Te Rito Hāpori - Integrating Medicinal Cannabis Outdoor Cropping Within Established Farming Operations in Southland

Challenges, Opportunities, and Practical Insights in a New and Emerging Industry

(A research project enabled by the Our Land and Water National Science Challenge Rural Professionals Fund)

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EXECUTIVE SUMMARY

Project Overview

As an emerging option for farmers, commercial outdoor growing of medicinal cannabis remains a relatively new and somewhat untested endeavour, particularly in the Otago-Southland region. As a result, considerable knowledge gaps and uncertainties remain which hinder development and growth of this potentially high-value, low-carbon, chemical-light, niche sector.

The Te Rito Hāpori research project sought to respond to the most obvious knowledge gaps and uncertainties by capturing and sharing knowledge from a commercial growing operation in Eastern Southland during the 2022/2023 growing season.

Project Aim

In order to support the uptake of commercial outdoor growing of medicinal cannabis:

a. Identify regionally relevant, best practice crop management techniques (plant and paddock scale considerations); and
b. Identify regionally relevant factors for integrating medicinal cannabis cropping within existing farm systems (farm and business scale considerations).

Team

- Donald Morrison (farm owner)
- Jaye Cavaye-Astle (grow expert)
- Phil Morrison (research support)

Location/farms: Gore region, Eastern Southland

Key findings

A number of key outcomes were derived from the Te Rito Hāpori research project including:

a. Validating the potential for outdoor grown medicinal cannabis cropping in the Southland region.
b. Identifying a range of regionally relevant best practice crop management techniques.
c. Identifying a range of regionally relevant factors for integrating medicinal cannabis cropping within existing farm systems.
d. Establishing plant and crop performance baselines against which future medicinal cannabis cropping operations can be benchmarked.
e. Identifying a range of potential future research focus areas.

INTRODUCTION

Outdoor grown medicinal cannabis is becoming an increasingly viable option across New Zealand as regional supply chains emerge, develop, and mature. Medicinal cannabis growing lends itself to integration within many existing commercial farming systems, providing opportunities for diversification of both farm activity and income, and demonstrates potential for expansion at pace. Such diversification contributes to increasingly resilient and sustainable farming businesses, diversification of regional supply/value chains, and new regional employment opportunities.

Yet, as an emerging option for farmers, commercial outdoor growing of medicinal cannabis remains a relatively new and somewhat untested endeavour, particularly in the Otago-Southland region. As a result, considerable knowledge gaps and uncertainties remain which hinder development and growth of this potentially high-value, low-carbon, chemical-light, niche sector.

The Te Rito Hāpori research project sought to respond to the most obvious knowledge gaps and uncertainties by capturing and sharing knowledge from a commercial growing operation in Eastern Southland during the 2022/2023 growing season.

The research project had an explicit Otago-Southland regional focus, but it is expected that many of the insights will be transferable and adaptable to other regions of New Zealand.

Research Aims. In order to support the uptake of commercial outdoor growing of medicinal cannabis the aims of the research project were to:

a. Identify regionally relevant, best practice crop management techniques (plant and paddock scale considerations); and
b. Identify regionally relevant factors for integrating medicinal cannabis cropping within existing farm systems (farm and business scale considerations).

Research Outcomes. The anticipated outcomes from the research project were to generate very practical, user-focused resources to flatten learning curves and de-risk the transition to commercial outdoor medicinal cannabis cropping as part of an integrated farm and business system.

Research Origin. In the growing season prior to the research project, the research team undertook an initial commercial grow of 2,000 medicinal cannabis plants, at the same growing site. This experience:

a. revealed the degree of knowledge deficit hindering crop management and performance, and

b. surfaced a range of planning and management questions and considerations for the subsequent growing season.

It was this knowledge shortfall and the associated questions that were the catalyst for this research project.

Research Setting. This research project was embedded within a commercial medicinal cannabis growing operation, on an operational Eastern Southland sheep farm. Of necessity, pursuit of the research objectives had to be balanced against some very practical considerations during the busy summer growing season. These considerations included farm work-force availability, availability of existing infrastructure and mechanical equipment, and wider farm management considerations (such as animal welfare, pasture management, and winter-feed harvesting). The journey map shown at Figure 1 below illustrates the broad phases of the 2022/2023 growing season.

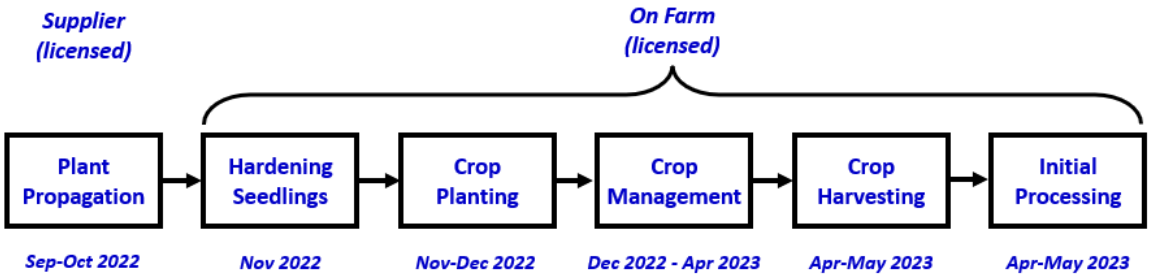

Figure 1: Journey map – broad phases of the 2022/2023 growing season.

Research Values. The Te Rito Hāpori research team were guided by the following core values:

a. **Integrity:** Ma te ngakau aroha koe e arahi (let a loving heart guide your decisions).
b. **Sustainability:** Maku te ra to ana; kei a koe te urunga o te ra (let mine be the setting sun; yours is the dawning of a new day).
c. **Transparency:** E huri to aroaro ki te ra, tukuna to ataarangi ki muri i a koe (turn and face the sun and let your shadow fall behind you).

Licensing Arrangements. During the 2022/2023 growing season the licensing arrangements which supported the commercial growing operation evolved and changed. Whilst this was not anticipated at the outset of the research project, in practical terms this was a fortuitous change, enabling extended learning and insights. The key changes which presented the opportunity for additional learning were:

a. Upon harvest initial processing was undertaken on-farm (drying and plant bucking). This change did alter the planned harvesting schedule, delaying the harvest period to run from 31 March to 25 May 2032.
b. Estimates of dry weight product yields.
c. Laboratory analysis of product yields.

Image 1: Medicinal cannabis seedlings in the improvised hardening off facility.

METHODOLOGY

Farm Characteristics. Located in rolling hill country of Eastern Southland, the intergenerational family farm is a 465-hectare property, with a well-established sheep genetics business. 7500 stock units are farmed including 2000 stud ewes and replacements. Cropping operations are integrated in the farm operation (winter-grazing crops, and barley sold for livestock feed). The farm routinely functions with an FTE workforce of 4.0 staff, with additional temporary or casual staff added during periods of peak activity. The permanent workforce of the farm includes the farm owner, farm manager, farm owner's son, and a farm trainee.

Site Characteristics. The paddock used for the research grow was 3.3 hectares in size, on gently undulating land with an elevation difference ranging from 121 to 131 metres above sea-level. A treeline of very large, well-established macrocarpa trees on the western fence line provided a significant wind-breaking shelter to mitigate the prevailing south-westerly wind and weather direction. A mixed treeline of younger poplar and conifer trees provided a limited early-morning sun-shading effect on the eastern fence line. An established farm track provided access to the growing site along the southern fence line. An existing farm implement storage shed in the south-western corner of the paddock provided an improvised greenhouse (for plant hardening), a servicing shelter and, subsequently, a plant drying shelter at harvest. Figure 2 below shows the broad site characteristics.

Figure 2: Commercial medicinal cannabis growing site (2022/2023)

Site Preparation. The paddock used for the research grow had been used for a more limited medicinal cannabis crop the previous year, and then returned post-harvest to a short rotation winter pasture. In preparation for planting the paddock was intensively grazed in spring, then ploughed and power-harrowed twice. Between each power-harrowing, the paddock was treated with an application of 400kg/ha of Cropzeal16N and lime at a rate of one tonne per hectare. The second power-harrowing occurred immediately prior to planting. The power harrow used was 3.5 metres in width and, thus, efficiently marked the 3.5 m spacing between planting lines.

Seedling Hardening, Preparation and Planting. 4,529 medicinal cannabis seedlings were planted in two tranches, a decision primarily influenced by the two different times at which the seedlings were first received from the supplier. Tranche one seedlings were received on 3 November 2022, hardened for 13 to 14 days, and planted on 16 and 17 November 2022 (2,828 seedlings). Tranche two seedlings were received on 21 November 2022, hardened for 10 days, and planted on 1 December 2022 (1,701 seedlings).

Tranche	Quantity Received	Seedlings Received	Seedlings Hardened	Seedlings Planted	Date Planted
1	3,000	3 November 2022	13/14 days	2,828	16/17 November 2022
2	1,900	21 November 2022	10 days	1,701	1 December 2022

Table 1: Key Seedling Hardening and Planting Dates

Prior to planting, the process of 'hardening off' the seedlings (acclimatising the young indoor-raised plants to cooler temperatures, lower humidity, and increased air movement) was undertaken in an improvised greenhouse - a modified farm shed adjacent to the growing site.

On receipt of tranche one seedlings there was evidence of aphid and spider-mite infestation. This demanded a tight control protocol, including isolation, inspection, and treatment of each individual seedling (including the soil surface), and significant defoliation to mitigate the risk of the entire crop being compromised. This was labour intensive, requiring a high level of specialist knowledge, and extended the duration of the hardening off process for the first tranche of seedlings.

Prior to planting each seedling was inspected and a number of non-viable seedlings were identified and destroyed. A small number of less robust, 'seconds' seedlings were also identified and set aside to be planted as a lower priority.

Planting the seedlings was a labour-intensive activity, drawing fully upon the available full-time and part-time farm workforce of six people. Clear leadership of the planting team was necessary to ensure a well-planned, well-coordinated, and efficient team effort on planting days. Planting technique was important and thus, specialist coaching and guidance was required to ensure the planting team were applying best practice.

Paddock Layout. The two tranches of medicinal cannabis seedlings were planted within a total of 39 rows in the paddock. Tranche one consisted of the first 24 rows, while rows 25 to 39 made up tranche two. The centreline of each row was spaced 3.5 metres from the adjacent row, and this allowed for a 3.0 metre service lane between each row. 8.0 metre wide access areas were left at the exterior margins of the field, and a 5.0 metre wide service lane running midway across the paddock was left unplanted. Figure 3 below is an aerial image showing the paddock layout in December 2022.

Figure 3: Aerial image showing the 2022/2023 growing season paddock layout.

Plant Spacing within Rows. For the majority of rows, plants were spaced at 1.2 metre intervals. To explore the influence of spacing on plant health, crop yield, and ease of crop management, a small number of selected rows were planted with plants at three different spacings as follows:

a. Tranche 1, Row 7: 1.0 metre spacings.

b. Tranche 1, Row 8: 0.8 metre spacings.

c. Tranche 1, Row 9: 1.5 metre spacings.

d. Tranche 1, Row 18: 1.0 metre spacings.

e. Tranche 2, Row 30: 0.8 metre spacings.

f. Tranche 2, Row 31: 1.0 metre spacings.

g. Tranche 2, Row 32: 1.5 metre spacings.

Crop Management. The crop management approach adopted represents what might appropriately be described as a low-intensity care system and involved three key activities at different stages of the growing season.

Additional targeted defoliation was undertaken to pre-emptively mitigate the risk of plant rot emerging later in the growing season by removing:

a. any low-lying, heavy lateral branches, and
b. any storm damaged branches.

Once the plants commenced flowering, full crop inspection was necessary to identify any plants transitioning from female to a hermaphrodite state – which would have compromised the entire crop (and any other similar crops within kilometres, depending on wind strength and direction). These inspections were undertaken on a weekly basis for four weeks from the commencement of flowering. Any plant identified as transitioning was immediately destroyed (only one was detected).

From the time of plant flowering inspections for mould, mildew, and botrytis were routinely conducted following periods of heavy rainfall and/or elevated humidity.

Weed Management. Weed management remains an important consideration when growing medicinal cannabis outdoors. Weeds provide crop competition for sunlight, water, nutrients, and growing space, and also elevate the risk of product contamination at harvest.

In the case of this research project the overall growing cycle was based on a nil-chemical treatment programme to maximise organic market opportunities and meet GMP[1] best practice standards. The following three different forms of manual weed control were undertaken on different rows during the growing period:

a. Weeds were manually pulled out by the roots and placed between plants as mulch cover.

b. Weeds were manually pulled out by the roots and placed in the service lane between each planted row.

c. Weeds were chopped or trimmed at ground level with hedge loppers, but roots were not removed.

Image 2: Saturday afternoon weeding (January 2023).

[1] New Zealand Code of Good Manufacturing Practice for Manufacture and Distribution of Therapeutic Goods

Pasture Management. Given that the medicinal cannabis grow was integrated within a functional sheep farm there was an interest in 'companion pastures' – the pasture types sown in the service lanes and access areas within and surrounding the medicinal cannabis rows. Rather than leaving these areas as bare soil following cultivation, establishing companion pasture offers a number of advantages, including:

a. mitigating the need for weed control in these areas,
b. minimizes weed spread from uncultivated service lanes,
c. stabilising soils against run-off during heavy rainfall,
d. building soil fertility,
e. generating fodder for livestock feed following harvest (or alternatively for baleage), and
f. allowing for full use of service lanes and working areas for crop management and harvest.

The following three different forms of pasture mix were trialled within the working lanes between the medicinal cannabis rows:

a. contemporary perennial pasture mix (ryegrass and clover),
b. specialist clovers (white and red clover), and
c. drought resistant pasture (timothy and red clover).

These companion pastures were sown in equal measure (in every third working lane) after the medicinal cannabis planting was complete. Sowing occurred in January 2023 (later than originally planned). Companion pasture yields were measured in September 2023.

Pest Control. No additional farm pest control measures were taken despite the presence of rabbits, and somewhat surprisingly for the district, evidence of wild deer traversing the paddock shortly after planting.

Soil Nutrient Testing. A transect of soil nutrient tests were taken in the paddock each spring (2021, 2022 and 2023). Soil testing included the following parameters:

a. Acidity (pH),
b. Calcium,
c. Magnesium,
d. Phosphorus (Olsen P),
e. Potassium,
f. Sodium, and
g. Sulphate Sulphur.

Harvest. The decision to harvest a plant is largely determined by trichome development, guided by an inspection of the flowers and flower pistils on each individual plant. Despite being planted at the same time, plants may mature at varying times, and thus harvest schedules must remain reflexive to these differing maturity times, informed by frequent crop inspection.

On this occasion, due to licencing changes, harvest was delayed, with the first harvesting activity occurring from 31 March 2023.

At the point of harvest each individual plant was recorded by plant number, row number, and total plant biomass (kg). Selected plants were then either:

a. recovered for drying and further processing, or
b. discarded for subsequent destruction.

Dried Flower Yield Estimates. As a final stage of initial processing, flowers were removed from dried plants (a process referred to as bucking). A small number of representative dry plants were selected, weighed prior to bucking, and the flower yield weighed after bucking. This provided an indication as to what percentage of marketable dry flower yield might be expected from total plant biomass.

Dried Flower Laboratory Testing. Following crop harvest and initial processing, selected samples of dry medicinal cannabis flower were sent for testing at two different laboratories. Cannabinoid analysis only was undertaken at the first lab. At the second lab, a more thorough analysis was undertaken, including the following parameters:

a. Cannabinoid Analysis (Cannabinoids),
b. Terpenes in Cannabis (Terpenes),
c. Aerobic Plate Count 35°C (APC35petCannH),
d. Yeasts & Moulds (YMCcannH), and
e. Foreign Matter (ForeignMatCann).

The full results of laboratory analysis are shown at Appendix 1.

Image 3: Hosting a field visit by interested potential growers (February 2023).

RESULTS

Plant Survivability and Yield. Of the 4,529 seedlings planted an overall survival rate of 92.38% resulted - 4,184 plants survived, and 345 plants died during the growing season. Total biomass yield at harvest was 28,327.89 kg, with an average biomass yield of 6.29 kg per plant. The largest individual biomass yield recorded was 16.7 kg. The smallest individual biomass yield recorded was 0.2 kg. The plant survivability rates and yield results, differentiated by planting tranche and plant spacing within rows, are summarised in Table 1 below.

Plant Spacing	Planting Tranche	Survival Rate (%)	Average Yield (kg of biomass)
0.8 m	Tranche 1	92.97	5.59
	Tranche 2	95.62	5.00
	Combined	**93.80**	**5.29**
1.0 m	Tranche 1	94.00	6.43
	Tranche 2	93.42	5.29
	Combined	**93.71**	**5.86**
1.2 m	Tranche 1	95.46	6.60
	Tranche 2	89.51	6.22
	Combined	**93.08**	**6.44**
1.5 m	Tranche 1	97.12	6.48
	Tranche 2	94.39	6.67
	Combined	**95.75**	**6.57**
	Tranche 1	**93.55%**	**6.10**
	Tranche 2	**90.51%**	**6.40**
	All Plantings	**92.38%**	**6.29**

Table 2: Plant Survivability and Yield Results from 2022/2023 Growing Season

Dried Flower Yield Estimates. After harvest and drying, the weights of dry flower yield were measured for eleven representative plant samples. The results are summarised in Table 2 below. This provides some indication of the marketable product that might be derived from the total plant biomass. This suggests potential marketable dry flower yield of 937.2 grams per plant was achieved on average.

Serial	Plant Identification by Row & Number	Plant Wet Weight (kg)	Plant Dry Weight (kg)	Dry Flower Weight (kg)	Dry Flower as % of Wet Plant Weight	Dry Flower as % of Dry Plant Weight
1	Row 1, Tag 7	6.2	1.27	0.66	10.64	51.96
2	Row 1, Tag 38	4.5	1.60	0.95	21.11	59.38
3	Row 1, Tag 51	5.0	1.20	0.72	14.40	60.00
4	Row 2, Tag 47	5.0	1.20	0.74	14.80	61.67
5	Row 4, Tag 19	6.0	1.60	0.87	14.50	54.38
6	Row 4, Tag 30	5.7	1.77	0.99	17.37	55.93
7	Row 5, Tag 49	4.6	1.14	0.67	14.57	58.77
8	Row 5, Tag 61	2.4	1.58	0.71	29.58	44.94
9	Row 7, Tag 13	4.4	1.05	0.64	14.55	60.95
10	Row 36, Tag 25	6.5	1.3	0.74	11.38	56.92
11	Row 38, Tag41	6.0	1.18	0.72	12.00	61.02
13	**Average**	**5.1**	**1.35**	**0.76**	**14.90**	**56.30**

Table 3: Representative Dried Flower Yield Estimates

Plant Quality. The results from laboratory testing of dried flowers undertaken in April and May 2023 are summarised at Appendix 1. The results establish a baseline of plant quality against which to benchmark future plant quality outcomes. Of note was the differing results from different laboratory tests for Total CBD and Total THC, and significantly, Total CBG, summarised in Table 3 below.

Serial	Total Cannabinoids	Abbreviation	Laboratory 1 % (w/w)	Laboratory 2 % (w/w)
1	Total Potential THC	Total THC	0.046	0.060
2	Total Potential CBD	Total CBD	18.593	15.000
3	Total Potential CBG	Total CBG	6.631	0.500

Table 4: Comparison of Laboratory Test Results (Total Potential THC, CBD and CBG)

Companion Pastures. The average yields of each type of companion pasture were measured in September 2023, prior to commencing spring livestock grazing. The results are summarized in Table 2 below. Companion crop plantings had no discernible influence on the 2022/23 cannabis harvest yields.

Serial	Companion Pasture Mix	Dry Matter Yield (tonne/ha) (September 2023)
1	perennial pasture mix (ryegrass and clover)	2.33
2	specialist clovers (white and red clover)	0.75
3	drought resistant pasture (timothy and red clover)	1.38

Table 5: Companion Pasture Yields (September 2023)

Soil Nutrients. The results of the soil nutrient tests (averaged) taken in the paddock each year (2021, 2022 and 2023) are summarised in Table 3 below.

Serial	Analysis	Nov 2021	Jun 2022	Jul 2023	Optimum Range
1	pH (pH units)	5.94	5.8	5.9	5.8 – 6.2
2	Olsen Phosphorus (mg/L)	9.0	23.0	21.7	20 - 30
3	Sulphate Sulphur (mg/kg)	5.5	24.0	9.3	10 - 12
4	Potassium (MAF units)	2.3	8.0	5.3	6 - 8
5	Calcium (MAF units)	6.2	7.0	7.0	4 - 10
6	Magnesium (MAF units)	7.3	10.0	8.3	8 -10
7	Sodium (MAF units)	3.3	4.0	7.0	

Table 6: Soil Nutrient Analysis Results – 2021 to 2023

Weed Management. Planting into freshly cultivated soils meant no weed competition for the cannabis seedlings in the early stage allowing maximum establishment. From 14 to 21 days after planting, weed presence became evident. As the growing season progressed, the following invasive weeds were prominent:

a. fat-hen,
b. night shade,
c. wild chamomile,
d. wireweed,
e. Californian thistle,
f. scotch thistle,
g. dock,
h. shepherd's purse,
i. plantain, and
j. yarr.

Weeds were evident both within the rows of medicinal cannabis, and in the service rows. Most problematic of these weeds was the fat-hen which was prolific in all areas (with a year-on-year risk of increased spread), and the shepherd's purse for the potential risk it presented to crop contamination once trichrome development commences.

Pest Management. There was evidence of occasional clusters of a type of Shield Beetle on mature plants in the late summer. There was no evidence of plant damage resulting from these clusters. It is hypothesised that they may have been attracted by the opportunity to feed on aphid or white moth larvae.

DISCUSSION

Site Selection. Site selection for an outdoor grow is a key preliminary consideration. Based on experience to date the following consideration factors are recommended (listed in priority order):

1. A growing site or paddock that meets the security and compliance expectations as defined by current regulations.
2. A suitably dry area, but with a soil capacity to retain summer moisture.
3. A suitably wind-sheltered site (the more wind sheltered the better).
4. A site that is not overly steep and allows relatively easy farm access to allow for crop servicing and management.
5. Proximity to existing service buildings, or buildings that can be adapted, for hardening off seedlings and drying harvested plants.
6. A site that is non-shaded or minimally shaded.
7. A site with optimal levels of Phosphorus, Potassium, and other key nutrients.

Site Preparation. A central outcome from site preparation is a weed-free soil-bed ready to accommodate the planting of hardened seedlings, ideally within a paddock of established pasture. Based on experience to date a recommended approach would be to cultivate only 1.0-metre-wide planting rows, leaving the surrounding pasture undisturbed as service lanes and access areas. This approach assumes that appropriate mechanical horticulture equipment is available for cultivating 1.0-metre-wide planting lanes. Such an approach is not only assessed as mitigating potentially negative environmental effects (for example, minimising soil runoff during heavy rain events), but it is efficient both in respect of site preparation and for subsequent site management (especially for weed control during and beyond the growing season).

A pre-planting application of fertiliser to optimise the soil nutrient profile is recommended following the first cultivation, followed by a second cultivation at either of the following times:

a. If finances and site considerations allow the use of weed-matting or an organic mulch on planting rows, then it is optimal to allow a three-week period between cultivation and planting (to allow the soil microbiome to re-adjust).
b. If there is no capacity for weed-matting or mulch to retard weed growth following cultivation, the second cultivation might be deferred until immediately prior to planting to dislodge any early-growth invasive weeds emerging within the planting rows.

Site Layout - Service Lanes and Access Areas. Based on experience to date it is recommended that planting lanes are spaced at 3.5 metre centres, which provides for service lanes between rows of 2.5 to 3.0 metres width. This allows light vehicle access between the planted rows to support the different phases of crop establishment, management, and harvesting. 8.0 metre wide access areas around the external edges of the planting rows allow space for light vehicles with trailers to manoeuvre and turn.

Plant Hardening Off. Plant hardening off is ideally undertaken in close proximity to the final growing site. At minimum ten days is recommended for hardening off young plants, and ideally up to 21 days for long-flowering cultivars. For auto-flowering cultivars (fast growth, with a shorter lifespan) 10 days is probably sufficient.

Ideally, hardening-off will be achieved on-site in a compliant greenhouse or building adapted for the purpose. In reality a farm-implement shed can be adapted at relatively minimal expense for this purpose. The functional needs of such a structure are to allow for both aeration and heat retention. This allows for the young plants to progressively adjust to cooler temperatures, lower humidity, and increased air movement.

Ideally, the following additional features are provided for within such a structure:

a. Sufficient space within to undertake plant inspections and carry out any defoliating that may be necessary to promote plant health prior to planting.
b. Isolation areas to allow for separation of different batches of seedlings, or any seedlings suspected of carrying unwanted infestation of pests.
c. Access to a supply or storage of fresh, clean water for watering the young plants during the hardening off period.
d. An approved means of destruction of any discarded plant material.

Plant racks offer a management advantage, providing good ergonomics, but improvised solutions can also work, making best use of existing infrastructure.

Planting Timing. For seedlings that are cloned the germination rate is not a consideration and they can be planted within four weeks of initial root development. For seedlings that are propagated, consideration of the germination rate is appropriate, and seedlings might be expected to take 5 to 7 weeks to germinate and sprout prior to hardening off.

The established wisdom (rules of thumb) from those with experience growing medicinal cannabis is that:

a. Hardened seedlings can survive two frosts within the first three weeks of planting.
b. Soil temperatures should ideally be 15 degrees or more for planting seedlings.
c. Plant within two weeks of an ascending full moon.

In Eastern Southland the ideal window for planting medicinal cannabis is currently assessed as being during the last two weeks of November. Soil temperatures are likely to be warm enough, and the risk of frost damage diminished during the three-week period immediately after planting. Planting at this time gives the plants greatest opportunity to benefit from the long growing days experienced during Southland's summer months.

Plant Spacing. Having trialled four different plant spacings within the context of this research project, the research team agree that plant spacing of 1.2 metres achieves the optimal balance for efficient use of land area, plant survivability, plant expression, plant 'community effects', and reasonable access for plant management and weeding. It is important to note that the plant spacing decision might be modified by different growing contexts (for example, less space), and the intended product to be derived from the crop (for example, products for topical, tincture, vapour, sublingual, or edible consumption).

Image 4: Tranche 1 seedlings four days after planting (November 2022).

Weed Control. Weed control is a very important consideration for medicinal cannabis growing at scale. For this research project, weed control was a very time consuming/labour intensive activity from two weeks after initial planting.

The best results were achieved by manually pulling out weeds by the roots and placing them between plants as mulch cover. This disrupted weed growth and spread, and inhibited further weed growth in the areas between plants where mulch was placed.

Trimming weeds at ground level without removing roots was considered the least effective approach, as weeds re-emerged more quickly during the growing season and post-harvest.

While it was not a feature of this research project, experience suggests there may be utility in organic weed matting or organic mulch within the planting rows to inhibit weed growth and reduce the labour effort needed during future growing seasons.

Shade is Your Enemy. A key insight from this research project is that shade is your enemy. Where one row of plants experienced a localised shading effect in the early morning from a mixed treeline of poplar and conifer trees on an adjacent fence line, plant yield was 15% lower than the average yield for rows of a similar spacing planted at a similar time. This difference is attributed primarily to the observed shading effect.

Shelter is Your Friend. A further key insight from this research project is that a sheltered growing area is highly beneficial to plant survival and performance. Some evidence of wind/storm damage to growing plants was evident even within a relatively highly sheltered area. The provision of wind-shelter must be balanced against the potentially negative impacts of sun-shading.

Harvest Times. Whilst the harvesting decision is determined by plant trichome development, like many summer crops, moisture is an unwanted element as harvest approaches in Autumn. Harvesting in windy conditions can compromise plant yield, and moist rainy conditions are considered unsuitable for harvest activity. Calm, dry conditions offer the best conditions for harvest. The valuable nature of each plant and the vulnerable nature of the flower demands a high degree of careful handling at harvest.

Based on experience to date, it is estimated that a team of four people (equipped with a light vehicle and trailer, pruning saws or loppers, and digital scales for weighing each plant) can harvest approximately 200 plants per day. The size of the plants will influence this – where bigger plants are

being harvested, less plants might be harvested daily. Also, the point to which harvested plants are being delivered/transferred will also influence this – a longer drive time from the paddock to plant drying shelter will also reduce daily output.

It is efficient for the harvesting team if those plants ready for harvest are identified and indicated ahead of their work within each row to focus their attentions. It should be noted that the speed and quantity of plants harvested may be constrained either by the capacity of plant drying facilities (if being dried on-site), or by onward transport capacity (if being moved off-site). Quality control is also an important consideration at harvest time, and some degree of training and coaching of a harvesting team is considered beneficial, alongside a well communicated harvesting plan.

As a further post-harvest quality control consideration, batch harvesting is recommended. This supports more effective management of the subsequent drying process, ensuring plants with different moisture levels are not mixed during the drying period. Moisture control in this context is primarily concerned with reducing the mould risk in harvested plants.

Image 5: Weed growth in the central service lane (April 2023).

Companion Pasture. Of the three companion pastures trialled the perennial pasture mix (ryegrass and clover) was considered most compatible with medicinal cannabis cropping. This pasture type inhibited weed growth to the greatest degree, generated the highest levels of dry matter yield, and offered the greatest utility/ease of management to the farmer for paddock use outside of the cannabis growing season.

As discussed above, in an ideal setting the planting lanes would be cultivated within an established pasture. Failing this, if the entire field is cultivated, pasture can be sown ahead of planting the medicinal cannabis – the sooner the young pasture is established, the less weed control effort is likely to be needed in service lanes and access areas.

Genetic Stability. Following an initial two years of commercial growing experience, genetic stability of the medicinal cannabis stock grown is recognised as an important factor for success. Where plant genetics are stable greater consistency of plant expression is observed, crop management is simplified, and plant yield is both higher and more consistent.

It is expected that the supply of genetically stable plant stock will improve as the industry continues to mature, and suppliers who can demonstrate genetic reliability stand to benefit from a positive reputation and associated market rewards. For growers entering the industry, it is recommended that advice is taken from a trusted rural professional with sound knowledge of supply options.

Business/Farm-Scale Opportunity. When first embarking upon commercial outdoor cropping of medicinal cannabis within an established farming system, a key recommendation is to be realistic, start small, and avoid over-reach within the first two years. The work of planting, managing, and harvesting a crop of medicinal cannabis can be labour intensive and does require access to specialist knowledge. A steep learning curve can be expected within the first two years, alongside an emerging understanding of how to balance the needs of existing farm activities alongside the needs of a new venture.

With the learning, experience, and confidence that comes from one or two initial smaller cropping efforts it is likely to be easier over time to increase one's capacity and scale. Industry value chains will continue to evolve, develop, and mature in the next five years which may yet influence the development of incentives, barriers, and opportunities for growing at larger scales.

Industry Entry. A key requirement for any established farmer to undertake market entry as a grower is to meet the licencing requirements defined by the Ministry of Health's Medicinal Cannabis Agency. Not all farmers will have a crop-suitable, legally compliant growing site as an important preliminary requirement.

Assuming the requirement for a compliant growing site can be met, the current choices are to:

a. obtain a cultivation licence, or
b. grow under an existing licenced grower using an "amended site licence".

Access to a high degree of specialist knowledge is required as a one-off, up-front investment in order to meet the information needs associated with a successful licence application. This is particularly so in respect of preparing supporting, compliant Standard Operating Procedures (SOP) matched to the growing site and proposed operation. There is a complexity in preparing and applying for a cultivation licence that should not be underestimated. Engaging the support of a knowledgeable advisor is recommended. Alternately, growing under an existing licence holder can be a less-demanding entry pathway, assuming sound levels of trust, communication, and collaboration can be established.

Workforce Considerations. Planting, weeding, and harvesting medicinal cannabis can be labour intensive and will likely require additional labour units to supplement existing 'business as usual' workforce demands on farm. The periods of peak activity for medicinal cannabis crop management may also compete for work-force attention against existing summer farm activities such as various animal welfare tasks, pasture management, and winter-feed harvesting.

Medicinal cannabis specialist knowledge is needed alongside some hands-on training and supervision of the workforce engaged in various aspects of managing the medicinal cannabis crop. For sound crop management and perfomance there is much utility in engaging a specialist growing advisor for the duration of the growing season.

Infrastructure. Experience has shown that the infrastructure needs of growing medicinal cannabis at smaller scales are relatively low, and existing farm sheds can be temporarily adapted to use at a relatively low cost. Makeshift, improvised solutions are possible and help to off-set the costs of gaining initial experience and confidence, but always with an eye to ensuring site compliance expectations are being met. Thus, infrastructure needs must be considered and included within one's cultivating licence application.

Machinery and Equipment. Various existing farm machinery and equipment can generally be adapted to use when growing medicinal cannabis. Given the relatively modest areas likely to be used for cropping medicinal cannabis, an initial investment in specialist dedicated equipment may not be warranted. Borrowing, hiring, or adapting equipment should be considered until more enduring equipment needs become obvious.

Industry Knowledge and Confidence. The medicinal cannabis industry in New Zealand remains a nascent and developing industry. Pathways to market (domestic and international) are still developing and evolving. Regulations and compliance expectations continue to evolve. Various actors are investing in different parts of the value-chain and in different regions of the country. Some actors demonstrate trusted behaviour, whilst other behaviours might be challenged as unhealthy and undesirable, undermining confidence in the young industry.

Further, it is interesting to reflect that a mature, lucrative, illicit market persists in parallel. There is much established but informal, uncodified knowledge held by individuals with growing experience from the illicit market. Naturally there is some flow of talent and knowledge between the illicit and regulated industry sectors – the emerging regulated sector is dependent on these flows. Yet for those with experience in illicit markets, they approach the regulated sector with persistent levels of suspicion, reserve, and guardedness. There is anecdotal evidence that some have been exploited for their knowledge and for access to quality plant genetic material with little compensation, reward, or recognition.

Until more knowledge and experience is established as a foundation to anchor and guide the development of the legal medicinal cannabis industry, some risk of exploitation remains for those new and/or naïve to the sector. Despite the influence of market competition, knowledge sharing, transparency, and openness offers the best antidote to mistrust, supporting healthy development of the sector to become a valued contributor within the NZ food and fibre sector.

Further Research. A number of potential future research areas warrant consideration, including:

a. More accurate time-logging to monitor and cost labour inputs on an hourly basis at different stages of a commercial medicinal cannabis grow.
b. The integration of organic weed matting or mulch solutions within a large outdoor commercial medicinal cannabis growing context.
c. Production, yield, and cost outcomes that might be derived from a more intensive plant care and management regime.
d. The potential for different plant ‘caging’ or support structures to promote individual plant health and production.
e. Identifying cultivars that are optimised for regional outdoor growing conditions.
f. Identifying cultivars and supporting crop management techniques aligned with delivery of different market-focused value propositions (for example, vapour-based products compared to oil or infusion products).

A broader industry need remains to further define, establish, and stabilise various customer-focused pathways to market, promoting value-chain growth and integration. That broad need demands a response featuring collaboration, innovation, and entrepreneurial confidence.

Image 6: Planting tranche 2 medicinal cannabis seedlings (December 2022)

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APPENDIX ONE: LABORATORY ANALYSIS RESULTS

Laboratory One: Cannabinoid Analysis (Cannabinoids) Test Results (6 April 2023)

Serial	Compound	Abbreviation	mg/gm of sample	% (w/w)
1	Tetrahydrocannabivarin	THCV	0.087	0.009
2	Tetrahydrocannabivarinic Acid	Δ9-THCVA	0.191	0.019
3	(-)-Δ8-Tetrahydrocannabinol	Δ8-THC	0.313	0.031
4	(-)-Δ9-Tetrahydrocannabinol	Δ9-THC	< 0.01	<0.001
5	(-)-trans-Δ9-THC acid A	Δ9-THCA-A	0.522	0.052
6	Cannabidiol	CBD	0.820	0.082
7	Cannabidiolic acid	CBDA	211.021	21.102
8	Cannabidivarin	CBDV	0.825	0.082
9	Cannabigerol	CBG	2.178	0.218
10	Cannabigerolic acid	CBGA	73.105	7.311
11	Cannabinol	CBN	0.266	0.027
12	(±) Cannabichromene	CBC	9.567	0.957
13	(±)-Cannabicyclol	CBL	< 0.01	< 0.001
	Total Cannabinoids *		**298.895**	**29.890**
	Total Potential THC	Total THC	0.458	0.046
	Total Potential CBD	Total CBD	185.935	18.593
	Total Potential CBG	Total CBG	66.308	6.631

Notes
* Total Cannabinoids = sum of all measured cannabinoids
Total Potential THC = Δ9-THC + Δ9-THCA-A*0.877
Total Potential CBD = CBD + CBDA*0.877

Laboratory Two: Cannabinoid Analysis (Cannabinoids) Test Results (26 May 2023)

Serial	Cannabinoids	Abbreviation	g/kg	% (w/w)
1	**Total Potential Tetrahydrocannabinol**	**Total THC**	**6**	**0.6**
2	**Total Potential Cannabidiol**	**Total CBD**	**150**	**15.0**
3	Δ9-Tetrahydrocannabinol	Δ9-THC	< 1.0	< 0.10
4	Tetrahydrocannabinolic acid	THCA	6.2	0.62
5	Cannabidiol	CBD	2.2	0.22
6	Cannabidiolic acid	CBDA	169	16.9
7	**Total Potential Cannabichromene**	**Total CBC**	**7**	**0.7**
8	**Total Potential Cannabigerol**	**Total CBG**	**5**	**0.5**
9	**Total Potential Cannabinol**	**Total CBN**	**< 2**	**< 0.2**
10	**Total Potential Tetrahydrocannabivarin**	**Total THCV**	**< 2**	**< 0.2**
11	Cannabichromene	CBC	< 1.0	< 0.10
12	Cannabichromenic acid	CBCA	8.5	0.85
13	Cannabigerol	CBG	< 1.0	< 0.10
14	Cannabigerolic acid	CBGA	4.9	0.49
15	Cannabinol	CBN	< 1.0	< 0.10
16	Cannabinolic acid	CBNA	< 1.0	< 0.10
17	Δ8-Tetrahydrocannabinol	Δ8-THC	< 1.0	< 0.10
18	Tetrahydrocannabivarin	THCV	< 1.0	< 0.10
19	Tetrahydrocannabivarinic acid	THCVA	< 1.0	< 0.10

Laboratory Two: Terpenes in Cannabis Test Results (25 May 2023)

Serial	Terpene	mg/kg
1	alpha-Bisabolol	3,400
2	alpha-Pinene	210
3	delta-3-Carene	< 50
4	beta-Caryophyllene	2,100
5	Geraniol	< 50
6	alpha-Humulene	660
7	Terpinolene	< 50
8	Nerolidol	520
9	4-Isopropyltoluene (p-Cymene)	< 100
10	Guaiol	1,100
11	1,8-Cineole (Eucalyptol)	< 100
12	alpha-Terpinene	< 50
13	Linalool	840
14	delta-Limonene	2,500
15	beta-Myrcene	570
16	Caryophyllene oxide	105
17	beta-Pinene	380
18	gamma-Terpinene	< 50
19	Camphene	64
20	Ocimene	< 100
21	Isopulegol	< 100

Notes:
1. Nerolidol is the sum of (E)-nerolidol and (Z)-nerolidol.
2. Ocimene is the sum of (E)-beta-ocimene and (Z)-beta-ocimene.

Laboratory Two: Aerobic Plate Count 35°C (APC35petCannH) Test Results (22 May 2023)

Serial	Aerobic Plate Count 35°C	cfu / g
1	Test Sample	1,400,000

Laboratory Two: Yeasts & Moulds (YMCcannH) Test Results (22 May 2023)

Serial	Yeasts & Moulds	cfu / g
1	Test Sample	18,000

Laboratory Two: Foreign Matter (ForeignMatCann) Test Results (22 May 2023)

Serial	Physical examination followed by gravimetric determination of foreign matter	% w/w as rcvd
1	Test Sample	< 0.01