

## **Evaluation of Phosphorus Application Rate on Broccoli Performance within a Commercial Planting at Pukekawa, New Zealand, During the 2025–26 Season**

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### **Summary**

Phosphorus is an essential nutrient in brassica production, particularly for early root growth and crop establishment. In the Pukekohe–Pukekawa district, soil phosphorus levels are frequently elevated due to long-term fertiliser inputs and intensive cropping. Olsen P values in these volcanic ash soils commonly sit at, or above, the upper end of the recommended range for vegetable crops. As a result, the probability of achieving a yield response to additional phosphorus is often reduced where soil reserves are already high.

A field trial was conducted within a commercial broccoli crop at Pukekawa during the 2025–26 growing season to assess crop response to increasing phosphorus rates under high soil P conditions. Four rates (0, 50, 100 and 200 kg P/ha) were evaluated.

Baseline soil testing (0–150 mm depth) returned an Olsen P of 113 mg/L, exceeding the typical sufficiency range of 50–100 mg/L for vegetable production. This confirmed that the site was well supplied with plant-available phosphorus prior to treatment application.

Phosphorus rate did not significantly affect establishment, vigour, head weight, head diameter or marketable yield.

Under the soil fertility status and seasonal conditions experienced, increasing phosphorus above the grower standard rate of 50 kg P/ha did not improve production outcomes. These results indicate limited responsiveness to additional phosphorus where Olsen P levels are already elevated.

### **Method**

The trial was conducted within a commercial broccoli crop at Pukekawa, New Zealand. The experiment was established as a randomised complete block design with four replicates per treatment. Individual plots consisted of a single grower bed measuring 1.7 m in width and 6 m in length.

Four phosphorus treatments were applied at transplanting (25<sup>th</sup> Nov) using a banded fertiliser application. Nitrogen was applied uniformly across all treatments at a rate of 150 kg N/ha to ensure phosphorus effects could be assessed independently of nitrogen supply.

Prior to treatment application, soil samples were collected from a depth of 0–150 mm across the trial area (Ash soil type) to determine baseline fertility status.

Crop assessments included establishment counts, vigour ratings expressed as a percentage scale, vegetative frame size measurements, head weight, head diameter, yield and marketable head counts.

**Table 1.** Phosphorus treatment details within a commercial broccoli planting

Treatment	Phosphorus Rate
1	0 kg P/ha
2	50 kg P/ha (grower standard)
3	100 kg P/ha
4	200 kg P/ha

## Statistical Analysis

Data was analysed using ANOVA in ARM with treatment as a fixed effect and replicate as a random effect.

Mean separation was conducted using Tukey's HSD ( $P = 0.05$ ). Treatment effects were considered significant at  $P \leq 0.05$ . Coefficient of variation (CV), standard deviation (SD), replicate F and treatment F statistics are reported.

## Results

### 1. Establishment

**Table 2.** Effect of phosphorus rate on broccoli establishment.

Treatments		Nov-25-2025	Dec-15-2025
1	0 kg P/ha	40.5-	40.0-
2	50 kg P/ha	41.0-	41.3-
3	100 kg P/ha	40.8-	40.5-
4	200 kg P/ha	40.3-	39.3-
Tukey's HSD $P=0.05$		2.24	2.94
SD		1.01	1.33
CV		2.5	3.31
Replicate F		10.135	4.219
Replicate Prob(F)		0.0030	0.0404
Treatment F		0.405	1.594
Treatment Prob (F)		0.7528	0.2581

## Discussion

Plant establishment was consistent across all phosphorus rates at both assessment dates (25 November and 15 December 2025). Mean plant numbers ranged from 39.3 to 41.3 plants per plot, and coefficients of variation were low (2.5–3.3%), showing good trial uniformity and reliable data.

There was no clear trend between the phosphorus rate and plant population. Even at 0 kg P/ha, establishment was comparable to the higher rates, suggesting background soil phosphorus levels were adequate to support early root growth and transplant recovery.

Overall, under the block conditions at this site, phosphorus rate had no measurable effect on early crop establishment.

## 2. Vigour Assessment (%)

**Table 3.** Effect of phosphorus rate on broccoli vigour (% rating).

Treatments	Dec-1-2025	Dec-15-2025	Jan-5-2026
1 0 kg P/ha	60.0-	65.0-	75.0-
2 50 kg P/ha	70.0-	60.0-	70.0-
3 100 kg P/ha	70.0-	75.0-	65.0-
4 200 kg P/ha	65.0-	65.0-	65.0-
Tukey's HSD P=.05	21.14	34.71	46.68
SD	9.57	15.72	21.15
CV	14.45	23.73	30.76
Replicate F	1.000	0.371	0.950
Replicate Prob(F)	0.4363	0.7761	0.4566
Treatment F	1.000	0.640	0.205
Treatment Prob (F)	0.4363	0.6079	0.8904

## Discussion

The vigour assessments showed moderate variability across assessment dates, with coefficients of variation increasing from 14.5% in early December to 30.8% by early January. This increase reflects natural plant-to-plant variability as the crop canopy developed.

Mean vigour scores ranged between 60–75% across treatments and assessment timings. Although minor differences were observed (e.g., 100 kg P/ha recording 75% vigour mid-season), these differences were inconsistent over time and did not follow a clear rate-response relationship.

The 0 kg P/ha treatment performed similarly to the higher phosphorus rates at each assessment timing. By the final assessment on 5 January 2026, vigour scores were closely aligned across all treatments, with minimal separation between rates.

Across the assessment period, there was no consistent or statistically distinct response to increasing phosphorus rate in vegetative growth. Within the range evaluated, phosphorus application rate did not alter crop vigour during the trial.

### 3. Harvest Assessments

**Table 4.** Effect of phosphorus rate on harvest parameters (29 January 2026).

Treatments	Frame Size (cm)	Head Weight (kg)	Head Diameter (mm)	Sample Yield (kg per 16 plant sample)	Marketable Count (Sample Size = 16)
	Jan-23-2026	Jan-29-2026	Jan-29-2026	Jan-29-2026	Jan-29-2026
1 0 kg P/ha	56.3 ab	0.476-	212-	7.62-	5.5-
2 50 kg P/ha	56.5 ab	0.425-	196-	6.80-	8.0-
3 100 kg P/ha	55.5 b	0.408-	191-	6.52-	8.3-
4 200 kg P/ha	58.7 a	0.434-	197-	6.95-	9.8-
Tukey's HSD P=.05	2.85	0.12	2.97	1.85	8.25
SD	1.29	0.05	1.35	0.84	3.74
CV	2.28	12.02	6.77	12.02	47.47
Replicate F	12.15	0.74	1.71	0.74	0.30
Replicate Prob(F)	0.002	0.56	0.23	0.56	0.82
Treatment F	4.45	1.23	1.76	1.23	0.89
Treatment Prob (F)	0.0354	0.3537	0.2245	0.3537	0.4832

Means followed by the same letter do not differ significantly ( $P = 0.05$ , Tukey HSD).

## Discussion

### Frame Size

No significant differences were detected between the untreated control and any of the phosphorus treatments. A statistical difference was identified between Treatment 3 (100 kg P/ha) and Treatment 4 (200 kg P/ha). However, this separation most likely reflects random variation rather than a true treatment response.

### Head Weight

Mean head weights ranged from 0.408 kg (100 kg P/ha) to 0.476 kg (0 kg P/ha). Variation between treatments was moderate (CV 12.02%), and no statistically significant differences were detected between phosphorus rates ( $P = 0.3537$ ).

There was no consistent response in head weight with increasing phosphorus application. Notably, the 0 kg P/ha treatment produced the highest numerical head weight, indicating that additional phosphorus inputs did not improve harvestable biomass under the conditions of this trial.

### Head Diameter

Head diameter ranged from 191 to 212 mm across treatments, with no clear trend associated with increasing phosphorus rate. Variability across plots was relatively low (CV 6.77%), and differences between treatments were not statistically significant ( $P = 0.2245$ ).

These findings indicate that phosphorus rate did not influence head sizing characteristics under the conditions of this trial.

### Yield & Marketable Count

Average total yield (kg per 16-plant sample) ranged from 6.5 to 7.62 kg across treatments, while marketable head counts (sample size = 16) ranged from 5.5 to 9.8 heads per plot. Variability in total yield was low to moderate (CV 12.02%), whereas marketable yield showed greater variability (CV 47.47%), reflecting natural differences in head quality and grading outcomes.

No treatment demonstrated a consistent or statistically meaningful advantage for either total yield or marketable yield. Numerically, the highest average total yield was recorded in the 0 kg P/ha treatment (7.62 kg per sample), while the highest marketable count was observed at 200 kg P/ha (9.8 heads per plot); however, these differences were not significant.

These results indicate that increasing phosphorus beyond the grower standard did not improve either overall yield or marketable yield under the conditions of this trial.

## Soil Test Results

- **pH:** 6.4 (optimal range 5.8–6.5)
- **Olsen Phosphorus:** 113 mg/L (above medium range of 50–100 mg/L)
- **Potassium:** 1.24 me/100 g (within range)
- **Calcium:** 8.5 me/100 g (within range)
- **Magnesium:** 1.27 me/100 g (within range)
- **CEC:** 17 me/100 g (moderate nutrient holding capacity)
- **Total Base Saturation:** 65% (within range)
- **Potentially Available Nitrogen (0–15 cm):** 146 kg/ha (within range)
- **Sulphate Sulphur:** 4 mg/kg (below recommended 20–50 mg/kg)
- **Extractable Organic Sulphur:** 6 mg/kg (below recommended 12–20 mg/kg)

The elevated Olsen P value confirmed that the site had high background phosphorus availability prior to fertiliser treatments.

## Overall Discussion

Across all measured parameters, phosphorus rate had limited influence on broccoli performance under the soil and environmental conditions present at Pukekawa during the 2025–26 season.

Baseline soil testing showed an Olsen P of 113 mg/L, which is well above the recommended range for vegetable brassica production. This indicates that phosphorus availability was already sufficient, and crop growth was unlikely to be phosphorus-limited during either vegetative or reproductive development.

The only statistically significant treatment effect observed was for vegetative frame size, where the 200 kg P/ha treatment produced larger plants than the 100 kg P/ha treatment. However, frame size at 200 kg P/ha was not significantly different from either the untreated control or the 50 kg P/ha treatment. Importantly, the increase in vegetative growth did not translate into improvements in head weight, head diameter, total yield, or marketable yield.

Head weight and head diameter showed no consistent response to increasing phosphorus rate, with no significant treatment effects detected. Likewise, total yield and marketable count varied numerically between treatments but were highly variable and not statistically different. Interestingly, the untreated control recorded the highest numerical total yield, while the highest marketable count occurred in the 200 kg P/ha treatment, further demonstrating the lack of a consistent agronomic response to added phosphorus.

These results indicate that background soil phosphorus levels were already adequate to satisfy crop demand, and phosphorus was not a limiting factor under the conditions of this trial. Consequently, increasing phosphorus application above the grower standard is unlikely to provide either a yield advantage or an economic return in soils with similarly high baseline phosphorus levels.

## Conclusion

Across establishment, vegetative growth, and harvest assessments, the data demonstrated a limited crop response to increasing phosphorus rate under the soil and seasonal conditions present during the 2025–26 production cycle at Pukekawa. Baseline soil phosphorus status (Olsen P 113 mg/L) was already above the recommended sufficiency range, which likely explains the absence of significant yield responses across treatments.

The trial findings suggest that:

- Baseline soil phosphorus levels were sufficient to meet crop demand.
- Phosphorus was not a limiting factor for head development or yield formation.
- Additional phosphorus inputs above the standard grower practice did not improve productivity or marketable yield.
- Increased vegetative growth at higher phosphorus rates did not translate into improved harvest outcomes.

In summary, increasing phosphorus application above the grower standard provided no measurable agronomic or yield benefit under the conditions of this trial.