Dry matter response of swede crops to nitrogen and phosphorus application in Southland and central North Island regions of New Zealand

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Abstract

Swede crop establishment and subsequent growth are affected by nutrient availability, particularly nitrogen (N) and phosphorus (P). The effects of N and P supply on swede dry matter yield were examined in four field experiments across New Zealand. N applied as urea was split applied at sowing and mid-season to give a total of 0, 120 or 150 and 300 kg ha^{-1}. Phosphorus, applied as triple superphosphate at 0, 25 or 50 and 100 kg P ha^{-1}, was either hand broadcast and soil incorporated before sowing or banded below the seed at sowing. The meta-analysis across sites showed DM yield increased with N application, from a mean of 7.0 t ha^{-1} at 0 kg N ha^{-1} to 9.7 and 10.5 t ha^{-1} for the medium and high N rates, respectively, irrespective of the rates and/or methods of P application. The crops with no P applied consistently produced lower DM yields than when P was applied. Banded high P crops produced the highest yield of 12 t ha^{-1} when high N (300 kg ha^{-1}) was applied. This high yield was attributed to the high leaf DM yield, as there were no differences in bulb DM yield between the medium and high rates of N. The banded medium P and broadcast high P crops produced optimum yields of about 10 t ha^{-1} at medium rates of N (120 and 150 kg ha^{-1}). However, there were no differences among the broadcast medium and high P, as well as the banded medium P at both the medium and high levels of N. Under similar conditions to the current experiments, farmers are recommended to apply 25-50 kg P ha^{-1} and 120-150 kg N ha^{-1}, depending on background soil fertility. These trials have shown the importance of managing the co-limitation of N and P. Adding P fertiliser had no effect on yield without the addition of N fertiliser.

Additional key words: *Brassica napus* ssp. *napobrassica,* exploratory data analysis (EDA), meta-analysis, nutrient availability, restricted maximum likelihood (REML)

Introduction

Appropriate fertiliser management is central to the profitability and sustainability of crop production. Nutrient supply needs to be closely matched to crop demand. Sub-optimal nutrient supply will result in poor yield, while excess nutrient application can lead to accumulation of these nutrients in the environment. Actual amounts applied will depend on background soil fertility. Two of the most important nutrients for crop growth are nitrogen (N) and phosphorus (P).

The New Zealand dairy industry has set two goals to achieve by 2015 (FoRST, 2007):

(1) to increase metabolisable energy (ME) by 50% from grazed forage crops, from the current levels of 11-12% (Chakwizira *et al.*, 2011; Glassey *et al*., 2010).

(2) to reduce nutrient losses by 50%; from about 90 kg N ha^{-1} per year (Schipper *et al*., 2007) and ≥2 kg P ha^{-1} (McDowell *et al*., 2005).

These seemingly opposing objectives can only be achieved by an improved understanding of optimum nutrient use and management for specialist forage crops such as swedes (*Brassica napus* L. ssp. *napobrassica* (L.) Rchb.). To achieve increased dry matter yields and ME and simultaneously reduce environmental risks associated with leaching of N and run off of particulate P into underground and surface waters requires the use of appropriate methods and rates of application of N and P fertilisers.

Swedes are an important winter forage crop for Southland, Otago and central North Island regions of New Zealand (Stephen and Kelson, 1974; 1975; Percival *et al*., 1986). Swedes are the second most grown forage brassica after bulb turnips (*Brassica rapa* L. var. rapifera; syn. *B. campestris* L.) (White *et al*., 1999), occupying over 50,000 ha, annually. Surprisingly there has been very little research that has reported on the effects of N and P on the growth and yield of swede crops in New Zealand. Limited research on yield responses to N and P was carried out during the 1960s and 1970s in New Zealand (McLeod, 1965; Stephen and Kelson, 1974; 1975) and overseas (Reith and Inkson, 1963; Gately and McBride, 1972). The results were inconsistent; there was no response to N in New Zealand experiments but a reduction in bulb DM and an increase in leaf DM for overseas experiments. P has been shown to increase swede DM yield, in both New Zealand and overseas experiments. This was attributed to improved establishment (McLeod, 1965). However, since then our understanding of the importance of appropriate methods and rates of applying N and P fertilisers have changed (e.g. Wilson *et al*., 2006; Reid *et al*., 2002). Furthermore, since that time newer higher yielding swede varieties have been released (Gowers *et al*., 2006). Therefore, it is appropriate now to re-examine the yield response of swedes to N and P fertiliser. There is a growing realisation that the establishment and subsequent growth of brassica crops in general are limited by nutrient availability, as reported in recent publications on leaf turnips (*Brassica rapa* L. syn. *B. campestris* L.) (Wilson *et al*., 2006; Chakwizira *et al*., 2009b); kale (*Brassica oleracea* L. ssp. *acephala* DC.) (Wilson *et al*., 2006; Fletcher *et al*., 2007; Chakwizira *et al*., 2009a; 2010) and bulb turnips (Hayward and Scott, 1993).

Swede crops can produce dry matter (DM) yields of 15-20 t ha^{-1} (Gowers *et al*., 2006; de Ruiter *et al*., 2009). Despite this high yield potential, swede yields are often low and variable (3-10 t ha^{-1}) (Stephen and

Kelson, 1974; 1975; Percival *et al*., 1986; Stevens and Carruthers, 2008). This is because the crop is grown in a range of climates and soil fertility situations (Wilson *et al*., 2006) with varying levels of management expertise. Inadequate soil moisture has also been shown to affect DM yield in other brassica crops such as bulb turnips (Fletcher *et al*., 2010). Phosphorus availability is associated with root development and hence crop establishment (McLeod, 1965) while N is essential for growth throughout the season.

The only recent detailed experimental work on N and P reported for swedes is by Stevens and Carruthers (2008). This work was carried out in the drier Otago region and suggests N application rates of about 140 kg ha^{-1}. However, it is unclear whether this is enough for the wetter regions, with high yield potential, such as Southland and the central North Island where most of the New Zealand swede crops are grown. The current paper reports on four field experiments that investigated the effects of method of P application, rate of P and rate of N application on swede dry matter accumulation. The specific objectives were to:

(1) measure the yield responses to different rates of N and P, and
(2) determine yield responses to P fertiliser application method.

Materials and Methods

The four experiments were grouped by sowing year. There were two sites each year and these are referred to as, Experiment A (2008) and Experiment B (2009). Experiment A sites were at Invercargill (46°24'S; 168°24'E) on a Waikiwi silt loam soil (Drewry and Paton, 2000) and Taupo (38°77'S; 176°23'E) on yellow-brown pumice soil (Selby and Hosking, 1973). Experiment B sites were at Waimumu (46°7'S; 168°48'E) near Gore on a Waimumu silt loam soil (Carran *et al*., 1982) and Otamauri (39°50'S; 176°48'E) in Hawke's Bay on a Twyford fine sandy loam (Fluventic Haplumbrept) (Magesan *et al*., 2003) soil. The four experimental sites were located in farmers' fields, following long term pasture and none of the crops were irrigated.

All experiments were laid out in a randomised complete block designs with four replicates of 15 treatments. A soil test to 150 mm depth was taken from all 60 plots individually at sowing. Plot sizes were about 24 m^2 each in 2008 and 16 m^2 each in 2009. The average Quick test results before sowing are shown in Table 2. A range of N and P fertiliser rates were applied. The actual rates and treatment structures applied differed across sites (Table 1), depending on background soil N and P fertility (Table 2). P applied as triple superphosphate (TSP; 21% P) was either hand broadcast and soil incorporated before sowing or banded below the seed at sowing. N applied as urea (46% N) was split applied (broadcast) at 6 and 12 weeks after sowing. The only exception was at Waimumu where a third of the total N was applied on the day of sowing (Table 2) and the remainder 4 weeks later.

Table 1: The rate of phosphorus and nitrogen applied per site.

Site	Phosphorus rate (kg P ha^{-1})			Nitrogen rate(kg N ha^{-1})		
	Low	Medium	High	Low	Medium	High
Invercargill[1]	0	30	100	0	120	300
Waimumu	0	50	100	0	150	300
Taupo	0	50	100	0	120	300
Otamauri	0	25 or 50	100	0	-	300

[1]Rates for N and P were based on soil tests results (see Table 2). P was either banded or broadcast.

Table 2: Details of swede trial at four sites during 2008-10 periods. Values in brackets represent the range of soil test values.

Site detail	Location			
	Invercargill	Taupo	Waimumu	Otamauri
Sowing date	3 Dec 2008	28 Oct 2008	1 Dec 2009	10 Dec 2009
First N application	20 Jan 2009	2 Dec 2008	1 Dec 2009	15 Jan 2010
Second N application	17 Feb2009	21 Jan 2009	27 Jan 2010	22 Feb 2010
Harvest date	21 May 2009	12 May 2009	19 May 2010	17 Jun 2010
Field bulk density (g cm^{-3})	0.87	0.66	0.99	1.03
pH	6.2 (5.9-6.4)	5.8 (5.6-6.0)	5.8 (5.6-6.0)	5.7 (5.5-5.9)
Available N (kg N ha^{-1})	185.9 (126-244)	61.1 (41-90)	193.6 (141-229)	197.6 (102-263)
Olsen P (mg kg^{-1})	11.5 (7-18)	3.4 (26)	8.3 (5-14)	7.6 (4-13)
Potassium (K)[1]	3.0 (2-8)	5.0 (3-7)	4.3 (3-6)	10.2 (7-17)
Magnesium (Mg)	14.0 (11-18)	4 (3-6)	14.0 (11-18)	23.6 (18-30)
Calcium (Ca)	10.0 (9-11)	3 (<2-6)	8.5 (7-10)	8.0 (6-10)
Sodium (Na)	7.0 (5-12)	6.0 (3-8)	6.7 (6-8)	3.5 (2-7)
Phosphate retention (%)	-	45 (30-60)	38.1 (33-41)	89

[1]All cations are in MAF units.

Base fertiliser was applied at 1.5 kg ha^{-1} boron, 100 kg K ha^{-1} applied as muriate of potash. Seed was drilled with an 11 row cone seeder in 150 mm rows at Invercargill and Waimumu and a 14 row 'Taege' drill at Taupo and Otamauri, at approximately 20 mm depth in cultivated seed beds. Soil preparation involved conventional cultivation after deep ploughing. 'Aparima gold' swede was sown at 1.5 kg ha^{-1} of viable seed. Seed was pelleted with 'Superstrike®' which contains both systemic insecticides to control springtails (*Bourletiella* species) and fungicides to control *Pythium* and *Fusarium* diseases (Salmon and Dumbleton, 2006). Apart from fertiliser and an initial insecticide treatment (in a few cases a second insecticide) of Diazinon 800 EC was applied at 1 l ha^{-1}. The crops were managed the same as the surrounding fields. All crops were managed using best practices (de Ruiter *et al*., 2009) to minimise the risk of weeds, pests and diseases throughout the season.

Measurements

The crops were harvested between mid-May and mid-June. For each plot a 4 m^2 quadrat was harvested, the number of plants counted and fresh weight was determined.

A representative three-plant sub-sample was taken and separated into leaf and bulb fractions. Samples were dried in a forced air oven at 60°C to constant weight. Total DM yield at each site was compared with the potential yield; defined as the maximum yield which could be obtained by the crop (Abeledo *et al*., 2003) at each site.

Meteorological conditions

No site-specific weather data were available for all the experiments and therefore data from the nearest weather station are shown in Table 3.

Table 3: Mean rainfall and temperature data for the experimental period[1] at four sites for swede crops sown in 2008 and 2009. Numbers in parenthesis are the long term average rainfall and temperature ranges for each site for the experimental period (NIWA, 2011).

Site	Year	Distance from site (km)	Location of the weather station	Rainfall (mm)	Mean temperature (°C)[2]
Invercargill	2008	7-8	46°42'S; 168°33'E	534.3 (565)	12.3 (-3.1-28.7)
Waimumu	2009	2	46°12'S; 168°89'E	542.3 (560)	12.2 (0.2-26.1)
Taupo	2008	15	38°74'S; 176°08'E	290.4 (550)	14.6 (-2.5-30.4)
Otamauri	2009	48	39°50'S; 176°48'E	463.4 (410)	16.1 (-2.3-32.6)

[1]Experimental period was from date of sowing to harvesting shown in Table 2.

[2]Temperatures at all sites were within 0.3°C of the long term averages.

Total rainfall for the first three weeks after sowing was higher at both Southland sites, at >60 mm compared to <20 mm for the North Island sites.

Data analysis

All statistical analyses were carried out in GenStat v.13 (VSN International). Initially, the data were assessed using exploratory data analysis (EDA) (Good, 1983) to obtain an understanding of results within each site. Each site was then analysed using a mixed model fitted with restricted maximum likelihood (REML) (Gilmore *et al*., 1995). Finally, the complete data set was analysed using a meta-analysis mixed model (Adams *et al*., 1997) fitted with REML. An indication of the variability associated with predicted means is given by the least significant difference (LSD) tests (α=0.05). Where values show P<0.1, a trend is indicated in the text. A covariance analysis (Van Der Krift and Berendse, 2002) was performed to determine the effects of background fertility at site and meta-analysis levels.

Results

Plant density determined at the final harvest (Table 2) was consistently higher at 24-31 plants m^{-2} for the Southland sites compared to 10-14 for the North Island sites. The meta-analysis (Figure 1) shows that total DM yield increased with application of N from a mean of 7.0 t ha^{-1} at 0 kg N ha^{-1} to 9.7 and 10.5 t ha^{-1} for the medium and high N rates, respectively, irrespective of the rates and methods of P application. The crops with no P applied consistently produced less dry matter than when P was applied in the presence of N. The banded high P produced the highest yield of 12 t ha^{-1} when high N (300 kg ha^{-1}) was applied, while the banded medium P and broadcast high P crops produced optimum yield at medium rates of N (120 and 150 kg ha^{-1}). However, there were no differences between the broadcast medium and high P treatments, or between the banded medium P at both the medium and high N treatments and therefore the medium rate of 120 or 150 kg N kg ha^{-1} was the recommended N rate.

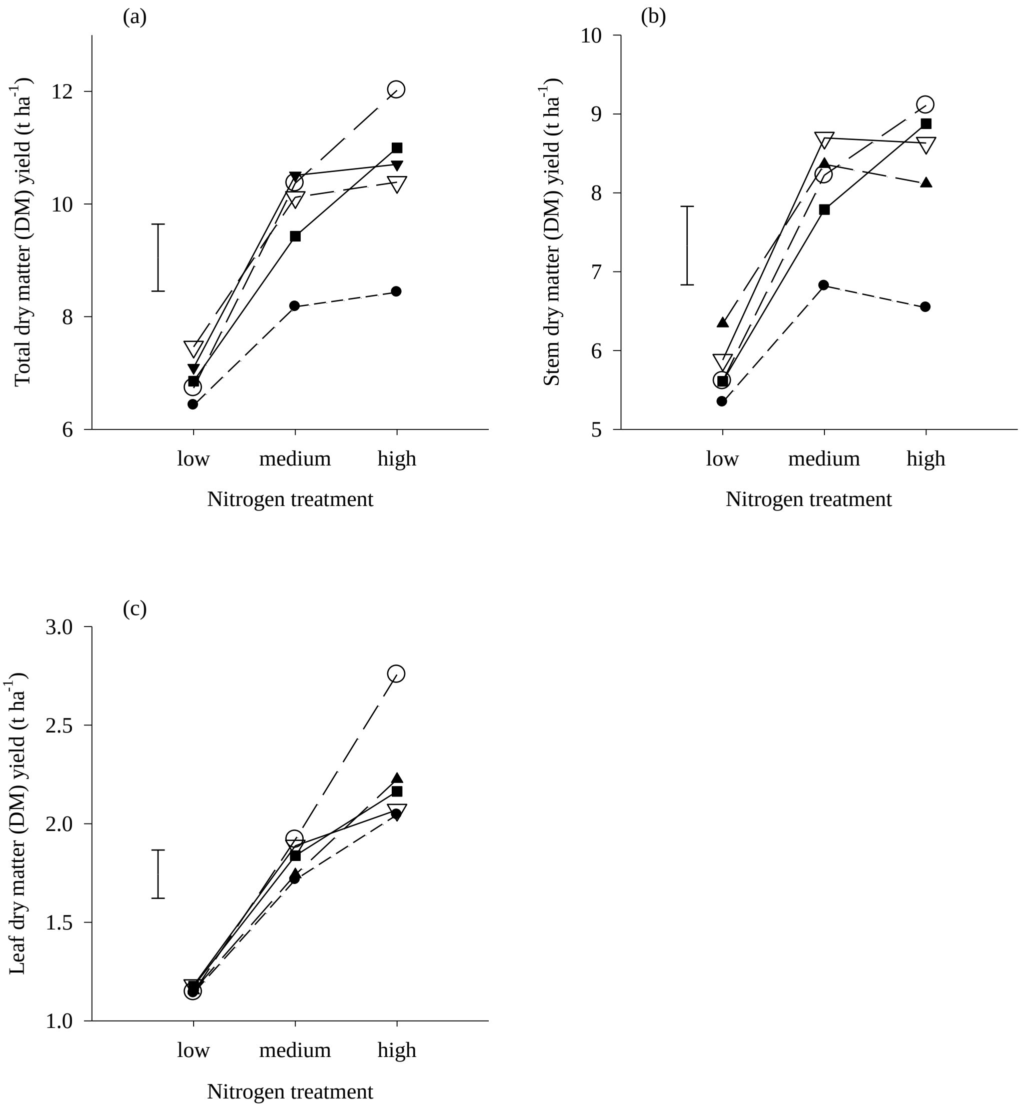

Figure 1: Total dry matter (a), bulb (b) and leaf dry matter yield (c) (t ha^{-1}) for swede crops grown with three levels of phosphorus per site; control (-●-), medium (25, 30 or 50 kg ha^{-1}) and high (100 kg ha^{-1}) kg P ha^{-1}, two methods of P application, ▼banded medium or ○ banded high P and ■ broadcast medium or ▽ broadcast high P and at three nitrogen levels, low (0), medium (120 or 150) or high (300) N kg ha^{-1}, at four sites in New Zealand. Bars represent 5% LSD, at 122, 158 and 170 degrees of freedom (df) for (a), (b) and (c) respectively.

The overall high yield for the banded high P of about 12 t ha^{-1} was attributed to the high leaf DM yield (2.8 t ha^{-1}; Figure 1c) produced by these crops, as there were no differences in bulb DM yield between the medium and high rates of N.

Experiment A: Invercargill and Taupo sites

There was an interaction (P=0.08) between the rate of P and N and the method of P application at Invercargill (Figure 2; Table 4). There was a moderate potential yield of 12 t ha^{-1} at this site.

Total DM yield increased (P<0.001) with N application, but there were no differences between the higher rates of N. When P was banded the yield was constant at about 13 t ha^{-1} but ranged between 10 and 13 t ha^{-1} under broadcast P. Figure 2 shows that most of the total dry matter yield was from the bulb component, with the leaf contributing about 25%. Total and component DM did not respond to P treatments in the absence of N, increasing by about 40% (4-5 t ha^{-1} for the total) when P treatments were applied with N. Banded P yield was consistent across the treatment but yield was lower (P=0.08) when P was broadcast at the highest rates of both P and N. These results were not expected with the low soil P value and the high soil N (Table 2).

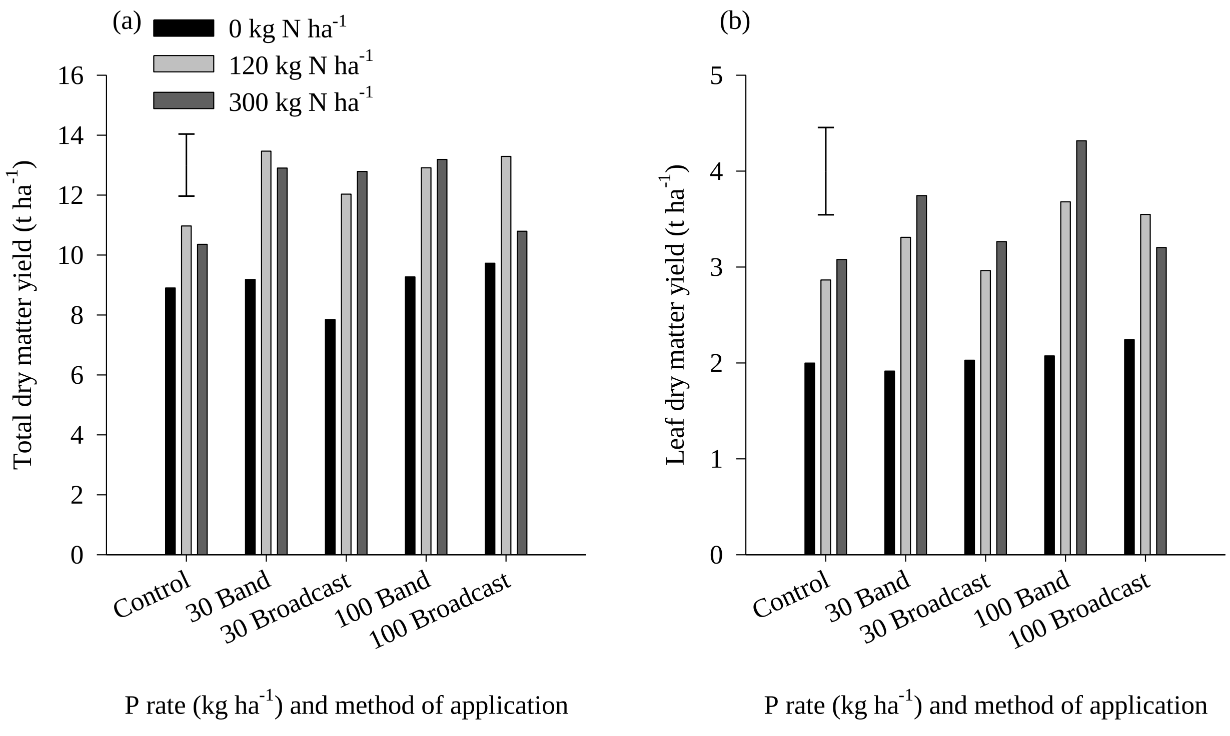

Figure 2: Total dry matter yield (a) and leaf dry matter yield (b) (t ha^{-1}) for swede crops grown with three rates of nitrogen (N=0, 120 and 300 kg ha^{-1}), three rates of P (Control, 30 and 100 kg ha^{-1}) and two methods of phosphorus (P) application (Banding and Broadcast) at Invercargill, Southland in 2009. Bars represent 5% LSD with 42 df.

At the Taupo site there were interactions between rate of P and method of P application (P=0.0015) and rate of P and N (P<0.001) (Figure 3). Specifically, there were no DM yield differences between the methods of P application when 50 kg P ha^{-1} was applied but yield was higher for the banded P crops (7.3 t ha^{-1}) compared with 5.4 t ha^{-1}, when broadcast at 100 kg P ha^{-1}.

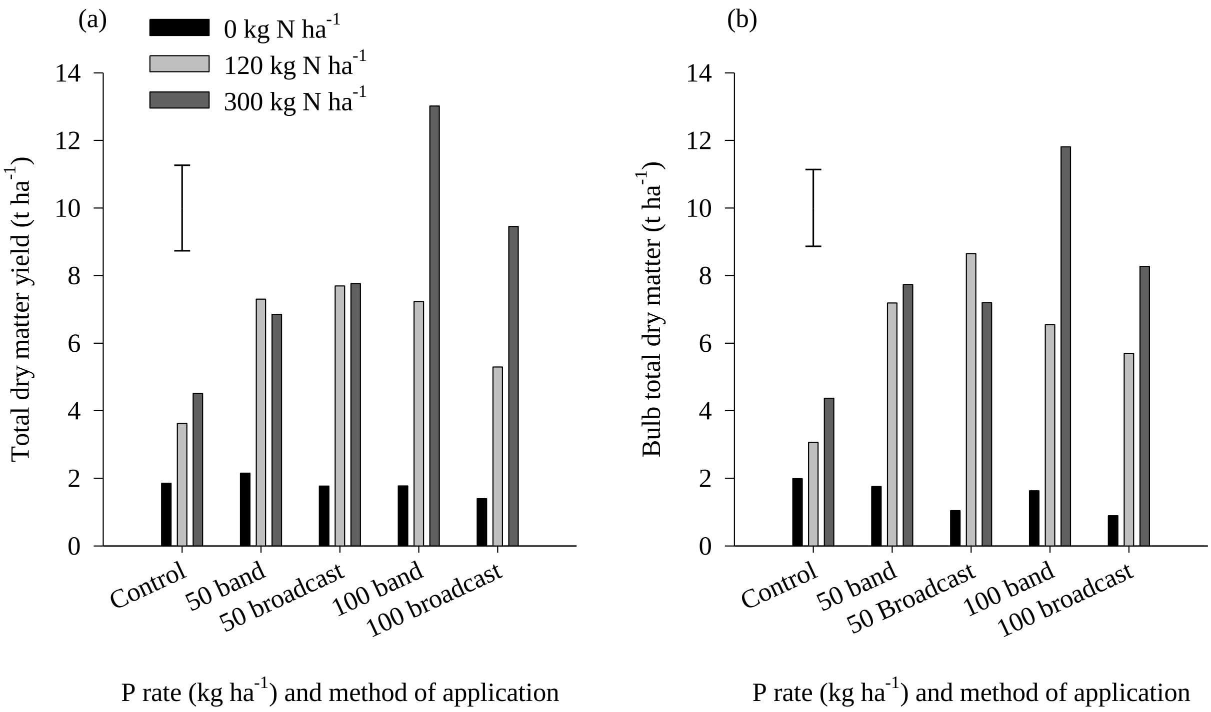

Figure 3: Total dry matter yield (a) and bulb dry matter yield (b) (t ha^{-1}) for swede crops grown with three rates of nitrogen (N=0, 120 and 300 kg ha^{-1}), three rates of P (Control, 50 and 100 kg ha^{-1}) and two methods of phosphorus (P) application (Banding and Broadcast) at Taupo, central North Island in 2009. Bars represent 5% LSD with 42 df.

When no N was applied the lowest yield (1.6 t ha^{-1}) was obtained when 100 kg P ha^{-1} was applied and when 120 kg N ha^{-1} was applied the least yield was for the control treatments. At 300 kg N ha^{-1} yield increased with P supply; from 4.5 t ha^{-1} for the control crops to 7.3 and 11.2 t ha^{-1} for the 50 and 100 kg P ha^{-1}, respectively. DM yield increased (P<0.001) with N application from 1.8 t ha^{-1} to about 4 t ha^{-1} when no P was applied and to 7 and 9.3 t ha^{-1} when 50 and 100 kg P ha^{-1} were applied, respectively. Figure 3 also shows that the bulb component contributed most to the total dry matter in this crop.

Experiment B: Otamauri and Waimumu sites

Nitrogen increased yield (P<0.001) from about 11 t ha^{-1} for the control crops to about 14 t ha^{-1} (Figure 4a) at Waimumu. There were no DM yield differences between the higher rates of N. Phosphorus application had no effect on DM yield, which is surprising given the low soil P and high soil N (Table 2). The potential yield at this site was average at 16 t ha^{-1}.

At Otamauri, there was an interaction (P=0.004) between method of P application and N supply (Figure 5). Specifically, yield increased from 4.9 t ha^{-1} when no N was applied to 6 t ha^{-1} for the 300 kg N ha^{-1} crops when P was banded but there was no yield response to N when P was broadcast. Total dry matter yield increased (P=0.01) with rate of P application from 3.8 t ha^{-1} to 5 and 6 t ha^{-1} when 25 or 50 and 100 kg P ha^{-1} were applied, respectively. The background soil P fertility also affected (P=0.005) total dry matter at this site.

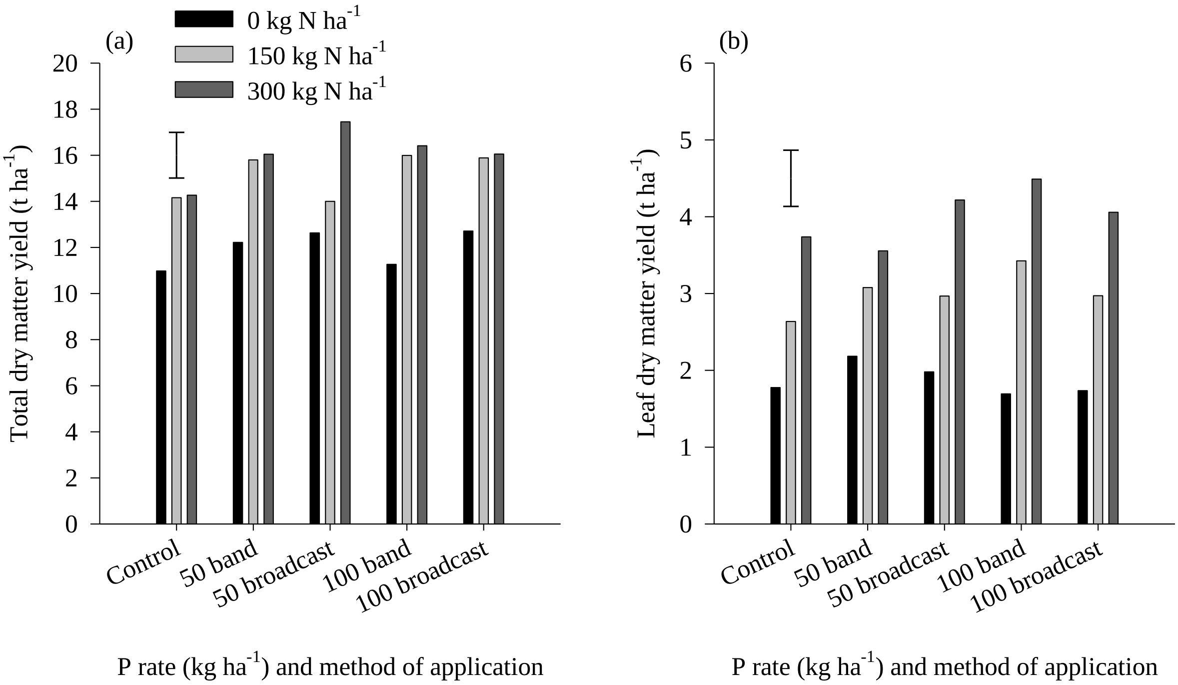

Figure 4: Total dry matter yield (a) and leaf dry matter yield (b) (t ha^{-1}) for swede crops grown with three rates of nitrogen (N=0, 150 and 300 kg ha^{-1}), three rates of P (Control, 50 and 100 kg ha^{-1}) and two methods of phosphorus (P) application (Banding and Broadcast) at Waimumu, Southland, in 2010. Bars represent 5% LSD with 42 df.

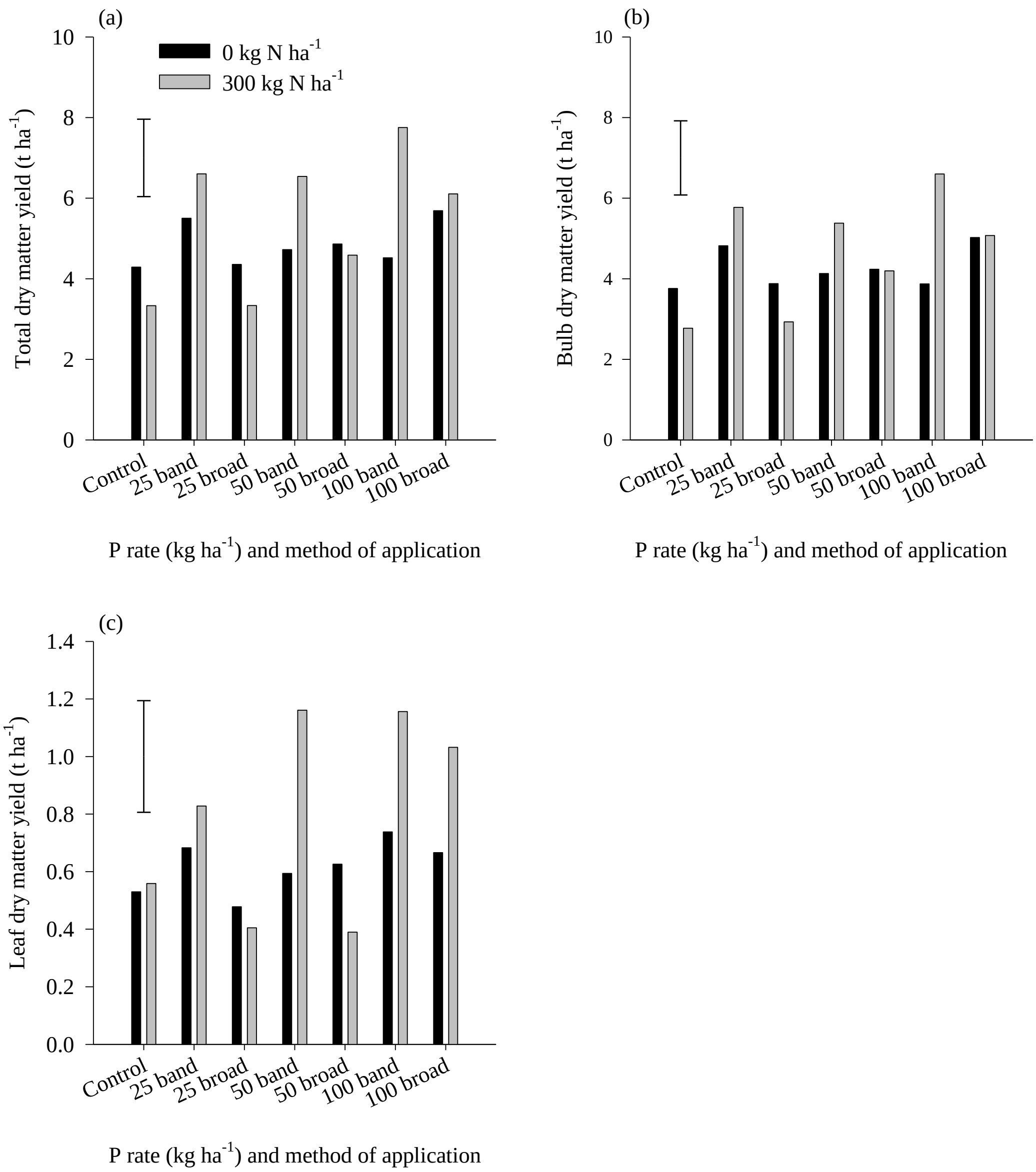

Figure 5: Total dry matter (a), bulb (b) and leaf dry matter yield (c) (t ha^{-1}) for swede crops grown with two rates of nitrogen (N=0 and 300 kg ha^{-1}), two methods of phosphorus (P) application (Banding and Broadcast) and four rates of P (Control, 25, 50 and 100 kg ha^{-1}) at Hawke's Bay, North Island, New Zealand, in 2010. Bars represent 5% LSD with 25 df.

The bulb DM made up more than 85% of the total dry matter yield, which explains why the non-response of the leaf DM to the combined treatments was not reflected in the total yield.

Table 4 shows response to N across sites, even though background N was higher than 180 kg ha^{-1} (Table 1) except for Taupo. Phosphorus rate and method of application only increased DM yield at Otamauri in Hawke's Bay. This is despite the fact that the Olsen P levels were lower (<12 mg kg^{-1} soil) across the sites.

Table 4: Summary of swede dry matter yield responses to nitrogen (N) and phosphorus rate (Pr) and method (Pm) of application and their interactions at four sites across New Zealand.

Site	Yield range ($t\ ha^{-1}$)	Response to[1]: C vsTrt[2]	N rate	P rate	P method	Interactions: Olsen P Covariate	PrPm	NrPr	NrPm	PrPmN
Invercargill	8.9-13.3	√	√	x	P=0.08	x	x	x	x	P=0.08
Taupo	1.6-13.0	√	√	x	x	√	√	√	x	x
Waimumu	11-16.0	√	√	x	x	x	x	x	x	x
Otamauri	3.3-7.4	√	√	√	√	√	x	x	√	x

[1]√=responded; x=no response.
[2]Control versus Treatment (N rate x P rate x P method).

Discussion

Although the results of these trials were variable and difficult to interpret individually, the yields for both the Southland and North Island sites are within the 10-15 t ha^{-1} reported by Gowers *et al.*, (2006) and the 3-9 t ha^{-1} reported by Percival *et al.*, (1986), respectively. This was consistent with the plant density for the individual sites. The plant density and subsequent DM yield variability can be attributed to site differences in total rainfall and to some extent background soil P ($P<0.1$) (Tables 2 and 3) and therefore different potential yields. Rainfall was low at both Taupo and Otamauri, at <20 mm during the first three weeks after sowing compared to >60 mm for the Southland sites during the same period. However, an attempt was made to describe the responses to P and N supply as a meta-analysis and this shows that while medium N supply of between 120 and 150 kg N ha^{-1} was adequate for the swede crops across the sites, higher rates could be applied with banded high P rates (Figure 1). These N rates are similar to the 140 kg recommended for forage swedes in Otago (Stevens and Carruthers, 2008). Both the current experiments and that of Stevens and Carruthers (2008) were on high background soil N (approximately 200 kg N ha^{-1}) sites. The non-responses to N reported by Stephen and Kelson (1974; 1975) are difficult to interpret and compare to the current experiment as they did not include background soil fertility. Although the background soil P affected yield (Table 4) at the Taupo and Otamauri sites, both the exploratory data analysis (EDA) and meta-analysis showed that it was not a major factor ($P<0.1$) in determining total DM yield. The meta-analysis also showed that the medium rates of 25-50 kg P ha^{-1} were adequate for optimum yield production, except when P was banded, when rates of up to 100 kg P ha^{-1} could be applied together with higher N rates. The 25-50 kg P ha^{-1} rates are similar to recommendations for other brassicas (Wilson *et al.*, 2006; Chakwizira *et al.*, 2009b; 2010). The actual amount of N applied should depend on the background soil N level and the yield potential (N demand) of the crop (Wilson *et al.*, 2006), but our results suggest that in many cases fertiliser N rates as high as 150 kg N ha^{-1} may be justified.

The method of P application only had a significant effect on yield at one site, Otamauri (Table 4). Even at other sites with low Olsen P (<12 mg kg^{-1} soil) and strong yield responses to fertiliser, there were no yield differences between treatments receiving banded and broadcast P fertiliser. These results are in contrast to Wilson *et al*. (2006) which showed better response and hence DM yield for banded than broadcast P fertilised ‘Pasja’ and kale crops. These authors also showed that banded P fertiliser was used more effectively by weak rooted crops like ‘Pasja’, while the more extensively rooted kale utilised P efficiently regardless of whether it was banded or broadcast. However, other research on forage brassicas has also found no yield response to method of P application, for example ‘Pasja’ (Chakwizira *et al*., 2009b) and kale (Chakwizira *et al*., 2009a; 2010). This was attributed to low P retention capacities of the soils; similar to the other sites in the current experiments (Table 2) and hence most of the P was available to the crop irrespective of method of application. Overall, our results suggest that at low soil P sites, such as the four trials reported here, the crops will respond to moderate rates of P fertiliser (25-50 kg P ha^{-1}), but there are unlikely to be yield increases with higher P fertiliser application rates, unless P was banded.

The variable nature of the response in the current experiments suggests that there was an interaction with some other environmental or management factors that were regulating the response. One possibility is that in dry seasons such as at Taupo which received about 52% of the long term average rainfall (Table 3), potential yield is reduced and hence the chances of a response to fertiliser application will be minimal. Fletcher *et al*. (2010) have demonstrated the significance of adequate water on DM yield for other bulb brassica crops like turnips. This, coupled with the medium to high P retention (Saunders, 1965) for the Taupo and Waimumu sites, may have led to the non-response to P supply. However, Otamauri had a high P retention of 89% and consequently both rate of P and method of P supply influenced yield. Alternatively, the low moisture levels are more likely to give a positive response to banded P (as opposed to broadcast P) because the increased availability of P early in the season may allow the plants to establish a more effective root system early in the season and thereby increase the amount of water available to the crop. In their review on a range of crops, Grant *et al*. (2000) concluded that plant response to P deficiency by either diverting resources to root production or increasing root proliferation in the high P regions. A larger root volume will result in improved nutrient and water uptake and the subsequent DM increase.

Conclusions

The economic optimum N rate for swede was the medium rates of 120 and 150 kg N ha^{-1}. The medium rates of 25-50 kg P ha^{-1} were also adequate for economic optimum yield production. Banding P was superior to broadcast at high rates of N. More work is needed to identify the effects of method P application on yield, probably with different water regimes.

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