and development freely.

Pedagogy refuses to be governed by one particular way of thinking as it overlaps and intertwines with itself endlessly (Loughran, 2013). However, its insights continue to change education for the better, developing more robust learning techniques and giving teachers better teaching tools (Windschitl, Thompson, & Braaten, 2011). Applying these learning theories to a different field of study may differ due to the nature of the study. Therefore, experimenting on the learning theories in the class is vital to grasp an effective teaching tool for a particular field (Dutton, 1987).

Researchers suggest a combination of learning theories as it addresses the different capabilities available in the class (Dutton, 1987). The combination of learning thoeries best suits indeginous Fijians for two main reasons. Firstly, how knowledge is best absorbed by indigenous students as instructors will consider including practical exercises to accommodate practical students rather than having a theory heavy approach. Secondly, the elimination of social bariers between indigenous Fijian students and the instructor, through social constructivism learning theories (Koya, 2015; Meo, 1989).

2.7 Pedagogy Practiced in Agriculture

Agriculture is a significant contributor to national economies, particularly developing countries (Kumar & Kumar, 2014). However, problems such as increased unemployment in agriculture, climate change, the decline in productivity and resource depletion contribute to a negative growth of GDP (Rivera, 1997; Valley, Wittman, Jordan, Ahmed, & Galt, 2018). These issues also contribute to the decline in the quality of education imparted to students to a great extent.

Given the globalisation and development of new technologies, higher education in agriculture is relevant to addressing society's present needs (Colasanti, Wright, & Reau, 2009). Agricultural universities and institutes are undoubtedly equipped to develop and offer knowledge for students to better address the market and the priorities of the nation's needs in an agricultural context (Kumar & Kumar, 2014). However, a challenge many agricultural institutes and universities face globally includes introducing radical changes in pedagogy to meet the current issues in agriculture. An approach that addresses this challenge is through a good understanding of agricultural pedagogy and the didactive of an instructor before entering the classroom (Mulder, 2017).

Teachers with high expectations of their students focus on positive and academic outcomes and commit to teaching that develops a better understanding. In a field that requires practical activity like agriculture, hands-on activity is regarded as the best approach for students to develop knowledge and understand the activity's concept (Knobloch, 2003; Poudel et al., 2005). Hands-on learning was how our primitive elders learned to farm, where agriculture developed over observation of nature (Harwood, 2020). Over the years, the adoption of hands-on learning in agronomy has concentrated on applying modern techniques to address the current agriculture problems (Corwin & Lesch, 2003; Xiong et al., 2015).

There is a need however to combine methods to execute effective learning for students. For example, the principles of an effective pedagogy approach from the Ministry of Education in New Zealand, a recognized agricultural country focusing on agriculture and horticulture are listed below (Ministry of Agriculture New Zealand, 2012; Trading Economy, 2021).

- Create a supportive learning environment.
- Encourage reflective thought and action.
- Enhance the relevance of new learning.
- Facilitate shared learning.
- Make connections to prior learning and experience.
- Provides sufficient opportunities to learn.
- Teaching as inquiry.
- E-learning and pedagogy.
- Assessment for learning.

The success of the agriculture industry is owed to the research and education system of the country. Well executed agriculture is the foundation of all trade and industries, and it is the foundation of the richest of nations (Brock, 2002). Quality education is required for better learning as youth are the leaders of tomorrow (Capowski, 1994). Therefore, the need to identify gaps and develop new measures for implementation to improve the production of crops is imperitive.

Covid 19 has significantly impacted the education system globally, where both instructors and students are forced to online platforms for classes (Tadesse & Muluye, 2020). This sudden flip from the traditional face to face and blended teaching method will be a challenge for practical subjects such as agriculture. A completely online agricultural university degree will not be as credible as there is a requirement for graduates to obtain practical knowledge prior to entering the workforce (Shetty, Shilpa, Dey, & Kavya, 2020). The attained practical knowledge aids graduates to have an insight into complications faced by farmers (Nick Roskruge, Pers Comm, Nov 2021).

Therefore, instructors need to also have a strategic online approach to cater for students' practical knowledge. Addressing this issue with field trials will lead to developing guidelines containing step-by-step research designs, conducting research, and reporting methods. The accomplishment of these guidelines for students to practise field trials at the comfort of their gardens and farms will add credibility to their degree upon graduation. However, no planting space might arise in town areas, and this can be countered by having small clusters, combining students with access to land with students that do not have access.

2.8 Agricultural Pedagogy Practiced in Fiji

The first agriculture college in Fiji was established in 1954 as Fiji College of Agriculture to meet the agricultural needs of Fiji and now developed into a university known as Fiji National University (FNU), which is host to the College of Agriculture, Fisheries and Forestry (CAFF) (Fiji National University, 2021). CAFF is the most prominent and extensive agricultural college in the South Pacific, with internationally recognised qualifications. Along with other institutes such as the University of the South Pacific and a few technical schools such as Navuso Agricultural School (NAS)[4] and Nasau Technical School (NTS)[5].

These colleges and institutes have graduated some of Fiji's finest in agriculture (Fiji National University, 2021). Offering various fields of study, ranging from agriculture, fisheries, animal husbandry, and forestry. With qualifications such as certificates and degrees and short-courses, Bachelors in various fields and most currently Masters in

[4] https://www.facebook.com/NavusoAgricultural/
[5] http://www.youth.gov.fj/

specific fields. The programmes offered at these institutes are focused on hands-on training in the field and, at the same time, ensure that the student is prepared for the ever dynamic agricultural profession in terms of scientific research (Fiji National University, 2021).

FNU hosts the first functioning aquaponics system in the country under the fisheries department and has established the only veterinary program in the South Pacific Islands under their veterinary department, followed by a collaboration with the major stakeholders (Pratap, 2018; The Fijian Government, 2013). However, there is minimal effort to formulate activities that will aid students in addressing the current agricultural issues in terms of horticulture and agronomy.

It is essential to implement and improve the current needs of students as a whole, in terms of technology, student access to information systems on a global basis, potential to have careers anywhere in the world. Pedagogy now recognises the technological influence, and statistics would struggle without these critical factors. Agricultural education is required to keep up with these critical factors whilst recognising the more efficient learning method.

Researchers and agriculture officers in Fiji are operating in new spaces, demanding rapid improvement in the farmer's livelihood resulting in large-scale adoption of new technology and crop management practices (De Roo et al., 2019). Being the leading institutes in agriculture in Fiji, these institutes are obligated to produce insights to cater to students, farmers, and agriculture in Fiji and the broader Pacific.

Field trials are a series of experiments in research stations, institutes, or farmer's fields to trial out the objectives of specific goals (Stone, 2003). A common feature among trials is testing whether altering factors in a system affect the variable of concern and how much (Food and Agriculture Organisation of the United Nations, 2021). With the inclusion of field trials into the agronomy curriculum at CAFF, students will be able to link with one another and use critical thinking to identify the gaps and needs of a particular commodity (De Roo et al., 2019). Similarly, students applying objectives will cater to the primary goal of obtaining knowledge from the practical activity and making sense of the theoretical experiences to cover the concept behind the trial.

Upon understanding the concept behind both theory and practical components of field trials, students can apply it to any crop and perfect their approach with every attempt to achieve a particular goal (Griffin, 1998; Hodson and Derek, 2009). Once students have identified a problem and set achievable objectives and goals, a trial passes as new technology for farmers to adopt. However, farmers involvement as participants in the trial and the right time to include them is crucial, as farmers need convincing for the new technology to be recognised (Ashby & Jacqueline A, 1987).

Field trials are proven to improve farmer knowledge in developed countries by addressing agronomic needs (De Roo et al., 2019). Therefore, the adoption of field trials in agricultural tertiary education in Fiji should be encouraged. Although it is time-consuming, curriculum developers must consider the research benefits to the institutes with results and recommendations (Top Crop Manager, 2017). Furthermore, with hands-on experience, students will be confident to conduct future trials for rural farmers development.

Most rural farmers in Fiji are practicing agriculture based on traditional knowledge transmitted down from their forefathers based on the conditions of Fiji a long time ago (Clarke, 1990). Climate change is the current threat to the agriculture sector, and rich traditional knowledge is not enough to cater to Fiji’s growing population (J. Barnett, 2011; Leonard, Parsons, Olawsky, & Kofod, 2013). With the adoption of field trials, farmers can understand what works on their farms in real-time, using the tools and resources available to increase their production.

An increase in production will be positive for Fiji's agriculture sector, as its primary goal is to create a diversified and eco-friendly sustainable agriculture economy in Fiji (Ministry of Agriculture, 2014). Fiji’s sustainability goal is associated with five objectives to address the country's needs.

1. To build modern agriculture in Fiji as an organised production system, processing and marketing crops, livestock and aquaculture products.
2. Develop integrated production, processing, energy, and transport infrastructure support system for agriculture.
3. Improve delivery of agriculture support services.

4. To enhance capabilities to generate funds and secure investment through foreign investment, public-private partnerships, and other innovative business arrangements.
5. Improve project implementation and policy formulation capability within the MOA and its partner institutions.

Pages 1-5 in Fiji 2020 Agriculture Sector Policy Agenda[6]

These objectives can be achieved by including field trials in the university curriculum. The positive effect of field trial adoptions in developed countries proves how valuable and precise field trials address agricultural needs. However, there are vast opportunities for improvement in Fiji's agricultural sector regarding climate-smart agriculture, sustainability, and market demands. Adopting trials at the tertiary or university level by a developing country with a vulnerable agriculture sector such as Fiji can increase production and revive the industry to optimum capabilities.

2.9 Assessments

Assessments are the process of evaluating and measuring an individual's achievement, typically done with assessment tools (Orlich, Harder, Callahan, Trevisan, & Brown, 2012). Instructors adopt various assessment tools; however, the level of education and field of study determines which assessment tools promote learning for students. Instructors who adopt assessments for student learning involve their students in ongoing self-assessment in ways relevant to the learners (Stiggins & Chappuis, 2012).

Nowadays, various types of assessments have different focus areas to gauge how students retain knowledge best. Globally, five types of assessments are recognised and adopted, as it applies to a wide range of fields.

1. **Diagnostic Assessments:** Acts as a pre-assessment that assesses student's strengths, weaknesses, knowledge, and skills before instruction (Leighton, Jacqueline, & Mark, 2007).
2. **Formative Assessments:** assesses a student's performance during instructions and occurs regularly throughout the instruction process (Black & Wiliam, 2009).

[6] https://pafpnet.spc.int/pafpnet/attachments/article/219/fiji-2020-agriculture-sector-policy-agenda.pdf

3. **Summative Assessments:** measures a student's achievement at the end of the instruction (Harlen & James, 1997).
4. **Non-Referenced Assessments:** uses a comparison method that compares a student's performance against other students (Harlen & James, 1997).
5. **Criterion-Referenced Assessment:** is measured by comparing the student's performance against a goal, specific objective, or standard (Popham, 1971).

A quality assessment agency reviewed the assessments undertaken in higher education noted that assessments and feedback in higher education remain an area of concern for students (Lynam & Cachia, 2018). The evidence for what factors within assessments contribute to student engagement is not fully understood, and more research is required.

Out of respect and fear, indigenous Fijian students often withdraw from questioning the instructor's seniority. Strategies to encourage academic maturity and reduce stress and fear in students could promote a more constructive approach to learning (Tam, 2021; Van Ryzin & Roseth, 2021).

Elaborated earlier, indigenous people are practical people and how practical activities boost their interest in learning. However, assessing indigenous students' knowledge gained from field trials plays a crucial role in judging the knowledge students absorb. In the case of field trials, a consistent application of assessments is sufficient to implant the objective required, such as:

- To practically participate in constructing field trials guided by templates produced by instructors is an assessment on its own, as this educates students on how to design and conduct research.
- The interpretation of the recorded data through a graphical representation and identifying the critical points, with a visual comparison of on-field crops, engages students in critical thinking.
- Producing a full report describing the trial and its objectives introduces students to scientific result reporting.

2.10 Sustainable Development Goals

The 2030 Agenda for Sustainable Development is a plan of action for individuals, Earth and prosperity formulated by the United Nations (Biermann, Kanie, & Kim, 2017). This agenda includes seventeen Sustainable Development Goals (SDGs), united and incorporating economic, social, and environmental dimensions (see Figure 2.1).

Figure 2. 1 Sustainable Development Goals forwarded by the United Nations for 2030

Furthermore, the fourth sustainable development goal included in the sustainability agenda stresses education, where it aims to ensure comprehensive, reasonable and quality education and promote lifelong learning opportunities for everyone (United Nations, 2019a). The fourth sustainable development goal target include:

Target 4.1: ensure both genders globally complete free, equitable and quality primary and secondary education, leading to relevant and effective learning outcomes.

Target 4.2: ensure that both genders worldwide have access to quality early childhood development, care and pre-primary education, preparing them for primary education.

Target 4.3: ensures equal access for both genders globally to affordable and quality technical, vocational and tertiary education, including university.

Target 4.4: substantially increase the number of youths and adults with appropriate skills, including technical and vocational skills, for employment to decent jobs and entrepreneurship.

Target 4.5: eliminating gender differences in education and ensuring equality through access to all levels of education and vocational training for the vulnerable, including people with disabilities, indigenous people and children in vulnerable situations.

Target 4.6: ensures that all youths and a considerable quantity of adults achieve literacy and numeracy.

Target 4.7: ensures that all students obtain the knowledge and skill required to encourage sustainable development, among others, through education for sustainable development and sustainable lifestyles, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and cultures contribution to sustainable development.

Pages 31 – 33: The 2030 Agenda and the Sustainable Development Goals[7]

2.11 Testimonies from Other Disciplines

Like agriculture, most fields require a good combination of both theory and practical for indigenous Fijians to promote positive learning for students. The following testimonies of individuals from different disciplines supporting the inclusion of practical activities to supplement the theoretical experience in the classrooms are given:

1. ***Mrs Ana Naio***

   Mrs Naio is a teacher by profession, where she elaborates on the importance of practical experience over theory-based learning. Fiji encounters a flood of teachers ready to take the field every year where some new graduates tend to opt for other professions that have no relation to their fields, such as cashiers, service station attendants, hairdressing industry and other commercial factories.

   With the rise of Covid 19, there was rapid rollover of vaccinations, where front liners (the force and health workers) were given the first chance to be vaccinated. Soon after, all civil servants were given the ultimatum to be vaccinated or face redundancy. With the unvaccinated experienced teachers being threatened to be

[7] https://repositorio.cepal.org/bitstream/handle/11362/40156/25/S1801140_en.pdf

removed from the equation, new graduates with no experience through internship over the covid phase are expected to participate in the field.

Mrs Naio, who has been a teacher for more than ten years, states that the experienced teachers shoes will be difficult to be filled by new graduates as they do not have the required practical experience to work in the field. Therefore, new graduates' performance in the field will significantly benefit future generations as graduates start from square one with their experiences compared to the experienced teachers in the field.

2. ***Mr Emosi Koroi***

Explains his involvement in the culinary industry, where he spent his internship at one of Fiji’s prominent resorts (Kokomo Island Resort). Mr Koroi stated that he was constantly pressured to succeed by the head chef from day one. However, he recognises the experience as a development, where he was forced to perform to the best of his ability to exceed the head chef’s expectations.

Covid 19 caused redundancy throughout Fiji’s workforce, and the tourism industry was affected significantly. Through the years, in his efforts to search for employment, he found himself back in the kitchen of a newly established restaurant (Kanalevu). Mr Koroi stated that he received praises daily for the standard and experience he presented at Kanalevu kitchen. However, the other kitchen crew are not qualified and are employed based on personal experiences. This situation proves that theoretical experience and exposure are key in practical fields.

3. ***Academic (informant 3)***

Informant 3 shared her experience as a nursing school graduate and compares students graduating with a degree to a diploma when entering the workforce. She further stated that nurses graduating with diplomas adapted quickly into the workforce as their studies were more practical driven. However, over the years, the nurses who graduated with degrees adapted and excelled with the development of the field, while the students graduating with diplomas had a somewhat stagnant knowledge and had a hard time adapting to the developments in the field. On the other hand, the nurses who graduated with degrees were complained about as they had less practical knowledge and more theoretical knowledge of the field.

This experience proves that critical thinking at the tertiary level is vital, as students tend to have limited knowledge and find it challenging to produce critical thinking when entering the workforce. Students who develop critical thinking at the tertiary level can blend and adapt to the changing developments of their respective fields.

The workforce is a practical field that students prepare for at the tertiary level and are tested during their internship. If the student performs well during the internship, they are most likely to be absorbed into that particular industry. Apart from performance, other positions may require experience, meaning there is a need for practical experience. On the other hand, critical thinking needs to be developed at the tertiary level to include theory. Quality education is demanded globally; A balanced theory and practical activity with equal opportunities given to individuals will promote positive learning for indigenous students.

Chapter Three

Methodology

3.1 Introduction

This chapter will evaluate the scopes and boundaries of the research governed by a revision of the proposed methodology adopted for this study. These are followed by an overview of the methodological approach to address the objectives of the research. Furthermore, a generic methodology is utilized to accumulate the general standard practices under-taken in this research.

3.2 Scope and Boundaries of the Research

The research focused on including field trials at the tertiary level pedagogy to impact students' development, awareness, and critical thinking. These factors contribute to improving Fiji's vulnerable agriculture sector through tomorrow young leaders to support farmers in addressing climate change and food security by producing agronomic trials. The agronomic trials are suitable for farmers to adopt and modify through investigating the effectiveness of the current pedagogy approach to agronomy relative to Fiji and comparing it with globally recognised institutions.

The investigation identified opportunities to explore and design a suitable pedagogical approach for Fiji's agricultural graduates. Findings and new information achieved in this research will help students, farmers, the Ministry of Agriculture, and researchers alike.

3.3 Research Approach

Scientific research is the most powerful tool for discovering truths about the world, exploring new theories, and performing empirical validation (Flanagan, 2013). The research drew from a mixed methodology approach, and a literature review designed the way forward (see table 3.1). The literature identified the most current understanding of the pedagogy approaches effectiveness and limitations adopted in Fiji's tertiary levels. The pedagogy approach adopted by New Zealand is globally recognised in terms of education and is utilised to design an approach that increases the development and awareness of agronomy students at Fiji universities.

The literature review is followed by interviews with key informants following the Talanoa Research approach described by Baba (Baba, 2008) and other Fijian indigenous scholars. The Talanoa approach is a popular research method adopted by the indigenous people of the Pacific, where it is often associated with narrative interviews (Fa'avae, Jones, & Manu'atu, 2016). This approach is described as an open, informal, constructive convocation between a person or a group of people, where their personal thought, stories and feelings towards a topic is shared. However, Covid 19 impacted on the ability to undertake the usual physical face to face Talanoa to an adaptable online visual method.

An added advantage is that the researcher is an indigenous Fijian, which provided a unique opportunity for a more precise interpretation required on the perceptions given by the individuals being informally interviewed. Gaining an insider’s perspective is an undeniable value. However, value is the ability to collect well-balanced and accurate perspectives from which correct judgments are drawn from the potential of introducing technical agronomic trials to students to improve their understanding.

A mixed-methodology approach was utilised to obtain factual data to answer the research question (Queirós, Faria, & Almeida, 2017). The adoption of qualitative and quantitative methods is proven to draw out the necessary information to support the research.

The adopted trials focused on:

1. Photosynthesis rates
2. Variety differences
3. Fertiliser application

3.4 Summary of Methods

Table 3. 1 How the objectives are addressed by the method of approach

Objectives	Methods
Understanding the current agriculture trend (agronomy) in Fiji, including limitations, which can be addressed through the education system.	• Literature review • Personal communications
To compare the effectiveness of the Fiji University pedagogy approaches with international examples	• Literature review • Personal communications

Design a pedagogy approach for practical training suitable for the South Pacific, focussing on Fiji.	• Literature review • Personal communications
Undertake, assess and review a range of agronomy trials for future application in Fiji.	• Three short term agronomy trials • Data collection • Data analysis • Review

3.5 Applied Research Methodology

Scientific research is the most powerful tool for discovering truths about the world, exploring new theories, and performing empirical validation (Flanagan, 2013). This research will draw from a mixed-methodology approach, where a combination of qualitative and quantitative paradigms are utilised to obtain factual data to answer the research question (Queirós et al., 2017). The adoption of qualitative and quantitative methods proves to draw out the necessary information to support this research potentially. However, most importantly, the approach is deemed fit for this paper by the researcher after critical considerations.

3.5.1 Qualitative and Quantitative Paradigms

Both qualitative and quantitative research approaches hold critical positions in the research field (Onwuegbuzie & Leech, 2005). However, researchers acknowledge the methodological differences between these two paradigms. The differences between the two paradigms create a gap in their ideology (Creswell, John, & Poth and Cheryl, 2016). While quantitative research is rooted in the positivism paradigm, qualitative research is based on the interpretivism paradigm (Firestone, 1987).

Quantitative research seeks to explain the roots of changes, primarily through objective measurement and quantitative analysis, utilising numbers to study phenomenon and occurrences (Merriam, 2002). The adoption of this approach is to quantify responses and subsequently interpret them to make decisions. Quantitative research also focuses on validating or invalidating a hypothesis based on many observed data (Firestone, 1987). With the adoption of complex statistical tools to aid in generalising extensive data. This method of collecting data requires observation throughout the growing period of the crop to gauge the different impacts of the treatment on the crop.

For this thesis, quantitative measurements are obtained to investigate complex situations with multiple variables under analysis. Weekly data is obtained from three separate trials; fertiliser, variety, and photosynthesis trials. The fertiliser trials were on a potato crop, where measurements such as the fresh and dry weight of stems, roots and tubers were collected to demonstrate the effect of fertiliser on these plant parts. The photosynthesis trial was on spinach crops by measuring the amount of chlorophyll on different positions of the leaves. Similarly, broccoli was adopted to demonstrate the variety trial.

Qualitative research explores the meaning as understood by the participants in a natural setting (Merriam & Tisdell, 2015). This method of collecting data also seeks to bring to the researcher by employing different methods such as conducting a Literature review and informal interviews (Denzin & Lincoln, 2008).

A literature review is completed to design the way forward. It exposes agronomy from a global perspective, field trials, and its potential to address climate change and food security. Simultaneously, the most current understanding of the agronomy pedagogy approaches and limitations in Fiji's tertiary levels. The pedagogy approach adopted by globally recognised institutes and its utilisation to design an approach that increases the development of critical thinking and awareness of agronomy students at Fiji universities.

Informal interviews with key informants were undertaken in a casual setting. This method of interviewing has proven its capability of combating biasedness found informal interviews (Moeller, Mescher, More, & Shafer, 1980). As the name informal interview states, there is no particular structure to the discussion (Barnett, Miller-Perrin, & Perrin, 2005). Its usefulness in past research is due to its less stressful and calm approach which allows the questioned personal to comfortably share knowledge (Moeller et al., 1980). Most of the interviewees herein are Fijian and express themselves fully by conversing through the Fijian language.

Gaining an insider's perspective is an undeniable value. However, value is the ability to collect well-balanced and accurate perspectives from which correct judgments are drawn from the potential of introducing technical agronomic trials to students to improve their understanding. An added advantage is that the researcher is an indigenous Fijian, which will provide a unique opportunity for a more culturally driven interpretation and translation from interviews.

3.6 Generic Methodology for the Trials

The adopted trials were conducted at the Plant Growth Unit (PGU) at Massey University, Palmerston North, New Zealand (40•22’55” S, 175•36’22” E), where the photosynthesis and variety trial were cultivated in experimental plots (see Figure 3.1). In contrast, the fertilizer experiment was conducted in a neighbouring field previously used for vegetable trials. Each trial had a specific number of treatments and control aligned to research goals,

Planting materials were sourced from trustworthy seedling producers for the photosynthesis and fertilizer experiments, while the variety trial was cultivated from raised seedlings. Both experiments (photosynthesis and variety) were transplanted at six weeks to encourage good seedling establishment, while the fertilizer trial (potatoes) was planted directly.

An accepted Massey University teaching standard-based yearly planting and crop husbandry practice was adopted as a basis for the photosynthesis trial (Assurance Red Tractor, 2017; Lutaladio, Ortiz, Haverkort, & Daniel, 2009; Roskruge, 2020). All three experiments received fertilizer treatments (NPK/Cropmaster and urea) as basal and side dressing applications. Weekly measurements were conducted on each trials for data collection.

The experiments adopted simple tools to carry out the trials; however, the equipment used are trial specific. This approach aimed to achieve results with minimal effort, which students and farmers can adopt with everyday tools and materials that are available. Materials required for the operation of the adopted trials are pegs, string, soil auger, garden spade and fork, knapsack sprayer, fertilizer, electronic scale, oven, and the relative humidity thermometer. However, the chlorophyll content meter is the only piece of equipment explicitly adopted to the photosynthesis trial.

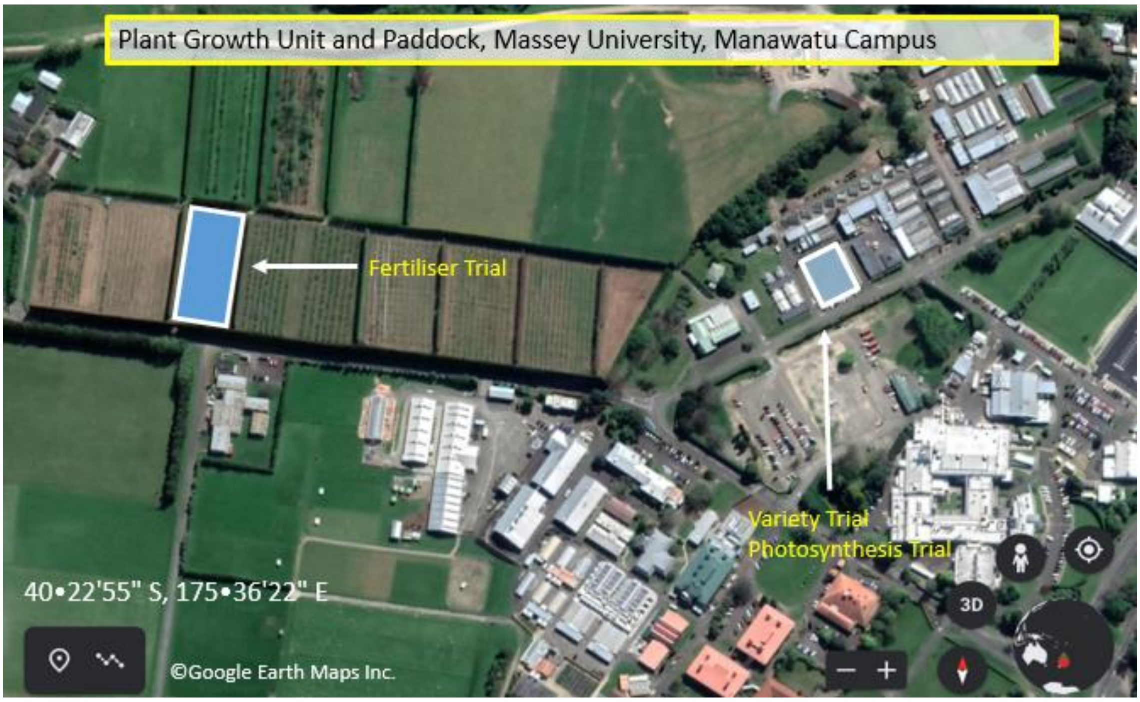


Figure 3. 1 Geographical location of the three trialled experiments[8]

3.7 Talanoa Methodology

The talanoa methodology was carried out in three different levels; 1. final year students, 2. Scholars with five to ten years in the field and 3. Scholars with more than 20 years of experience in the field. The idea was to explore their perception of how the education system is, or was, during their period in respective agricultural tertiary education in Fiji and their feeling towards its association to the work force.

Covid restrictions affected the ability to interct with these informants. Various online virtual platforms were therefore utilised to conduct the talanoa research approach, such as facebook, whatsapp and viber due to the preference of the interviewee. The Talanoa session was limited to thirty minutes to one hour with five key questions

1. Their recall and elaboration on the pedagogy approach during their tertiary study in Fiji.
2. To discuss whether the pedagogical approach/experience had a balanced or an uneven distribution between theory and practical.

[8]https://earth.google.com/web/@40.7998944,175.3101282,709.99560599a,4505062.98534636d,35y,0h,0t,0r/data=CmEaXxJZCiUweDZkMmMyMDBlMTc3Nzk2ODc6MHhiMWQ2MThlMjc1NmE0NzMzGYmXp3NFc0TAIYrG2t9Z3GVAKh7guJnguLTguKfguIvguLXguYHguKXguJnguJTguYwYAiAB

3. To explain which type of approach in practical activity best suits their needs or expectations:
    - A practical class that is totally different from the theory being taught in class, introducing new knowledge for broad understanding
    - A practical class that is similar to the theory being taught in class, elaborating on the theory for clear understanding.
4. To discuss the impacts of pedagogical approach in the work force.
5. Their thoughts on what pedagogical approach should be considered for the training of future leaders in the sector.

A total of fifeteen participants were informal contributors through a Talanoa approach, where the above questions were used as a guide that gave rise to other question that contributed to a discussion flow in Talanoa. Participants included five current final year students, five scholars with one to three years of experience in the workforce and five scholars with five to ten years in the workforce. These stages were selected to obtain a holistic understanding on the impacts of the past, current pedagogy approaches and what can be done to improve the system.

Chapter Four

Field Trials for Teaching Purposes

4.1 Introduction

The critical components required for a field trial are revised in this chapter. This includes elaborating on the key components of a field trial and why they are crucial to perform, with an overview of the three selected trials; photosynthesis, variety, and fertiliser trials.

4.2 Designing Field Trials

Field research, especially with high farmer involvement, is more appropriate for answering doubts and is crucial to developing a more suitable agricultural system. Field trial research can be a tool for students to test new methods to adapt and build critical thinking and farm resilience (Scholz, Bloch, Knuth, & Haring, 2017). However, other aspects of sustainable agriculture are more suitably studied at research station sites (Anderson, 1992). Therefore, practical competencies and specific field research education in agricultural universities are necessary.

Before conducting a field trial, there are vital factors instructors, researchers, students, and farmers need to consider (Stone, 2003). Without the proper understanding of these factors, the trial will not be as effective as it should be. From a learning perspective, these key factors can be manipulated for sufficient understanding to fit the criteria or the learning objectives (Anderson & McLean, 1974). Common vital factors necessary for field trial are goals and objectives, site selection and field history, seedling preparation, spacing uniformity, control treatment, randomization and replication, border or guard rows, measurements, data analysis, and clearing cleaning field.

4.2.1 Goal and Objectives

Goals are guidelines that explain what is to be achieved; these are usually long-term and represent a vision (Marzano and Robert, 2010). In contrast, objectives are implementation steps attained to identify the goals. Unlike goals, objectives are specific, measurable, and have a completion date. Farmers must have a straightforward statement of their objectives and the ambitious goal towards the trial (Low and Allan, 2019). This step is essential in running a successful on-farming trial. The goals and the objectives of a particular trial determine the site of the trial, plot size, plant population, treatments, and type of replication to be adopted (Ashby & Jacqueline A, 1986).

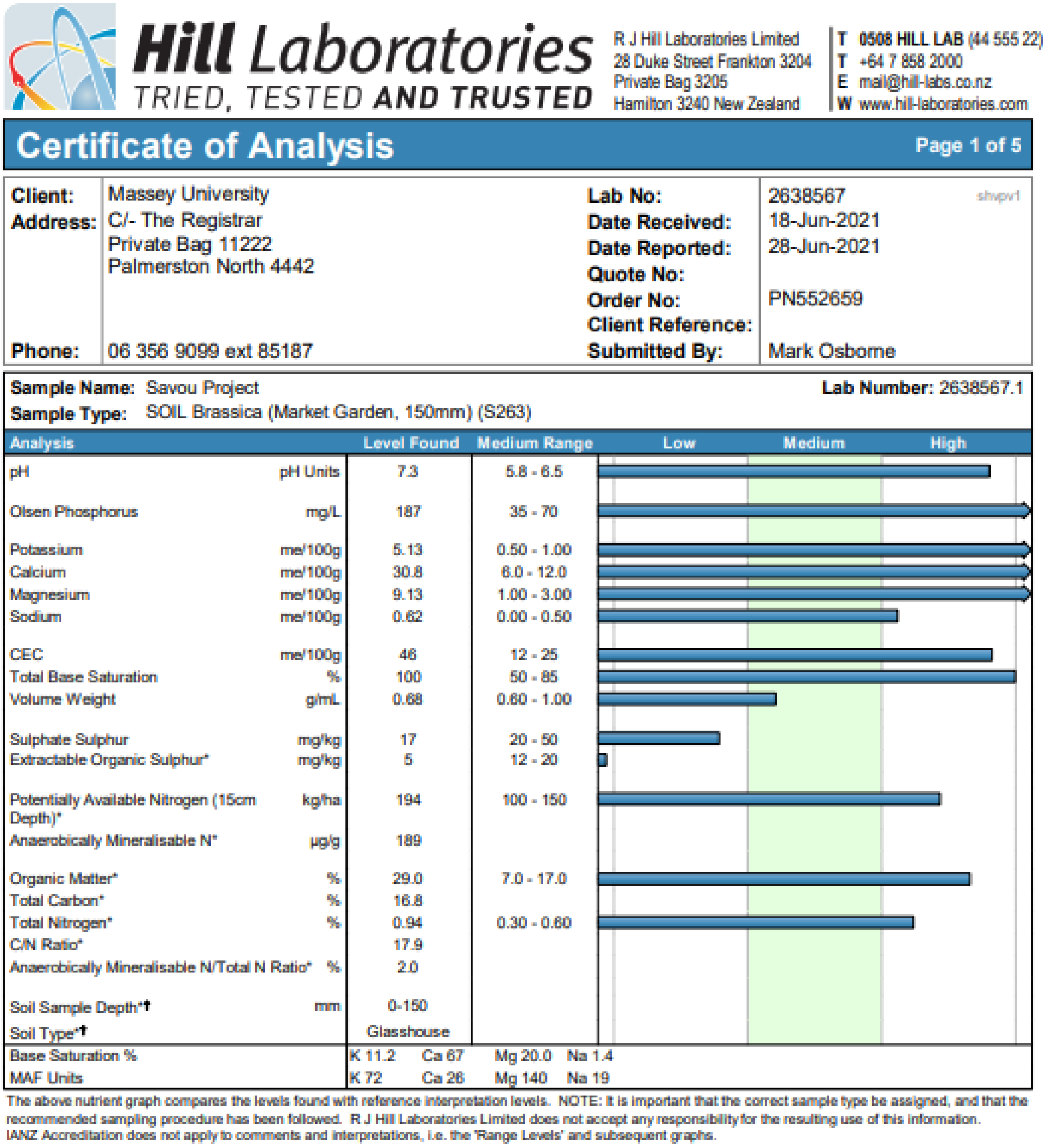
Goals are regarded as governing statements of the overall target that a farmer requires to achieve. As an example, due to the rising issue of food security, a common goal amongst researchers is to increase the gross margin or production per hectare (Miller et al., 2010; Suh & Moss, 2021).

4.2.2 Site Selection and Field History

Factors such as a trial, time, and space are significant contributors to a trial success; selecting a suitable site is crucial (see Figure 4.1). Whether in a research station, farm, or both, the trial location plays a vital role in the effectiveness of the trial (Tripp, 1982). The topography, soil, climate are a few aspects that influence the type of trial being adopted as favourable conditions are required for the trial (Stone, 2003). Space in terms of land area required for the trial may be a small-scale performance trial or a large-scale strip trial (De Roo et al., 2019). Time is essential, especially regarding seasons and crop requirements, as agriculture practices shadows time, and with time, everything changes (Food and Agriculture Organisation of the United Nations, 2021). The optimum time for planting, transplanting, irrigation, fertilizer, but most importantly, practicing the trial in its appropriate season, will determine the area selected for the trial (Zandstra, 1981).

A record of the cropping history and practices adopted before establishing the trial is viable information that can be used to determine the trial area or support the trial results (Licht & Witt, 2019). Such records include past tillage practices, type of crop, variety, crop rotation, fertilizer, and pesticide. Some form of soil test (see Figure 4.2) is compulsory to determine the available nutrients in the soil before establishing the trial to determine or regulate the needs of both soil and plant (Sahrawat & Wani, 2013).

Figure 4. 1 Site selected for the adoption of trials: I. Students experiment plots for photosynthesis and variety trials, II vegetable experiment field for fertiliser trial. Joeli Savou, Palmerston North.



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Certificate of Analysis — Page 1 of 5

Client:	Massey University	**Lab No:**	2638567
Address:	C/- The Registrar Private Bag 11222 Palmerston North 4442	**Date Received:**	18-Jun-2021
		Date Reported:	28-Jun-2021
		Quote No:	
		Order No:	PN552659
		Client Reference:	
Phone:	06 356 9099 ext 85187	**Submitted By:**	Mark Osborne

shwpv1

Sample Name: Savou Project **Lab Number:** 2638567.1
Sample Type: SOIL Brassica (Market Garden, 150mm) (S263)

Analysis		Level Found	Medium Range
pH	pH Units	7.3	5.8 - 6.5
Olsen Phosphorus	mg/L	187	35 - 70
Potassium	me/100g	5.13	0.50 - 1.00
Calcium	me/100g	30.8	6.0 - 12.0
Magnesium	me/100g	9.13	1.00 - 3.00
Sodium	me/100g	0.62	0.00 - 0.50
CEC	me/100g	46	12 - 25
Total Base Saturation	%	100	50 - 85
Volume Weight	g/mL	0.68	0.60 - 1.00
Sulphate Sulphur	mg/kg	17	20 - 50
Extractable Organic Sulphur*	mg/kg	5	12 - 20
Potentially Available Nitrogen (15cm Depth)*	kg/ha	194	100 - 150
Anaerobically Mineralisable N*	µg/g	189	
Organic Matter*	%	29.0	7.0 - 17.0
Total Carbon*	%	16.8	
Total Nitrogen*	%	0.94	0.30 - 0.60
C/N Ratio*		17.9	
Anaerobically Mineralisable N/Total N Ratio*	%	2.0	
Soil Sample Depth*†	mm	0-150	
Soil Type*†		Glasshouse	
Base Saturation %		K 11.2 Ca 67	Mg 20.0 Na 1.4
MAF Units		K 72 Ca 26	Mg 140 Na 19

The above nutrient graph compares the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information. IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

Figure 4. 2 Certificate of analysis from a trusted laboratory (Hill Laboratories)

4.2.3 Seedling Preparation

Plant life begins from seeds; therefore, a healthy seed from a reliable supplier is vital for obtaining optimum yields (Vendrame, Carvalho, & Dias, 2007). Seedling preparation is an essential step that can optimize germination and plant survival rates. Certain seeds are planted in-situ (directly in-ground), while others are grown in nurseries and transplanted (ex-situ) (Jakobsson & Eriksson, 2000). Seed sown in-situ are generally for lower value or commodity type crops and transplant seedlings produced for higher value crops because of their higher initial cost.

Factors applicable to seedling production include planting media, irrigation, sunlight, temperature for their optimal germination and as criteria also for transplanting (Mayer & Poljakoff-Mayber, 1982). The time and quantity of each factor play a crucial role in the germination and growth of seedlings that require transplanting. Specialist seed raising media are readily available; however, the depth at which seeds are planted will vary between crop, species or varieties (Benvenuti, Macchia, & Miele, 2001).

The survival of seedlings depends wholly on the criteria of transplanting. With favourable germinating conditions, most seeds start germinating within days and up to three weeks after planting (Rajjou et al., 2012) (see Figure 4.3). There are various criteria for transplant seedlings; the most reliable methods adopted globally are the number of true leaves and the age of seedlings. The older the plants and the more true leaves present on the seedling ensure high survival chances (Caruso et al., 2014). These approaches ensure strong establishment for the seedlings as roots are well developed, stems are firm, and leaves are fully opened to undertake photosynthesis.

Figure 4. 3 Seedling preparation for crops. Joeli Savou, Palmerston North.

4.2.4 Spacing and Uniformity

Spacing is a key agronomical attribute in crop production, both small and large-scale farming. Spacing refers to the plant population in a cultivated area, specifically the distance between a plants within and between rows (East Africa Agribusiness, 2020) (see Figure 4.4). Primary research has identified the spacing for various crops and varieties to optimize yield. Adequate spacing between plants will reduce competition for light, water, and soil nutrients (Grow Great Vegetables, 2021). Uniform plant spacing is required for plants for achieve uniform development and consistency for harvest criteria. Optimal spacing also acts as a preventive measure to reduce pest or disease pressure throughout the field (Croft, 2021).

Uniformity throughout the plants growing period is required for a successful experiment (Weiner, Griepentrog, & Kristensen, 2001). Uniformity begins from the size and shape of the plot to the transplanted seedlings to represent the experiment (Zuber, 1942). It is critical to have all biotic and abiotic conditions as uniform as possible to discourage any bias within the experiment.

Figure 4. 4 Spacing and uniformity for broccoli crop. Joeli Savou, Palmerston North.

4.2.5 Control Treatment

The inclusion of a control treatment acts as standardising practice compared to the other treatments available in the trial. Controls are not adopted to regulate yield results but deliver a baseline for the trial (Stone, 2003). A control commonly receives all the standard trending practices, such as weeding, irrigation, fertiliser, and pesticide application, compared to treatment plots that may receive a variation of inputs such as fertiliser quantity or irrigation.

4.2.6 Randomizing and Replication

Replication and randomization account for field variability and build statistical power to detect significant differences between the treatments (Kyveryga, Mueller, & Mueller, 2018). Replication and randomization are vital instruments to understand that variability exists within trials, and the lower the variability, the more confident the results are. The minimum number of replications that would account for the variability in the trial is four (Stone, 2003). Splitting the field into two for comparison purposes is insufficient to conduct trials as data will not be accurate enough to be adopted in other environments. Replication also aids to avoid bias decisions in the trial (Francis, 2012).

There are two commonly adopted designs while practicing farm agronomy trials of any sort; (i) Complete random design and (ii) Randomized complete block design. Complete random design is typical to practice on a uniform site, where the treatment allocations have an equal chance of any plot, including identical side by side treatments (Anderson & McLean, 1974; Fleury, 2021). A randomized complete block design is adopted when the possibility of obtaining a uniform site is nil (Ohio State University, 2010). Here each treatment is represented once in replication, and treatments are arranged in a diverse order in respective replication (see Figure 4.5). The randomized complete block design permits treatments to have the equivalent potential to produce results within the replication.

Figure 4. 5 Randomised and replication in potato trial. Joeli Savou, Palmerston North.

4.2.7 Border or Guard Rows

Border rows are applied throughout the trial to buffer treatment effects from neighbouring strips or plots (Langton, 1990; Licht & Witt, 2019). Border rows are essential for foliar applications to avoid any probable lateral movements of nutrients such as nitrogen to adjacent strips or plots. Treatments that intensely affect crop growth where neighbouring strips or plots are much taller or shorter should adopt border rows (Wang et al., 2017). While border rows increase each treatment strip or plot area, it is a simple approach to avoid confusing neighbouring strips or plots (Langton, 1990). For example, planting twenty-four plants and harvesting the economic parts of the inner eight plants, leaving the sixteen outer plants to absorb the border effects (Figure 4.6). A severe edge effect is recognized in trials with a clean cultivated border surrounding the plot. Plants at the edge of the plot have more significant water, light, and nutrients and are more susceptible to pests and diseases than plants within the plots. Therefore, it is impractical to surround the trial plot with additional crops.

Figure 4. 6 Outer border crops or guard row for broccoli are smaller compared to plants inside. Joeli Savou, Palmerston North.

4.2.8 Measurements

Trials consist of various objectives. The trial's objectives determine what, when, and how to measure for data collection. For instance, if the objective is to:

- Increase yield, then a measurement of fresh and dry weight is required at the minimum.
- Increase soil moisture or irrigation factors, then a soil water test is required.
- Increase net profit, then analysis of input and output is required, especially the harvest index.

Appropriate measuring treatments and data are essential for accurate conclusions (Kanari & Millar, 2004) (see Figure 4.7). A continuous collection of written records is required to interpret data and aids in sharing information with others. Observation notes throughout the trial of the impacts occurring due to treatment effects are crucial for understanding what is happening in the field (Licht & Witt, 2019). More planning and documentation undertaken for a trial increases confidence in the results. Consistent observations and measurements of critical stages of a crop, such as seedling emergence, flowering, and harvesting, are critical to obtaining a complete picture of the growth of each treatment (Food and Agriculture Organisation of the United Nations, 2021).

Figure 4. 7 Operation of the CCM-200 plus (chlorophyll content meter) on spinach. Joeli Savou, Palmerston North.

4.2.9 Data and Analysis

Data collected from different treatments of adjacent strips may differ depending on the trial objective upon comparison (Food and Agriculture Organisation of the United Nations, 2021). Apart from the treatment, other factors such as variation in soil and its fertility, moisture availability, pest pressure, field history, planting, and harvesting techniques contribute to the variation during comparison (Krueger, 2018). Variation is required to analyse data, and a minimum of three replications is standard for conducting statistical calculations in a trial. Statistics offer a rigorous process for comparing treatments, with the critical probability value (**p**-value) used as a matrix to determine the difference credited to treatments.

The lower the **p**-value, the more certainty that the treatments affect the independent variables (Halsey, Curran-Everett, Vowler, & Drummond, 2015). However, the higher the **p**-value, the fewer chances that the trial treatments affect the observed difference. In an experiment, 0.10 and 0.05 are the benchmarks for **p**-values. If the **p**-value of a trial is 0.10, it is stated to contain a 90 per cent confidence level that the treatment responses instigated the difference (Shrestha, 2019). Similarly, if a trial has 0.05 as **p**-values, it is stated to contain a 95 per cent confidence level that the treatment responses instigated the difference.

Due to their complexity, a good standard of statistics is generally underutilised in the field. Applying raw data as comparisons of treatments may produce a difference; however, these data mask a more significant answer (J. Taylor, McBratney, & Whelan, 2007). Statistical analysis can only determine the value of data collected from a trial. Furthermore, applied treatments that do not produce statistical differences are still considered valuable and must be published for future practitioners' reference (*ibid.*). Therefore, zero difference may be equivalent to a significant difference in a field trial.

4.3 Overview of Selected Trials for the Research

There are a few indicators when a trial is required, such as (Food and Agriculture Organisation of the United Nations, 2021);

- Recommended practices followed by the farmers produce low yields.
- Farm site has specific attributes, such as undulated or sloping lands.
- A group of farms produces lower yields than neighbouring farms despite their best efforts.

For this research, three experiments have been selected through their potential impact on Fiji's response to sustainability and climate change issues and for an improved pedagogical approach for Fiji's agricultural institutes. This research was focused on the learning aspects of agriculture, which stress the potential knowledge field trials offered to tertiary students in Fiji. Proven by various literature, field trials have gained wide acceptance globally and rapidly expanded in developed countries due to their ability to address climate change and food security (Kyveryga, 2019). The adoption of field trials in developing countries is forecasted to impact practitioners significantly, farmers, researchers livelihoods, understanding, and the agriculture sector in terms of production (J. A. Ashby, 1987; Carrillo-Reche, Vallejo-Marín, & Quilliam, 2018). Therefore, adopting several trials demonstrating a range of attributes students can address while conducting a field trial has potential to increase production and yields for farmers (Joshi, Azuma, & Feenstra, 2008).

The efforts to improve yield have gained recognition as the critical factor of any field trial. Yield is the return on any investment, calculated by the amount of output divided by input to determine a good or poor yield (Farlex, 2012) and to supply or produce something positive (Walter, 2008). Crop yield can be defined as the measurement of the economical portion of agricultural produce harvested per unit of land area (A. Hayes, 2021) Simply, crop yield refers to the utilised portion of the crop; therefore, a potato variety with an oversized top and few or small tubers is a poor yielding variety than a variety with a small top and a good number and size tubers. Crops are classified into various categories, and depending on their utilisation, the yield evaluation is done.

The three trials undertaken herein to demonstrate the potential of field trials as teaching tools to develop understanding and improve production are a crop variety trial, photosynthesis trial, and fertiliser trial. Each of the trials demonstrates a particular attribute that contributes to a good learning experience for students. However, as different as they may seem, these trials will eventually impact yield and can be practised on any crop. The selected trials offer various learning objectives for students including:

- Understanding the effect of chlorophyll on the rate of photosynthesis to evaluate and understand the complex relationship that exists.
- A comparison of varieties utilising morphological characteristics of broccoli to understand the nuances of variety selection.
- Evaluation of the effect of fertiliser on the yield of potatoes to determine its impact on traditional and modern varieties.

Chapter Five

Photosynthesis Trial Experiment

5.1 Introduction

This chapter presents the first on-field experiment, the photosynthesis trial, elaborating on how photosynthesis works and the aim of the trial. The importance of spinach as a trial crop, its cultivation, and why spinach is adopted as a learning tool for this trial is also presented. Furthermore, a detailed explanation of the photosynthesis trial followed by data analysis is made, concluding with a sequential template that is recommended to be adopted to ensure smooth completion of the photosynthesis trial in a tertiary learning situation.

5.2 Experiment One

Photosynthesis is a biological phenomenon in which energy from the sun is captured and stored by a series of events that converts pure energy into free energy (Blankenship and Robert, 2014). It is a phenomenon performed by green plants where the captured (power) energy is utilised to convert carbon dioxide (CO_2), mineral deposits, and water into organic compound or chemical (free) energy required to power life in plants and oxygen (O_2) as by-products (Rabinowitch, 1951).

The energy for photosynthesis originates from the sun and arrives at the earth as sunlight (Calvin, 1974; Chevrier et al., 2020). This light has a wave, and particle nature photons are the smallest unit of light that oscillates along a path measured in wavelengths (Chevrier et al., 2020) (Zhen & Bugbee, 2020). The light discharged from the sun contains photons in a broad spectrum of wavelengths, called the electromagnetic spectrum; however, photosynthetic organisms use only a tiny portion of the electromagnetic spectrum ranging from 400 nm to 740 nm (Song et al., 2020). This range of the electromagnetic spectrum is known as visible light.

Photosynthetic organisms contain pigments known as chlorophyll that facilitate the capture of wavelengths of light in the visible light range (Zeng et al., 2019). The pigment colour comes from the wavelengths of light reflected. Plants are green as they reflect yellow and green light wavelengths and absorb red and blue wavelengths of light absorbed by these pigments, which provide the energy used for photosynthesis (Calvin, 1974). The process of photosynthesis provides the base for living things and has dramatically transformed Earth over time, providing food and energy to biological life.

Depending on the reaction to light by plants, photosynthesis is divided into light and dark reactions (Lambers, Bassham, & James, 2021). The light reaction consists of C3 and C4 plants, while CAM plants are categorized under the dark reaction (see Figure 5.1). Both the light and dark reactions pull water and minerals from the soil with the help of roots, as the stomata take up carbon dioxide from the atmosphere at night (Zhang & Xie, 2021). However, the number of carbon molecules and their storage site plays a considerable role in converting free energy.

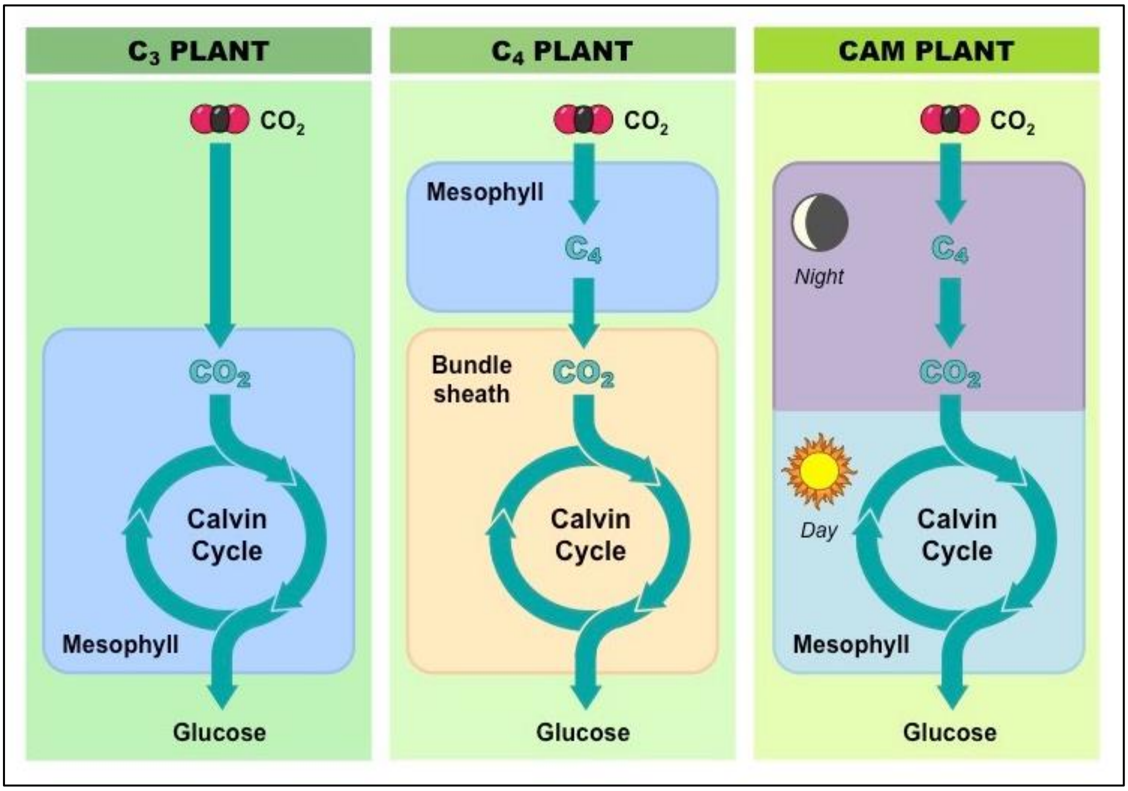


Figure 5. 1 Comparison of the different carbon fixation pathways[9].

[9] https://ib.bioninja.com.au/higher-level/topic-8-metabolism-cell/untitled-2/c3-c4-and-cam-plants.html

Most plants are categorized as C3 photosynthesis. C3 plants have a unique mechanism of converting absorbed elements to free energy compared to C4 and CAM plants (Ehleringer & Pearcy, 1983). In favourable conditions, stomata open, CO_2 enters from the leaf's underside to the mesophyll cell where the Calvin cycle occurs, establishing a 3-carbon molecule bond (see Figure 5.2). As stomata are open, CO_2 enters, and O_2 exits from the cell (Khan, 2016). However, under hot or dry conditions, O_2 accumulates in the cells, inhibiting C3 production. C3 plants include potatoes, cotton, tobacco, and many more.

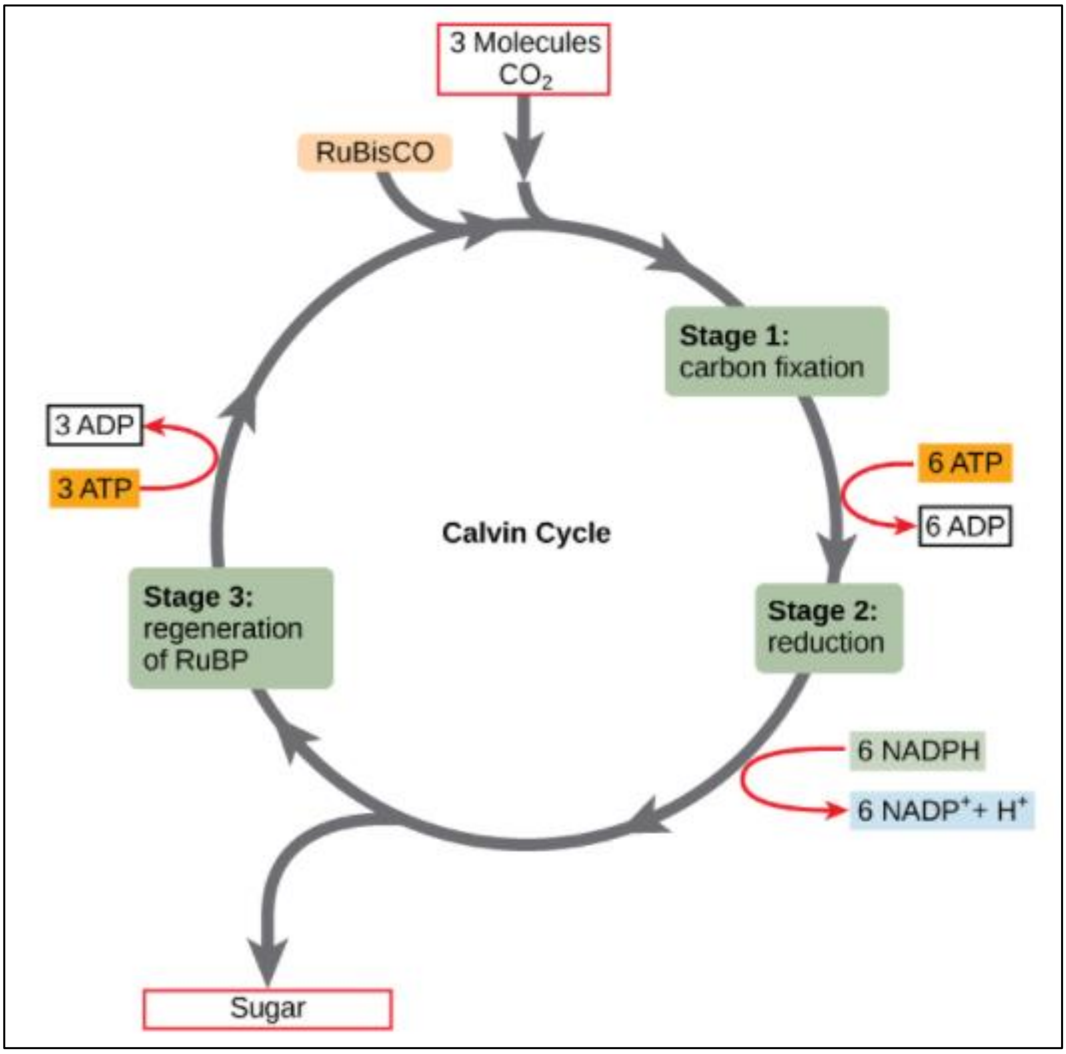


Figure 5. 2 The three stages of the Calvin cycle: Stage 1 - the incorporation of the carbon dioxide to organic molecules by the RuBisCO, Stage 2 – the reduction of organic molecules, Stage 3 – The generation of RuBP (initiation molecule)[10].

Some plants have evolved in an adaptation that allows them to tolerate dry and hot conditions. These plants are categorized as C4 photosynthesis (Ehleringer & Pearcy, 1983). During C4 photosynthesis, CO_2 moves into the mesophyll cell and is immediately

[10] https://courses.lumenlearning.com/suny-biology1/chapter/the-calvin-cycle/

fixed into a 4-carbon molecule. The anatomy of C4 plants varies from a C3 plant. In a C4 leaf, chlorophyll is located inside the mesophyll cell; however, they are also found in bundle sheath cells surrounding the leaf vein (Khan, 2016). CO_2 moves from the mesophyll cells to the bundle sheath cells, where the Calvin cycle occurs. This movement of CO_2 is an adaptive feature of C4 plants to tolerate dry or hot environmental conditions by protecting the plant from the oxygen built up in the mesophyll. Sugarcane, sorghum, and maize are examples of C4 plants.

CAM photosynthesis is similar to C4 photosynthesis in many ways; however, addressing the accumulation of oxygen in the mesophyll is the most prominent. The mechanism behind CAM photosynthesis differs as it acts on the time photosynthesis occurs. During CAM photosynthesis CO_2 is taken up during the night when stomata are open and are fixed into a 4-carbon (see Figure 5.3) (Khan, 2016). These 4-carbon molecules are stored in the mesophyll until daylight as an intermediate molecule which gives the CAM cycle its name. This adaptation allows photosynthesis to occur in drier climates than both C3 and C4 photosynthesis. Examples of CAM plants are cactus and pineapple.

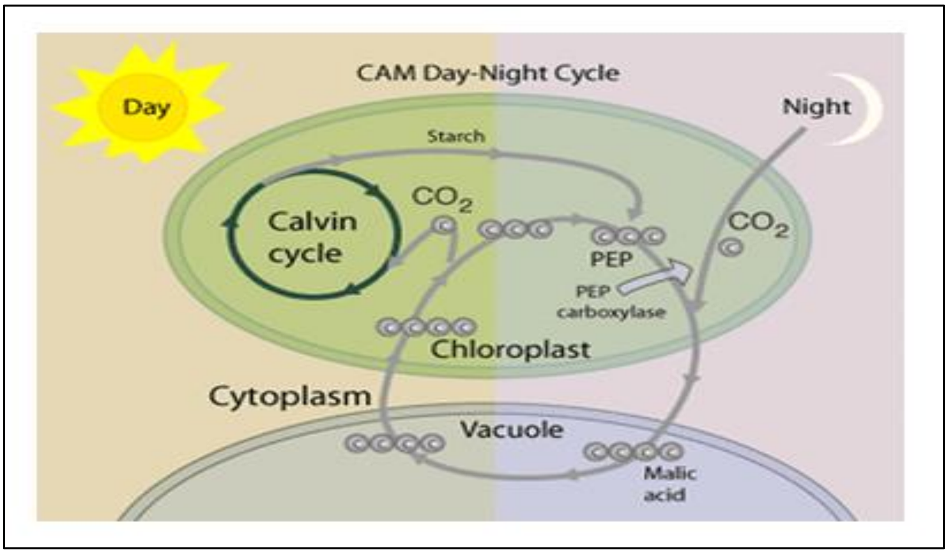


Figure 5. 3 The CAM cycle illustration elaborated on stomatal closure during the day (water conservation) and the intake of CO_2 at night and stored at the vacuole, using C4 reaction and converting it to starch in the morning with the Calvin cycle[11].

Research has identified the internal factors that affect photosynthesis. Early investigations of photosynthesis focused on the effect of various external conditions on the photosynthesis rate in plants. Recent studies have recognized that internal factors also

[11] https://photosyntheticmethods.weebly.com/cam.html

play vital roles in the rate of photosynthesis (Constable & Rawson, 1980; Salvucci & Crafts-Brandner, 2004; Teskey, Sheriff, Hollinger, & Thomas, 1995).

Chlorophyll is the most tangible internal factor researched (Baker, 2008; Norris, Uphaus, Crespi, & Katz, 1971). Over recent decades, various efforts to determine the effect of chlorophyll on the rate of photosynthesis have been the attention for some time. With new and improved technology and instruments, researchers have proven that chlorophyll content is associated with the rate of photosynthesis (Buttery & Buzzell, 1977) (see Figure 5.4).

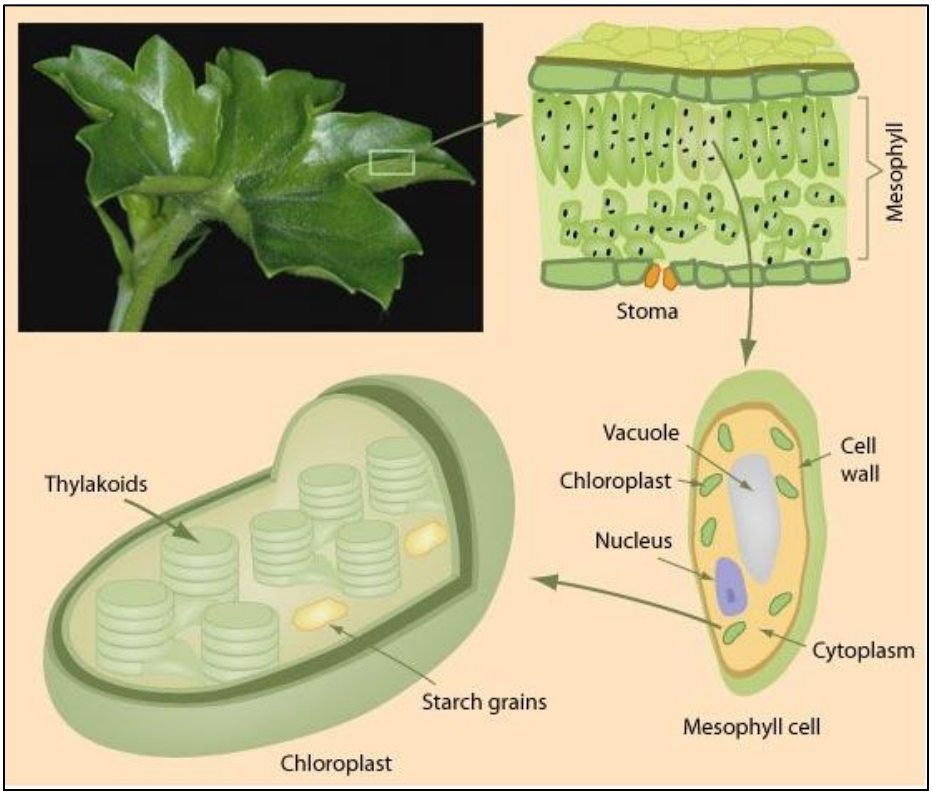


Figure 5. 4 The diagram carefully illustrates a zooming effect of a whole leaf to a horizontal view of the leaf cross-section exposing the mesophyll cell and further inside the chloroplast (site of photosynthesis)[12]

The photosynthesis trial investigates the effect of leaf age on the rate of photosynthesis, with nitrogen being the principal factor. Nitrogen is essential as it plays a key role in photosynthesis as chlorophyll declines under nitrogen stressed conditions (Bojović & Marković, 2009). As photosynthesis and chlorophyll are associated, a comparison of

[12] https://www.quora.com/Why-is-chlorophyll-located-under-the-leaves

chlorophyll in different leaf stages determines the rate of photosynthesis between young and old leaves.

A handheld dual-wavelength meter (SPAD 502, Chlorophyll meter, Minolta Camera Co., Ltd., Japan) was used to determine the chlorophyll content. This instrument calculates the amount of chlorophyll present within a section of the leaf (Markwell, Osterman, & Mitchell, 1995). There have been links to a decrease in chlorophyll content as leaves age, which leads to less absorption of solar energy and a low photosynthetic rate (Drążkiewicz, Tukendorf, & Baszyński, 2003. Therefore, the data from different leaf stages are utilised to determine the photosynthetic rate of the leaf.

5.2.1 Aim of Photosynthesis Trial

This trial aimed to demonstrate to students the mechanism of photosynthesis and how the mechanics are associated with achieving crop yield. Wh en this mechanism is manipulated, the fundamental objectives are set to how and whc jat happens to the crop yield. The trial aims are to:

- Design and implement a template suitable for photosynthesis or phenomenon alike as a teaching resource.
- Understand photosynthesis, its mechanism and its relationship with yield.
- Adoption of new scientific tools and equipment to improve both teaching and learning experience for indigenous instructors and students.

5.2.2 Spinach as a Learning Tool

Spinach production has increased up to 33.3% in Fiji's exports from 2017 to 2019. This alludes to the potential increase in spinach demand in the local Fijian market (Selina Wamucii, 2021). Spinach in Fiji is also in great demand for the tourism sector and cafes and restaurants that serve international dishes. However, its availability is limited in the local market and supermarkets (Southwick, 2021). This observation supports Fiji's need to produce more spinach to cater to its tourism and local markets.

Spinach is a readily available crop suited to the photosynthesis trial as it is a fast growing and leafy vegetable. Apart from its availability and growing habit suited to a photosynthesis trial, spinach can be harvested within the duration of a semester (four to five months) which is appropriate for student learning.

5.2.3 Variety Profile

Spinach (*Spinacia oleracea*) is an economically important crop cultivated and consumed globally. This leafy green vegetable is a powerhouse of nutrients (Handelsman, 2018). Spinach produces a rosette of 5 – 30 centimetres of dark green leaves with prominent midribs with either crinkled or smooth leaves, depending on the variety (Tort, 2019). Leaves are more prominent in size at the plant base than the leaves higher on the flowering stem. Flowers found on the spinach plants are inconspicuous, green-yellow, and mature into a small, solid, dry, lumpy fruit cluster containing seeds.

Although its origin is uncertain, spinach is believed to have been first cultivated in Iran around 2000 years ago (Ribera, van Treuren, Kik, Bai, & Wolters, 2021). From Iran, this vegetable was distributed towards China, Nepal, Europe and eventually their neighbouring countries (Boswell & Victor R, 1949; Elisseeff, 2000). Currently, countries such as China, the United States and Japan are significant spinach producers (*ibid.*). However, the largest producer is China, which accounts for 90% of the spinach production globally. Spinach leaves are very nutritional containing traces of micronutrients, minerals and vitamins (Chun et al., 2005; Roberts & Moreau, 2016).

Popeye is a variety of spinach (see Figure 5.5) known to have consistent performance in home gardens and commercial production (Zealandia Horticulture, 2021). This fast-growing variety takes 5 to 6 weeks to mature. The leaves are positioned in a compact rosette manner, dark green, medium bubbly, glossy with a slight wavey edge (Etsy, 2021). This vegetable demands moisture and soil fertility for growth to produce optimum yield. Weeding is a necessary inter-cultural operation as the spinach crop has less tolerance to weed competition.

Figure 5. 5 Fully grown Popeye spinach. Joeli Savou, Palmerston North.

5.2.4 Cultivation of Spinach

The spinach crop thrives in cool climates, where it can survive in the ranges between 5°C to 25°C and temperature beyond this tends to inhibit growth. However, 10°C – 16°C is considered ideal for favourable growth (Wallace, 2000). Soil pH of 6.0 – 7.0 is considered favourable for spinach cultivation (*ibid.*). This preferably transplanted vegetable is weed sensitive in the establishment phase; therefore, extreme care is required. Sow seeds directly into the garden bed, 1 cm in-depth with 30cm x 35cm apart. The emergence of seedlings usually takes 2 – 3 weeks.

Planting time varies between regions; for instance, sowing during summer through autumn in subtropical climates, late summer through autumn in temperate zones, and autumn through winter in cold areas (Fenton-Smith, 1995). However, due to climate change, spinach cultivation in these zones may differ slightly as variations in environment including temperature occur.

5.2.5 Key Agronomic Activities

Even though spinach is regarded as a short-term crop, key agronomic activities are essential for optimum yield including fertiliser timing and application, irrigation, mulching and weeding (Dkhil, Denden, & Aboud, 2011). Crop management within the first four weeks of planting is crucial as the establishment phase is the most vulnerable time for spinach (University of California, 2021b).

Fertiliser requirement is highly recommended for commercial spinach production, and a well-balanced NPK application is favourable a few days before planting to initiate chemical breakdown (Wallace, 2000, (Backyard Vegetable Garderning, 2021). However, as a leafy vegetable, a concentration of nitrogenous fertilisers is required for optimal growth. A side dressing of urea three to four weeks after transplanting gives the required boost for the first harvest with healthy marketable leaves (Barker, Peck, & MacDonald, 1971). Using granular fertiliser during side-dressing must be adopted with safety precautions as urea contact with leaves may lead to burning. In the absence of fertiliser on poor soil the variation in growth will be prominent compared to plants that receive fertiliser (see Figure 5.6).

Weeding throughout the spinach season is an essential intercultural activity to achieve marketable yield (Fernandes, 2015). This crop has a low tolerance towards weeds and is susceptible to crop loss caused when infested with weeds. Unlike other crops, early-season weeding for spinach is more or less compulsory as it is an inferior competitor against weeds (University of California, 2021b). Adopting an integrated approach to weed control is recommended for spinach cultivation in a trial setting, such as hand weeding, dense planting, and mulching.

The irrigation of spinach depends on a few factors, such as the environment, soil water potential and water holding capacity of the soil (Bianchi, Masseroni, & Facchi, 2017). Spinach needs soil with good moisture retention; therefore, two to three irrigations a week is sufficient at the establishment phase (Tema, 2021). Both sprinkler and drip irrigation are proven to impact the growth of spinach positively and efficiently use water than other irrigation methods (Imtiyaz, Mgadla, Chepete, & Manase, 2000).

Figure 5. 6 Photosynthesis trial of spinach (Popeye variety) at 4 weeks (weeding, urea side application, irrigation and moulding or hilling of plants. Joeli Savou, Palmerston North.

5.2.6 Data Component

Higher plants can potentially use almost all vegetative and reproductive structures to perform photosynthetic CO_2 assimilation (Aschan, Guido, Pfanz, & Hardy, 2003). Leaves produce the highest rate of photosynthesis than other parts of the plant (Pessarakli, 1996). The rate of photosynthesis is affected by various factors such as light intensity, the concentration of carbon dioxide and temperature (Ghannoum et al., 2010).

Several experiments to demonstrate photosynthesis have been published (Field, Ball, & Berry, 2000). Simple experiments such as floating leaves and cut aquatic plants submerged in water indicate the liberation of oxygen as by-products adopted to demonstrate the phenomenon of photosynthesis (Woitke, Hartung, Gimmler, & Heilmeier, 2004). Further research has led to the manufacture of complex equipment, such as the chlorophyll content meter and the Licor machine, to measure this phenomenon accurately.

This trial focused on measuring the rate of photosynthesis of leaves at different positions of the plant. Plants from plots with and without fertiliser applications were measured in three different sets using the chlorophyll meter. Measurements were conducted on the innermost fully expanded leaf throughout the cultivation period. The measurements focused on:

1. The outermost leaf throughout the cultivation period.
2. The innermost fully expanded leaf throughout the cultivation period.

5.2.7 Photosynthesis Trial on Spinach (*Spinacia oleracea*)

Photosynthesis is generally known as the process of plants producing their food and oxygen as by-products. With light being the critical factor behind this phenomenon, a chlorophyll content meter is utilised to reflect the light from the leaves. The reflected light calculates the concentration of chlorophyll present in leaves, which gives a fair idea of the rate of photosynthesis. This trial attempts to identify different positions and ages of leaves with their rate of photosynthesis. Spinach is adopted as a tool to represent the photosynthesis concept. However, this concept is not confined to a particular crop, climate, or soil type: therefore, this trial can be utilised in most crops.

This trial offers an in-depth understanding of how photosynthesis co-exists with chlorophyll content and how nitrogen is a critical factor that facilitates the process. The trial aims for students and farmers to recognise the complex relationship between nitrogen, chlorophyll and their importance during photosynthesis (see Figure 5.7). This link is a sensitive relationship prone to many factors such as leaf size, leaf type, light intensity, carbon dioxide concentration and temperature (Sharma et al., 2020). These factors, if addressed practically, will increase a sense of understanding as students observe the factors on the crop and develop critical thinking as they will start to question the mechanics behind photosynthesis. Furthermore, increasing students' potential to identify current photosynthesis issues and address them directly.

Figure 5. 7 Growth comparison of different fertiliser treatments in spinach (from left nitrogen applied and no nitrogen application). Effect of nitrogenous fertilizer on rate of photosynthesis in plants. Joeli Savou, Palmerston North.

5.2.8 Photosynthesis Trial Materials and Methods

The trial was based on a single variety of spinach (Popeye) measured weekly with the help of a CCM-200 plus (chlorophyll content meter[13]) (see Figure 5.8). The chlorophyll content meter was utilized to calculate the photosynthesis activity of different leaf positions by determining the plant's nitrogen status (Netto, Campostrini, de Oliveira, & Bressan-Smith, 2005). The trials were commenced from 3 July to 2 September 2021.

The CCM-200 plus is an updated version of the CM-200 instrument, and it is a reliable leaf absorption style meter with over 4oo research citations. This equipment includes programmable measurements averaging options ranging from two to thirty possible samples for nitrogen measurements. The main feature of the CCM-200 plus or chlorophyll meter include fast, non-destructive measurement, large memory for data logging, files that can be transferred to excel, portably designed for fieldwork, and presents the chlorophyll content index.

[13] https://www.optisci.com/ccm-200.html

Figure 5. 8 CCM-200 plus chlorophyll content meter[14].

The spinach seeds were sourced from a local plant nursery. One hundred and fifty seeds (10% more than the required amount to allow variation among the seed lot) were sown in a transplanting tray and put into a glasshouse for germination (B. Singh, Deka, & Ramakrishna, 2014). The transplanting trays were hydrated with the help of a flood and drain tray, where the tray flooded three times a day for five minutes, then the water drained naturally (Slota, Maluszynski, & Szarejko, 2016).

A replication trial was applied to have a sense of comparison between the blocks and to validate the findings. The trial included comparing two plots, treatment which received 800 grams of cropmaster NPK fertiliser (14:8:10:10) as basal application, where each plot received 16g and 1.5g urea as side-dressing applications (Khatiwada, 2001). The control plot received no additional fertiliser. Comparisons between the two plots determined the difference in the chlorophyll level and identified the working leaves based on position, and its relationship with yield (Islam, Haque, Akter, & Karim, 2014; Lin, Deng, Shi, Chen, & Wang, 2010; Pagola et al., 2009).

Spinach seedlings transplanted into the experimental plots, with dimensions of 2m x 6m containing growing medium (soil and compost). Soil tests were obtained at the beginning of the experiment (see Section 4.2.2) to determine the nutrient availability and

[14] https://www.optisci.com/m/ccm200.html

avoid nutrient deficiencies or toxicity (Bekunda, Bationo, & Ssali, 1997). A weekly observation to assess the germination and establishment process until six weeks after sowing was adopted to ensure the spinach was mature enough and less vulnerable to environmental factors to establish themselves when transplanted (Heisswolf et al., 2004).

5.2.9 Layout and Design

The raised bed was divided into two 4m^2 plots, one each for the experiment and control (Iowa State University, 2019). These two divided plots contained twenty-five randomly selected seedlings where the outer sixteen plants act as guard rows and commit to the edge effect (Brockman et al., 2020) (see Figure 5.9). The remaining nine plants within the guard rows are used as representatives to obtain the data analysed for any statistical difference (Simel, Samsa, & Matchar, 1991). A 40cm x 40cm spacing was adopted to allow uniform distance among seedlings and equal distribution of nutrients (Khatiwada, 2001; Terranova, 2021). Cropmaster 15[15] was the NPK fertiliser added to the trial in three splits, a base application followed by a side dressing at week three post-transplanting (Khalili & Nejatzadeh, 2021; Linwattana, Protacio, & Mabesa, 1997).

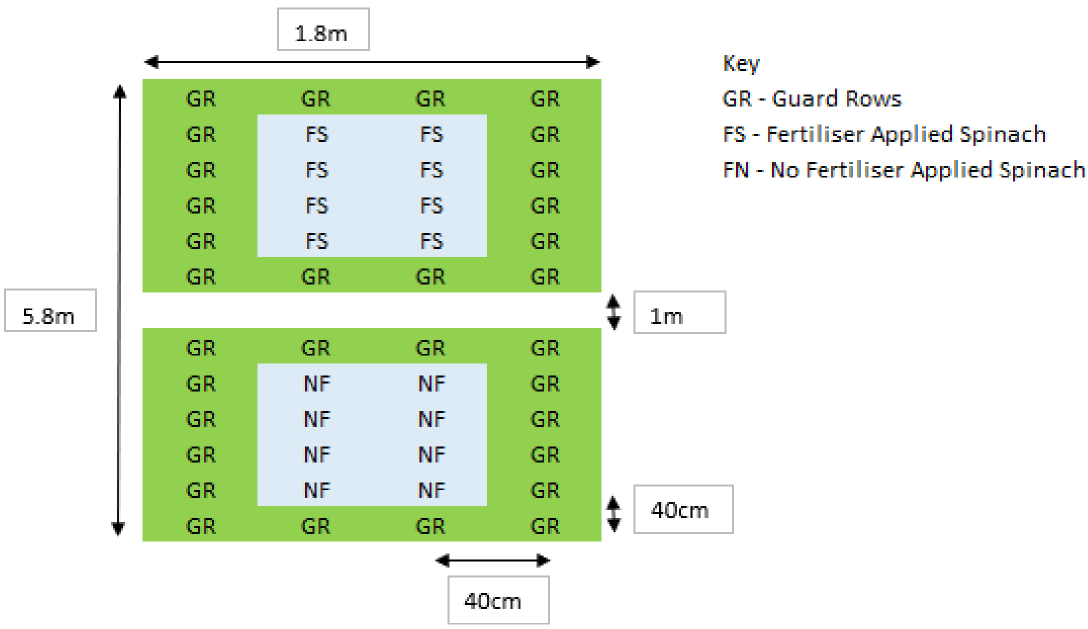


Figure 5. 9 Design and layout of the spinach trial. Joeli Savou, Palmerston North.

[15] fertiliser ratio 14.8:10:10:7.4:0 – see https://www.ravensdown.co.nz/products/fertiliser/cropmaster-15

5.2.10 Photosynthesis Trial Data Analysis

Understanding the complex relationship of how photosynthesis co-exists with chlorophyll and why nitrogen is the key facilitator. as well as to identify the leaf stage that produces maximum photosynthesis are the key objectives of this trial. The complex relationship between photosynthesis and crop yield is exposed with the help of a SPAD meter. A single variety of spinach was adopted in the trial, where nitrogen-based fertiliser was applied as treatment.

Weekly observations were undertaken from week five post- transplanting as leaves were too small to be measured. The observation was undertaken alongside a visual comparison. A chlorophyll content meter was the key instrument used in this experiment, where it reflects radiation onto the leaves. At the same time, calculations taken by the machine result in the amount of chlorophyll present in the leaf (Yuan et al., 2016). The results show that plots that received nitrogenous fertiliser contained more chlorophyll than plots without nitrogen fertiliser application. Furthermore, visually, the yield of the spinach crops that received nitrogen fertiliser was of a higher standard than the spinach crops without fertiliser application (see Figure 5.10). This trial therefore demonstrates to students the complex relationship between photosynthesis, nitrogen fertiliser and yield.

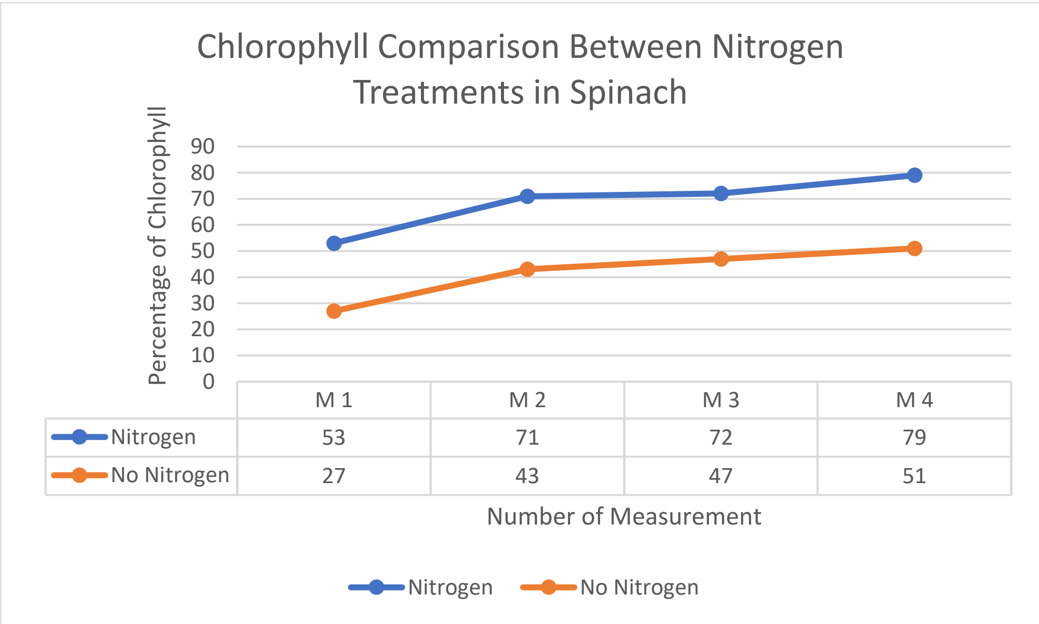


Figure 5. 10 Percentage of chlorophyll between nitrogen treatments

By utilising the photosynthesis template (Section 5.2.1) with its straightforward procedures contributes to simple execution of the trial. A hands-on approach allows students to experience the process both physically and visually. However, determining the successful transfer of knowledge is vital to fulfilling the pedological process for indigenous students, which then contributes to the assessment of students' knowledge.

In this trial, specific assessments must be carried out to gather enough proof that indigenous students have fully understood the phenomenon of photosynthesis and its complex relationship with crop yield. These assessments may include a short graph presentation of the trial outcome, followed by a full report of the necessary details and an examination to complete the process. Passing all these assessments would indicate to the instructor that the knowledge has transferred successfully.

Various physiological elements of plant growth contribute to crop yield, and specific instruments can measure them accurately. Linking these instruments with practical classes to address the current plant physiological knowledge and approaches present in Fiji will aid students to develop critical thinking with proper guidance from instructors. Handling the instruments by students will also improve knowledge regarding the instrument, thus giving confidence in their use. Along with the chlorophyll meter, some specialist instruments can be used by students and researchers. These include (Dzined, 2021):

1. OS5p+ Advanced Modulated Fluorometer:[16]

The OS5p+ is most improved to a range of chlorophyll Fluorometer. This equipment is used to signify the photosynthetic energy transformation in a plant, where it identifies a wide range of plant stress and investigations into the photosynthetic process (see figure 5.11). With this equipment, experiments are not limited to light or dark-adapted conditions, and the OS5p+ offers researchers unique control over each experiment. The OS5p+ is designed with the highest degree of automation. A series of simple menus achieve full programming and operation on a large backlit, colour, touch screen display. Various stress tests are pre-programmed into the OS5p+, which significantly simplifies

[16] https://www.adc.co.uk/products/os5p-advanced-modulated-fluorometer/

the experimental setup, where calculated parameters and real-time fluorescence transients are presented on the colour graphic display[17].

Figure 5. 11 OS5p+ Advanced Modulated Fluorometer (http://envcoglobal.com/catalog/agriculture/plant/leaf/os5p-advanced-chlorophyll-fluorometer)

2. MPM-100 Multi-Pigment-Meter:[18]

The MPM-100 Multi-Pigment-Meter uses a mixture of proven techniques to measure various plant pigments simultaneously. This equipment is a compact handheld meter that gives an accurate and non-destructive that utilises ratio fluorescence to measure anthocyanin and flavanol content and leaf transmission in the near and far infra-red to measure 6the chlorophyll content (5.12). The results from the findings are adopted to determine the nitrogen flavanol index of a plant from a leaf. The MPM-100 has a high resolution, colour, screen display with 4GB flash memory and a USB port for downloading data to an excel spreadsheet. An internal GPS module is used to geolocate data for field applications.

[17] http://envcoglobal.com/catalog/agriculture/plant/leaf/os5p-advanced-chlorophyll-fluorometer
[18] https://vsinstruments.com/mpm-100

Figure 5. 12 MPM-100 Multi-Pigment-Meter (https://www.agriculture-xprt.com/products/optiscience-inc-model-mpm-100-chlorophyll-anthocyanin-flavonol-and-nitrogen-flavonol-index-meter-741250)

3. LCi T Compact Photosynthesis System:[19]

The LCi T is a major development based on the popular LCi-SD system, and this equipment is the only photosynthesis system proven to measure combined gas exchange and inflorescence from leaves (5.13). This portable equipment is easy to use, accurate and reliable while reporting photosynthesis rate, transpiration rate and stomatal conductance. The LCi T also measures leaf temperature, chamber temperature, barometric pressure and light level. Weighing up to 2kg, the LCi T is easy to use, ultra-compact with a USB outlet port and a removeable 32GB memory card for data output. The LCi T, is convenient, which is beneficial for researchers and students' application[20].

[19]https://www.cid-inc.com/plant-science-tools/photosynthesis-measurement/ci-340-handheld-photosynthesis-system/
[20] http://envcoglobal.com/catalog/agriculture/plant/leaf/lci-t-ambient-photosynthesis-system

Figure 5. 13 LCi T Compact Photosynthesis System (http://envcoglobal.com/catalog/agriculture/plant/leaf/lci-t-ambient-photosynthesis-system)

5.2.11 Photosynthesis Trial Template

In line with the pedagogical need for structure, a template has been created to allow students to have an investigational approach which can absorb a variety of crops and trials. It is constructed in a step-by-step manner which provides a smooth transition to cater for the aim and objective of a trial (see Table 5.1). This template allows for consistent practice throughout any photosynthesis trial on different crops.

Table 5. 1 Template for a photosynthesis trial

Photosynthesis Trial Teaching Template			
Step	**Research Procedure**		**Questions to ask (Students)**
1	Pre-trial	The right concepts	• Is the aim clear? • What are the trial objectives? • what crop will you use for the trial?
2		The right treatments	• Will adding treatments to the trial offer the required information? • Do the treatments differ?
3		Measurement sorting	• Have before, during, end, after, and trial measurements all been planned/scheduled?
4		The right design needs to meet the analysis procedure to follow the trial	• How will the plots be marked out? • Is there a replication of the trial, and how many? and how arranged? • Will randomisation be practised?
5		The right site	• Why is the selected site best for the trial? • Why do you need a soil test? • How will you interpret the soil tests?
6		Proceeding to the trial	• Are the agronomic activities uniform? • Are there records of site conditions and past cultivation available? • Is measuring equipment available? • Has a data sheet been formulated?
7	Trial	Monitoring of the trial	• Are agronomic activities applied correctly and timely? • Have during trial measurements been made as planned? • Is the equipment calibrated and appropriately utilised?
8	Post trial	Concluding the trial	• Is the harvest area selected and marked? • Is there proper harvesting equipment? • Is the harvesting procedure straightforward? • Are data sheets complete?
9		After the trial	• Have samples been saved for quality analyses? • Are differences between treatments apparent (visual) or significant?
10		Analysing the results	• Are the data complete and accurate? • Are the data entered? • How will the statistical data be analysed? • How will the results and conclusions be presented and recorded?

The implementation of the photosynthesis trial as practical to supplement the theory learnt in class provides clear understanding for this complex topic. The interpretation of data will aid indigenous Fijian students to relate to the importance of light absorbtion, gas exchange, the calvin cycle as a whole and the relationship between the plant cell (chloroplast) with the rate of photosynthesis providing a clear understanding of knowledge. This approach will ultimately give rise to critical thinking and constructive questions which further develops indigenous students and farmers knowledge.

Chapter Six

Variety Trial Experiment

6.1 Introduction

This chapter focuses on the second field experiment, the variety trial highlighting the difference between a cultivar and a variety, reproduction in plants and the various plant breeding techniques. Guided by a set of aims, the trial is discussed as a learning tool as well as the variety profiles adopted for the trial, and the data components measured.

6.2 Experiment Two

In times past, people cultivated various crops to access a wide range of food types and nutrition. This system granted people particular types of crops within a growing season. However, agriculturists have engineered hybrid crops, either variety or cultivar, that can produce optimum yields throughout the year.

Often the terms variety and cultivar are used interchangeably. However, these words contain two distinct definitions (Beaulieu, 2019). A variety refers to a plant found to grow and reproduce naturally in the plant kingdom. These are plants grown from seeds and are often true to type (Haynes, 2008). On the other hand, a cultivar is short for cultivated variety and is commonly utilized in discussing plant taxonomy. Cultivars originate as mutations or sports on plants; others combine two hybrid plants (Finley, 2021). These are plants propagated from vegetative parts, not true to type, but it retains some features of the mother plant when propagated.

Plant breeding is the process of changing the genetic traits of plants in order to create the desired plant types that are better suited for cultivation and produce better yields (Hallauer, 2011) (see Figure 6.1). Breeding of plants has been practiced in earlier generations, where plants were deliberately crossbred to closely related plant varieties to produce a new plant with desired traits. Today plant breeders attempt to incorporate desirable traits such as improved crop yield, crop quality, increased resistance to pathogens, tolerance to pests and tolerance to environmental stresses such as salinity and extreme climatic conditions (He & Liu, 2003). There are four approaches to producing new hybrids: selection, the most ancient and primary method in plant breeding and hybridization, the most frequently adopted breeding technique, polyploidy and mutation.

- The selection technique comprises three phases;
    - selection: where genetically variable original populations are selected in bulk
    - observations: progeny rows are grown from individual plant selections over the years to observe their performance under different environmental conditions, and at the same time, poor-performing cultivars are eliminated.
    - comparison: selected inbred lines with the existing commercial cultivars, with the high-performing inbred cultivar being selected for distribution.
- Hybridization is a more complex plant breeding technique, where the main aim is to amalgamate desired traits found in various plant lines into one plant line through cross-pollination. In this method, the first phase is to create homozygous inbred lines. These pure lines are then outcrossed, and the progeny is selected to combine with the desired traits. However, if a trait is undesirable, a back-cross with the crop parent is repeated until the unwanted traits are removed.

Figure 6. 1 Carrot colours engineered to attract consumer and meet consumer needs[21].

[21] http://snaplant.com/vegetables/a-rainbow-of-carrot-colors/

- Polyploidy and induced mutation are adopted during special treatments. Most crops are diploid; polyploidy involves plants that contain three or more complete sets of chromosomes. Chromosomes set per cell can be increased by inducing colchicine, which leads to an increase in size and genetic variability. However, polyploidy plants have lower fertility and are slow growing. Induced mutation is the least utilised breeding technique due to the application of chemicals and radiation (see Figure 6.2).

Figure 6. 2 Boundaries on improving maize due to harmful mutation genetically linked to beneficial gene combinations that were selected for during domestication and breeding[22].

In nature, plants within species can differ significantly from other members of the same species by their morphological features such as the colour of the flower, the number of leaves, shape of leaves and physiological features such as seed dormancy and germination (Photita, Taylor, Ford, Hyde, & Lumyong, 2005). These variations among species are due to the genetic make-up of the individual species. Furthermore, external factors such as climate, altitude, water availability, soil fertility and topography play a vital role in the genetics of the plant to aid in adaptation to surrounding conditions (Hamrick, Godt, & Sherman-Broyles, 1992).

Figuring out what variety of vegetables to grow commercially is not easy for farmers, as their livelihoods depend on it (Brown, Van den Bergh, de Bruin, Machida, & van Etten, 2020). Many look up descriptions in catalogues and online, while others cultivate

[22] https://www.morningagclips.com/crops-can-hold-onto-harmful-mutations/

whatever is provided to them by the government. Some follow recommendations from others; however, environmental conditions differ, and considerations need to select varieties aligned to consumer preferences (Dawson & Healy, 2018).

Seeds are the first defence of farmers in the field, and the basis for identifying the best variety is through a field trial (Dawson, 2021). Growers rely on varieties that produce high yields in their local climate and environmental conditions, including essential production characteristics like disease tolerance and resistance to meet market demands (Brown et al., 2020). Field trials help farmers manage risk by identifying optimal genetics for a growers unique environmental and market conditions.

A field trial to determine suitable varieties can be incorporated into an annual farm plan to help researchers and growers optimize their operations to avoid several common production pitfalls (Dawson, 2021). The benefits of variety trials are extensive. A few critical points and reasons to incorporate variety trials into farm plans include:

- Finding varieties to fill the market.
- Replacing a dropped variety or reducing dependence on a variety
- Addressing climate change.
- Addressing pest and diseases pressure.
- Complying with organic certification requirements.

The broccoli variety trial sought to compare two varieties. All agronomic activities practised during the trial are similar for cultivated varieties. The adoption of a weekly measurement was applied to record the growth of both the broccoli throughout its life cycle (Brown et al., 2020; Roldan-Ruiz et al., 2001).

With climate change and food sustainability affecting the agricultural sector in Fiji, there is a need to educate students and farmers about the benefits of variety trials. This knowledge will aid in achieving food security and re-adjusting planting schedules to suit the climate trend and predict the future by increasing the survival and vigorous chances of crops in general.

6.2.1 Aims of Variety Trial

This trial aims to undertake a variety trial on a short-term vegetable crop that can align with a set of learning objectives. In this case, broccoli is the adopted crop, where the two varieties being compared were calabrese and Chinese broccoli. The objectives of this trial were to:

- Determine a trial template for variety comparison.
- Identify the quality components of a particular crop.
- Collect and analyse vital characteristic measurements for discussion.

6.2.2 Broccoli as a Learning Tool

Broccoli in Fiji has grown in importance in the Fijian market (Koema, 2019). In order to minimise imports of broccoli, there is a need to adopt sound agronomic activities that will increase the local production of broccoli. Projects have proven the availability of opportunities to replace imported fruits and vegetables such as capsicum, tomato, melons and broccoli, (Nasokia, 2018). However, due to consumer preference, there is a need to improve broccoli production in Fiji to meet the growing consumer expectations.

With time, numerous varieties of crops are developed to suit growing conditions, tolerate pests and diseases, and cater to specific markets. The selection of broccoli to be adopted in the variety trial was carefully considered with the varieties available. The distinctions in the selected varieties are prominent in size, maturity and consumer preferences, making the two varieties of broccoli the most suitable crop available for the variety trial.

6.2.3 Profile of Broccoli Varieties

Since the sixth century, broccoli (*Brassica oleracea*) has been a cruciferous vegetable of the brassica family (The Spruce Eats, 2021). In Italian, the word broccoli means little sprouts, originated from the Italian plural of broccoli, meaning the flowering crest, and the Latin *brachium* translates to shoot, branch or arm (Gray, 1982). Grown for its edible flower buds, leaves and stalk, food historians believed the Etruscans developed broccoli in the Tuscany region of Italy around 600 BC as they tried to hybridise an early-blooming form of cabbage (*Brassica oleracea*). Over the years, broccoli spread within Italy, across the Mediterranean and into Asia (McMurray, 1999). However, the recognition of the word broccoli in the English language began in the 18th century.

Over the past decade, broccoli production has been dominated by ten countries worldwide: Poland, Bangladesh, Turkey, Italy, Spain, Mexico, France, China, India, and the USA, leading the production table (Mulderij, 2016). The broccoli production totals up to 23.8M metric tonnes. China, India and the USA account for 88% of the total production, while the remaining seven producers contribute the other 12% (Tridge, 2019).

Broccoli is among the most popular vegetables globally due to its health benefits and is edible, raw or cooked and easy to prepare (Latté, Appel, & Lampen, 2011). Globally broccoli is considered a superfood with low calories and a/ wealth of nutrients, antioxidants that support many aspects of human health (Abdel-Aal, Akhtar, Zaheer, & Ali, 2013).

Broccoli comes in many different shapes, sizes, and colours. Some are early varieties harvested in less than 60 days (Home Stratosphere, 2021). Approximately twenty varieties of broccoli are favoured for cultivation under a range of conditions. Among the twenty varieties, three are produced on a large scale and traded globally. The three commonly cultivated varieties consist of *Calabrese, Gaai laan* and *Broccolini*. Morphological variations between the three cultivars are prominent and are a target by specific markets.

Calabrese

Calabrese broccoli (*Brassica oleracea*) is an heirloom variety and the most popular variety globally. Cultivation during the cooler months is suited for broccoli as the cold weather aids in flavour (Robbins, Keck, Banuelos, & Finley, 2005). The *Calabrese* is a medium to large broccoli with deep green heads consisting of tight florets and tiny flowers (B. Hayes, 2021) (see Figure 6.3). This variety matures sixty-five days after transplanting and is renowned for its prolific sprouting side shoots following the first harvest (Marshall & Thompson, 1987; Vegetables.co.nz, 2021).

Figure 6. 3 Fully grown calabrese broccoli variety[23]

Chinese Broccoli

Heirloom Chinese broccoli (*Brassica oleracea* var. *alboglabra*), also known as kai-lan/kailaan, jie lan or gaai laan, and do not do well in hot conditions (Home Stratosphere, 2021). This variety is leaf governed, with blue to dark green colours, depending on variety (see Figure 6.4). The stems of this variety grow to 15-20cm in height and 2cm in grith, with its stalk covered in white flowers, which is approximately 50 to 70 days after transplanting, depending on climatic conditions (Schiller, 2020). This broccoli produces multiple shoots with large florets similar to broccoli heads (Vegetables.co.nz, 2021).

[23] https://www.redemptionseeds.com/green-sprouting-calabrese-broccoli-seed.html

Figure 6. 4 Fully grown Chinese broccoli variety[24]

6.2.4 Cultivation of Broccoli (*Brassica oleracea*)

Broccoli is an annual crop that favours temperatures for seed germination from 20 – 23 ^{o}C. This crop is planted during late spring to early summer in cool climates, late summer to autumn in warmer zones, and autumn to winter in tropical areas (Fenton-Smith, 1995). Broccoli flourishes in moderate to cool climates of 25 ⁻ 26 ^{o}C day temperatures and 16 – 17 ^{o}C at night (Sawant, 2021).

This crop is either sown directly or transplanted from a nursery bed into a preferred soil pH of 6.5 – 7.5 (Nassef & Nabeel, 2012). This crop vigorously grows up to 60 – 90 cm tall (Britannica Encyclopaedia, 2020). The nature of growth consists of upright and branching growth with leathery leaves (Hills & Campbell, 1968). Broccoli produces condensed green clusters of flower buds at the central axis and the branches. These buds

[24] https://naturnoa.com/gb/oriental-vegetables-/502-kailaan-kichi-chinese-broccoli-untreated-seeds

bear four-petaled yellow flowers and produce silique fruits if left unharvested. The head reaches harvest in 60 – 150 days, depending upon the variety and climatic conditions.

6.2.5 Key Agronomic Activities

Broccoli is a hardy winter that requires essential agronomic activities for optimum crop yield. Like most vegetables, the establishment phase is regarded as the vulnerable stage requiring care and maintenance. Key agronomic activities include fertiliser application, weeding, and irrigation (Hyde, 2021).

Fertiliser application is standard in commercial production (Wills, 2002) (Rawat, Saxena, & Sanwal, 2019). Broccoli benefits from a basal application of NPK, followed by a side dressing of urea to encourage leaf growth through to the maturity stage (Tremblay, Belec, Jenni, Fortier, & Mellgren, 2008).

Weeds in any production system causes yield reduction, as they compete with crops for nutrients, sunlight, water and air (Van Heemst, 1985). Weeding needs to be undertaken at least for 30 days post-transplanting to reduce competition (Brainard & Bellinder, 2004).

Irrigation is an essential practice to improves crop yield and quality (Hagos et al., 2009). Adequate irrigation is vital for plants to activate photosynthesis; however, over-irrigating may cause disease infestations or drowning crops. Broccoli have shallow root systems that suit drip irrigation. However, light and frequent irrigation should be applied in intervals depending on the weather conditions to maintain the rhizosphere and plant’s moisture (Aishah, Saberi, Halim, & Zaharah, 2011; Saeed & El-Nadi, 1998).

6.2.6 Data Component

Evaluating a variety trial depends on the objectives and the goals identified for the trial (Erez & Zidon, 1984). This evaluation can be focused or extensive depending on the available time and the trial’s intent (Oregon State University, 2020). Evaluations of a variety trial usually occur throughout the plant growing period to capture the different growth stages, beginning from seedling germination to harvest (Smith, Cullis, & Thompson, 2005) (see figure 6.5). The evaluation process involves a combination of data collection and notes throughout the growing period of the crop (Hurst et al., 2015; Kelly, 2010). Data collection offers a clear picture and detailed record of individual morphological traits as field notes provide context to the measured data.

Figure 6. 5 Evaluating at 4 weeks after transplanting, comparing growth between two varieties of broccoli (from left Calabrese broccoli and Chinese broccoli). Joeli Savou, Palmerston North.

This variety trial dealt explicitly with evaluating traits of two clearly different broccoli varieties, which allows for the comparison of morphological components. Various qualities are measured in a variety trial, such as; seedling vigour, length of productivity, weed competitiveness, uniformity, yield, flavour, holding and storage qualities (Oregon State University, 2020) (see Figure 6.6). The qualities measured in this trial covered seedling, transplanting and establishment phases, recording the number of leaves, dimension of leaves, plant height, and flowering.

Various assessment approaches measure the quality; however, selecting which approach to utilise relies significantly on its precision and time to capture quality data. This variety trial is a simple comparison exercise for students to understand the variation found in varieties and the correlation of quality traits with consumer preferences (size, tight head, maturity etc.) as learning factors.

Figure 6. 6 Two different varieties of broccoli at week 7 exhibiting their different qualities (from the left Calabrese broccoli and Chinese broccoli). Joeli Savou, Palmerston North.

6.2.7 Variety Trial on Broccoli

Busy farmers might think variety trials appear to be extra work on a farm. In the long run, however, integrating trials into an annual farm plan can aid farmers to optimise their operations to avoid several common production drawbacks.

Variety trials are often overlooked as a tool for managing risks in agriculture (Colley & Myers, 2007b). Adopting basic scientific methods when conducting trials brings a level of assurance to the results. Whereas simply trying a new variety without an experimental design can give misleading and even invalid information. Selecting suitable crops and varieties for the local climate, field conditions, and market can significantly minimise loss and increase agricultural success while avoiding the expense of investing in poorly adapted or poorly performing varieties.

This experiment will teach students the importance of risk management approaches in crop production, where crops morphological characteristics are assessed to make the necessary crop selections (see Figure 6.7). Similarly, quality components of crops are identified and utilised to compare between varieties to determine their differences. This way, students can distinguish one variety from the slightest morphological variations.

However, students require a template to guide them through achieving a standard level of information.

Identifying the most suitable variety to cultivate for maximum economic return is a goal that researchers and growers share (Dawson, 2021). The variety trial exercises the student's ability to analyse and identify the appropriate varieties to address current agricultural problems and by aligning to consumer preferences (Colley & Myers, 2007a).

Figure 6. 7 Morphological assessment of Variety trial of broccoli at week 5 (from left Calabrese broccoli and Chinese broccoli). Joeli Savou, Palmerston North.

6.2.8 Variety Trial Materials and Methods

The experiment included two varieties of broccoli, *Calabrese* broccoli and Chinese (kaai laan) broccoli, from 22 April 2021 to 23 July 2021. Specific measurements included plant height, number of leaves and leaf dimensions accumulated weekly to account for the variety's growth curve.

Sixty seeds of each variety were sown into transplanting trays 30% more than the required amount to allow variation among the seed lot. The seeds were sourced directly from a commercial supplier. The transplanting trays were hydrated with the help of a flood and drain tray, where the tray flooded three times a day for five minutes, then the water drained naturally (Slota et al., 2016).

Both the trialled varieties received 16 grams Cropmaster NPK (14:8:10:10) as a base application, followed by a side dressing of urea at 1.6 grams of urea per plant for both the varieties (Ravensdown, 2021; Tremblay et al., 2008). Daily irrigation was applied to keep the soil moist; water quantity was dependent on weather conditions. Finally, a replication trial was applied to have a sense of comparison between the blocks and to validate the findings.

Broccoli seedlings were transplanted onto the experiment plots, with dimensions of 2m x 6m containing a well-decomposed potting mix. Soil tests were taken (see section 4.2.1) to determine the nutrient availability before planting to avoid nutrient deficiencies or toxicity (Bekunda, Bationo, & Ssali, 1997). A weekly observation to assess the germination process until the sixth week was adopted to assure the broccoli is mature enough and less vulnerable to environmental factors to establish themselves when transplanted (Heisswolf et al., 2004.

6.2.9 Layout and Design

The total area used for cultivation on the raised bed was 5.8m x 1.8m. The raised bed was divided into two $4m^2$ plots, comprising uniform varieties in both plots. These two divided plots contained twenty-four randomly selected seedlings where the outer sixteen plants act as guard rows and commit to the edge effect (Brockman et al., 2020) (see figure 6.8). The remaining eight plants within the guard rows are used as representatives to obtain and compare the statistical difference (Simel et al., 1991). A 50cm x 50cm spacing was adopted to allow uniform distance among seedlings, avoid overcrowding and equal distribution of nutrients (Khatiwada, 2001; Terranova, 2021).

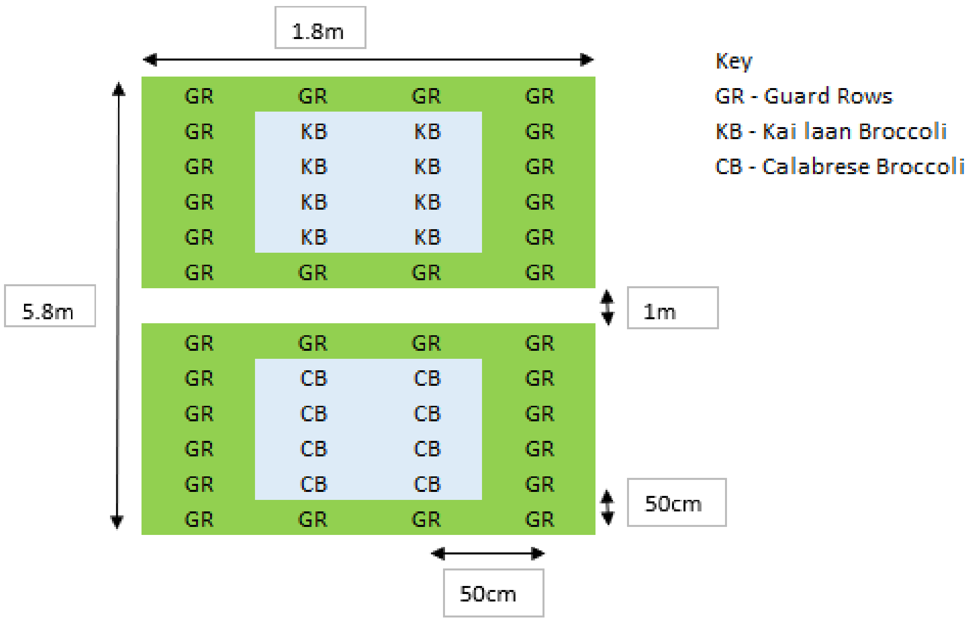


Figure 6. 8 Layout and design of broccoli trial. Joeli Savou, Palmerston North.

6.2.10 Variety Trial Data Analysis

Once data are collected, the task remains of assessing the results. The first step is to review the trial goal and depending on the goal, the data assessment is approached from different angles (Erez & Zidon, 1984). However, the type of data collected will influence the type of analysis adopted. The traits selected to set a scene to distinguish the morphological differences between the two varieties in this case. Morphological variations play a crucial role in selecting which variety to adopt. In a variety trial, students will identify individual variety differences, strengths, and weaknesses. Differences may be in their germination percentage, establishment phase, growing nature, vigorous nature, weed competition, adaptability with the environment, harvest time, and shelf-life. These differences allow students to explore different consumer preferences and the availability of the market locally and globally.

Throughout the production period of the broccoli crop, weekly observations were carried out to monitor the differences in the critical quality components from both varieties (Ordiales et al., 2017). These components included leaf dimensions, plant height, bud initiation, head maturity, and harvest attributes. As expected, both these varieties expressed morphological differences under all the measured components.

Among the four broccoli key quality components assessed, plant height, number of leaves with bud formations were dominated by the Chinese broccoli (see Figures 6.9 and 6.10), while leaf dimensions were higher for calabrese broccoli (see Figure 6.11). However, Chinese broccoli has exceeded its harvesting stage, which led to its increase in height. The Chinese broccoli initiates its buds at six weeks after sowing and appropriate harvest judged by height of the plant in weeks 7 to 8 making it an early variety. However, calabrese broccoli initiates budding at week nine and based on past research, reaching the acquired harvest height takes three months, making this variety a late variety (Burpee, 2021). However, for this trial the time frame is not an issue harvest characteristics and consumer preferences the most important.

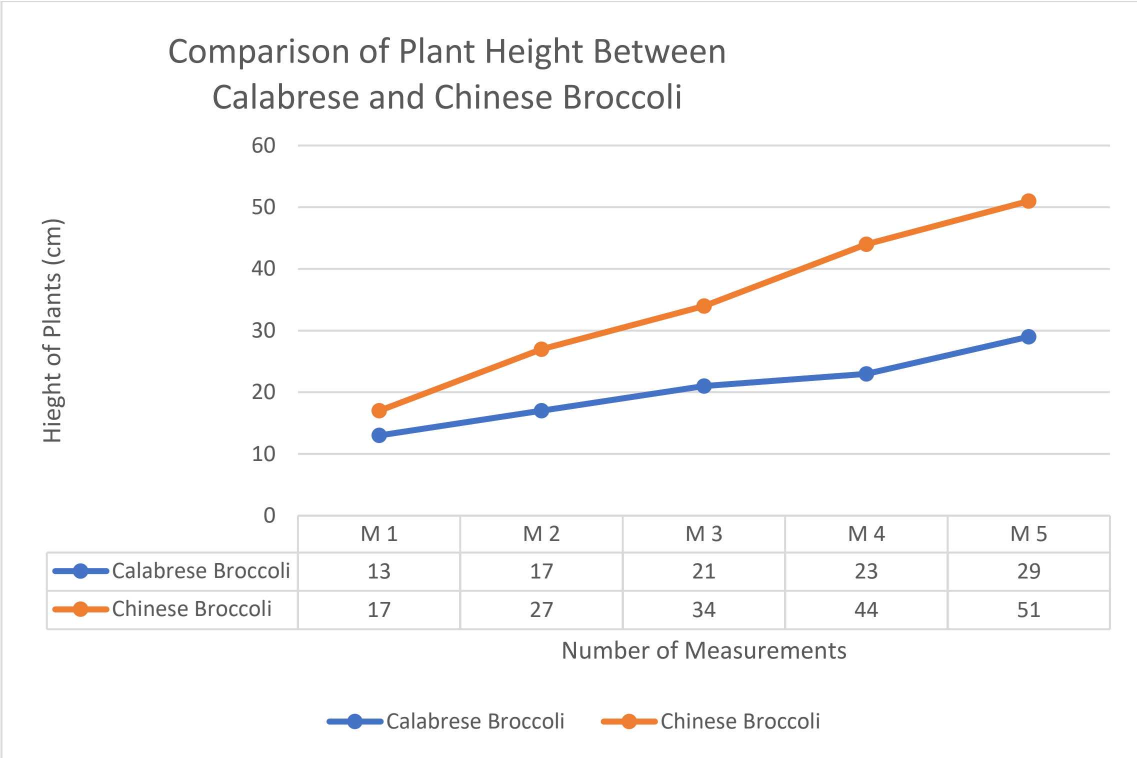


Figure 6. 9 Comparison between the height of two varieties of broccoli

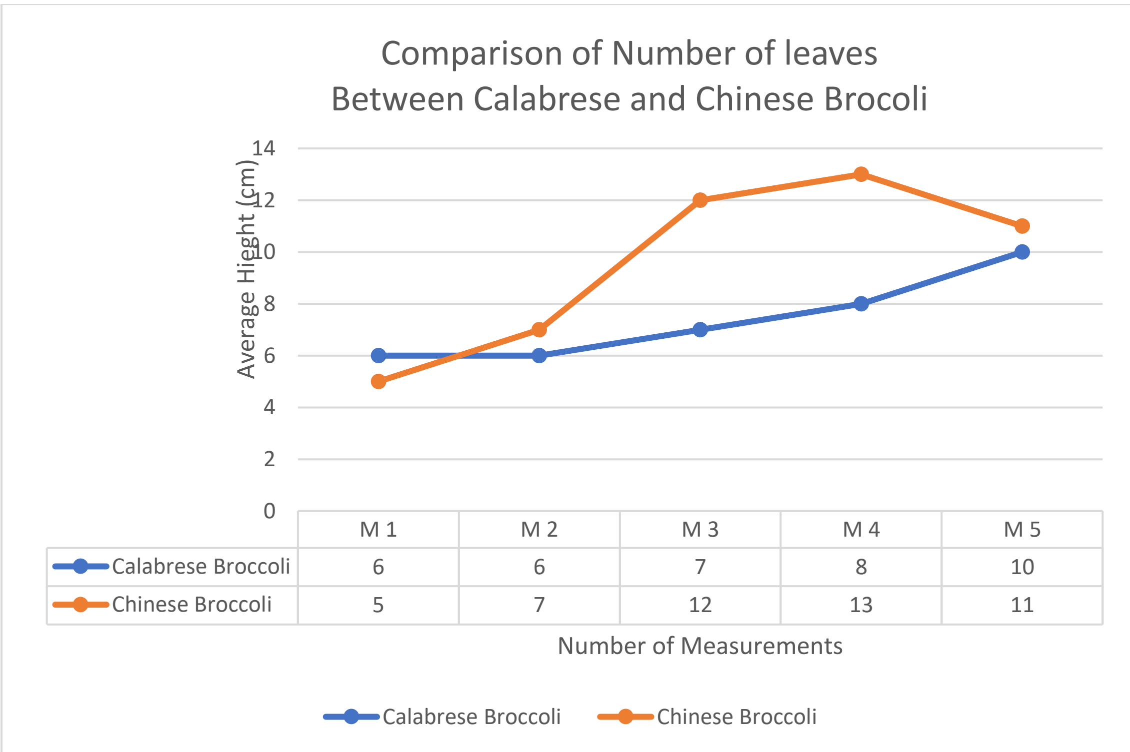


Figure 6. 10 Comparison of the number of leaves of two varieties of broccoli

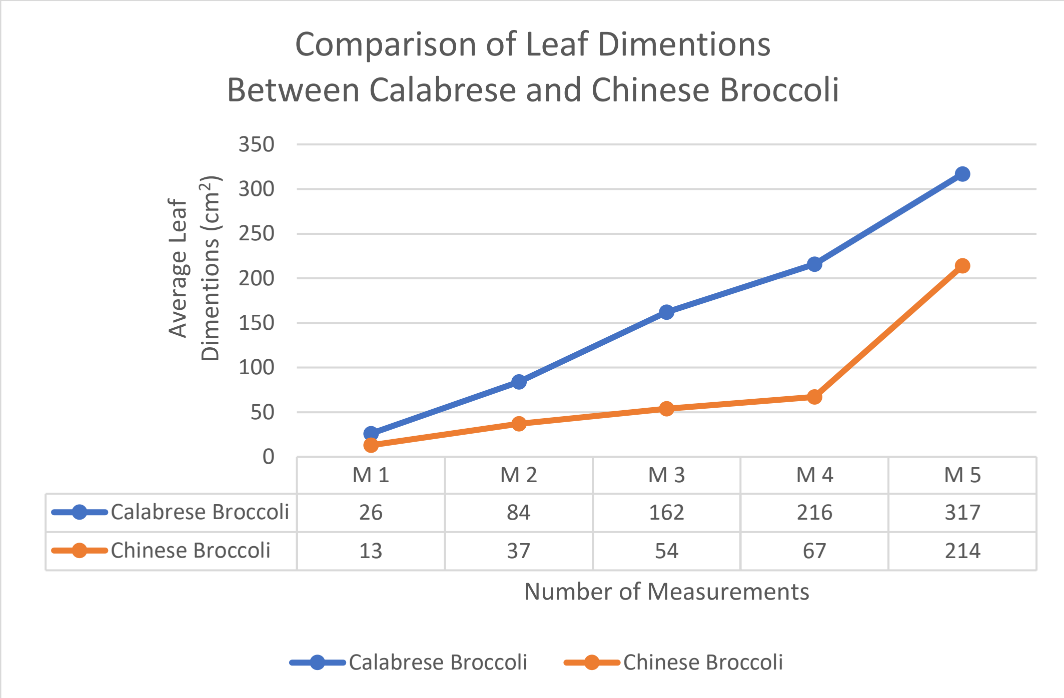


Figure 6. 11 Comparison of leaf dimensions of two varieties of broccoli

Early and late varieties have their merits and demerits; however, it is crucial to consider their properties to eliminate their demerits. The available market and consumer preference play a vital role in adopting a particular crop or variety (Asante et al., 2013). Therefore, there is a need for students and farmers to understand the difference between mass cultivation and strategic cultivation to produce optimum yields with minimum input.

The variety trial is straightforward while adopting the template and practising the sequential process step by step. However, meeting the pedagogical processes that facilitate students' absorption and interpretation of knowledge is challenging for this trial. The template can be utilised for the variety trial to adapt to any crop; however, considerations must be taken as crops differ in their economic parts (Fabioclass, 2021; Food and Agriculture Organisation, 2010). Some are valued for their leaves and stems, while others for their fruits and roots. Therefore, while the crops follow the same procedure on the template, spinach, broccoli, tomato, and potatoes require different approaches.

There are many aspects to consider when adopting variety trials. With the help of the learning objectives to identify which aspect of the variety trial is addressed. Linking the variety trial and practical experience at the tertiary level helps create critical thinking for students, which can be utilised to address current issues such as environmental suitability, production needs, morphological and physiological characteristics, adaptability to climate change, and market preferences.

6.2.11 Variety Trial Template

In line with the pedagogical need for structure, a template has been created to allow students to have an investigational approach which can absorb a variety of crops and trials (see Table 5.1). This template allows for consistent practice throughout any variety trial on different crops.

Table 6. 1 Template for a crop variety trial

Variety Trial Teaching Template			
Step	**Research Procedure**		**Questions to ask (Students)**
1	Pre-Trial	The right concepts	• Is the aim clear? • Are the Trial Objectives clear? • What crop/varieties will be used?
2		The right treatments	• Will a morphological comparison offer the required information? • Are the treatments uniform?
3		Measurement sorting	• Are there before, during, and after trial measurements?
4		The right design needs to meet the analysis procedure to follow the trial	• Is the selected site best for the trial? • Is there a replication of the trial, and how many? • Will randomisation be adopted in this trial? • Have the plots been arranged for optimal results?
5		The right site	• How will the plots be marked out? • Will there be before trial measurements ? • what is the role of a soil test and analysis?
6		Proceeding to the trial	• Are the agronomic activities uniform? • Will records of site conditions at planting time be taken? • Are the cultivation records available for the field?
7	Trial	Monitoring of the trial	• Are agronomic activities applied correctly and timely? • Have during trial measurements been made as planned?
8	Post-Trial	Concluding the trial	• Is the harvest area selected and marked? • Is there proper harvesting equipment? • Is the harvesting procedure straightforward? • Are data sheets complete?
9		After the trial	• Have samples been saved for quality analyses? • what qualitative assessments are required??
10		Analysing the results	• Are the data entered complete and accurate? • How will the statistical data be analysed? • How will the results and conclusions been presented?

The variety trial provides a sence of understanding for indigenous Fijian students to practically distinguish between two varieties, visually identifying the physical characteristics of each variety rather than watching pictures in books and the internet. This practical activity offers life-long and is a risk management tool that has a wide scope to address the market expectations such as, consumer preferences and market demand. Similarly, this trial can be utilised as a climate smart approach to identify planting time and the variety suitable for cultivation at a specific location.

Chapter Seven

Fertiliser Trial Experiment

7.1 Introduction

This chapter summarises the fertiliser trial. The importance of fertiliser is addressed with a focus on nitrogenous fertiliser and its effects on crops. An overview of the selected crop, potato (*Solanum tuberosum*), the design and practices, and its data components are presented. This trial was governed by carefully constructed objectives concluding with a template to adopt to promote positive learning for indigenous Fijian students.

7.2 Experiment Three

The human population is booming with a growing food demand (Rozema & Flowers, 2008). Farmers of this generation are pressured to increase production globally, leading to the expansion of farmlands followed by intensive agriculture (Liliane & Charles, 2020). Understanding the dynamics involved in food production is essential for the enhancement of food security.

Crops are divided into five significant classifications: food, cash, plantation, commercial, and horticultural crops (Food and Agriculture Organisation, 2010). Yield represents the economic part of the plant that consumers utilize. Depending on the type of yield, crops are further separated from one another with the category of their economic parts: grains, seeds, cereals, tubers, bulbs, rhizomes, fruits and vegetables (Fabioclass, 2021). The quality of these economic parts determines the value of the yield.

Several factors affect crop yield and are inter-dependent, which poses significant risks (Omnia, 2017). Broadly these factors are classified under three categories; technology (managerial decisions and agricultural practices), biological (weeds, pest and diseases), and the environment (climate, topography and soil quality) (Liliane & Charles, 2020). However, the focus is on soil quality as this trial deals with comparisons between the effects of fertilizer on the yield of traditional and modern potato cultivars.

The quality of soil vastly influences crop growth (Liliane & Charles, 2020) (see figure 7.1). The soil profile comprises four key components: air, water, minerals, and organic matter from decomposing dead plants, animals, fungi, and bacteria. Understanding these components is crucial as different crops tolerate different conditions; some grow best in water-rich soils, while others grow best in mineral-rich soils with optimum water (Ominia, 2017). A specific combination per crop of these critical components is required for their growth and survival.

Figure 7. 1 A visual comparison of a good soil and poor soil[25].

The capacity of the growing medium (soil) to provide nutrients and minerals essential for plant growth is known as soil fertility (Turner, 2016). These elements are required for a plant to complete its life cycle, they cannot be replaced, and any deficiency leads to poor plant growth (Imran & Gurmani, 2011). These elements are present in the soil naturally and can also be supplied to the soil through chemicals known as fertilizer.

Fertilisers are chemical substances that contain essential nutrients required by plants for improved growth and yield (Manyong, Makinde, Sanginga, Vanlauwe, & Diels, 2001). Fertiliser is key to rejuvenating the soil by providing nutrients the plants need to grow healthy. In nature, there are seventeen critical plant nutrients and these are termed as macro and micro nutrients (Meena, Sharma, & Rawat, 2006). These nutrients are provided by the soil. However, the soil cannot keep up with the pace of agriculture that attempts to feed a growing population. When crops are harvested the nutrients taken up by the crops also leave the soil, leading to the removal of important nutrients draining the

[25] https://www.starkbros.com/growing-guide/article/soil-health

soil of nutrients (Setiyono, Walters, Cassman, Witt, & Dobermann, 2010). This is where fertilisers are applied to replenish the lacking nutrients.

This trial investigated the effect of fertilizer application on the yield of traditional and modern potatoes. The focus is on the impact of nitrogenous fertilizer on potato yield (see Figure 7.2). Nitrogen (N) is an essential nutrient required by potato plants in considerable amounts; however, the application timing impacts crop yields (Fandika, Kemp, Millner, Horne, & Roskruge, 2016). High yields in potatoes are influenced by N as it acts as a fuel for growth, especially during the establishment phase.

N targets important growth characteristics in potatoes such as leaf and stem formation and growth, supporting tuber growth (Maier, McLaughlin, Heap, Butt, & Smart, 2002; Millard & Marshall, 1986; Ojala, Stark, & Kleinkopf, 1990). Research has proven the beneficial effects of nitrogenous fertiliser on potatoes, and different doses have been suggested for different cultivars among researchers. Potatoes generally need more N than the soil resource can supply, and therefore the supplemental application of fertilisers is required (Ojala et al., 1990).

Optimizing fertilizer is an integral part of any cropping operation (Akpan, Nkanta, & Essien, 2012). The rate, type and method of fertilizer application can significantly impact the costs and receipts of production. In addition, inefficient fertilizer use can cause off-farm problems that create environmental and human health difficulties (Savci, 2012). Developing a sound plan for fertilizer use is good practice for modern farmers.

Figure 7. 2 Two fertilisers that supplement nitrogen in Fiji, urea (left) and NPK (19:19:19)[26] (right)

[26] http://www.elteechemindia.com/fiji/npk-fertilizers.htm

This trial utilised four varieties of potatoes; two traditional and two modern varieties. These varieties were put in two plots; treatment receives fertilizer application while no fertiliser application is on the control. These two plots are replicated for comparison between treatments and varieties. Cropmaster 15, (14:8:10:10) fertilizer, was used as a base at planting.

7.2.1 Aim of Fertilizer Trial

This fertiliser trial aims for students to gain a basic understanding of the impact of at least one macronutrient through fertiliser placement in a crop production cycle. The macronutrient selected for this trial is nitrogen, as it plays a crucial role in potatoes and is essential for many crops. However, while this trial deals with potatoes, other subterranean or traditional crops such as taro, cassava or sweetpotato could be a substitute. The objectives of this trial are to:

- Design and implement a trial template suited to fertiliser inputs and teaching resources.
- Measure critical plant responses such as growth rates and photosynthesis.
- Undertake a critical review of the fertiliser requirement for a sample crop.

7.2.2 Potato as a Learning Tool

Fertiliser plays a vital role in agriculture, with its effects witnessed throughout a crop cycle. The selection of potato to be adopted in the fertiliser trial was the most appropriate crop available, as it required 3 to 4 fertiliser applications during its growing period. Differences were visible with every application.

Whether commercial or traditional, imported or cultivated, potatoes are found globally and come in different colours, shapes, and sizes. A total of 100 to 180 species of wild potatoes and more than 4200 landraces are found in the Andean region (Panta et al., 2015; Struik, 2008). This experiment trials four different types of varieties in New Zealand two traditional varieties: Tutaekuri and Moemoe, and two modern varieties: Nadine and Taurus (see Figure 7.3).

Potatoes are grown in the high lands of Sigatoka and Naitasiri in Fiji, where the growing conditions are favourable (Iqbal, 1982). With rural to urban migration, high costs of traditional root crops, and consumer preference, potatoes can cater to the growing population as a healthy alternative (Vurebe, 2018). However, adopting the right agronomic combinations towards the cultivation of potatoes with favourable climatic conditions will increase the production of potatoes in Fiji.

7.2.3 Profile of Potato Varieties

Potato (*Solanum tuberosum*) is a starchy, tuberous staple food crop grown in more than 100 countries under tropical, sub-tropical and temperate conditions (Reddy, 2018). Temperature is the main limiting factor affecting production: this is an excellent cool-weather crop. The potato is a herbaceous annual plant with a short vegetative period, and it produces a tuber called a potato, an enlarged portion of an underground stem or stolon (FAO, 2008).

Potato is a crop attached to history and part of the ancient civilisation (Erickson, 2000). This crop is proven to have been cultivated 8000 years ago near Lake Titicaca, which sits at the mountain range of South America, on the border between Bolivia and Perú (Spooner, McLean, Ramsay, Waugh, & Bryan, 2005). This is believed to be the place of origin based on chloroplast DNA sequencing.

The potato crop is the most important non-grain food crop globally and ranked 4th in terms of the total production of all crops (FAO, 2008), after rice and wheat and maize. Potatoes play a much more significant role in history than just a dietary staple worldwide. From the 1960s, the cultivation of potatoes began expanding in the developing world. For China and India alone, total production rose from 16 million tonnes in 1960 to almost 100 million in 2006 (Scott & Suarez, 2012). Other countries like Bangladesh, and Southeast Asia and the highlands of 32 African countries have also tapped into the growing demand for potatoes from food industries as starch and alcohol production (FAO(Food and Agriculture Organisation, 2008).

Traditional Varieties

Maori are the indigenous Polynesian people of New Zealand and have cultivated traditional potato varieties for over 200 years (5adaynz, 2013). These varieties are relatively smaller than the modern varieties and come in various shapes and many colours (McConnell, 2021). This generation has experienced the loss of a few traditional varieties[27]; however, few were recovered with indigenous gardening and research encouragement (New Zealand Museum, 2021).

Tutaekuri is the most famous traditional potato in New Zealand; however, they are much more than just small purple potatoes associated with Maori whakapapa or lineage (McConnell, 2021; Roskruge, 2014). Physically, tutaekuri is a long yam-like shape with dark purple skin and purple flesh and is consumed through baking, boiling or chips (New Zealand Museum, 2021). Also known as Urenika, this Maori potato takes at least three months for the first harvest and can be left for as long as 4 to 5 months for a sizeable harvest and better storing (Awatea Organics, 2021). The seed tubers are planted after the frosts from September to August. Tutaekuri can persist in the soil for long periods as ground storage.

Moemoe refers to the good storage factors of this potato variety, and similar to tutaekuri, it is associated with Maori whakapapa (Roskruge, 2014). This traditional variety is an oval round-shaped, medium-sized, creamy fleshed potato with mottled light purple and creamy skin (Newtons Seeds, 2021). Moemoe is cultivated after the frost months and is a late variety harvested in 4 months after planting (Smith-Dawe, 2021). Best consumed baked, boiled, or chips they have an excellent keeping if stored in a cool, dry area and stored well underground.

Figure 7. 3 Fully matured traditional and modern potato varieties (from left moemoe, Nadine, taurus, Tutaekuri). Joeli Savou, Palmerston North.

[27] see www.tahuriwhenua.org (Tahuri Whenua - National Maori Horticultural Collective)

Modern Varieties

The introduction of modern potatoes to New Zealand was believed to have arrived with early whalers, explorers and sealers (New Zealand Museum, 2021). Te Horeta Te Taniwha recalled childhood memories of the first introduction of foreign potatoes to New Zealand by Captain James Cook in 1793 during his first voyage (Roskruge, 2014). However, in the 1790s Lieutenant Philip King introduced white potatoes and influenced their adoption to the Maori diet (*ibid.*). In more recent times the breeding and importation of more tolerant, resistant and yielding varieties has occurred to improve potato production in New Zealand (Sood, Bhardwaj, Pandey, & Chakrabarti, 2017).

Nadine is an early-season high yielding cultivated mid-July and matures 80 to 100 days after planting, making it an early potato crop known for having absent or low flowers (Morton Smith-Dawe LTD, 2021; Science and Advise for Scottish Agriculture, 2019). The main crop can be harvested in 4 months after planting. This modern variety is round, white-skinned with yellow flesh potato that tends to be slightly waxy (Wilcox, 2021). Consumption is preferred through boiling, soup and salads. Nadine is known to have good keeping properties under a temperature of ~5^{o}C in cool, dry and rodent free areas. Ground storage until required is also an option; however, waterlogged conditions is not favourable for storing Nadine (Seeds and Cereals, 2016).

Taurus is a medium late, a great yielding variety that matures in four to five months after planting (McDonald, 2021). This variety is robust with broad adaptation, expressing resistance to a range of diseases and is tolerant to dry conditions (Horster Zwem & Polo Club, 2021). The tubers are short and oval, light yellow flesh and yellow skin with a pink with very shallow eyes (Potato council, 2021). Taurus is a crisp variety that is mainly preferred to be fried and utilised to produce chips. This variety has excellent storability, where favourable conditions fall under 8^{o}C to 10^{o}C. Taurus can also ground store until required (Horster Zwem & Polo Club, 2021).

7.2.4 Cultivation of Potato

Potato has a temperature range for production from 10^{o}C to 30^{o}C; beyond these temperatures, potato yield is sharply inhibited (Food and Agriculture Organisation, 2008). However, temperatures ranging from 18^{o}C to 20^{o}C is proven to have positive effects on potato yield. This crop is planted in early spring under temperate zone conditions, late winter in warmer regions and cooler months in tropical climates (Reddy, 2018). There are many improved and traditional varieties available globally.

Potato prefers loam and sandy soils for cultivation, which are loose and have less resistance for tuber enlargement (Dkhil, Denden, & Aboud, 2011). Accompanied with good drainage and aeration with a soil pH of 5.0 to 5.5 is considered ideal for potato cultivation (Fenton-Smith, 1995). The potato crop is usually grown from small tubers of 40 to 60 grams, known as seed potatoes. Seed potatoes are sown at 5 cm to 10 cm depth, 30-35 cm apart within rows which are a meter apart and will emerge 3 – 4 weeks post-planting depending on the variety.

7.2.5 Agronomic Activity

Crop care is critical throughout the life cycle of the potato crop. During the development of the canopy, extra care must be given to the crop a competitive advantage during the establishment phase (Adoukonou-Sagbadja, Dansi, Vodouhè, & Akpagana, 2006). Key agronomic activities are weeding, irrigation, hilling, fertiliser application and the control of pests and diseases (PotatoPro, 2021).

The application of fertiliser depends on the level of available nutrients in the soil which can be determined through a soil test (see Section 4.2.1). A base application of NPK is applied at planting to support the establishment of the crop, followed by two and sometimes three side-dressing of fertilisers over the next 3 months including urea to encourage growth to the maturity stage (Tremblay et al., 2008).

Proper intercultural operations as weeding and mounding are necessary for good plant growth (Food and Agriculture Organisation, 2008). During the first month of potato establishment, weeding is necessary to avoid the competition of nutrients between the crop and the unwanted plants. The presence of weeds simultaneously contributes to the difficulty in carrying out field operations such as mounding, which loosens the soil for appropriate tuber development (Reddy, 2018). The mounding operation is required for two reasons; to hold the plant upright and prevent the exposure of tubers above ground. Good timing for the mounding operation can also serve as the weeding exercise.

Irrigation is a key factor in determining the yield and quality of potatoes. It is important that soil moisture content is maintained in the field at a relatively high level (Food and Agriculture Organisation, 2008). Positive yield outcomes require 500 mm to 900 mm of water throughout the crop cycle. However, irrigation requirements vary between varieties, soil type and weather conditions (Reddy, 2018). Generally, water deficiency in the middle or late potato life cycle tends to decrease yield more than a deficiency in the early parts of the growing period. Due to its shallow root system, yield responses to frequent irrigation is considerable, and high yields are obtained with the adoption of sprinkler irrigation (Ünlü, Kanber, Şenyigit, Onaran, & Diker, 2006). Adequate irrigation is vital for plants to activate photosynthesis; however, over-irrigating may cause disease infestations or drowning crops.

7.2.6 Data Component

The two key components that describe the effect of fertiliser on plant growth are the plant's fresh and dry weights. The inclusion of control plots with no fertiliser is adopted to compare how fertiliser has contributed to potato growth in the plot where fertiliser was applied. Evaluating a fertiliser effect on growth requires a combination of notetaking during the experiment and a total weight measurement at the end of the growing period.

The measured components in this experiment included the physical and morphological changes of each variety taken through note-taking, for instance, germination percentage, or the appearance of cotyledons and flowers (Science Buddies, 2021). These measurements are followed by the end of the growing period measurements, including the fresh and dry weight measurements to capture enough data on the plant's overall yield.

Measuring the fresh weight of plants can be very tricky as the water content of the plant is continuously changing. Therefore, it is critical to measure fresh weight in the cooler period of the day, of each of the top growth, roots and tubers (see Figure 7.4) as soon as possible to avoid any inaccuracy in measurements. The measurement of fresh weight includes three simple processes:

1. Removal of plant from the planting medium and carefully wash off any loose soil on the plant.
2. Removal of excess water from plants with tissue or paper towel.
3. Weighing the plant immediately.

The dry weight of any plant is the exact mass of the plant and is constant. Measuring the dry weight of plants is straightforward, where the same plant material obtained for fresh weight is utilised. This process involves removing water from the plants and measuring to represent the dry biomass of the crop.

1. Place dried plants in the oven set to low heat of 60°C to 80°C 24hrs or longer.
2. Remove plants and allow them to cool and weigh them on a scale.
3. The scale also needs to measure milligrams as dry biomass can be significantly low when removing water from the pants.

Figure 7. 4 Potential data component of Potato (leaf, stem, root, and tubber). Joeli Savou, Palmerston North.

7.2.7 Fertiliser Trial on Potato (*Solanum tuberosum*)

The fertiliser provides nutrients to plants that are not readily available in the soil, fostering plant growth and increased yields. Careful and efficient nutrient use should be the cornerstone of any production system, as too little may lead to nutrient deficiency and too much leads to nutrient toxicity.

Nitrogenous fertiliser adopted as a nutrient supplement plays a crucial role in developing a crop (Leghari, Wahocho, Laghari, HafeezLaghari, MustafaBhabhan, HussainTalpur, Bhutto, et al., 2016). Nitrogen is an essential nutrient for potatoes as it is a core component of both the internal and external metabolic processes (Novoa & Loomis, 1981). These processes include:

- The plant structure, growth and development, cell membrane, and chlorophyll are vital for the plant (Leghari, Wahocho, Laghari, HafeezLaghari, MustafaBhabhan, HussainTalpur, & Lashari, 2016).
- The formation of genetic materials of the plant, which aids in transferring traits and characteristics to the future generation of plants (Anbessa, Juskiw, Good, Nyachiro, & Helm, 2009).
- The main component of chlorophyll, which is responsible for photosynthesis and the green pigment of the plant (Dobermann, 2005; Novoa & Loomis, 1981).

Deficiency symptoms of nitrogen in plants include shorter plants, pale yellow leaves, purple colourations underneath certain plants' leaves, and stems (Leghari, Wahocho, Laghari, HafeezLaghari, MustafaBhabhan, HussainTalpur, Bhutto, et al., 2016). Severe cases of nitrogen deficiency may lead to the death of plant cells which ultimately kills the plants.

The key objective of this trial was to understand the relationship between nitrogen and its role and impact on plants. Once this is understood, an attempt to formulate the optimum rate and time to apply fertilizer can be practiced. However, the principle behind this trial is not restricted to a particular crop, nutrient or fertilizer. An extension from this trial would allow students and farmers to explore the effect of this or other nutrients on other crops and finally formulate an optimum rate that will produce optimum yield.

Furthermore, the purpose of this experiment is to transfer knowledge to students regarding the importance of fertilisers in crop production, identifying critical nutrients required by crops, time of application followed by the application dose suitable for crops. The manipulation of fertiliser inputs requires skills and critical thinking to attain accurate information to suit the requirement of any particular crop (Hunter et al., 2009). However, students require a template to guide them through achieving a standard level of information.

Figure 7. 5 Cultivation of potato under fertiliser application with the spacing of 50cm within rows and 1m between rows. Joeli Savou, Palmerston North.

7.2.8 Fertiliser Trial Materials and Methods

An accepted commercial standard-based planting and crop husbandry for potatoes was adopted (Roskruge, Pers. Comm.). Four varieties were selected to represent both modern varieties (Nadine and Taurus), and traditional varieties (Moemoe and Tutaekuri) and they were planted on 2 December 2020 and harvested on 29 March 2021.

Seed tubers were planted on the Manawatu sandy-loam soils on an area tested to have deficient nitrogen levels. The application of 2kgs per block of Cropmaster 15 fertiliser at planting and side dressing eight weeks after planting. This fertiliser is a blend of DAP, chipped Potassium Chloride and Ammonium Sulphate Granular at a ratio of 14:8:10:10 (N:P:K:S), respectively. This fertiliser is commonly used in cropping situations in New Zealand where nitrogen is required at establishment.

Weeds, pests, and diseases were controlled using Fusilade™, Sencor™ , Glyphosate™ (herbicides) and Ridomil™ (fungicide) at appropriate times and industry approved dosages. Mounding was done in week five after planting, which lasted throughout to harvest of the crops. The potatoes were irrigated equally two times a week, depending on available rain and soil conditions.

7.2.9 Layout and Design

According to the spacing and number of replications, a total area of 30 m^2, consisting of four 7m^2 blocks with six rows of potatoes in each block (see Figures 7.5 & 7.6) was utilised. The rows of potatoes were 1m apart, where each row had a uniform total of twenty-one potatoes with a planting distance of 35 cm within rows (Palmer et al., 2013). The spacing between neighbouring blocks consists of 1m, restricting fertiliser influence between blocks (Vanclay, 2006).

The adoption of a standard Randomised Complete Block Design (RCBD) compares the effects of different fertiliser applications grouped into blocks or replicates (Peter , Pearson, & Bendall, 2003). Replication of treatments was adopted to provide further validity and preciseness to the results compared to one another and the originally forecasted outcome (Makel, Plucker, & Hegarty, 2012). However, there can be a problem when dealing with treatments of a small number, and significant variations may lead to errors.

Each of the four blocks contained four potato varieties, with different planting sequences within the respective blocks. A row of the trialled varieties consisted of fifteen potato plants. Blocks one and four received a standard commercial fertiliser dose at planting and side dressing eight weeks after planting, whilst blocks two and three were without fertiliser.

Guard rows are adopted as it aids in crop separation and avoid the extensive edge effect (Langton, 1990; Mountier, 1964). Each block's first and last rows were used as guard rows, covering two sides of the block, with three plants on each row's end (see Figure 7.6) Apart from the four trialled varieties, Agria, a commercial potato variety in New Zealand, was adopted as guard rows for the experiment.

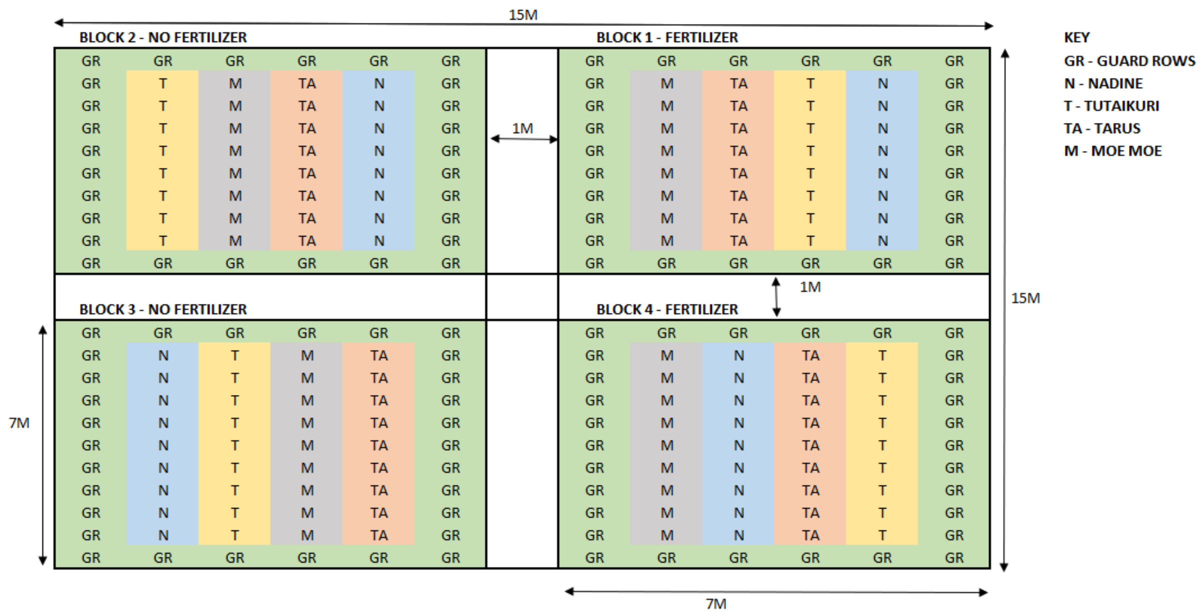


Figure 7. 6 Complete randomised block design of potato trial demarcating the guard rows from the various varieties (GR – guard row, N – Nadine, T – Taurus, M – Moemoe, TA - Tutaekuri). Joeli Savou, Palmerston North.

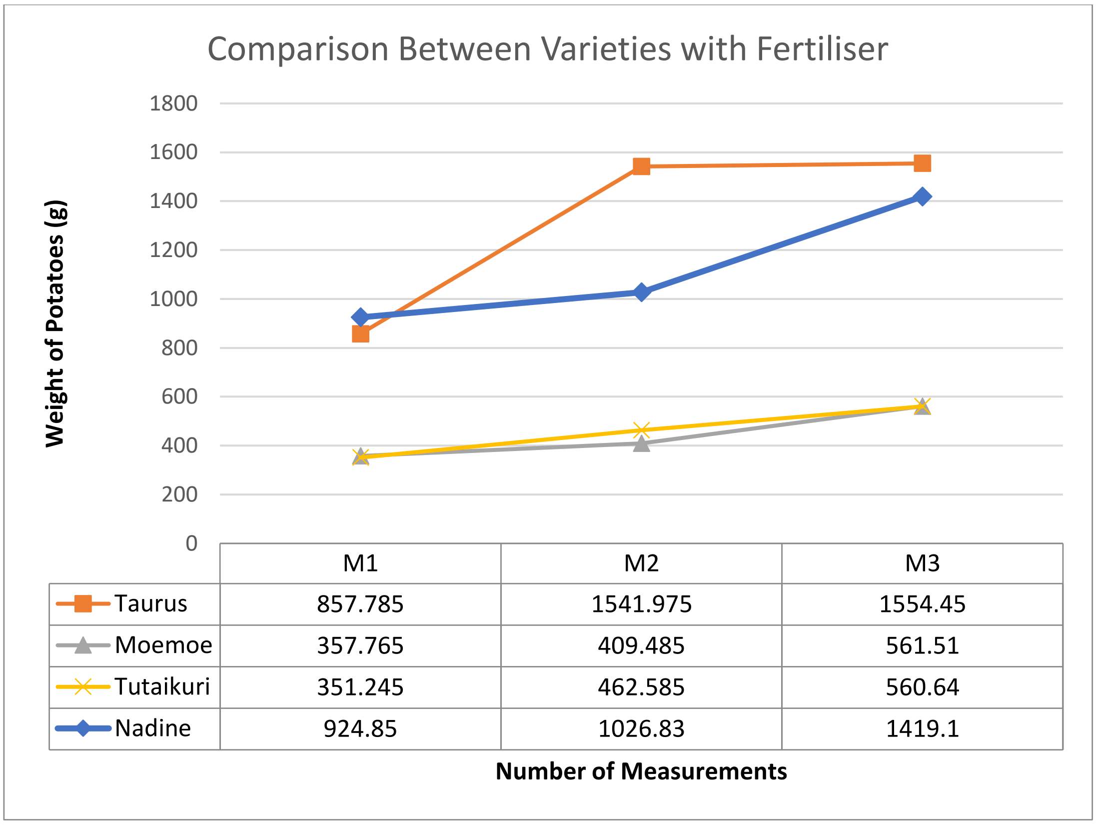
7.2.10 Fertilizer Trial Data Analysis

In this fertiliser trial, students identify the distribution of nitrogen throughout the plants and their roles in those allocated areas. However, the adoption of different varieties will also uncover the reactions of these varieties on the applied nitrogen fertiliser (Regassa, Tigre, Mellise, & Taye, 2016). Students may further expand this experiment by adopting the same principle on different fertilisers or a combination of fertilisers on various crops and record its impacts.

Critical observations were conducted weekly from planting to harvest to monitor the nitrogenous fertiliser's impact alongside a visual comparison. A destructive harvest was undertaken at weeks thirteen, fifteen and seventeen to measure the tubers at three different production stages (establishment, post establishment and maturity). The results were as predicted for the modern varieties with significant nitrogenous fertiliser impacts. However, the traditional varieties differed, showing only slight changes (no statistical difference) between plots that received nitrogenous and plots without fertiliser.

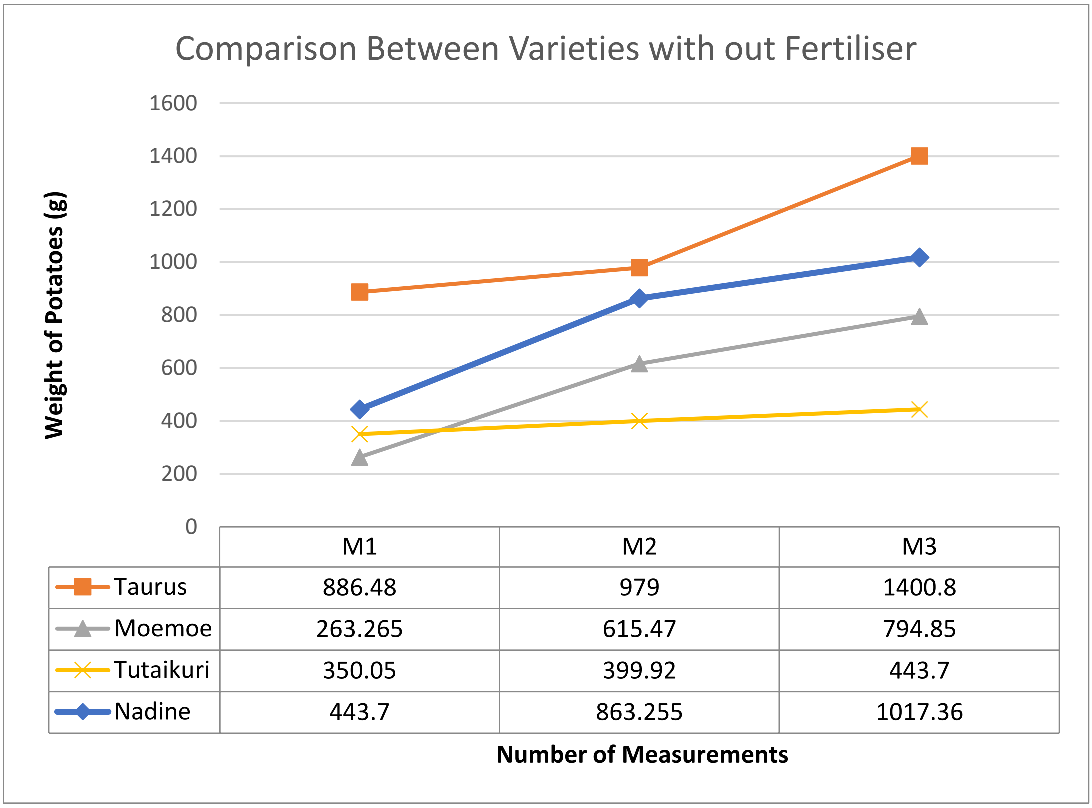
The fertiliser trial proves that modern potatoes (Taurus, Nadine) are more responsive to nitrogen applied fertiliser than traditional varieties (Moemoe, Tutaekuri) (see figures 7.7 and 7.8). However, traditional varieties such as Moemoe can produce as much marketable yield as modern varieties. The results express that nitrogen is essential for both modern and traditional varieties, although in different ways. A similar result was obtained from past research (Fandika et al., 2016).

Undertaking the trial is a simple task when guided by the fertiliser template. The challenge lies in meeting pedagogical processes, especially for indigenous students, which facilitates students' absorption and interpretation of knowledge to be assessed.



	M1	M2	M3
Taurus	857.785	1541.975	1554.45
Moemoe	357.765	409.485	561.51
Tutaikuri	351.245	462.585	560.64
Nadine	924.85	1026.83	1419.1

Figure 7. 7 Impacts of fertiliser application on traditional and modern potato varieties



	M1	M2	M3
Taurus	886.48	979	1400.8
Moemoe	263.265	615.47	794.85
Tutaikuri	350.05	399.92	443.7
Nadine	443.7	863.255	1017.36

Figure 7. 8 Impact of no fertiliser application of traditional and modern potato varieties

Various forms of plant growth are impacted by nitrogenous fertiliser, which contributes to the yield of potatoes. These include the size and number of leaves, stems, and roots. Further studies can include:

- Effect of nitrogenous fertiliser on these plant parts and its overall impact on potato yield.
- Comparing two fertiliser rates as treatments for a particular crop to identify which treatment produces the better yield.
- Impact of favourable application rates on the surrounding environment.

There are numerous aspects to address while dealing with the impact of fertiliser on any crop (Zhenbang, 2003). It depends on the learning objectives on which aspect of the effect of fertiliser is addressed. Linking this practical activity with the current fertiliser issues present in Fiji aids students to develop critical thinking and a life-long experience that can be passed on or utilised by students in their farms (Jarvis and Peter, 2004).

7.2.11 Fertiliser Trial Template

The template provides an experimental approach suitable for adoption on a wide range of crops for students (see Table 7.1). It is designed in a sequential order to enable students to plan, establish, execute, and analyse a fertiliser trial on a single crop. The template provides a uniform practice which can adopt any fertiliser application on various crops.

Table 7. 1 Modified template of a fertiliser trial

Fertiliser Trial Teaching Template			
Step	**Research Procedure**		**Questions to ask (Students)**
1	Pre-Trial	The right concepts	• Is the aim clear? • Are the trial objectives clear?
2	Pre-Trial	The right treatments	• Will a comparison of fertiliser be applied and no fertiliser applied to offer the required information? • Do the treatments differ? • Can the treatment be accurately applied? • How is the fertiliser application calibrated?
3	Pre-Trial	Measurement sorting	• Have before, during, end, after, and trial measurements been planned?
4	Pre-Trial	The right design needs to meet analysis procedures to follow the trial	• Is the selected site best for the trial? • Is there a replication of treatments, and how many? • Have the treatments been randomised? • Have the plots been arranged to get the best results from the site?
5	Pre-Trial	The right site	• How will the plots be marked out? • Have before trial measurements been done? • Has a data sheet being prepared?
6	Pre-Trial	Proceeding to the trial	• Have pre-trial soil tests been taken? • Is the fertiliser being applied uniformly? • Are there records of site conditions at planting time?
7	Trial	Monitoring of the trial	• Are fertiliser rates applied correctly? • What measurements are being targeted? • How regular will the measurements be? • Do you need to record weather information?
8	Post-Trial	Concluding the trial	• Is the harvest area selected and marked? • Is there proper harvesting equipment? • Are there data sheets prepared? • Is the harvesting procedure straightforward?
9	Post-Trial	After the trial	• Have samples been saved for quality analyses? • Do you need to do any follow up soil tests?
10	Post-Trial	Analysing the results	• Are the data complete and accurate? • Are the data entered? • How will the statistical data be analysed? • Have the results been recorded and concluded?

The fertiliser trial addresses one of Fijis major agricultural weaknesses. This trials offers first hand knowledge of both the positive and negative impacts of the application of fertilisers. Visually identifying the effects of fertiliser addition and timing to plants will encourage questions relating to the absorbtion of nutrients, its conversion to energy and its utilisation by the plants. Similarly, addressing the impacts of nutrient addition on soil and environment, which should come naturally for an agricultural student will automatically contributing to critical thinking.

Chapter Eight

Discussion

8.1 Introduction

This chapter discusses the findings presented earlier to answer each of the research questions.

8.2 Primary Findings

Traditional knowledge adopted by early indigenous Fijians is passed down over generations through conversations, stories, songs and dances (Lagi, 2021). Observing and practicing through trial and error are the fundamental learning tools of indigenous Fijians as this involves hands on learning that implants knowledge and is refined at each practice..

Holistically, agronomy is most applicable to global issues as it integrates several key sciences (Lichtfouse et al., 2009). Developed countries have involved farmers for an easy adoption (Makowski et al., 2014). Therefore, trials can be conducted on farmers' land for adoption and modification if required. Literature confirms the potential of on-farm trials in developing countries such as Fiji (Kyveryga, 2019).

Learning theories adopted world-wide promote methods to address student learning, where learning is driven through teacher or student oriented approaches (Watkins & Mortimore, 1999). However, education specialists suggest a comination methods to cater for the needs of the class as students respond differently to the mentioned approaches (Dutton, 1987). Indigenous Fijians as highlighted throughout this paper are practical people, therefore a combination of methods is required to address indigenous learning.

Introducing practical work to supplement the theoretical activities to substitute a theory heavy system is a positive approach to target indigenous Fijian learning. The proposed approach further contributes to students technical knowledge, critical thinking and decision making while encountering similar activities at university or at the field of work. The adopted trials meet the research aims of this thesis as a clear understanding can be attained based on the learning theories of indigenous people and the researcher's experience as an indigenous student and instructor engaged in tertiary education at Fiji's prominent agricultural university. In line with the objectives, the results obtained from the designed pedagogy contain sufficient evidence to develop critical thinking and experience by indigenous students.

The results clearly indicate that although the three trials had different objectives, all are aimed to improve or promote learning for indigenous students by including practical activities to supplement the theoretical experiences they engage in. The results from each trial expressed similar patterns that were visible both practically and graphically between the treatments and the control. The graphical representation of the results in the different trials presented distinct variations which aid in understanding the respective objectives.

The inclusion of templates of individual field trials supports students to carry out the trials in a sequential manner to achieve their objectives. The templates contain ten simple procedures directed by appropriate questions that vary depending on the objectives of trials. With the help of the formulated templates, students can plan, establish, execute, and analyse a trial on a crop or crops for a more advanced approach towards an objective. Students need to also keep a dairy for the duration of the trials which include environmental factors such as weather in case there is a need to refer to it in the later stages of the trials.

Students' knowledge absorption is judged through assessments. The utilisation of assessment tools such as the practical activity, recording and interpretation of data and scientific result reporting is deemed sufficient through the research experience to promote learning. These selected assessment tools have tremendous implications for students learning, not only in the classroom but in the workforce itself. These continuous assessments will further aid the consistent tracking of student development and understanding.

The justification of each assessment is;

- To practically participate in constructing field trials guided by templates produced by instructors is an assessment on its own, as this educates students on how to design and conduct research.
- The interpretation of the recorded data through a graphical representation and identifying the critical points, with a visual comparison of on-field crops, engages students in critical thinking.

- Producing a full report describing the trial and its objectives introduces students to scientific result reporting.

Reviewing a range of agronomy trials to address Fiji's agricultural issues such as food security and climate change by students with farmer participation will support positive results and improve production.

Upon the completion of a trial through the adoption of the templates, indigenous Fijian students and farmers will gain a sense of development through the improvement of their technical knowledge and utilise critical thinking to address current agricultural problems. However, the assessments adopted to measure the amount of knowledge gained by students is only proper to be designed by pedagogical experts in Fiji and the Pacific. This paper only provides recommendations on how students' knowledge absorption is assessed based on the researchers experience as a student and an instructor.

The adopted analyses and equipment utilised to gather and interpret data in this paper are based on their availability in New Zealand tertiary institutions. This may differ in Pacific conditions, however there are other equipment available that can be utilised to obtain similar results. Practioners should not be discouraged with the lack of specialised tools, adaptive and innovative ideas of trials to address the current agricultural problems is integral. Furthermore, purchasing of such equipment will guarantee an easier, quicker and accurate data collection. Similarly, the selected crops act as a vehicle that drives the experiment, there is no issue of what crop is utilised if the templates are followed and directed with appropriate questions.

8.3 Implications of the study

The experiment provides new insight into the relationship between the inclusion of field trials at the tertiary level and its potential to promote learning for indigenous Fijian students. The concept behind field trials has been practised for decades by developed countries, where the main idea is to compare and evaluate different practices, production and technology under realistic growing conditions. Adopting field trials by developing countries to improve their agriculture sector is recommended as reviews confirmed the development of knowledge and critical thinking of farmers participating in field trials. Hence, the importance of its implementation at the tertiary level in Fiji and also the wider Pacific.

The fourth sustainable development goal established by the United Nations focuses on quality education. This goal contains seven targets, and among the seven targets, three directly support the arguments of this paper. They are:

1. Target 4.4: substantially increase the number of youths and adults with appropriate skills, including technical and vocational skills, for employment to decent jobs and entrepreneurship.
2. Target 4.5: eliminating gender differences in education and ensuring equality through access to all levels of education and vocational training for the vulnerable, including people with disabilities, indigenous people and children in vulnerable situations.
3. Target 4.7: ensures that all students obtain the knowledge and skill required to encourage sustainable development, among others, through education for sustainable development and sustainable lifestyles, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and cultures contribution to sustainable development.

   Pages 31 – 33: The 2030 Agenda and the Sustainable Development Goals[28]

Implementing field trials in agricultural tertiary education in Fiji is a broader approach to learning, where the key objective is for students to develop understanding, technical knowledge and critical thinking with enforced practical activities that supplement theoretical experiences. Having students participate in carefully constructed field trials

[28] https://repositorio.cepal.org/bitstream/handle/11362/40156/25/S1801140_en.pdf

and their analysis to present the findings in a report will undoubtedly tick these capability boxes. Therefore, the results support the existing theories of field trials; however, its adoption at the tertiary level makes it the first of its kind to be documented.

The Secretariat of the Pacific Community (SPC) has stressed the need for extension officers to be trained to conduct field trials and disseminate it to the farmers (Secrateriate Pacific Comission, 2021). Stakeholders have identified field trial research as key to reviving agriculture in the Pacific and/or responding to wider issues such as climate change and food security. However, extension officers lack of knowledge and technical skills currently puts these projects on hold.

There is potential for implementing field trials at tertiary levels to promote learning and introduce students to what they will face in the field when they graduate. With developing understanding, technical knowledge and critical thinking, students will be well equipped with demanding new knowledge to impact the agricultural workforce. Guided by formulated templates, students can plan, establish, execute, and analyse a trial on a crop or crops for a more advanced approach towards an objective.

Furthermore, the sequential (and repetitive) procedure needed to complete a trial offers enough information for students to grasp the essential requirements to cultivate a particular crop, focusing on current conditions and practices. Students can adapt the field trials with farmer involvement as a tool to learn, target and address current agricultural problems such as climate change and food security. With the adoption of formulated templates and establishing key trials, agricultural tertiary providers in Fiji can serve a dual purpose of educating students and providing a much-needed service to local farmers. Some of the critical trials include:

- Trialling varieties that thrive in different areas due to their climatic conditions to improve production.
- Trialling fertiliser types, applications, and doses to produce optimum yield with low environmental hazards.
- Trialling various crops at different seasons to readjust to the changing climate.
- Trialling tillage operations to suit the cultivation situation of various crops.
- Trialling pesticides to control pests and improve yield with minimal environmental hazards.

- Trialling irrigation methods to attain optimum yield with minimal water use.
- Trialling physiological responses of plants to light for optimum growth.
- Trials for weed control and its suitability for different crops.
- Trials for integrated pest management practices to capitalise on cost, and effectiveness.
- Trials for soil management practices and erosion control to safeguard the soil and crops.

Farmers in developed countries utilise field trials as a risk management tool to test new methods and ideas to adapt and build farm resilience (Secretariat of the Pacific Community, 2015). The inclusion of farmers to participate during the trials is a necessity to impact Fiji's agriculture. This way, there is communication between farmers and researchers regarding the current constraints being faced by them. The researcher-farmer engagement aids the researcher to understand the micro-climate of the specified farmer region, which is a crucial element required to implement trials. However, most importantly, to convince the farmers to adopt a new practice, farmers need to be physically present to witness the benefits of the trialled practice.

Being a risk management tool, farmers adoption of field trials will save them time. Time is vital for a farmer as they rely on the seasons to cultivate certain crops. With the changing climate and the move to achieve Climate Smart Agriculture, crops also tend to adjust to the most favourable conditions leading to a shift in time for cultivation. As an example, prior to the usual seasonal mass cultivation or adoption of new crops and practices, farmers can run a trial to see the response of crops to climate change followed by the implementation of the most favourable result; this is a capability building procedure and also a contribution to Climate Smart Agriculture. However, climate change is just one factor that affects crop production. Other factors include irrigation, pest and weed control, fertiliser use, and economic determinations.

Similarly, cash flow regarding inputs and outputs plays a significant role in farming as farmers try to produce optimum yields with minimal inputs to make the most profit. Cultivating a crop out of place reduces the chances of obtaining profit, as, without its favourable climatic conditions, the crop will not produce optimum yields. Good examples of crops ostensibly out of place in Fiji are rice and potatoes, and the agricultural sector has funded the cultivation of these crops, investing millions of dollars only to continue to import these goods from neighbouring countries to meet the growing populations demand [29][30]. Setting up field trial research with the potential factors and attributes such as location, micro-climate factors or new varieties being addressed to optimise production and returns will have a positive effect on Fijis agricultural sector.

Currently, farmers rely on the Fiji Ministry of Agriculture's extension officers to bring about new practices and cultivation methods, which becomes an issue as extension officers lack numbers and innovative practices to revive the agricultural industry (Pers. Comm.). However, farmers participating in field trial research attain knowledge of the current agricultural practices for example, to mitigate pests and diseases or increase crop production. This involvement develops into critical thinking leading to personal development and utilisation of field trials to cater to farmer's needs . With the acquired knowledge, local farmers can act on their learning without waiting for extension officers. With the involvement of farmers in field trials, there will be a guaranteed increase in production which is a positive for Fiji's agricultural sector.

Adopting field trials will create potential for critical thinking and technical knowledge for indigenous Fijian students at the tertiary level. Similarly, with the participation of farmers in the management of the trials, the experiment will broaden their views on this risk management approach (Elias et al., 2016; Tanaka, 2021). Supported by the agricultural sector, the implementation of field trials has the potential to adapt to climate change with the formulation of more resilient approaches and ultimately lead to an increase in production, resulting in sustainability which addresses food security.

For decades, agricultural universities in Fiji have moved from a practical-driven approach to currently a theory-driven approach, seeking an appropriate space that promotes learning for students. Past researchers state that a combination of pedagogical approaches is the key to unlocking students' absorption of knowledge. Recent studies also state that learning is further promoted by providing a comfortable environment for students.

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29 https://analytics.wfp.org/t/Public/views/FijiAgricultureStatisticsOnlineDataLibrary/Trader?%3Adisplay_count=n&%3Aiid=6&%3Aorigin=viz_share_link&%3AshowAppBanner=false&%3AshowVizHome=n&%3AisGuestRedirectFromVizportal=y&%3Aembed=y#2

30 https://analytics.wfp.org/t/Public/views/FijiAgricultureStatisticsOnlineDataLibrary/Trader?%3Adisplay_count=n&%3Aiid=6&%3Aorigin=viz_share_link&%3AshowAppBanner=false&%3AshowVizHome=n&%3AisGuestRedirectFromVizportal=y&%3Aembed=y#2

Indigenous communities around the world are known to be practical people as they learn through observing and practising (Lagi, 2021). A change in the pedagogical approach in agricultural universities by including field trials and linking them with the theoretical experience forming a balance is guaranteed to promote learning for our Fijian indigenous students.

Adopting a series of field trials at the tertiary level as a practical activity to supplement the theoretical aspects of agronomy learning has been identified as a new practice in the education system. A standard practice in the future will be the manipulation of the given templates to suit the teaching objective to achieve a smooth-running operation of a field trial.

A boost in the agriculture sector is what Fiji needs now more than ever. The sector has been labelled vulnerable as it depends on imports to cater for the growing population wants (Shah et al., 2018). Climate change and food security can be partially addressed by implementing field trials throughout the Fiji's agriculture system. Addressing these current issues requires trials that aid in managing crops to achieve climate smart agriculture, simultaneously achieving self-sustainability with an increase in production. Similarly, supporting a healthy population through the consumption of fresh and safe locally produced goods and an improvement in the economy through reduction of import and increase in export.

Chapter Nine

9.1 Conclusion

Agriculture was once known as the backbone of Fiji's economy and is now a vulnerable sector with high food security risks. The core reasons for this label are the traditional mindset of local farmers, lack of critical thinking of agricultural graduates from local universities, inadequate extension services and climate change.

This research aimed to identify a practical pedagogical approach in agronomy to promote tertiary students critical thinking and technical knowledge. Based on the literature and review of current pedagogies and the quantitative and qualitative analysis of the experimental trials undertaken, it can be concluded that the inclusion of appropriate practical classes to supplement the theory being taught in class will promote positive learning. This paper adopted the use of field trials, where the results indicate its potential to develop critical thinking and life-long learning for indigenous Fijian (and the wider Pacific) students at agricultural universities.

For the past few decades, agriculture in Fiji has transitioned from a traditional sustainable method to more capital-focused cultivation (Shah et al., 2018). This transition has led to diversification in search of better alternatives and adopting crops out of place, such as potatoes and rice. The encouragement of these crops forces Fiji's agriculture sector to spend millions on obscure production through research, not realising the potential to invest in traditional or more common crops that thrive in Fiji's conditions.

With the sustainable development goals set for 2030 to improve the quality of education through forbidding discrimination and empowering both genders, different age groups, to free education with the emphasis to develop students with critical thinking and life-long learning, is the gap that this paper attempts to fulfil in an agricultural context. Aligned with this is the Fiji government sustainable goal for agriculture which is: produce more locally for local consumption, supporting their vision that states: creating a competitive, sustainable and resilient agriculture sector.

A mixed methodology approach was adopted in this research, where a combination of qualitative and quantitative paradigms was utilised to obtain factual data to answer the research question. The adoption of qualitative and quantitative methods proves to draw out the necessary information to support this research. The ability of the selected methodology to answer the research questions is expressed below.

The qualitative method included a literature review supported by Talanoa approach as informal interviews with Fijian students. They served a mutual purpose of accumulating information of the past and current agricultural pedagogical approach practised at the tertiary level in Fiji compared to international standards.

The quantitative approach involved a combination of trials and their weekly and concluding measurements providing core data. The trials were implemented supported by the contribution of a literature review, which stated that field trials are most suitable for improving technical knowledge and creating critical thinking for indigenous Fijian students.

In this process, three carefully considered trials and crops were adopted: spinach photosynthesis trial, broccoli variety trial, and potato fertiliser trial. The crops are merely tools acting to drive the experiment, and the templates produced from this research can be used to view the response of other crops to the same objectives. Collectively, this methodology contributes to designing necessary templates that aid indigenous Fijian students, farmers, and the agricultural sector to practice a risk management approach towards farming. The templates produced from this research can be used to view the reaction of other crops to the same objectives or produce more templates to address other agronomic factors.

The research also clearly illustrates the potential to promote learning for indigenous Fijian students, develop farmers and positively impact the agricultural sector. However, the dawn of Covid 19 and its impact on the education system forcing practical subjects like agriculture to adapt to online learning reminds us of the need for a strategy to practice field trials in an ever-changing world including emerging technology.

It can be concluded that:

- Indigenous Fijians are practical learners and a combination of pedagogical methods will contribute to positive learning.

- The adoption of appropriate practical experience to supplement theoretical acitivity will promote a clear understanding of knowledge.
- The implementation of on-farm trials at tertiary level has the potential to develop critical thinking and life-long learning.
- The introduction of on-farm trials to indigenous extension officers and farmers has the ability to promote resilliance in Fiji's agricultural sector.
- The formulated trial template in this paper is an appropriate guide to produce trials

9.1.1 Limitations of the Research

Similar to any research, limitations to this study must be accredited so that future opportunities can respond accordingly. Firstly, the current covid-19 situation has impacted the research at all stages, particularly at the data collection stage, where minimal data was collected to produce results for each trial because of site access restrictions amongst other restrictions. This was further impacted due to the restriction of movement within and between New Zealand and Fiji, especially for interaction with indigenous scholars and informants.

Second is the research's major limitation: the inability to conduct interviews, especially in a culturally appropriate manner, of agricultural academics at Fiji's tertiary institutes to get insight into applying field trials and pedagogy. Knowledge obtained from these people would have contributed wholly towards the research conclusion. However, past and present students compensated for the information gap, accompanied with the researcher's knowledge as a horticultural instructor for the past seven years.

The third limitation lies in the incapability of the research to fully expand the topics that would contribute to solid research due to time constraints. Topics such as:

- Incorporating field trials for an online world.
- Assessment of farmer participation during a field trial.
- The Vula Vaka Viti traditional cultivation is incorporated with field trials in Fiji's agricultural institutions.
- Exploring the importance of Fiji's traditional cropping systems
- Finding an equilibrium approach suitable for a combination of traditional and modern agriculture that produce optimum yield and is environmentally friendly.

9.1.2 Recommendations and Future Studies

A number recommendations can be made as an outcome of this research. The limitations put forward introduce research prospects that should be pursued in the future but should not detract from the overall outcome of this research: that practical field trials for tertiary agricultural education will contribute to the agricultural sector and country as a whole and should be implemented based on the templates provided as a positive learning experience for all involved.

Mo na cakacaka va kaukauwa ka kana mai na buno ni yadremu, me yacova na gauna o na lesu tale ki na qele. Ni o a buli ga mai na qele, o na suka tale kina qele.

Vakatekivu 3:19

Na kena mai vaka cavari na pepa qo, au vaka dei taka ni sega ni vei raurau na vei ka mera vulica na luveda nai taukei kei na vaitagedegede ni vuli e soli vei ira.

Na gauna ga oqo e nomu, yadra, tucake, vala taka - sara mai tauri vaka mamada ko ira na noda I liuliu ni mataka.

Sa noqu masu ni na laveti keda na kawa i taukei na leweni pepa qo.

Glossary

Anthocyanin – water-soluble vascular pigments that appear black, blue, purple or red depending on the vascular pigments pH. This phenomenon occurs in tissues of all higher plants.

Basal fertiliser application – the initial application of fertiliser to cater for the establishment of crops.

Behaviourism – a learning theory that states behaviours are learned from the environment, where innate or inherited factors have very little influence on behaviour.

Climate change – a long-term change in the average weather patterns in local, regional and global climate caused by factors such as pollution.

Climate-smart agriculture - methods that aid and guide actions to transform agri-food systems towards green and climate-resilient approaches.

Connectivism – a learning theory that suggests learners should share their thoughts, theories and general information in a useful manner.

Constructivism - a learning theory that states students construct on existing knowledge to learn new information rather than inertly take in information.

Cultivar - the outcome of selective breeding which produces various types of variety that contains a trait suitable for its purpose.

Didactive – systematically planning, designing or intending to teach individuals something.

Diploid – cell or organism that has paired chromosomes, one from each parent.

E-learning - learning conducted through electronic platforms provided by the internet.

Fertiliser side dressing – the application of fertiliser along the sides of the plants.

Food sovereignty – the right and ability of an individual to define and consume food that is healthy and produced through sustainable methods.

Guard rows – cultivated rows of crops at the edge of the fields that receives and absorbs the outside effects of foreign pests, disease, practices and unfavourable weather conditions.

Homozygous – consisting of two identical alleles of a particular gene or genes.

Indigenous – originating or naturally occurring in a particular area, and this may apply to people, plants, animals and other living organisms.

Indigenous knowledge – a local knowledge or information unique to a given culture or society.

Interpretivism – refers to theories of how humans gain knowledge of the world, focusing on how humans are attached to their actions.

Monoculture – the cultivation of a single crop in a particular area.

Morphological – relates to the division of biology that focuses on the forms of living organisms and the relationships between their structures.

Photoperiodism - the response of an organism to seasonal changes in day lengths.

Photoreaction – the chemical response of plats to light.

Pigments – refers to the natural colours formulated in plants, usually four types of chlorophyll (green), anthocyanins (purple, blue or black), carotenoids (yellow, orange or red) and betalains (red and yellow).

Polyploidy – organisms possessing more than two complete pairs of chromosomes and is heritable.

Rhizosphere – refers to the soil around the vicinity of plant roots, where the exchange of nutrients, respiration ad growth occurs.

Stomata – microscopic openings on the underside of leaves and stems, the main function is to aid in respiration of plants.

Variety – a variety relates to a population of plants of a particular species selected and planted to produce features that meet the needs of men.

Vegetative Structure – specialised vegetative structures which are utilised in propagation (tuber, rhizomes, runners, corms and bulbs).

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