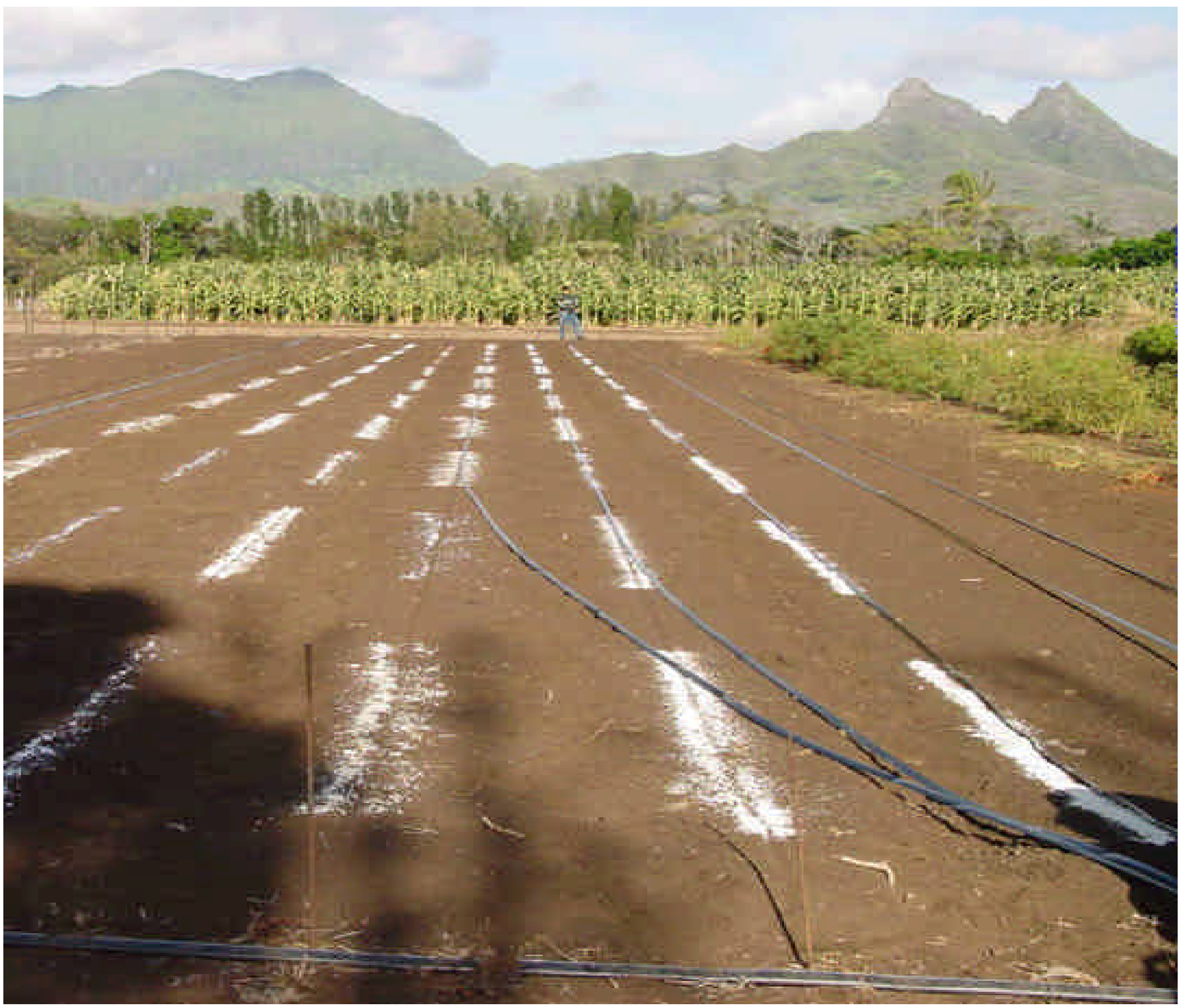
Phosphorus Fertilizer Calibrations for Vegetable Farms in Hawaii

Hector Valenzuela, Ted Goo, Dave Wall, Roger Corrales, Susan Migita, and Milton Yamasaki
University of Hawaii at Manoa
College of Tropical Agriculture and Human Resources

Cooperators: Ray Uchida, Russ Yost, Jim Silva, Jonathan Deenick N.V. Hue, Chris Smith (NRCS), and Bernie Kratky.

Funding Sources/Grants:
DOA/GACC CONTRACT NO.: 49031
NRCS Grant No. 69-9251-2-580
NRCS-EQUIP Contract No. 74-9251-1-560








Phosphorus Fertilizer Calibrations for Vegetable farms in Hawaii

Hector Valenzuela, Ted Goo, Dave Wall, Roger Corrales, Susan Migita, and Milton Yamasaki
University of Hawaii at Manoa
College of Tropical Agriculture and Human Resources

Cooperators: Ray Uchida, Russ Yost, Jim Silva, Jonathan Deenick N.V. Hue, Chris Smith (NRCS), and Bernie Kratky.

Contact Information:
Hector Valenzuela
Vegetable Crops Extension Specialist, UHM-CTAHR
3190 Maile Way No. 102
Honolulu, HI 96822
t. 808.956-7903
hector@hawaii.edu

Executive Summary
Five experiments, consisting of 3 successive plantings per experiment (for a total of 15 field trials, or 39 individual cultivar/P rate trials) were conducted over a 2 year period to evaluate the response of three mustard cabbage varieties to five rates of phosphorus fertilizer applications. The P applications ranged from 0 to 400 lbs/Acre, applied to experimental fields that according to current UH-CTAHR recommendations already had *very high* P levels, which would thus be expected to require no additional P applications. The trials were conducted at three different sites, representing three distinct soil types (representing Mollisols, Oxisols, and Inceptisols groups), at three elevations (70, 880, and 2200 ft asl), and were conducted during different parts of the year (including cool, warm, and hot planting seasons). Overall, out of the total number of 39 individual trials conducted, 64% showed a response to external P applications. The greatest percentage response rate to P applications occurred at the high elevation sites (100% in Lalamilo and 73% of all the trials conducted in Poamoho, compared to 45% for Waimanalo, and 8% when grown in Waimanalo during the summer months), and when the experiments were conducted during the cooler parts of the year. The three varieties evaluated showed a differential response to P, with Mizuna showing a response to P on 66% of the trials, compared to 58% for Joi Choi, and 50% for Quing Choi.

Continues...

Executive Summary, cont.

The results from these trials indicate that CTAHR soil fertility recommendations may need to be tuned-up to better synchronize the soil P levels that are needed to reach 95% of maximum yields for vegetable crops. The recommended nutrient tissue levels necessary to reach high yields may also need to be modified upward. When data from all trials were averaged the optimal P tissue levels that were associated with the highest yields of all three varieties was 0.61% P. The respective optimal soil P levels that were associated with high yields for these varieties was about 340 ppm P. As indicated in the results section of this report, the data obtained from these experiments can be explored in closer detail to come with more tailored recommendations (recommended tissue and soil nutrient levels, and amount of fertilizers needed to reach the appropriate levels) with respect to the production of vegetables at different locations, elevations, and at different times of the year (summer vs. winter months). The differential varietal response to soil fertility shown in these experiments also point out that this type of calibration research needs to be revisited periodically as new improved varieties are introduced in the marketplace. This research also indicates that, as part of the selection criteria, varieties can be selected to improve nutrient resource utilization on the farm, resulting in potential envionmental and economic benefits (less fertilizers used) to the farmer.

Acknowledgements.
Gary Kam, from NRCS-Kamuela brought to my attention in early 2001 the need to conduct P calibration studies to support the Kamuela vegetable growers. I would like to thank Gary and Dwight Sato for their initial suggestions, consulting with vegetable growers, for brainstorming ideas to set up this project, and for their help in suggesting and seeking financial support from NRCS. Ken Kaneshiro, and Larry Shinshiro, both at NRCS, also provided help to obtain research and educational grants from NRCS. We would like to thank Ray Uchida and the staff of ADSC for help with the many tissue and soil nutritional analyses conducted, and for their ongoing encouragement in support of fertilizer calibration research in Hawaii. Ted Goo did an excellent job with the extensive logistical needed to conduct relatively large sized concurrent experiments at two different sites, and with helping to maintain the integrity of the many fertilizer treatments in the rotational plots that needed to stay in place over three consecutive plantings. We would like to thank farm managers Roger Corrales, Susan Migita, and Milton Hamasaki, and their dedicated staffs at the Waimanalo, Poamoho, and Lalamilo Experiment stations for their extensive logistical and field support in helping to maintain these experiments for a period of over two years. Without their help and attention to detail in all aspects of the project, including field establishment, maintainance, scheduling operations, and extensive data collection, these trials would have not come up to fruition. We would like to thank the cooperators of this project (listed above) who helped with brainstorming to prepare the experimental design and provided suggestions throughout the duration of the project. Christine Crosby, research associate, helped with data collection and data input. Thank-you to Dave Wall for his willingness and dedication, shortly after his arrival to the Big Island, to conduct the research trials and data analysis in Lalamilo, which involved many long round trips from Hilo to Kamuela, and coordinating activities with the staff in Lalamilo. Lina Huang, student assistant, helped with data input. The NRCS-EQUIP project, NRCS, and the DOA kindly provided grants to finance this project.

I. **Contents**

List of Tables

List of Tables, cont.

TITLE: Phosphorus Fertilizer Calibrations for Vegetable farms in Hawaii

ABSTRACT:

A series of 15 field experiments were conducted at three locations (three different soil types and three different elevations; Waimanalo, Poamoho, and Kamuela) during the winter and summer growing seasons to evaluate the response of three mustard cabbage varieties to five different phosphorus fertilizer application rates. The experimental protocol consisted on applying 5 P rates (from 0 to 400 lb/Acre) and then to plant three consecutive mustard crops on the same plots without any additional P applications, to evaluate the P nutrient release rates, and corresponding nutrient uptake throughout the duration of the experiments. The experiments were conducted on soils with fertility similar to those found in commercial fields (with high initial Phosphorus levels) that required no P applications according to current CTAHR fertility recommendations. The results from this set of experiments indicate that vegetable crops do in fact respond to moderate P fertilizer applications (as high as 200 lbs/Acre), even in soils with high initial P levels (ca 300 ppm P). The response to P applications was more evident at high elevations (cooler soils) or during the winter plantings. The results from this research indicate that CTAHR may have to tune-up its current soil P recommendations, to indicate that small amounts of P may be necessary for intensively grown crops, especially when plantings are conducted in the winter or at high elevations. In some cases and/or with some crops the recommended soil P levels may need to be raised to be as high as 300 ppm P, as the threshold where additional P applications will result in no additional yield increases. The data from this project also illustrates that crop varieties may have differential responses to soil P fertility levels. This indicates that growers need to adapt their fertilizer regime depending on what variety is being grown, and that it may be possible to select crop varieties that are better adapted (more efficient in terms of nutrient utilization) for production on specific locationsResults from this research were presented to UH extension faculty and researchers and to NRCS staff at a nutrient management workshop held at UH-Manoa.

PROJECT OBJECTIVES:

1. To evaluate the yield response of mustard cabbage to P fertilizer applications in soils that show initial high levels of available P in the soil solution. This research will be conducted in two islands.
2. To evaluate the seasonal effect (summer vs. winter) of P fertilizer applications by conducting this research over two years, and during both summer and winter planting seasons.
3. To conduct educational programs for vegetable growers concerning proper P fertilizer management.

1.0. Materials and Methods

Five experiments consisting of fifteen crop plantings (three continuous plantings per experiment) were conducted from 2001 to mid 2003 to evaluate the response of three mustard cabbage varieties to five rates of phosphorus fertilizer applications. To conduct the research in sites that reflected soil fertility conditions found in typical commercial farms experiments were conducted in soils that showed initial high levels of available phosphorus. To evaluate the gradual release over time, of the applied P, we planted a series of three continuous mustard cabbage plantings on each experimental site, after the initial phosphorus application was made. The reseach was conducted on three locations (Waimanalo, Poamoho, Kamuela) representing three elevations (70, 870, and 2200 ft), and three different soil types (see Table M.1). Because local vegetable growers claim to observe greater response to P applications during the cooler winter months, plantings were conducted during different months of the year to evaluate the uptake of P during both warm and cooler soil conditions. The schedule of plantings is listed on Table M.2. Three mustard cabbage varieties were used in this research to evaluate differential responses to available P uptake, which would aid in developing P recommendations for vegetable crops production in Hawaii.

Each experimental plot consisted of a 10-ft long double row (two rows of crop per plot), with 4 replications per treatment. Treatments included applications of 0, 100, 200, 300, or 400 lbs/acre of TSP. The three varieties used in the experiment were Joi Choi (white stemmed pak choy variety), Ming Quing Choi (green pak choy variety), and Mizuna, all from Sakata Seed. Each experiment thus had a total of 60 plots (5 P rates x 3 varieties x 4 replications). The P fertilizer was applied prior to sowing the first planting. P was applied over a 1 ft wide band along the middle of each plot, along with an initial application of NK & Ca fertilizer. The rows were rototilled to a depth of 4-6 inches to incorporate the applied fertilizer. Following the first planting, two additional plantings were established on the exact same plots, with a different variety being grown on each individual plot on each experiment (using the sequence Joi Choi, followed by Mizuna, and followed by Ming Quing Choi). No additional P was applied for the second and third plantings. Thus the second and third plantings only received NK and Ca applications, as needed. Data collected for each experiment included soil fertility prior to starting the experiment and after experiment completion (after 3rd planting), initial seedling height (20 measurements per plot), nutrient tissue levels at mid-growth, and final head weight (yield) and length (20 measurements per plot).

Table M.1. Site Description.

Waimanalo, Oahu. 70 ft elevation; Mollisols, The soil is a Waialua (Waimanalo variant) silt clay (Vertic Haplustolls, very-fine, kaolinitic, isohyperthermic) containing predominantly a montmorilonitic clay that with approx. 4-5% OM.; 45 in. median annual rainfall. CEC ca. 33 NH_4OAC. High base saturation of 80%. Mollisols represent about 4.3% of land area in Hawaii. Available water-holding capacity is about 1.8 inches per foot in the surface layer and 1.6 inches per foot in the subsoil. High inherent fertility. Capability Classification is IIe (erosion, if irrigated). The mean annual soil temperature is 73F. Mollisola are among the most fertili and productive soils in the state.

Poamoho, Oahu. 870 ft elevation; Oxisols, Wahiawa silt clay (Tropeptic Eutrustox clayey, kaolinitic, isohyperthermic) containing predominantly kaolinitic clay and iron oxides with approx 2% OM; 45 inches median annual rainfall. CEC ca. 17 NH_4OAC, Base saturation 44%. Highly weathered soils, in Hawaii derived from basaltic rocks or alluvium, composed primarily of kaolinite and the oxides of iron and aluminum. Oxisols represent about 5% of land area in Hawaii. Occurs on the old surfaces of old volcanoes. It has the ability to 'fix' large amounts of added soluble phosphate fertilizers, but these phosphates are not as tightly held as in many other soils, so that the plants may obtain the phosphates over a long period of time. Available water-holding capacity is about 1.3 inches per foot in the surface layer and 1.6 inches per foot in the subsoil. Bulk density is 1.31 g/cc. This soil, as well as other Oxisols have been extensively used for sugarcane and pineapple production in Hawaii. Capability Classification is II (erosion, irrigated or non-irrigated).). The mean annual soil temperature is 72F.

Lalamilo (Kamuela, Big island). - 2,200 ft elevation, Inceptisols, Waimea loam (typic eutrandepts, medial, isothermic), volcanic ash soils with a high base status, median annual rainfall reported as 25-30 in, temp range 60-73F. CEC ca. 59 NH_4OAC. Base saturation 60%. The surface is very fine sandy loam to loam, the subsoil is dark brown silt loam. Inceptisolas are young soils with only moderate weathering. Located on a Reddish Praire soil which is excellent for vegetable production. OM≈8-9%. The Kamuela soils is originally developed from Volcanic ash and has a very high infiltration rate. The minimum infiltration rate is about 1.5 in per hour. Mean annual soil temperature is about 60F.

Table M.2. Planting Schedules for Phoshphorus Fertilizer Experiments.

Location	Expt. No.	Planting date	Initial Height	Harvest
Waimanalo	1-1	Oct. 3, 2001	Oct. 24	Nov. 7
Poamoho	2-1	Oct. 9, 2001	Oct. 30	Nov. 13
Waimanalo	1-2	Dec. 11, 2001	Jan. 3	Feb. 1, 2002
Poamoho	2-2	Dec. 14, 2002	Jan. 15	Feb. 5, 2002
Waimanalo	1-3	Mar. 15, 2002	Apr. 9	Apr. 26
Poamoho	2-3	Mar. 17, 2002	Apr. 3	Apr. 24
Waimanalo	3-1	Jul. 15, 2002	Aug. 7	Aug. 30
Poamoho	4-1	Jul. 30, 2002	Aug. 23	Sept. 10
Waimanalo	3-2	Nov. 15, 2002	Dec. 17.	Dec. 23
Poamoho	4-2	Oct. 1, 2002	Oct. 30	Nov. 12
Waimanalo	3-3	Apr. 30, 2003	May 20	Jun. 16
Poamoho	4-3	Feb. 11, 2003	NA	Mar. 25
Lalamilo	5-1	Aug. 19, 2002		Sept. 24
Lalamilo	5-2	Oct. 15, 2002	NA	Nov. 25
Lalamilo	5-3	Dec. 5, 2002	NA	Jan. 24, 2003

NA= data not collected

2.0. Results

2.1. Experiments 1 and 2 (Waimanalo and Poamoho).

The first plantings were conducted during the cooler months of the year. However there was a temperature differential between the two sites (Waimanalo at low elevation, Poamoho at higher elevation) where the trials were conducted. The soil P levels prior to making any P applications (about 340 ppm and 350 for Waimanalo and Poamoho, respectively) were considered very high according to current CTAHR recommendations (Table 22). In Waimanalo, P applications had no significant effect on the growth and yield of Joi Choi and Quing Choi on the first planting, even though a trend (4%) toward higher yields was observed for Joi Choi in response to applications of 200 lbs/Acre of P (Table 1). Yields were actually depressed for Joi Choi and for Mizuna at the highest P application rate (400 P), compared to the controls (no P applied). For Mizuna, which was planted at higher plant densities (2-3 inches vs. 6 inches for the other two varieties) greatest initial seedling height was obtained with applications of 300 lbs/Acre P, and greatest yields were obtained with 200 lbs/Acre of P, showing a greater response to P than the other two varieties. For the first planting in Poamoho (conducted concurrently to the one in Waimanalo), for Joi Choi greatest initial growth and final yields were obtained with 200 lbs/Ac P, while 100 P resulted in the greatest yields for Quing Choi and Mizuna (Table 4). The highest P rate (400 P) actually depressed yields for Joi and Quing Choi, while applications of 200-400 P also depressed Mizuna yields.

The second planting for Expt. 1, was conducted from December 2001 until early February of 2002. In Waimanalo, for Joi Choi and Mizuna greatest initial and final plant heights were obtained with 100 lbs/Acre of P. For Mizuna, P rates actually depressed yields compared to the controls, while for Joi Choi greatest yields were obtained with P applications of 100 to 400 lbs/Acre (Table 2). For Quing Choi grown in Waimanalo, P applications (100-300) increased initial plant height but had no effect on final height, and P applications also depressed yields (Table 2). For the second planting in Poamoho P applications had no effects on initial plant height, final height and yield of Joi Choi (Table 5). P applications of 100 lb/Acre resulted in greater initial plant height for Quing Choi and Mizuna. P had no effect on final height of Mizuna and it also depressed height in Quing Choi. While P had no effect on the yield of Mizuna, 100 and 400 lbs/Acre P resulted in the greatest yields for Quing Choi in Poamoho (Table 5).

For the third planting in Waimanalo conducted between March and April, P had no effect on initial nor on final plant height for all three cultivars (Table 3). Yields however, were greatest with 100, 200, and 400 lbs/Acre P for Mizuna, Quing Choi, and Joi Choi, respectively. For the third planting in Poamoho all P treatments increased the initial plant height of Joi Choi. P had no effect on the initial plant height of Mizuna, while 0 and 200 P resulted in the greatest initial plant height among all treatments for Quing Choi. P applications of 100, 200, and 200 resulted in the greatest final plant height for Mizuna, Quing Choi and Joi Choi, respectively, in Poamoho (Table 6). For the third planting in Poamoho P had no effect on final yields for Joi Choi and Quing Choi, while 400 lbs/Acre of P resulted in the greatest yields for Mizuna.

2.2. Experiment 3 and 4 (Waimanalo and Poamoho).

The first planting for Experiment 3 in Waimanalo was conducted during the warm months of the year, from July to August 2002. The soil P levels prior to beginning the experiments (354 and 173 for Waimanalo, and Poamoho, respectively) were considered to be very high, according to current CTAHR soil fertility recommendations (Table 24). In Waimanalo P applications had no effect on initial or final plant height for the Joi Choi variety (Table 7). For Quing Choi initial plant height was greatest with 400 P, but no P effects were observed with respect to final plant height. For Mizuna, all P applications increased initial and final plant height, compared to the controls (0 P). P applications had no effect on final yields for any of the varieties for the first planting in Waimanalo (Table 7). At the cooler site in Poamoho, application of 300 lbs/Acre P increased the initial height of Joi Choi and Mizuna, compared to the other treatments (Table 10). Similarly, 200- and 400-P resulted in a greater final plant height for Joi Choi and Mizuna, respectively, than the other P levels. P levels had no effect on the initial nor final plant height of Quing Choi. Applications of 200-P and 400-P resulted in the greatest yields for Joi Choi and Mizuna, respectively. While there was no statistical difference in P treatments for Quing Choi (from 0-300 P), there was a trend toward greater yields with applications of 300 lbs/Acre of P (Table 10).

The second plantings for Expts. 3 and 4 were conducted between November and January for both locations. For the second planting in Waimanalo P-treatments had no effect on the initial plant height of Joi Choi nor Mizuna (Table 8). For Quing Choi, however, applications of 400-P resulted in a greater initial plant height, compared to the other treatments. Final plant height was not affected by P levels for either Quing Choi nor Mizuna, while 100-400 P levels resulted in a greater final plant height than for the controls for the Joi Choi variety. P levels also had no effect on final yields (top weight) for either Quing Choi or Mizuna, while 100-400 P applications resulted in greater yields than for the controls for Joi Choi. Contrary to the results obtained in Waimanalo, P applications of 100, 200 and 300 lbs/Acre resulted in greater initial plant height for Mizuna, Quing Choi, and Joi Choi, respectively, compared to the other treatments. While P treatments did not affect final plant height for Joi Choi nor Quing Choi, applications of either 100 or 400 lbs/Acre P resulted in greater final plant height in Mizuna (Table 11). In Poamoho applications of 200-P and 200 or 400 P increased the yield of Quing Choi and Mizuna, respectively. However for Joi Choi, P applications of 300-P did not increase final P yields, compared to the controls (Table 11).

The third planting was conducted during the warm season (May to June) in Waimanalo, and during the cool season (Feb. to March) in Poamoho. In Waimanalo P applications did not affect initial plant height for either Quing Choi or Mizuna, but 200 P resulted in greater initial plant height for Joi Choi (Table 9). Applications of 200 P, and of 100 or 400-P increased the final plant height of Quing Choi and Mizuna, respectively, but P applications did not increase final plant height, compared to the controls, for Joi Choi. Similarly P applications increased the final yields of Quing Choi (200 and 400P), and Mizuna (100, 300 & 400P), but had no effects on the yield of Joi Choi (Table 9). In Poamoho, applications of 100, 200, and 400 lbs/Acre P resulted in the greatest final plant heights for Quing Choi, Joi Choi, and Mizuna, respectively, compared to the other treatments (Table 12). Similarly, P applications resulted in greater plant yields compared to the controls for Quing Choi (100-400 P), Joi Choi (200-P), and Mizuna (300 & 400-P).

2.3. Experiment 5. Lalamilo Station, Kamuela

A similar sequence of three consecutive plantings was conducted in the Lalamilo Station on Kamuela (2,200 ft elevation), with 5 different P applications (from 0-400 lbs/Acre) made only prior to beginning the first experiment, and with no additional P applied thereafter. For logistical purposes, only one variety, Joi Choi, was used for this experiment. The soil P levels prior to beginning the experiment were 213 ppm, which were quite higher than those currently recommended by CTAHR for those soils (38 ppm). The first crop was sowed on August, one of the warmest months of the year. The field where this trial was conducted had a relatively high level of compaction (6-12 inch depth), which may be similar to conditions found in conventional farms in the Kamuela area, which is in part due to erosion and to the high number of tillage operations that are conducted with each successive planting. For the first experiment the greatest initial and final plant heights were observed with applications of 300 and 400 lbs/Acre P, respectively (Table 27). Greatest yields were observed with 400-P applications. The second experiment was sowed in October. Applications of 200 lbs/Acre P resulted in the greatest plant heights and yields in the second planting. For the third experiment, which was sowed in the cooler month of December, the greatest plant height and yields were obtained with applications of 200 and 300 lbs/Acre of P, respectively.

2.4. Soil and Tissue Phosphorus Levels associated with High yields

The recommended tissue levels for head cabbage to reach high marketable yields in warm growing areas is 0.5 ppm P. The current recommended soil P soluble levels in Hawaii for vegetable crops is between 25 and 35 ppm P. Little literature exists in Hawaii or elsewhere reporting recommended tissue nutrient levels for the commercial production of mustard cabbage. The data below describes the results obtained with the different mustard cabbage varieties in our trials.

When data from all cultivars was pooled together, optimal P tissue levels associated with the greatest crop yields ranged between 0.6-0.7 when averaged over the three successive plantings (after an initial P application) (Table 32). The respective optimal P fertilizer application rates to reach high yields ranged between 150-200 lbs/Acre for the first two plantings, and between 200-250 lbs/Acre for the third successive planting, with these levels referring to the P applications made prior to starting the first planting. (Table 32). When data from all plantings and treatments was pooled together, the P tissue levels that were associated with the greatest yields for each variety were 0.64 ppm P for Joi Choi, 0.63 ppm for Quing Choi, and 0.58 for Mizuna (Table 32). Overall, these tissue levels were associated with P fertilizer rates (made prior to the first planting on a series of 3 plantings) of 150-200 lbs/Acre for Joi Choi and Quing Choi, and of 200-250 lbs/Acre for Mizuna (Table 32).

Joi Choi. In the first experiment, the tissue P levels associated with high yields in Waimanalo for the first planting ranged between 0.73 and 0.78 ppm P (Tables 1 & 13). The tissue levels associated with the highest yields increased to 0.75-0.85 ppm P for the second planting, and to 0.84 ppm P for the third planting, when cooler temperatures prevailed (Tables 2, 3, 15 & 16). In experiment 3, tissue level of 0.62 ppm P (Table 9) were also associated with high Joi Choi yields during a warm planting period (3rd planting), while tissue P levels of 0.73 to 0.79 were associated with high yields during the second planting (Table 8). The soil P levels associated with the highest yields for Experiment 1 in Waimanalo were between 268-365 ppm P for the first planting (warmer growing conditions) (Table 1), between 332-370 for the second planting (Table 2), and 370 ppm P for the third planting of experiment 1 (cooler growing conditions for the 2nd and 3rd plantings) (Table 3). For experiment 3 in Waimanalo, soil P levels associated with the highest yields ranged between 368-397 ppm P (first planting) (Table 7), increased to 397-460 by the 2nd planting (Table 8), and was 368 ppm soil P for the third planting (Table 9).

Similar tissue and soil P levels were obtained with Joi Choi in Poamoho. The level of tissue P associated with the highest yields in Poamoho was 0.71 (first planting, warm temperatures), 0.8 (second planting), and about 0.73 (third planting) (Tables 4, 5 & 6, respectively). The soil P levels associated with high yields of Joi Choi in Poamoho were 339 ppm P (first planting, warm temperatures), 311 (second planting), and about 315 ppm (third planting) (Tables 4, 5 & 6, respectively)..

In Lalamilo, the tissue P levels associated with high yields were 0.59 ppm P (1st planting, hot temperatures), and 0.51 (3rd planting, cooler temperatures). The corresponding soluble P soil levels associated with high yields were 384 (1st planting), and 238 ppm (for 2nd, and 3rd plantings) (Table 27).

Overall fertilizer and tissue recommendations for Joi Choi, based on a correlation of nutrient tissue levels, soil fertility, and conditions that lead to the greatest yields in our experiments are listed on Tables 32-34.

Quing Choi. The tissue P levels associated with high yields for Quing Choi on the first Experiment in Waimanalo ranged between 0.59 and 0.84 ppm P (first planting), between 0.68-0.8 (second planting), and was 0.64 ppm P (third planting) (Tables 1, 2 & 3, respectively). For experiment 3, conducted under warmer temperatures, the optimal P tissue levels for Quing Choi ranged between 0.66 and 0.79 ppm P (second planting), and was 0.59 (third planting, under relatively hot temperatures) (Tables 8 & 9, respectively). The optimal soil P levels associated with high yields of Quing Choi in Waimanalo on Experiment 1 ranged between 268-365 ppm P (first planting), between 268-332 (second planting), and between 483-460 ppm for the third planting (Tables 1, 2 & 3, respectively).

Similar tissue and soil P levels were obtained with Quing Choi in Poamoho. The levels of tissue P associated with the highest Quing Choi yields on Experiment 2 in Poamoho were 0.81 (first planting, warm temperatures), 0.86 (2nd planting), and 0.62 (third planting) (Tables 4-6). For experiment 4 the optimal tissue P levels for Quing Choi were 0.58 (1st planting, hot temperatues), 0.72 (2nd planting, warm temperatues), and ranged between 0.54 to 0.60 (third planting, cooler temperatures) (Tables 10, 11& 12, respectively). The corresponding soil P levels obtained with the high-yielding treatments for Quing Choi were 319 ppm P (1st and 2nd planting), and ranged between 311-403 ppm P for the 3rd planting (Tables 11-12). For experiment 4 in Poamoho, the soil P levels associated with high Quing Choi yields ranged between 144-318 ppm P (first planting, hot temperatures), 315 (2nd planting, warm temperatures), and ranged between 144-315 ppm P (3rd planting) (Tables 10, 11& 12, respectively).

Overall fertilizer and tissue recommendations for Quing Choi, based on a correlation of nutrient tissue levels, soil fertility, and conditions that lead to the greatest yields in our experiments are listed on Tables 32-34.

Mizuna. In Waimanalo on experiment 1 the P tissue levels associated with high yields in Mizuna were about 0.65 ppm P (1st and 2nd plantings), and 0.68 (3rd planting) (Tables 1-3). On experiment 3 in Waimanalo, these tissue levels ranged between 0.68 and 0.71 (2nd planting, warm temperatures), and between 0.51-0.68 (3rd planting, hot temperatures) (Tables 8 & 9). The soil P levels associated with high yields in Waimanalo on the first experiment were 370 ppm P (first planting, warm temperatures), 268 (2nd planting), and 332 ppm (3rd planting) (Tables 1-3). On experiment 3 the soil P levels associated with high yields in Mizuna ranged between 474-483 (1st planting, hot temperatures), 397-483 (2nd planting, warm temperatures), and 397-474 ppm P (3rd planting, hot temperatures) (Tables 7-9).

In Poamoho, the corresponding tissue P tissue levels for Mizuna on the first experiment (Expt. 2) were 0.62 ppm P (1st planting), ranged between 0.65-0.72 (2nd planting), and were 0.54 for the 3rd planting (Tables 4, 5 & 6, respectively). The tissue levels associated with high yields in Expt. 4 were 0.47 ppm P (1st planting, hot temperatures), ranged between 0.50-0.52 (2nd planting, warm temperatures), and was 0.48 (3rd planting) (Tables 10-12). In Poamoho, the corresponding soil soluble P levels for Mizuna on Expt. 1 were 108 ppm P (1st planting), ranged between 311-350 (2nd planting), and was 403 ppm P for the 3rd planting (Tables 4-6). For experiment 4 in Poamoho the corresponding soil P levels for Mizuna were 386 (1st planting, hot temperatures), ranged between 315 to 386 (2nd planting), and between 318-386 (3rd planting) (Tables 10-12).

Overall fertilizer and tissue recommendations for Joi Choi, based on a correlation of nutrient tissue levels, soil fertility, and conditions that lead to the greatest yields in our experiments are listed on Tables 32-34

2.5. Nutrient tissue levels over time (in response to successive plantings after an initial P application), effects of temperature and elevation

.

Overall, the tissue analysis showed a trend toward a 10% decline in the P tissue nutrient content from the first to the third plantings (Table 32), reflecting on the gradual depletion of P in the soil with each successive planting. This pattern was again observed by correlating the optimal P application rates associated with the best yielding treatments over the three successive plantings on each experiment. By the third planting, the optimal P fertilizer applicaton rates needed to reach high yields were estimated to be about 22% greater (233 lbs/Acre P), compared to the levels needed for the first planting (192 lbs/Acre P) (Table 32).

When the data were pooled to determine the effect of elevation, it showed that production at high elevations required about more external P than at low elevations for Mizuna, but the inverse was true for Joi Choi (Table 33A). Tissue P levels, however were greater at the low elevations for both Mizuna and Joi Choi but elevation had no apparent effect on tissue levels for Quing Choi. This may indicate that P uptake is not affected as much at higher elevations for Quing Choi, as it was for the other two varieties (Table 33A).

To make better direct tissue level, yields, and soil fertility comparisons between the two elevations, we compared the data for Expts. 1 and 2 only, because these trials were better synchronized in time, and soil fertility at the time was also similar between the two sites (Table 33B & Table 22). Again, the P tissue levels were greater at the low elevation for both Joi Choi and Mizuna, and conversely, greater P tissue levels were observed at the high elevation for Quing Choi. The optimal soil P levels to reach high yields were greater at low elevations also for Joi Choi and Mizuna. In terms of the external P required to reach high yields, higher rates were required at low elevations for Joi Choi, higher rates were required at high elevations for Mizuna, while similar rates were required for Quing Choi at both elevations (Table 33B). These data may point out the differential adaptability of these cultivars for production at different elevations, reflected by their ability to uptake the available P to reach high yields.

To further analyze differential varietal responses to P applications the data was sorted by temperature (classified as cool, warm, or hot, depending on the months between planting and harvest) during the growing cycle (Table 34). Overall, all varieties had greater P tissue levels when grown during warm or cool months as compared to hot conditions. The greatest yields for both Joi Choi and Mizuna were obtained during hot growing cycles, while Quing Choi showed greater yields during cool growing months (Table 34). With respect to external P needs, Joi Choi required greater external P when grown during cooler months, while Quing Choi and Mizuna required greater external P when grown during hot months of the year.

2.6 Yield Response to Phosphorus applications based on growing temperature and elevation.

To further evaluate the response of mustard cabbage to phosphorus fertilizer applications based on elevation, temperature during the growing season (cool, warm, or hot), and differential cultivar response to these factors, we tabulated the number of experiments (N= 36 trials) where significant yield responses were observed in response to P fertilizer applications. The growing months were arbitrarily defined, based on historical monthly temperature data, as follows: cool, between Dec. to March; Warm between Oct. to Nov. and March. to May; and hot between June to September. The results of this tabulation is summarized on Table 35, and is based on percentages. When both sites were pooled, the response rate to P applications was 44, 42, and 66% for hot, warm, and cool growing conditions, respectively. Overall, a greater response to P was observed at high elevations (73%) compared to low elevations (45%). When the three varieties were grown under both *high elevations* and during the *cooler* months of the year, the average percentage rate response to P applications was 44% compared to 8% when it was grown at *low elevations* during the *warm or hot* months of the year. Likewise, a greater overall response to P with respect to yields was observed when mustard was grown during the hot months of the year at high elevation (16%), compared to the response observed during hot months at low elevation (8%). Similar results were obtained with respect to initial and final plant height measurements. Initial height evaluations showed a 61% rate response to P at high elevations compared to 55% at low elevations. Similarly, final plant height showed a 55% rate response to P at high elevations, compared to 44% at low elevations.

All cultivars had a similar low rate (8%) of response to P applications when grown at low elevations during hot or warm months of the year. However, a differential varietal response was observed at high elevations when grown during the cool months of the year, showing response rates of 58, 42, and 33% for Mizuna, Joi Choi, and Quing Choi, respectively.

2.7. Differential cultivar response to P fertilizer applications

When data from Poamoho and Waimanalo (N= 12 experiments/cultivar) were pooled together (Table 36), the data showed that the greatest response to fertilizer P applications was observed for Mizuna (66% of experiments showed a yield response to P) followed by Joi Choi (58%), and by Quing Choi (50%). As indicated earlier a greater overall response was observed at the high elevations (100% in Lalamilo, and 73% in Poamoho), compared to the low elevation (45%). At the high elevation site in Poamoho, Mizuna showed the greatest response to applied P (83%, obtained by dividing 5/6 on Table 36), compared to the other two varieties (66% response each). At the low elevation site, both Mizuna and Joi Choi showed the greatest response to external P (50% rate response each), compared to Quing Choi (33%). Similar results were obtained with respect to initial and plant height (summarized data not shown). At the high elevation site in Poamoho, both Mizuna and Joi Choi showed the greatest response to P (66%) with respect to initial plant height, compared to 50% for Quing Choi. At low elevations, Mizuna showed the greatest response trend (50% of experiments showed a response to P) compared to the other two cultivars (33%). Similarly, with respect to final plant height, at high elevations Mizuna showed the highest response rate (66%), compared to Joi Choi and Quing Choi (33% each); and at the low elevation site Mizuna showed an 83% response rate to P applications, compared to 50% for Joi Choi, and 33% for Quing Choi.

2.8. Nutrient uptake in response to P fertilizer applications

The tissue nutrient levels, determined from sampling of the most-recently matured leaves at the pre-'heading' or mid-growth stage are an indication of the nutrient uptake patterns in response to the P fertilizer application treatments. When data from all experiments was pooled together, Joi Choi showed a trend toward greater N levels, and significantly greater K and K/P uptake ratio levels than the other two varieties (Table 37). Mizuna showed a trend toward lower P levels, significantly lower K and K/P levels, and significantly greater N/P ratios than the other two cultivars. The relatively lower P uptake levels observed for Mizuna, may be correlated with its greater response to external P applications (as shown on Table 36 and as discussed in the previous section), compared to the other two varieties. When data from both sites were pooled together, Poamoho showed significantly greater NPK, N/P, and K/P ratio levels than Waimanalo (Table 37). In general, tissue nutrient levels in Poamoho were about 10% greater for P, 20% greater for N, and 28% greater for K, resulting in 37% greater N/P ratios and 48% greater K/P ratios, than in Waimanalo (Table 37). The greater nutrient uptake levels observed in Poamoho may explain for the overall 64% greater pooled yields observed in Poamoho than in Waimanalo (Table 33). When data was pooled across cultivars and locations, all P application treatments showed statistically similar N and K levels, higher P tissue levels for those treatments that received external P compared to the control, and greater N/P and K/P ratios were observed for treatments that received no external P (bottom of Table 37).

When the nutrient tissue data was summarized for each individual variety on Table 38, a similar pattern of nutrient uptake was observed. Overall, trials at high elevations resulted in greater N and K levels and in greater N/P and K/P ratios than at low elevations. Also, the trials at low elevations showed greater P tissue levels, than at high elevations, for each of the three varieties evaluated (Table 38). The greater P tissue levels observed at the lower elevations may be explained by the faster P uptake that occurs under warmer soil temperatures, which was corroborated by the greater response to external P applications observed at the higher elevations (Tables 35 & 36). When the tissue nutrient levels were analyzed for each individual cultivar in response to P applications, the data showed no significant differences in N tissue levels (Table 38). The reatments that received 0 P showed a trend toward lower P tissue levels with a level of significance observed only for Quing Choi. Treatments that received 0 or 0 &100 P showed a trend toward greater K tissue levels while 0 P treatments for Joi Choi and Mizuna also had a trend toward greater N/P and K/P ratios. The 0 P treatments for Quin Choi showed did show significant greater N/P and K/P ratios than treatments that received P (Table 38). These data indicates that soil fertility may have an effect on the level and ratio of nutrient uptake into the plant which may result in nutrient imbalances (greater or reduced uptake of some nutrients in relation to each other), growth imbalances (top/root ratio), hormonal imbalances (affecting top/root ratio), pest damage (in plants with relative high N ratio levels or excessive vegetative growth), and in postharvest shelf-life and quality (as affected by N & K ratios, and other nutrients).

3.0. Conclusions

Five experiments, consisting of 3 successive plantings per experiment (for a total of 15 field trials, or 39 individual cultivar/P rate trials) were conducted over a 2 year period to evaluate the response of three mustard cabbage varieties to five rates of phosphorus fertilizer applications. The P applications ranged from 0 to 400 lbs/Acre, applied to experimental fields that according to current UH-CTAHR recommendations already had *very high* P levels, which would thus be expected to require no additional P applications. The trials were conducted at three different sites, representing three distinct soil types (representing Mollisols, Oxisols, and Inceptisols groups), at three elevations (70, 880, and 2200 ft asl), and were conducted during different parts of the year (including cool, warm, and hot planting seasons). Overall, out of the total number of 39 individual trials conducted, 64% showed a response to external P applications. The greatest percentage response rate to P applications occurred at the high elevation sites (100% in Lalamilo and 73% of all the trials conducted in Poamoho, compared to 45% for Waimanalo, and 8% when grown in Waimanalo during the summer months), and when the experiments were conducted during the cooler parts of the year. The three varieties evaluated showed a differential response to P, with Mizuna showing a response to P on 66% of the trials, compared to 58% for Joi Choi, and 50% for Quing Choi.

The results from these trials indicate that CTAHR soil fertility recommendations may need to be tuned-up to better synchronize the soil P levels that are needed to reach 95% of maximum yields for vegetable crops. The recommended nutrient tissue levels necessary to reach high yields may also need to be modified upward. When data from all trials were averaged the optimal P tissue levels that were associated with the highest yields of all three varieties was 0.61% P. The respective optimal soil P levels that were associated with high yields for these varieties was about 340 ppm P. As indicated in the results section of this report, the data obtained from these experiments can be explored in closer detail to come with more tailored recommendations (recommended tissue and soil nutrient levels, and amount of fertilizers needed to reach the appropriate levels) with respect to the production of vegetables at different locations, elevations, and at different times of the year (summer vs. winter months). The differential varietal response to soil fertility shown in these experiments also point out that this type of calibration research needs to be revisited periodically as new improved varieties are introduced in the marketplace. This research also indicates that, as part of the selection criteria, varieties can be selected to improve nutrient resource utilization on the farm, resulting in potential envionmental and economic benefits (less fertilizers used) to the farmer.

4.0 Tables

Table 1. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Waimanalo, Expt. 1, first planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	11.8 A	37.0 A	334.0 A	0.77	268
	100	12.3 A	36.3 A	322.5 AB	0.69	332
	200	11.9 A	37.8 A	347.8 A	0.78	370
	300	11.3 B	41.4 A	346.7 A	0.73	365
	400	12.2 A	38.8 A	295.3 B	0.73	370
Ming Q. Choi	0	10.8 A	29.4 B	239.0 A	0.59	268
	100	10.8 A	28.4 B	234.1 A	0.64	332
	200	10.4 A	29.0 B	235.1 A	0.84	370
	300	9.8 B	29.0 B	221.6 A	0.73	365
	400	10.7 A	35.2 A	223.5 A	0.82	370
Mizuna	0	14.2 B	49.4A	132.1 AB	0.54	268
	100	14.5 AB	50.1A	142.4 AB	0.73	332
	200	14.8 AB	54.9A	148.0 A	0.64	370
	300	15.4 A	50.0A	143.2 AB	0.66	365
	400	14.0 B	48.4A	126.3 B	0.67	370

Table 2. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Waimanalo, Expt. 1, Second planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	15.0 C	37.9 C	407.5 B	0.89	268
	100	17.3 A	40.5 A	495.9 A	0.85	332
	200	15.8 B	40.3 AB	514.5 A	0.76	370
	300	16.3 B	39.4 B	482.1 A	0.79	365
	400	15.5 BC	39.5 AB	494.4 A	0.75	370
Ming Q. Choi	0	13.7 B	28.9 A	372.9 A	0.68	268
	100	14.7 A	29.6 A	363.1 A	0.80	332
	200	14.1 AB	28.2 A	306.6 B	0.72	370
	300	14.7 A	29.1 A	336.7 AB	0.71	365
	400	13.8 B	29.3 A	349.8 AB	0.79	370
Mizuna	0	15.7 C	56.0 B	227.4 A	0.65	268
	100	18.1 A	58.2 A	166.1 B	0.61	332
	200	15.8 BC	52.4 D	135.0 C	0.54	370
	300	16.4 B	55.6 B	178.0 B	0.60	365
	400	16.0 BC	54.0 C	165.7 B	0.60	370

Table 3. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Waimanalo, Expt. 1, Third planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	13.2 A	30.4 AB	173.3 B	0.67	268
	100	12.8 AB	29.7 B	144.2 C	0.76	332
	200	12.4 B	30.6 A	174.5 B	0.75	370
	300	11.8 C	29.0 C	138.2 C	0.79	365
	400	12.5 B	31.0 A	218.2 A	0.84	370
Ming Q. Choi	0	12.4 A	25.9 A	196.1 B	0.34	268
	100	11.5 B	24.6 B	158.7 C	0.67	332
	200	11.5 B	23.2 C	230.9 A	0.64	370
	300	10.5 C	23.5 C	122.7 D	0.59	365
	400	10.8 BC	24.6 B	156.2 C	0.64	370
Mizuna	0	13.5 A	32.2 D	51.9 C	0.56	268
	100	13.3 A	39.3 A	70.6 A	0.68	332
	200	11.8 B	32.5 D	62.4 AB	0.57	370
	300	11.1 C	34.7 C	58.8 BC	0.67	365
	400	11.7 B	36.5 B	61.2 B	0.62	370

Table 4. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Poamoho, Expt. 2, First planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	11.0 B	33.5 C	273.0 BC	0.65	311
	100	11.2 B	34.8 B	280.0 B	0.64	319
	200	12.2 A	36.3 A	309.2 A	0.71	339
	300	9.7 C	33.4 C	257.1 BC	0.62	350
	400	10.9 B	35.3 AB	252.1 C	0.65	403
Ming Q. Choi	0	10.2 B	28.7 A	217.7 AB	0.68	311
	100	10.9 A	28.7 A	232.7 A	0.81	319
	200	9.5 C	28.0 A	199.3 C	0.65	339
	300	9.2 CD	28.0 A	213.7 BC	0.78	350
	400	9.0 D	28.7 A	155.5 D	0.73	403
Mizuna	0	10.1 B	45.3B	79.9B	0.53	311
	100	11.0 A	48.4A	107.9A	0.62	319
	200	11.6 A	48.3A	88.9 B	0.56	339
	300	11.5 A	47.5A	83.7 B	0.50	350
	400	9.3 C	42.3C	87.8 B	0.53	403

Table 5. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Poamoho, Expt. 2, Second planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	23.4 A	39.8 A	644.1 A	0.80	311
	100	22.5 B	39.1 AB	589.10	0.94	319
	200	22.8 AB	38.1 AB	554.3 B	0.96	339
	300	22.5 B	39.1 AB	573.20	0.96	350
	400	22.3 B	37.9 B	639.10	0.98	403
Ming Q. Choi	0	17.1 AB	35.2 A	424.2 B	0.79	311
	100	17.4 A	30.8 B	532.5 A	0.86	319
	200	15.8 C	31.0 B	479.2 AB	0.84	339
	300	16.8 B	28.9 B	475.0 AB	0.82	350
	400	16.7 B	29.5 B	530.9 A	0.83	403
Mizuna	0	33.3 B	62.6 A	304.7 A	0.72	311
	100	35.1 A	61.4 A	237.9 B	0.78	319
	200	30.5 C	59.5 B	258.3 AB	0.72	339
	300	33.4 B	62.0 A	304.6 A	0.65	350
	400	33.5 B	61.0 AB	259.3 AB	0.79	403

Table 6. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Poamoho, Expt. 2, Third planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	9.9 B	36.3 B	549.0 A	0.72	311
	100	12.7 A	36.3 B	586.0 A	0.74	319
	200	12.3 A	37.7 A	581.4 A	0.72	339
	300	12.8 A	35.2 C	488.4 B	0.63	350
	400	12.2 A	37.2 AB	565.7 A	0.72	403
Ming Q. Choi	0	9.6 A	28.7 C	523.8 A	0.62	311
	100	8.6 BC	29.4 BC	549.9 A	0.62	319
	200	9.4 A	30.4 A	454.1 B	0.65	339
	300	8.3 C	29.2 BC	546.8 A	0.63	350
	400	9.2 AB	29.7 C	551.9 A	0.62	403
Mizuna	0	10.8 A	52.0 BC	258.6 B	0.56	311
	100	10.7 A	54.0 A	255.5 B	0.53	319
	200	11.0 A	52.9 ABC	257.2 B	0.57	339
	300	10.8 A	51.7 C	204.4 C	0.56	350
	400	11.0 A	53.5 AB	311.5 A	0.54	403

Table 7. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Waimanalo, Expt. 3, first planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P soil levels after 3rd crop (ppm)
Joi Choi	0	12.3 A	36.2 A	425.9 A	368.00
	100	12.0 AB	37.6 A	497.2 A	397.00
	200	11.7 AB	37.2 A	428.2 A	460.00
	300	12.0 AB	35.6 A	459.8 A	474.00
	400	11.3 B	36.4 A	440.4 A	483.00
Ming Q. Choi	0	11.6 BC	26.8 A	147.8 A	368.00
	100	11.6 BC	26.3 A	147.8 A	397.00
	200	11.9 B	25.1 A	161.2 A	460.00
	300	11.2 C	25.7 A	158.7 A	474.00
	400	12.8 A	25.1 A	171.6 A	483.00
Mizuna	0	11.4 B	38.7 C	227.3 A	368.00
	100	12.1 A	40.7 BC	230.5 A	397.00
	200	11.9 AB	40.2 BC	231.0 A	460.00
	300	12.1 A	41.8 B	231.9 A	474.00
	400	12.5 A	44.6 A	225.6 A	483.00

Table 8. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Waimanalo, Expt. 3, second planting.

Cultivar	P Rate	Height final cm	Total wt (gr/plant)	Top Wt. (gr/plant)	Root Wt. (gr/plant)	Top/Rt ratio (gr/gr)	P tissue level (ppm)	P soil levels after 3rd crop (%)
Joi Choi	0	37.7 A	317.2 B	311.8 B	5.4 A	63.3 A	0.92	368
	100	36.8 A	408.2 A	401.7 A	6.5 A	65.4 A	0.79	397
	200	38.6 A	439.4 A	432.8 A	6.6 A	66.9 A	0.73	460
	300	37.7 A	353.2 AB	347.9 AB	5.3 A	66.1 A	0.90	474
	400	38.6 A	419.6 A	413.3 A	6.2 A	68.5 A	0.85	483
Ming Q. Choi	0	27.5 B	234.5 A	228.5 A	6.0 A	51.7 AB	0.66	368
	100	28.9 AB	245.7 A	241.0 A	4.7 A	54.7 AB	0.79	397
	200	28.7 B	266.5 A	260.2 A	6.2 A	44.4 B	0.88	460
	300	28.7 B	271.9 A	267.7 A	4.2 A	68.6 A	0.78	474
	400	30.2 A	281.8 A	277.0 A	4.8 A	63.8 A	0.79	483
Mizuna	0	55.9 A	200.5 A	194.0 A	6.5 A	31.4 A	0.70	368
	100	53.8 A	193.0 A	186.0 A	6.7 A	30.5 A	0.71	397
	200	53.1 A	193.2 A	187.0 A	6.2 A	32.1 A	0.65	460
	300	52.2 A	201.0 A	194.0 A	7.0 A	30.2 A	0.70	474
	400	55.8 A	210.7 A	202.8 A	7.8 A	29.8 A	0.68	483

Table 9. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Waimanalo, Expt. 3, third planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	8.7 BC	16.2 A	665.2 A	0.62	368
	100	9.6 B	15.3 B	568.7 B	0.60	397
	200	10.7 A	15.0 B	533.5 B	0.60	460
	300	8.4 C	13.6 C	450.1 C	0.53	474
	400	6.4 D	11.8 D	410.4 C	0.57	483
Ming Q. Choi	0	10.1 A	11.1 B	356.5 B	0.54	368
	100	10.1 A	11.2 B	334.9 B	0.60	397
	200	10.4 A	11.9 A	419.5 A	0.59	460
	300	9.9 A	10.9 B	334.4 B	0.63	474
	400	10.1 A	11.8 A	429.5 A	0.59	483
Mizuna	0	10.7 A	15.0 B	257.0 B	0.57	368
	100	9.5 CD	16.8 A	336.6 A	0.51	397
	200	10.0 BC	15.8 B	249.9 B	0.56	460
	300	9.3 D	15.2 B	359.2 A	0.68	474
	400	10.3 AB	17.0 A	325.9 A	0.57	483

Table 10. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Poamoho, Expt. 4, first planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	13.4 B	35.7 B	436.9 CD	0.46	99
	100	12.1 C	32.1 D	395.7 D	0.58	144
	200	13.0 BC	39.0 A	638.9 A	0.60	315
	300	15.0 A	36.0 B	537.2 B	0.55	318
	400	13.2 BC	34.6 C	461.6 C	0.57	386
Ming Q. Choi	0	14.6 A	30.7 A	442.6 A	0.51	99
	100	11.8 A	30.3 A	434.8 A	0.58	144
	200	14.7 A	30.2 A	469.2 A	0.53	315
	300	11.9 B	30.5 A	473.7 A	0.58	318
	400	14.4 A	28.7 A	384.9 B	0.57	386
Mizuna	0	13.5 C	52.4 B	187.3 B	0.41	99
	100	12.9 C	50.7 B	203.0 B	0.45	144
	200	12.9 C	51.3 B	185.7 B	0.45	315
	300	15.6 A	51.3 B	194.6 B	0.50	318
	400	14.8 B	54.3 A	276.7 A	0.47	386

Table 11. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Poamoho, Expt. 4, second planting.

Cultivar	P Rate (lbs/Acre)	Height initial (cm)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	19.4 B	43.1 A	815.8 A	0.51	99
	100	16.4 D	41.5 B	632.0 B	0.48	144
	200	18.2 C	41.8 B	662.0 B	0.68	315
	300	21.9 A	42.5 AB	736.2 A	0.58	318
	400	19.9 B	43.2 A	679.8 B	0.55	386
Ming Q. Choi	0	14.3 C	31.0 A	423.0 C	0.53	99
	100	15.0 B	32.3 A	484.0 B	0.69	144
	200	16.0 A	32.8 A	578.6 A	0.72	315
	300	15.2 B	32.3 A	497.3 B	0.71	318
	400	15.2 B	32.1 A	526.3 B	0.68	386
Mizuna	0	17.6 C	59.4 B	408.3 AB	0.44	99
	100	20.8 A	61.4 A	347.0 BC	0.45	144
	200	18.2 C	58.7 B	438.9 A	0.52	315
	300	19.4 B	59.5 B	330.8 C	0.50	318
	400	19.3 B	61.5 A	429.9 A	0.50	386

Table 12. Effects of several phosphorus fertilizer rate applications on the growth and yield of mustard cabbage, Poamoho, Expt. 4, third planting.

Cultivar	P Rate (lbs/Acre)	Height final (cm)	Weight (gr/plant)	P tissue level (%)	P soil levels after 3rd crop (ppm)
Joi Choi	0	35.1 B	336.2 C	0.47	99
	100	34.9 B	405.7 B	0.52	144
	200	36.6 A	464.8 A	0.54	315
	300	35.3 B	419.9 B	0.53	318
	400	35.5 B	433.4 AB	0.55	386
Ming Q. Choi	0	27.9 C	317.9 B	0.49	99
	100	29.4 A	375.4 A	0.60	144
	200	28.5 BC	351.9 A	0.54	315
	300	28.4 BC	374.6 A	0.50	318
	400	28.8 AB	377.9 A	0.60	386
Mizuna	0	57.5 AB	213.9 AB	0.44	99
	100	56.0 B	204.9 AB	0.47	144
	200	56.9 AB	189.7 B	0.45	315
	300	56.4 AB	219.3 A	0.48	318
	400	58.0 A	218.9 A	0.48	386

Table 13. Nutrient Tissue Levels, Waimanalo, First Experiment, First Planting

Trt	N	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn	B
J 0	7.2	0.77	6.69	2.49	0.58	0.18	38	302	12	49	26
J 100	6.9	0.69	8.11	2.34	0.51	0.26	35	222	12	43	26
J 200	7.1	0.78	5.84	2.57	0.54	0.19	49	260	12	52	30
J 300	7.2	0.73	7.24	2.41	0.55	0.26	44	256	14	49	29
J 400	7.2	0.73	6.73	2.40	0.51	0.2	37	260	14	48	24
M 0	6.9	0.54	4.71	3.15	0.62	0.25	42	207	12	35	24
M 100	7.1	0.73	4.95	2.94	0.59	0.22	43	234	16	40	24
M 200	6.9	0.64	5.51	2.68	0.49	0.26	47	256	16	36	26
M 300	7.1	0.66	4.54	3.19	0.59	0.3	50	291	19	38	24
M 400	7.1	0.67	4.96	2.55	0.45	0.23	43	254	27	43	24
Q 0	6.6	0.59	6.77	2.95	0.53	0.25	35	325	23	39	26
Q 100	6.6	0.64	6.05	3.03	0.54	0.25	40	338	19	41	25
Q 200	6.8	0.84	6.44	2.81	0.52	0.3	47	437	28	52	30
Q 300	6.3	0.73	5.57	3.35	0.60	0.29	40	386	27	46	28
Q 400	6.5	0.82	7.03	3.18	0.54	0.25	43	270	32	46	28

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 14. Nutrient Tissue Levels Poamoho, Expt. 2, First Planting

Trt	N	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn	B
J-0	7.6	0.65	8.53	3.24	0.40	0.22	103	345	18	44	24
J-100	7.3	0.64	8.48	2.95	0.37	0.26	89	336	17	64	25
J-200	7.3	0.71	8.44	2.89	0.36	0.21	103	204	15	39	26
J-300	7.4	0.62	8.34	3.09	0.40	0.18	106	248	16	41	28
J-400	7.3	0.65	9.09	3.07	0.38	0.26	99	219	16	47	28
Avg.	7.4	0.654	8.576	3.05	0.38	0.226	100	270.4	16.4	47	26.2
M-0	7.3	0.53	5.26	3.89	0.42	0.26	147	180	17	35	21
M-100	7.2	0.62	5.72	3.91	0.43	0.21	145	161	15	36	24
M-200	7.2	0.56	5.48	3.80	0.39	0.18	175	159	15	35	22
M-300	7.0	0.50	5.38	3.81	0.38	0.18	182	139	17	30	23
M-400	7.2	0.53	5.24	3.58	0.37	0.20	182	259	16	39	21
Avg.	7.2	0.548	5.416	3.80	0.40	0.206	166.2	179.6	16	35	22.2
Q-0	7.0	0.68	7.34	2.89	0.31	0.16	93	345	15	40	23
Q-100	7.0	0.81	7.84	2.54	0.27	0.13	83	128	14	39	25
Q-200	6.8	0.65	7.46	3.12	0.31	0.16	81	204	13	31	24
Q-300	6.9	0.78	6.83	2.50	0.28	0.15	76	293	15	35	25
Q-400	7.0	0.73	7.49	2.58	0.32	0.17	74	165	15	40	23
Avg.	6.9	0.73	7.392	2.73	0.30	0.154	81.4	227	14.4	37	24

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 15. Nutrient Tissue Levels, Waimanalo (Expt. 1) and Poamoho (Expt. 2), 2nd. Planting

Trt	N	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn	B
Poamoho											
P-Q-0	6.37	0.79	4.96	1.82	0.2	0.1	906	75	39	18	28
P-Q-100	6.24	0.86	4.87	2.09	0.23	0.14	155	68	35	13	32
P-Q-200	6.08	0.84	4.96	1.91	0.21	0.09	321	77	37	12	30
P-Q-300	6.19	0.82	5.41	2.11	0.2	0.13	189	65	32	12	30
P-Q-400	6.13	0.83	4.77	2.35	0.23	0.18	220	69	37	14	26
P-J-0	6.10	0.80	4.76	2.14	0.24	0.11	176	95	40	15	28
P-J-100	6.48	0.94	5.25	2.41	0.28	0.14	191	98	38	15	31
P-J-200	6.20	0.96	5.16	2.32	0.26	0.12	197	90	39	16	32
P-J-300	6.23	0.96	5.73	1.91	0.27	0.11	674	82	41	19	31
P-J-400	6.34	0.98	5.14	1.93	0.26	0.18	499	95	44	22	31
P-M-0	5.94	0.72	4.17	2.85	0.33	0.15	299	119	37	27	30
P-M-100	6.36	0.78	4.17	2.68	0.33	0.17	241	126	36	21	29
P-M-200	6.87	0.72	4.06	2.97	0.32	0.14	180	144	34	26	30
P-M-300	6.21	0.65	3.9	3.06	0.32	0.19	358	136	34	26	30
P-M-400	6.05	0.79	4.09	2.97	0.32	0.14	172	119	36	27	31
Waimanalo											
W-Q-0	4.56	0.68	3.08	1.74	0.36	0.23	203	26	36	26	31
W-Q-100	4.92	0.80	3.16	1.74	0.35	0.31	311	28	39	26	32
W-Q-200	3.83	0.72	3.13	1.33	0.31	0.22	431	24	36	22	31
W-Q-300	3.96	0.71	2.72	1.61	0.32	0.3	334	25	32	24	33
W-Q-400	4.35	0.79	3.42	1.73	0.38	0.2	296	27	38	25	31
W-J-0	4.88	0.89	3.51	1.83	0.41	0.3	185	36	49	29	35
W-J-100	5.07	0.85	2.91	2.39	0.47	0.46	156	36	40	31	35
W-J-200	5.10	0.76	3.05	2.22	0.45	0.4	145	34	37	29	35
W-J-300	4.85	0.79	3.28	2.09	0.43	0.52	125	38	39	34	35
W-J-400	5.33	0.75	3.11	2	0.43	0.54	135	37	33	36	34
W-M-0	4.44	0.65	2.76	2.31	0.46	0.16	130	47	32	42	43
W-M-100	4.87	0.61	2.45	2.16	0.43	0.28	118	30	33	44	33
W-M-200	4.32	0.54	2.29	2.48	0.38	0.24	122	27	29	44	33
W-M-300	4.86	0.60	2.58	2.77	0.5	0.31	128	36	31	44	31
W-M-400	5.22	0.60	2.28	2.48	0.48	0.39	143	34	31	40	31

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Tables 16. Nutrient Tissue Levels, Waimanalo and Poamoho, Expts. 1&2, Third Planting.

Trt	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
Poamoho											
P-J-0	6.34	0.72	6.82	2.26	0.30	0.17	116	86	40	17	34
P-J-100	6.26	0.74	6.66	2.26	0.31	0.19	143	98	41	20	38
P-J-200	6.78	0.72	6.88	2.21	0.30	0.14	124	86	41	20	32
P-J-300	6.54	0.63	6.40	2.45	0.32	13.00	120	82	34	18	34
P-J-400	6.39	0.72	6.21	1.98	0.26	0.17	121	83	38	22	32
P-M-0	5.83	0.56	5.26	3.10	0.32	0.16	123	124	39	22	29
P-M-100	6.02	0.53	4.75	2.60	0.30	0.21	99	121	38	25	31
P-M-200	5.86	0.57	0.44	2.59	0.29	0.15	110	104	38	20	29
P-M-300	5.53	0.56	4.92	2.44	0.30	0.14	128	82	39	20	32
P-M-400	6.05	0.54	5.06	2.90	0.31	0.22	116	118	41	27	32
P-Q-0	6.09	0.62	6.55	2.19	0.25	0.18	106	71	40	25	30
P-Q-100	6.15	0.62	5.80	2.11	0.22	0.13	123	60	32	22	31
P-Q-200	6.30	0.65	6.07	2.16	0.22	0.16	124	78	38	22	28
P-Q-300	6.07	0.63	5.73	2.06	0.21	0.17	129	79	39	26	28
P-Q-400	6.26	0.62	6.05	2.04	0.24	0.20	98	63	32	27	28
Waimanalo											
W-J-0	4.07	0.67	3.81	1.78	0.39	0.25	135	24	33	22	26
W-J-100	3.53	0.76	4.41	2.11	0.43	0.24	187	25	35	21	30
W-J-200	3.54	0.75	4.17	2.04	0.41	0.36	113	24	30	24	30
W-J-300	3.36	0.79	4.44	2.31	0.46	0.28	298	28	33	23	30
W-J-400	3.72	0.84	4.50	2.02	0.42	0.32	152	26	38	27	29
W-M-0	2.71	0.56	2.21	2.04	0.39	0.29	87	21	36	32	30
W-M-100	3.17	0.68	2.44	2.72	0.52	0.28	96	26	38	30	31
W-M-200	3.63	0.57	2.52	2.69	0.47	0.18	94	25	33	28	27
W-M-300	3.52	0.67	2.56	2.59	0.46	0.18	124	25	36	25	29
W-M-400	3.60	0.62	2.77	2.52	0.41	0.17	183	28	36	29	31
W-Q-0	4.20	0.34	3.69	1.73	0.32	0.26	160	19	36	38	25
W-Q-100	3.87	0.67	3.75	1.87	0.34	0.18	116	18	38	32	27
W-Q-200	3.56	0.64	3.13	1.76	0.32	0.16	189	36	39	18	26
W-Q-300	3.85	0.59	3.45	2.06	0.38	0.17	183	23	35	20	25
W-Q-400	3.93	0.64	3.99	2.09	0.37	0.15	237	21	35	23	26

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 17. Nutrient Tissue Levels, Poamoho, Expt. 4, 1st planting.

Trt	N	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn	B
J-0	6.64	0.46	6.84	2.35	0.45	0.17	143	93	49	13	21
J-100	6.76	0.58	6.81	2.12	0.42	0.18	144	89	46	14	22
J-200	6.57	0.6	6.67	2.39	0.47	0.2	140	94	48	12	21
J-300	6.32	0.55	7.26	2.41	0.39	0.15	109	109	41	12	21
J-400	6.75	0.57	5.85	2.14	0.43	0.23	131	98	46	15	23
M-0	6.65	0.41	5.18	2.40	0.54	0.25	125	121	51	15	23
M-100	6.22	0.45	4.96	2.64	0.55	0.21	113	148	45	15	21
M-200	6.65	0.45	4.69	2.80	0.5	0.37	122	137	46	26	20
M-300	6.35	0.5	4.84	2.96	0.43	0.27	107	152	53	18	22
M-400	6.68	0.47	4.39	2.92	0.47	0.33	109	161	49	22	20
Q-0	6.75	0.51	5.80	1.95	0.31	0.14	115	84	50	16	21
Q-100	6.79	0.58	5.37	1.93	0.39	0.23	111	70	49	23	17
Q-200	6.56	0.53	4.58	1.78	0.31	0.19	100	69	43	21	17
Q-300	6.54	0.58	5.55	2.21	0.37	0.25	120	91	57	28	20
Q-400	6.81	0.57	5.25	1.72	0.32	0.18	137	93	53	25	19

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 18. Nutrient Tissue Levels, Waimanalo Expt. 3, 2nd planting

Trt	N	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn	B
W-J 0	6.01	0.92	6.11	2.04	0.51	0.34	198	33	41	9	35
W-J 100	6.61	0.79	7.34	2.22	0.52	0.25	231	37	40	8	33
W-J 200	6.77	0.73	6.93	2.25	0.59	0.32	248	35	40	8	28
W-J 300	6.53	0.90	6.32	2.09	0.51	0.32	256	36	40	9	33
W-J 400	6.69	0.85	5.84	2.14	0.55	0.41	498	43	40	10	32
W-M 0	6.33	0.70	4.32	2.74	0.57	0.27	344	42	37	10	34
W-M 100	6.84	0.71	4.78	2.71	0.65	0.25	388	42	38	9	26
W-M 200	6.61	0.65	4.51	2.80	0.64	0.30	364	43	38	9	28
W-M 300	6.30	0.70	4.04	2.64	0.58	0.29	397	45	40	9	35
W-M 400	6.61	0.68	5.18	2.60	0.58	0.22	283	43	40	9	23
W-Q 0	6.44	0.66	6.39	2.18	0.51	0.23	462	34	38	9	26
W-Q 100	5.99	0.79	5.74	1.83	0.41	0.28	477	32	38	11	29
W-Q 200	6.22	0.88	5.64	2.01	0.48	0.29	359	29	42	9	29
W-Q 300	6.20	0.78	6.01	2.00	0.43	0.19	242	31	41	9	28
W-Q 400	6.17	0.79	6.02	2.04	0.43	0.17	297	29	40	9	29

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 19. Nutrient Tissue Levels, Poamoho, Expt.4, 2nd Planting

Trt	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
J-0	6.81	0.51	6.71	2.86	0.49	0.43	118	120	42	13	22
J-100	6.56	0.48	6.64	2.65	0.53	0.34	120	107	39	14	21
J-200	6.74	0.68	5.93	2.16	0.42	0.37	157	110	45	18	22
J-300	6.64	0.58	5.62	2.53	0.41	0.37	123	154	38	17	26
J-400	6.59	0.55	6.55	2.85	0.45	0.67	135	123	35	23	21
M-0	6.76	0.44	4.24	3.23	0.56	0.41	144	137	48	22	19
M-100	6.39	0.45	4.44	2.86	0.59	0.45	113	130	38	19	19
M-200	6.54	0.52	3.90	2.84	0.54	0.44	148	122	44	23	18
M-300	6.37	0.50	4.05	2.94	0.58	0.48	122	179	42	22	19
M-400	6.57	0.50	3.55	3.01	0.56	0.40	146	123	40	26	19
Q-0	6.41	0.53	4.95	1.98	0.42	0.39	138	87	68	28	21
Q-100	6.58	0.69	5.04	2.16	0.46	0.35	154	106	58	27	21
Q-200	6.83	0.72	4.58	1.92	0.34	0.29	114	84	50	27	20
Q-300	6.84	0.71	4.97	2.23	0.39	0.23	130	101	52	25	21
Q-400	6.37	0.68	4.65	2.11	0.34	0.34	162	106	44	27	20

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 20. Nutrient Tissue Levels, Waimanalo, Expt. 3, 3rd planting

Trt	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
W-J-0	5.76	0.62	3.79	1.25	0.31	0.13	120	30	48	8	32
W-J-100	5.44	0.60	3.53	1.84	0.41	0.14	133	33	41	8	41
W-J-200	5.82	0.60	4.58	1.53	0.35	0.13	110	30	41	7	34
W-J-300	5.94	0.53	4.52	1.81	0.40	0.11	121	36	41	7	34
W-J-400	5.64	0.57	4.29	1.45	0.32	0.10	133	34	41	7	32
W-M-0	5.05	0.57	3.25	2.62	0.56	0.24	119	26	32	10	36
W-M-100	4.81	0.51	3.25	2.48	0.51	0.25	125	25	29	7	36
W-M-200	5.46	0.56	3.15	2.09	0.49	0.18	127	25	31	8	29
W-M-300	5.76	0.68	2.99	2.04	0.49	0.18	112	26	39	9	31
W-M-400	5.59	0.57	2.63	2.00	0.47	0.19	121	23	31	9	30
W-Q-0	5.46	0.54	3.22	1.63	0.34	0.11	128	29	41	7	33
W-Q-100	5.95	0.6	3.06	1.09	0.25	0.15	104	24	41	8	30
W-Q-200	5.69	0.59	2.73	1.18	0.27	0.1	111	26	47	8	35
W-Q-300	5.84	0.63	3.67	1.30	0.3	0.12	113	27	48	7	37
W-Q-400	5.15	0.59	2.98	1.46	0.31	0.15	129	27	39	9	34

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 21. Nutrient Tissue Levels, Poamoho, Expt. 4, 3rd planting.

Trt	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
J-0	6.80	0.47	6.31	2.43	0.53	0.20	166	173	62	17	33
J-100	6.47	0.52	6.39	2.47	0.52	0.18	128	153	51	16	29
J-200	6.85	0.54	6.05	2.31	0.42	0.16	117	149	53	15	26
J-300	6.89	0.53	6.11	2.47	0.42	0.19	145	151	44	14	27
J-400	6.92	0.55	5.78	2.52	0.42	0.16	140	169	54	15	26
M-0	6.45	0.44	3.79	2.66	0.53	0.27	120	150	46	15	25
M-100	6.23	0.47	4.10	2.81	0.61	0.24	150	177	58	15	33
M-200	6.26	0.45	5.25	2.55	0.53	0.22	125	177	49	15	26
M-300	6.40	0.48	3.72	2.62	0.53	0.28	127	158	45	14	27
M-400	6.30	0.48	3.98	2.55	0.51	0.17	130	157	49	15	26
Q-0	5.77	0.49	5.65	1.82	0.33	0.14	103	102	50	13	23
Q-100	6.08	0.60	5.31	1.63	0.33	0.19	111	114	53	15	25
Q-200	5.79	0.54	5.06	1.85	0.31	0.18	110	107	47	14	24
Q-300	5.61	0.50	5.21	2.12	0.33	0.14	180	125	47	13	21
Q-400	5.64	0.60	5.06	1.84	0.36	0.17	105	99	39	12	22

Note: J= Joi Choi variety, M= Mizuna; Q= Ming Quing Choi; The numbers under the treatment column (0-400) indicate the amount of P fertilizer applied in pounds per acre.

Table 22. Soil Fertility in Waimanalo and Poamoho prior to beginning of Expts. 1 & 2

Location	pH	P	K	Ca	Mg
Waimanalo	6.6	339	430	4922.00	1828.00
Poamoho	7.4	348	766	4284.00	470.00

Table 23. Soil Fertility in Waimanalo and Poamoho after completion of Expts. 1 & 2 (after harvest of 3rd crop).

P rate	Location	Date	PH	EC	P	K	Ca	MG	OC
0	nalo	5/13/2002	6.2	0.12	268.00	420	4642	1522	1.37
100	nalo	5/13/2002	6.1	0.11	332.00	368	4564	1528	1.34
200	nalo	5/13/2002	6.1	0.10	370.00	376	4632	1564	1.31
300	nalo	5/13/2002	6.3	0.13	365.00	422	4608	1524	1.32
400	nalo	5/13/2002	6.2	0.11	370.00	442	4682	1530	1.31
0	Poamoho	5/13/2002	7.3	0.36	311.00	756	3910	372	3.15
100	Poamoho	5/13/2002	7.4	0.26	319.00	734	4512	440	3.64
200	Poamoho	5/13/2002	7.6	0.29	339.00	792	5064	494	4.46
300	Poamoho	5/13/2002	7.5	0.30	350.00	914	3876	392	2.95
400	Poamoho	5/13/2002	7.3	0.32	403.00	862	3960	390	3.12

Table 24. Soil Fertility in Waimanalo and Poamoho prior to beginning Experiments 3 & 4.

Location	pH	EC	P	K	Ca	MG	Oc
NALO-P	6.1	0.33	354.00	594	4614	1654	1.43
P-POA	6.3	0.36	173.00	394	1558	320	1.96

Table 25. Soil Fertility in Waimanalo after completion of Expt 3 (after harvest of 3rd crop)

Treatment	Location	PH	EC	P	K	Ca	MG	Oc
Nalo P 0	Nalo	6.6	0.75	368.00	572	4816	1468	1.36
Nalo P 100Nalo	6.4	0.65	397.00	548	4860	1448	1.34	
Nalo P 200Nalo	6.7	0.70	460.00	608	4932	1480	1.39	
Nalo P 300Nalo	6.4	0.60	474.00	600	4856	1456	1.38	
Nalo P 400Nalo	6.4	0.43	483.00	556	4852	1466	1.33	

Table 26. Soil Fertility in Poamoho after completion of Expt. 4 (after harvest of 3rd crop)

Trt	PH	EC	P	K	Ca	MG	Oc
0	6.2	0.26	99.00	328.00	1220	242	0
100	6	0.35	144.00	342.00	1152	222	0
200	6.2	0.25	315.00	376.00	1422	238	0
300	6.1	0.38	318.00	346.00	1462	242	0
400	6.3	0.34	386.00	386.00	1604	264	0

Table 27. Growth and Yield of Joi Choi mustard cabbage in Lalamilo, Kamuela, Expt. 5

1st planting Cvr	P Rate	Weight	Height	Initial height	P tissue levels	P soil levels
Joi Choi	0	277.0	34.4	13.5	0.42	133.00
Joi Choi	100	325.0	35.1	15	0.48	219.00
Joi Choi	200	315.0	34.8	16	0.49	238.00
Joi Choi	300	318.0	35	16.4	0.55	302.00
Joi Choi	400	336.0	35.9	16	0.59	384.00

2nd planting		Weight	Height	P soil levels
Joi Choi	0	181.0	32.4	133
Joi Choi	100	243.0	34.6	219
Joi Choi	200	267.0	35.6	238
Joi Choi	300	262.0	34.4	302
Joi Choi	400	228.0	34	384

3rd Planting		Weight	Height	P tissue levels	P soil levels
Joi Choi	0	229.0	33.9	0.41	133.00
Joi Choi	100	296.0	34.8	0.48	219.00
Joi Choi	200	314.0	34.8	0.51	238.00
Joi Choi	300	282.0	35.2	0.46	302.00
Joi Choi	400	309.0	34.5	0.60	384.00

Table 28. Nutrient Tissue Analysis for Expt. 5, 1st planting in Lalamilo (Sept. 2002).

Trt	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
K-0	7.06	0.42	5.68	2.86	0.35	0.44	205	34	26	9	28
K-100	6.48	0.48	4.56	4.04	0.54	0.61	258	54	22	8	30
K-200	6.57	0.49	4.08	3.68	0.49	0.59	221	47	21	7	27
K-300	6.56	0.55	4.28	4.03	0.53	0.86	209	45	22	9	29
K-400	6.82	0.59	5.17	3.89	0.53	0.62	222	52	27	8	33

Table 29. Nutrient tissue analysis for Extp. 5, 3rd crop in Lalamilo (Jan. 2003).

Trt	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
0 P	6.06	0.41	7.74	3.07	0.39	1.05	485	38	26	10	36
100 P	6.20	0.48	5.70	3.12	0.41	0.86	542	44	26	10	32
200 P	6.33	0.51	5.51	3.38	0.45	1.16	464	42	24	12	32
300 P	6.23	0.46	5.25	3.59	0.45	1.21	517	39	22	11	32
400 P	6.04	0.60	5.42	3.38	0.46	1.05	446	38	22	10	31

Table 30. Soil analysis in Lalamilo prior to beginning Expt. 5.

HEAVY SOIL Soil Analysis	Results	Expected
_pH	6.2	6
P_ppm	213.0	37.5
K_ppm	567.0	250
Ca_ppm	5328.0	1250
Mg_ppm	745.0	350
OC_%	4.5	No criteria

Table 31 Soil analysis in Lalamilo after completion of experiment 5 (after harvest of 3rd crop).

P rate	PH	EC	P	K	Ca	MG	OC
0lb/A	6.4	0.30	133.00	1370.00	5176	558	4.48
100lb/A	6.3	0.34	219.00	1326.00	4938	534	4.5
200lb/A	6.3	0.33	238.00	1286.00	5232	570	4.48
300lb/A	6.3	0.43	302.00	1238.00	5246	586	4.32
400lb/A	6.3	0.34	384.00	1228.00	5276	566	4.49

Table 32. Tissue phosphorus levels, soil P levels, mean yields, and the levels of P applied which are associated with the highest significant yields (under yields column) obtained for each experiment.

Cultivar	Planting Sequence	P tissue level (%)	Soil P (ppm)	Yield (grams/head)	P applied average as fertilizer on Expt. 1 (lbs/Acre)
Pooled data for all cultivars					
	1st planting	0.66	332.5	316.60	191.60
	2nd planting	0.71	336.8	434.80	157.90
	3rd planting	0.62	359.8	368.50	233.30
Joi Choi	1st planting	0.69	338.2	437.40	150.00
Joi Choi	2nd planting	0.73	324.7	581.60	150.00
Joi Choi	3rd planting	0.68	342	478.80	187.50
Quing Choi	1st planting	0.7	323.6	269.30	162.50
Quing Choi	2nd planting	0.76	338.6	432.40	162.50
Quing Choi	3rd planting	0.61	357	389.50	250.00
Mizuna	1st planting	0.58	335.6	243.10	262.50
Mizuna	2nd planting	0.64	347.2	290.30	161.10
Mizuna	3rd planting	0.57	380.6	237.10	262.50
Joi Choi	all plantings	0.64	335	499.30	162.50
Quing Choi	all plantings	0.63	340	363.70	191.70
Mizuna	all plantings	0.58	354	256.90	228.70

Note: P tissue levels based on tissue levels collected from most recently matured leaves at the early heading or mid-growth growing stage. Soil P levels represent those levels found on each treatment after the completion/harvest of the 3rd planting; thus the soil P levels listed for the 1st and 2nd plantings are actually an underestimate of the actual P soil levels at the time. All values on this table are averages taken from those treatments (one or more) which showed the highest significant yield, compared to the other treatments.

Table 33A. High and low elevation comparison from concurrent experiments (Expts. 1-4) of tissue P levels, soil P levels, mean yields, and the levels of P fertilizer applied which were associated with the highest significant yields (under 'Yields' column) obtained for each experiment.

Cultivar	Elevation Site (70 or 800 ft)	P tissue level (%)	Soil P (ppm)	Yield (grams/head)	P applied average as fertilizer on Expt. 1 (lbs/Acre)
Pooled data for all cultivars					
	Low (Nalo)	0.72	371.5	269.10	176.30
	High (Poam)	0.65	307.2	461.13	193.30
Joi Choi	Low	0.79	462.1	481.50	250.00
Joi Choi	High	0.68	297.7	587.10	130.00
Quing Choi	Low	0.71	458.7	310.30	200.00
Quing Choi	High	0.72	308.2	466.90	180.00
Mizuna	Low	0.67	472.1	217.20	211.10
Mizuna	High	0.57	315.6	329.40	270.00

Note: Pooled data from experiments conducted concurrently at Waimanalo (low elevation site ca 80 ft) and Poamoho Stations (ca 800 ft). The soil P levels (2nd column) cannot be compared directly between the low and high elevation sites because P levels in Poamoho were significantly lower than the levels in Waimanalo, especially for the 2nd experiment.

Note: P tissue levels based on tissue levels collected from most recently matured leaves at the early heading formation state. Soil P levels represent those levels found on each treatment after the completion/harvest of the 3rd planting; thus the soil P levels used in the calculations for the 1st and 2nd plantings are actually an underestimate of the actual P soil levels at the time. All values on this table are averages taken from those treatments (one or more) which showed the highest significant yield, compared to the other treatments.

Table 33B. High and low elevation comparison from concurrent experiments (only Expts. 1 & 2) of tissue P levels, soil P levels, mean yields, and the levels of P fertilizer applied which were associated with the highest significant yields (under 'Yields' column) obtained for each experiment.

Cultivar	Elevation Site (70 or 800 ft)	P tissue level (%)	Soil P (ppm)	Yield (grams/head)	P applied average as fertilizer on Expt. 1 (lbs/Acre)
Pooled data for all cultivars					
	Low (Nalo)	0.72	332.4	258.1	166.7
	High (Poam)	0.71	311.3	417.6	144.4
Joi Choi	Low	0.8	345.8	349.20	266.70
Joi Choi	High	0.75	321.7	506.80	83.30
Quing Choi	Low	0.7	328	276.40	133.30
Quing Choi	High	0.76	331.7	434.30	133.30
Mizuna	Low	0.66	323.3	148.70	100.00
Mizuna	High	0.62	280.5	311.80	216.70

Note: Pooled data from experiments conducted concurrently at Waimanalo (low elevation site ca 80 ft) and Poamoho Stations (ca 800 ft). The soil P levels (2nd column) cannot be compared directly between the low and high elevation sites because P levels in Poamoho were significantly lower than the levels in Waimanalo, especially for the 2nd experiment.

Note: P tissue levels based on tissue levels collected from most recently matured leaves at the early heading formation state. Soil P levels represent those levels found on each treatment after the completion/harvest of the 3rd planting; thus the soil P levels used in the calculations for the 1st and 2nd plantings are actually an underestimate of the actual P soil levels at the time. All values on this table are averages taken from those treatments (one or more) which showed the highest significant yield, compared to the other treatments.

Table 34. The effect of temperature as determined by the time of planting (cool, warm, hot) on the tissue P levels, soil P levels, mean yields, and the levels of P fertilizer applied which were associated with the highest significant yields (under yields column) obtained for each experiment.

Cultivar	Time of Planting	P tissue level (%)	Soil P (ppm)	Yield (grams/head)	P applied average as fertilizer on Expt. 1 (lbs/Acre)
Pooled data for all cultivars					
	Cool	0.68	327.9	370.10	190.00
	Warm	0.68	328.3	352.60	187.00
	Hot	0.58	367.8	467.80	216.70
Joi Choi	Cool	0.74	332.4	476.70	200.00
Joi Choi	Warm	0.69	323.1	460.70	175.00
Joi Choi	Hot	0.61	355.2	588.30	83.30
Quing Choi	Cool	0.69	314.1	406.80	170.00
Quing Choi	Warm	0.74	344.6	323.20	187.50
Quing Choi	Hot	0.59	376	346.00	233.30
Mizuna	Cool	0.61	337.1	226.70	200.00
Mizuna	Warm	0.62	317.1	274.00	198.60
Mizuna	Hot	0.53	433.3	284.30	316.00

Note: The data included in this table is confounded with respect to temperature because it includes trials conducted at low elevation (warmer) and at high elevation (cooler). Nevertheless, trials were conducted at both sites during both warm and cool parts of the year.

Note: P tissue levels based on tissue levels collected from most recently matured leaves at the early heading formation stage. Soil P levels represent those levels found on each treatment after the completion/harvest of the 3rd planting; thus the soil P levels used in the calculations for the 1st and 2nd plantings are actually an *underestimate* of the actual P soil levels at the time. All values on this table are averages taken from those treatments (one or more) which showed the highest significant yield, compared to the other treatments.

Table 35. The effect of temperature during the growing season on the percentage of experiments that showed significant yield responses to phosphorus fertilizer applications. (out of a total number of 36 evaluations, or 12 trials for each of the 3 cultivars tested).

Location	Cool Temp. (%)	Warm Temp. (%)	Hot Temp. (%)
Waimanalo and Poamoho	66.0	42	44
Poamoho	55.0	66	75
Waimanalo	83.0	16	33
No. Expts.	15.0	12	9
Cultivar			
Joi Choi	25.0	16	8
Quing Choi	25.0	3	3
Mizuna	33.0	16	16
Average	27.7	11.7	9.0

Note: Percentages by location calculated based on the total number of experiments conducted under cool, warm, or hot conditions at each site. For example for Poamoho under cool conditions, the value 55% was obtained by dividing 5 experiments where P response was observed by 9 (9= total number of experiments in Poamoho under cool conditions). Therefore 5/9= 55%.

Table 36. The total number of experiments (expressed as percentage of total) that showed significant yield response to P fertilizer applications.

Cultivar	Waimanalo	Poamoho	Percentage
Joi Choi	3.0	4	58
Quing Choi	2.0	4	50
Mizuna	3.0	5	66
Total=	9/18	13/18	
Percentage	44.5	72	

Note. N=12 per cultivar, and N= 36 total number of individual no. of cultivar experiments

Table 37. Mean pooled nutrient tissue values for all three cultivars over time and locations, tissue nutrient levels by location (with cultivar data pooled together), and P rate response with data from all cultivars pooled together.

Cultivar	N (%)	P (%)	K (%)	N/P ratio	K/P ratio
Overall cultivar data pooled over time and across locations					
Joi Choi	6.24 A	.66 A	5.8 A	9.9 A	9.2 A
Mizuna	6.0 A	.58 A	4.0 C	10.6 A	7.1 B
Quing Choi	5.9 A	.66 A	5.1 B	9.0 B	7.8 B
Overall pooled data by location					
Poamoho	6.5 A	6.8 A	5.5 A	11.0 A	9.3 A
Waimanalo	5.4 B	6.2 B	4.3 B	8.0 B	6.3 B
Data from all cultivars pooled together across time and locations					
P rate					
0	6.0 A	.6 B	5.2 A	10.7 A	9.2 A
100	6.0 A	.65 AB	5.1 A	9.7 AB	8.1 AB
200	6.1 A	.65 AB	4.8 A	9.7 AB	7.6 B
300	6.0 A	.64 AB	4.9 A	9.7 AB	7.9 B
400	6.1 A	.66 A	5.0 A	9.6 AB	7.7 B

Table 38. Mean tissue nutrient levels of three mustard cabbage varieties, and the N/P and K/P uptake ratios as affected by location and by several P fertilizer application rates.

Cultivar	N (%)	P (%)	K (%)	N/P ratio	K/P ratio
Joi Choi (total of 15 experiments)					
Poamoho	6.7 A	.65 B	6.6 A	10.7 B	10.6 A
Lalamilo	6.4 A	0.5 B	5.3 B	13.1 A	11.0 A
Waimanalo	5.6 B	7.4 A	5.0 B	7.7 C	6.8 B
P rate for Joi Choi					
0	6.2A	.64 A	5.9 A	10.7 A	10.3 A
100	6.1A	.66 A	5.9 A	9.9 A	9.5 A
200	6.3 A	.68 A	5.6 A	9.6 A	8.5 A
300	6.2 A	.66 A	5.7 A	9.9 A	9.1 A
400	6.3 A	.69 A	5.7 A	9.5 A	8.6 A
Ming Quing Choi (N= 12 experiments)					
Poamoho	6.4 A	.66 A	5.6 A	9.9 A	8.7 A
Waimanalo	5.3 B	.68 A	4.4 B	8.0 B	6.6 B
P rate for Quing Choi					
0	6.0 A	0.58 AB	5.3 A	10.5 A	9.3 A
100	6.0 A	0.70 A	5.1 A	8.8 B	7.4 B
200	5.9 A	0.69 A	4.9 A	8.7 B	7.2 B
300	5.8 A	0.68 A	5.0 A	8.7 B	7.5 B
400	5.8 A	0.70 A	5.1 A	8.5 B	7.4 B
Mizuna (N= 12 experiments)					
Poamoho	6.4A	0.54 B	4.4 A	12.3 A	8.5 A
Waimanalo	5.4 B	0.63 A	3.5 B	8.6B	5.6 B
P rate for Mizuna					
0	5.8 A	0.56 A	4.1 A	11.0 A	7.7 A
100	5.9 A	0.59 A	4.2 A	10.3 A	7.3 A
200	6.0 A	0.57 A	3.8 A	10.8 A	6.9 A
300	5.9 A	0.59 A	3.9 A	10.3 A	6.9 A
400	6.1 A	0.59 A	4.0 A	10.7 A	7.0 A