Helicropping – the role of nitrogen and phosphorus in forage cropping with aerial no-tillage

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Abstract

Helicropping (aerial no-tillage) has developed from five hectare trial areas in 2001, to farmers doing full forage crop programs of greater than 100 ha annually (2017), prior to conversion back to perennial pasture. Often multiple crops are grown for finishing young stock and to build fertility for the new perennial pasture.

Helicropping has been carried out with commercial helicopters on a range of land classes, including flat land. No "hoof & tooth" is used. Helicropping of small seeded forage crops works without this, as long as good control is achieved of competing weeds and pests, and sufficient nutrients are applied.

In 2017, a small plot turnip crop was grown in the Waikato using "simulated Helicropping" techniques on a low fertility, long term pasture site to investigate the role of nitrogen and phosphate fertiliser in successful helicropping. This paper reports on the effects of Nitrogen and Phosphorus applied at sowing on a range of turnip crop establishment variables and final crop yield.

In general terms the more N and P applied at sowing, the faster the seedlings grew, the earlier crop canopy closure occurred, the greater the total turnip dry matter yielded. The targeted optimum rate of fertiliser at sowing (at 66N + 78P kg/ha) yielded 4.9 tonne turnip dry matter/ha at seven weeks, and after the nitrogen side dressing (92 kg N/ha), 8.7 tonne DM at 13 weeks. Approximately 30-35 plants/m^2 were established and maintained throughout the trial regardless of applied rate of N and P. The season was difficult with no rain from 7 days to 60 days after sowing.

Introduction

An approach by a North Waikato farmer, John Reeves, in 2000, led to the establishment of a three year project to investigate cropping on hill country with helicopters. The farmer was particularly interested in growing lamb finishing crops on a greater area of his hill country farm, with the goal of achieving a greater percentage of lambs finished or leaving the farm earlier than otherwise and freeing up feed for other animal classes. It was envisaged that after the crop the land would be re-established in improved perennial pasture, hence continuing to add value. The potential risk of soil loss was considered too great to cultivate these "hilly" areas. At the time no-tillage cropping was in its infancy, with few forage crops being established in the area using no-tillage techniques.

Trials were conducted using helicopters on four farms in the Northern North Island over three years beginning in 2001 (Lane *et al.* 2016) and investigated both crop establishment and the process of regrassing using a two spray (glyphosate) summer fallow. The trials were supported by Monsanto NZ Ltd, Wrightson Seeds Ltd, Ballance Agri-Nutrients and the C. Alma Baker trust.

Although small areas of Helicropping were subsequently carried out every year by innovative farmers, the idea generally floundered for some years. It was thought that helicopter companies would drive the business, however many believed the costs were too high and the returns not justified by the lamb prices at the time.

Then in 2010 innovative dairy farmer Colin Armer, (using the "how to do it" report from the earlier trials) began evaluating how the technique would fit into his farming system near Taupo. Within two years Colin was successfully sowing and harvesting brassica forage crops on 70 ha variable terrain pumice/ash soil, then regrassing back to perennial pasture. This was the boost the technology needed. Not only was helicropping shown to be an easily transferable technology (all decisions made from a six page report), but it was shown that it could be carried out successfully and economically over large areas, and in this case appearing to do little damage to the soil (free draining pumice).

Learnings continued over following seasons, with farmer adoption increasing to the point where this season, perhaps 1000 ha of brassica forage was successfully established by helicopter. The efficiency of the establishment technique is captured by a comment from Geoff Fitzgerald (farmer), he noted that his 40 ha rape crop for summer lamb finishing, was established in six hours, and they never even opened the gate! Cost of establishing the crop is driven by numerous variables, for example proximity of helicopter, but in general terms farmer budget to spend what it costs to establish the same crop with full cultivation. In the case of turnips, approximately $NZ1500/ha.

The question remains: Why does Helicropping work?

Called "spray & pray" by those who have experienced failed crops, it is clear that a major key to Helicropping success is successful control of the weeds and pests that would otherwise compete with the germinating seedlings. The non residual herbicide glyphosate is used to control existing pasture at a range of rates, and timings. Perennial weeds such as Kikuyu *(Cenchrus clandestinus)* and couch *(Elytrigia repens)* may need controlling the previous autumn (Lane *et al.* 2009). Insect pests such as slugs *(Deroceras reticulatum)* and snails *(Cornu aspersum)* should always be expected and should be controlled with appropriate rates of slug bait, broadcast with the seed. Similarly springtails *(Bourletiella hortensis)* and greasy cutworm *(Agrotis ipsilon)* should always be expected and be controlled by applying low rates of diazinon and alpha-cypermethrin (or similar) mixed with the glyphosate application. Treated seed should be used, to offer final protection against other insect pests such African black beetle *(Heteronychus arator)* and to protect against damping off diseases.

Application of glyphosate to the old pasture effectively stops transpiration within a few days, retaining soil moisture for the germinating crop. The crop seed germinates into undisturbed soil, and has a canopy of dying vegetation above it to protect it from desiccation by sun and wind. With all of the pests controlled it is an ideal seed bed for germinating seeds.

Nutrient application rates used in early Helicropping were adopted from standard cropping programs. It was clear that nitrogen and phosphorous were required, along with appropriate pH and potassium levels, and that a nitrogen side dressing applied 3-4 weeks after sowing enhanced results. Early work (Lane *et al*. 2016) demonstrated that "hoof & tooth" (that is grazing intensively with animals across the site following sowing), was not necessary and largely created a problem with appropriate animal classes not being available for the job in early spring.

No-tillage drilled brassica trials conducted by Ballance Agri-Nutrients (Lane *et al*. 2013) demonstrate the value of placement of phosphorus near the seed to make up for the lack of soil mineralisation (Havlin *et al*. 2005). From this it was speculated that more phosphorus applied with the seed, would lead to better establishment of seedlings in Helicropping, just as it does in no-tillage with seed drills. In no-tillage drilling, the phosphorus and seed are in close proximity in the soil, with Helicropping they are in close proximity, on the soil surface.

The trial reported here is the third of three trials investigating the effect of applied N and P rate in simulated Helicropping. The two earlier small plot trials were important, leading to technique and treatment refinement. This trial evaluates the effect of varying rates of N and P applied as Cropzeal Boron Boost (CZBB - Diammonium phosphate + boron: N:16.5%; P:19.5%; B:0.7%) on seedling establishment, growth and final crop yield. It is hoped that it will lead to more informed use of fertilisers leading to successful Helicropping adoption by farmers.

Materials and Methods

The small plot trial was established over a few hours, on 31st October 2017 using handheld equipment to simulate aerial helicropping. The trial was located on gently rolling Hamilton clay loam with a 5 degree slope near Hamilton, New Zealand. The site would be described as low fertility with runout pasture.

The small plot trial was designed as a randomised block, with eight replications of five treatments in 8m x 3m plots. The treatments evaluated are listed in Table 1.

A soil test consisting of 20 x 150mm deep samples, was taken randomly over the trial area (Table 2). Although the site has been in long term pasture, it had low total N, medium potentially available N, low Olsen P and an adequate pH at 5.8. No lime was applied to the site. Hence the only fertiliser inputs to this trial were applied as per Table 1.

On the day of treatment, glyphosate plus insecticides were sprayed first, followed by slugbait (broadcast to surrounding area as well), then individual seed and individual fertiliser treatments were applied to each plot using variable sized salt shakers, covering each plot multiple times, to ensure evenness of spread.

Label rates of glyphosate and insecticides were applied to control existing weeds, plus springtails and cutworm. Spraying was carried out early, under no wind conditions, using low drift nozzles, fitted to a 3m hand-held boom, applying 100 litre water/ha. Helicropping would be done using similar low drift, low volume technology such as Accuflow nozzles.

Table 1: Fertiliser treatments.

	Treatment	Product rate kg/ha	kg N/ha	kg P/ha	Side Dress kg N/ha
T1	No starter fertiliser + N side dress	0	0	0	92
T2	Starter fertiliser of Cropzeal Boron Boost + N side dress	200	33	39	92
T3	Starter fertiliser of Cropzeal Boron Boost + N side dress	400	66	78	92
T4	Starter fertiliser of Cropzeal Boron Boost + N side dress	600	99	117	92
T5	Starter fertiliser of Sustain (Agrotain treated Urea) + N side dress	145*	66	0	92

Note: Cropzeal Boron Boost is DAP with 0.7% Boron ie (N:16.5; P:19.5; S:1.0; B:0.7)
*Sustain (460 gm N/kg product) rate of N is equivalent to Treatment 3 (66 kg N/ha)

Table 2: Soil test results.

Soil Analysis Results

Sample Name: Helicropping
Lab Number: 1783858.1
Sample Type: SOIL Arable (S56)

Analysis		Level	Optimum
pH	pH Units	5.8	5.7 - 6.2
Olsen Phosphorus	mg/L	11	20 - 30
Potassium	MAF units	14	6 - 12
Calcium	MAF units	8	6 - 14
Magnesium	MAF units	19	12 - 25
Sodium	MAF units	9	0 - 14
Sulphate Sulphur	mg/kg	8	10 - 20
Potentially Available Nitrogen (15cm Depth)*	kg/ha	168	100 - 150
Anaerobically Mineralisable N*	µg/g	150	
Organic Matter*	%	7.4	7.0 - 17.0
Total Carbon*	%	4.3	
Total Nitrogen*	%	0.42	0.30 - 0.60
C/N Ratio*		10.2	
Anaerobically Mineralisable N/Total N Ratio*	%	3.6	3.0 - 5.0
Soil Sample Depth*	mm	0-150	

Base Saturation %	K 4.1	Ca 40	Mg 5.0	Na 1.2	
me/100g	K 0.92	Ca 9.1	Mg 1.14	Na 0.26	
Additional Properties	Cation Exchange Capacity (me/100g)				23
	Total Base Saturation (%)				51
	Volume Weight (g/mL)				0.75
Soil Type*	Sedimentary				

An in-crop weed control spray was applied 32 days after sowing using label rates of the grass herbicide (Clethodim). No broadleaf herbicide was applied. As with no-tillage from the ground, aerial no-tillage generates grass weeds not broadleaf weeds. An in-crop insecticide spray was included with this weed spray. Overall in crop weed and pest control was very good with almost no weeds, and few heliothis caterpillars at the 13 weeks harvest.

SuperStrike treated Barkant turnip seed was used, applying 5.0 kg/ha (1.5 to 2.0 times higher than typical application. Typical seed rates are 2.5 to 3.0 kg/ha.

Stock grazing had been excluded for several months prior to establishing the crop in an attempt to reduce the effect of stock urine patches.

As is often the case in the Waikato, November was dry. In 2017 this was followed by a very dry December, with expectation of a summer drought until rain fell early January. Approximately 50mm rain fell from 27th October to 10th November 2017. Almost no rain fell from 10th November to 31st December.

Seedling establishment counts were made at 37 days after sowing, using 9 x 0.2 m^2 quadrats chosen randomly per 8m x 3m plot. A total of 1.8 m^2 of each 24 m^2 plot was counted. Final crop plant numbers were gathered by counting bulbs harvested in the final $6m^2$ (2m x 3m) harvest area on 31st January 2018.

The turnip crop was harvested twice. With 25% of each plot (6.0 m^2) being harvested on 19th December 2017 (49 days after sowing). A further 25% of each plot being harvested on 31st January 2018 (92 days after sowing). A nitrogen fertiliser side dressing was surface applied after the December harvest. The final harvest therefore reflects the effect of the initial treatment fertiliser (T1-T5) plus the 92 kg N/ha applied as a December side dressing.

In the final harvest, leaves and bulbs were weighed separately from each plot, across replicates 1-4 to identify relative leaf and bulb yields.

Results

Seedling emergence

Seedling counts at five weeks after sowing showed no statistically significant differences between the treatments (P=0.05), with on average 27-31 seedlings being counted across all plots. The range varied from 21-39 seedlings/m^2 in individual plots.

Canopy closure

The ground cover score made at five weeks after sowing gave a much clearer picture of seedling establishment. Fertiliser treatments had no measurable effect on numbers of seedlings that germinated, but the N and P did affect seedling growth. The no fertiliser treatment (T1) with approximately 50% bare ground at five weeks was significantly poorer than all other treatments. The highest fertiliser treatment (T4) with 6% bare ground (or 94% canopy closure) was significantly better than the no fertiliser (T1), and the low fertiliser treatment (T2), but not T3 or T5. Canopy closure from the nitrogen alone treatment (T5 @81%) was not significantly different from canopy closure from the equivalent N rate plus phosphate (T3 @ 89%). Treatments T3 & T4 (both high N and high P) had statistically greater canopy closure than T2 (low N+P).

Plant numbers at maturity

A full harvest was carried out on 31st January 2018, 92 days (13 weeks) after sowing. Plant counts were part of this assessment. Bulbs were separated from leaf in replicates 1-4. On average there was 32-37 bulbs/m^2, with a range from 26-40 bulbs across all plots. This difference was not significant (P=0.05). Thirty to thirty five plants/m^2 is a good number for a productive turnip crop. Again, the fertiliser treatment rates had no observed effect on plant numbers establishing and reaching maturity. The observed difference was that more N and P resulted in early growth leading to earlier canopy closure, presumably capturing more light and suppressing weeds, leading to increased final crop yield.

Dry matter yield

DM yield figures for each of the two DM harvests are presented in Table 3. Figures 1 and 2 show these results graphically.

a. Fertiliser treatment effects

For perspective, 5 weeks after sowing in a drought season, T4 with the highest rate of N and P had almost full canopy closure. This compared to untreated with only 50% canopy closure.

Treatments T2 (200 kg/ha), T3 (400 kg/ha) and T4 (600 kg/ha) lifted yields over the unfertilised control treatment by 58%, 74% and 87% respectively. Each of these treatments were statistically different from each other at 7 weeks after sowing. However at this time the DM yield between T5 (N only) and T3 (P + equivalent N) was not significant.

b. Final crop yield at 13 weeks

The final DM harvest at 13 weeks, followed the application of 92 kg N/ha side-dress across all plots 6 weeks earlier. T1 (the no base fertiliser treatment) yielded 7160 kg DM/ha, T2 yielded 8300 kg DM/ha, T3 8700 kg DM/ha with T5 yielding just over 8000 kg DM/ha. T4, the treatment with the most N and P, yielded 9300 kg DM/ha, approximately 30% more than T1, and quite respectable considering the dry start to the growing season.

Table 3: Seedling and bulb number per m^2 at 5 and 13 weeks respectively, and dry matter (crop) yield at 7 and 13 weeks (kg DM/ha) for the five fertiliser treatments applied.

Trt	Seedling number at 5 weeks plants/m^2	Bulb number at 13 weeks plants/m^2	% Bare ground exposed at 5 weeks	Crop yield at 7 weeks kg DM/ha	%	Crop yield at 13 weeks kg DM/ha	%	% Leaf	% Bulb
T1	30 a	34 a	53 c	2800 a	100	7160 a	100	67	33
T2	31 a	37 a	24 b	4410 b	158	8310 bc	116	63	37
T3	37 a	35 a	11 ab	4880 c	174	8710 c	122	60	40
T4	31 a	32 a	6 a	5230 d	187	9300 d	130	60	40
T5	27 a	34 a	19 ab	3950 bc	141	8040 b	112	64	36

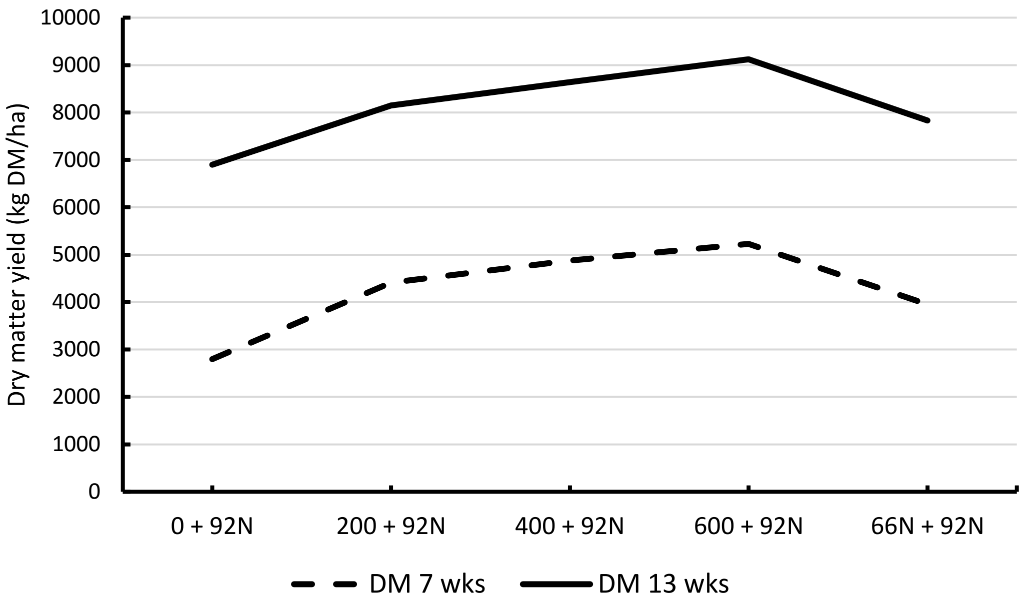

Figure 1: Turnip dry matter yield (kg DM/ha) at 7 weeks and 13 weeks after sowing.

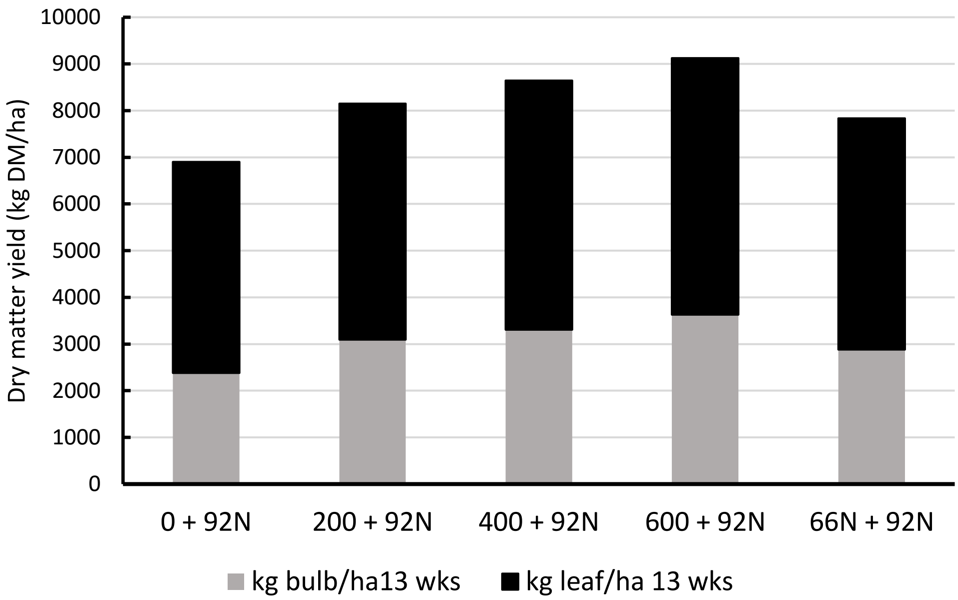

Figure 2: Turnip dry matter yield (kg DM/ha) - leaf and bulb components at 13 weeks.

T1 yield was significantly less than all other treatments. T4 was significantly better than all others. At 13 weeks dry matter yield from T5 (the N only treatment) was significantly poorer than T3 (P + equivalent N).

Interesting to note that the N only treatments (T1 and T5) yielded 7160 and 8040 kg DM/ha, and adding the extra P at sowing lifted the yield by a further 1550 kg DM/ha (T3) and 2140 (T4) kg DM/ha. Suggesting that the overall DM yield is not just a nitrogen effect, but that phosphate is important as well.

Bulb and leaf dry matter was measured separately at the 13 week harvest. Bulb dry matter yield increased as P fertiliser application rate increased. The dry matter increase as a result of the nitrogen side dressing, was similar across all treatments, implying that the potential crop yield was set by P + N application rate when sown.

During the 6 week period from N side dressing to final harvest at 13 weeks, dry matter yield from each treatment increased equally across the treatments. The order of highest to lowest total yield did not change.

Boron

By using Cropzeal Boron Boost as the source for N and P, the amount of boron applied per hectare at each application rate increased, giving an opportunity to assess seed germination and establishment at increasing boron application rates. The seed and the boron fertiliser, were both placed in close proximity on the soil surface.

At 200 kg CZBB/ha the amount of elemental boron applied is 1.4 kg B/ha. At 400 kg it is 2.8 kg/ha, and at 600 kg it is 4.2 kg/ha. A typical high application rate of boron, would be 3.0 kg/ha elemental boron. No boron damage to seedling turnips was observed in any of the plots.

Discussion and Conclusions

It would appear that regardless of fertiliser applied the seeds will germinate. What happens to them subsequently is determined by environmental factors such as pest predation, and weed competition for moisture light and nutrients.

The results of this trial show that, with application of brassica seeds to the soil surface in Helicropping, the application of N and P fertiliser with the seed improves early seedling growth rates. This enabled faster canopy closure leading to a higher yielding crop. More N and P applied with the seed was shown to be better than less.

There are a number of issues around "how much more" due to fertiliser cost. The number of seedlings/m^2 was unaffected by N and P rate and the crop yield from 200 CZBB/ha, though significant, was only1000 kg DM/ha less than that from 600 kg CZBB/ha. However observation clearly showed that when more N and P fertiliser is sown with the seed, faster crop canopy development occurs.

It could be argued that the high rate is important for two reasons:

a. Faster early seedling growth makes the seedling and therefore the crop more resilient, improving the reliability of the cropping technique.

b. Most of the areas targeted for Helicropping are likely to be low fertility areas of the farm. The helicrop is not only to supply a seasonal crop to improve animal growth rates, but also to lead to improved perennial pasture after the crop. Without lifting the fertility of the target area, it is likely the new perennial pasture would be short lived.

Cropzeal Boron Boost (DAP + small amount of Boron) was used as the standard source of N & P enabling an observation of seedling tolerance to boron. A useful observation from this trial is that even at the high rate of 600 kg/ha Cropzeal Boron Boost, applying 4.2 kg B/ha, no plant damage was observed.

Helicropping works for a number of reasons:

1. Good control of existing pasture species is important, not only because of reduced competition for light and nutrients but also because dead pasture doesn't transpire water, leaving any soil moisture for the growing crop. Plus the dying pasture canopy acts as a shelter against desiccation from sun and wind.

2. The key pests of germinating seedlings, such as springtails, cutworm, slugs & snails (and black beetle) are controlled, allowing the seedling to become large enough to overcome future challenges.

3. Adequate nitrogen and phosphate fertiliser is applied to enable seedlings to grow rapidly and canopy over, dominating the seeded area.

Helicropping holds great promise for improving farm productivity. Any area of the farm can be cropped with small seeded species, regardless of terrain. Whole paddocks can be converted to more productive, higher value stock feed, rather than be partially developed. Following seasonal brassica crops, other herb crops such as plantain plus clover, can be established for 2-3 years of lamb finishing, before being returned to productive pasture. The process is quick and efficient, leaving the soil uncultivated, leading to the advantages that come with intact soil structure with no effect on soil microbes and soil pest-predator balance.

Crop selection to optimise feed value and minimise soil damage will need to be part of early planning decisions. For example, large animals on steep land in mid winter, would seem inappropriate to most. However that same steep land could be cropped in a summer fed turnip or rape crop and be back in grass for winter.

Regardless of establishment techniques (even cultivated flat land) there is a need for introduction of "cover crops" on the grazed site over the 3-4 months prior to sowing the next crop, to reduce rain droplet impact (leaves), to hold soil together (roots) and to pull back soil nitrogen (deep roots). Now that we know how to grow the crops, the next phase of Helicropping will be developing "how to" introduce cover crops to protect the soil.

This paper has focussed on use of Helicropping for forage crops. It may be that in future Helicropping techniques will be used to re-establish native cover, such as Manuka on hills, or flax on riparian areas.

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