Fertility Guide

for Hops

HĀPI

HOP RESEARCH CENTRE

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Third party images used in this publication are acknowledged accordingly. All other images were taken by Katherine Dunbar.

Preface

E ngā iwi, e ngā reo, e ngā kārangarangatanga maha tēnā koutou katoa.

To the peoples, to the many voices, we greet you all.

Tēnei mātou te mihi atu ki a koutou i roto i ngā tini āhuatanga o te wā. He kairangahau hāpi (hops) mātou nō te pūtahitanga o Hāpi, e kimi nei, e hāhau nei i ngā momo hōu, i ngā huarahi hōu e tupu ai te ahumahi hāpi o Aotearoa ki tōna teitei.

We acknowledge you and your ancestors, and all of the things happening in our various worlds.

We are researchers into hops, from the research collective known as Hāpi, who are seeking out new varieties and methods of hop farming, to ensure the hops industry of New Zealand grows to its full potential.

E ū ana mātou ki ngā upoko o te Tiriti o Waitangi i roto i ā mātou mahi, ā, ka anga te titiro ki ngā iwi o te Tauihu o Te Waka, o te Upoko o Te Ika, otira ngā iwi katoa, e kui mā, e koro mā tēnā koutou katoa. Ko te hiahia kia haere ngātahi tonu ā tātou mahi kia puta he oranga mō ngā uri whakatupu.

We affirm our commitment to the pledges of the Treaty of Waitangi in our work, and in so doing acknowledge the people of the top part of the South Island and the lower North Island where we have a presence, to all the elders, sincere greetings. Our wish is to work in tandem with you in developing the industry for the benefit of coming generations.

E mahi tahi ana mātou me ngā kaipupuru pānga o Moutere, o Pōneke, me ētahi atu takiwā, me te Manatū Ahu Matua, i runga anō i te hiahia kia puta he he hāpi, he pia ahurei, nō Aotearoa anake, ka paingia e ngā iwi o te motu, o te ao, e tupu ai he huanga ā-ōhanga mō te katoa.

We work closely with our shareholders in Moutere, Wellington, and elsewhere, and with the Ministry for Primary Industries, with the common aim of producing uniquely New Zealand hops and beer which people nationally and internationally will enjoy, producing an economic benefit for the whole country.

Te mahi a te kotahitanga o Hāpi he whakahīato i te tangata, he whakawhiti mōhiotanga, he tūhura huarahi hou, ā, i te mutunga, he whakatupu i ngā hāpi pai rawa o te ao katoa.

Hāpi collective is about gathering people together, exchanging information, exploring new ways of working and in the end, producing excellent hops for the whole world.

New Zealand hop production encompasses only a small fraction of the global market; however, hops from New Zealand are highly sought after by domestic and international craft brewers. At the end of 2018 we launched Hāpi Research Ltd, with the vision to transform New Zealand's hop industry into a significant direct supplier of super-premium hops to the best craft breweries in the world. Our goal is to grow the value and volume of New Zealand premium craft beer and hop sales domestically and internationally, and to help New Zealand craft brewers create sustainable points of difference and access attractive new markets.

Hāpi Research Ltd. is a new collaborative industry-led hop breeding and market development company that seeks to support the growth of New Zealand craft beer and hop farming. We are doing this through the Hāpi - Brewing Success programme between Hāpi Research Ltd and the Ministry for Primary Industries. This programme is driving benefits for New Zealand's premium hops and craft beer industries through an advanced market-led hop breeding programme, precision farming and processing techniques, and international market collaboration with leading craft brewers.

Hāpi Research hosts an annual symposium, a gathering of craft beer and hop industry participants from across the globe, for a day of talks covering the latest research from the hop world, brewing techniques, and experiences from breweries and other industries. The event creates opportunities to build stronger, direct relationships, share best practices, and hear about the latest in hop research, brewing techniques, and market tastes and trends. The Hāpi Symposium provides a forum for domestic and international craft brewers, scientists, hop breeders and growers to engage in collaborative discussions, information sharing, and networking.

Hāpi Research is striving to create a platform for facilitating industry excellence and to become a resource centre for industry best practices in hops and craft beer. We aim to become a resource for new innovations, the latest research, and sustainability best practices. We strive to be a source of quality information on the hops and craft beer industries and to create opportunities to connect New Zealand craft beer and hop industry participants to markets.

This guide is intended to provide general information about the use of fertiliser with hops. The Hāpi Research website is also a valuable source of information and has useful and relevant resources. We continuously add to this material and strive to provide up-to-date and relevant information. Please visit the Hāpi Research website at Hapi.co.nz for more information and to access additional resources.

Cheers,

The Hāpi Team

HĀPI
HOP RESEARCH CENTRE

info@Hapi.co.nz

Purpose of this Guide

The purpose of this guide is to provide general information on hop fertility and the use of fertiliser with hops. Fertilisation recommendations vary widely from region to region, and amongst varietals, irrigation methods, soil type, and other factors, and are not part of the scope of this guide. It is important to consult an expert to determine an effective and economic fertiliser plan for your region and situation.

Introduction

Hops are a high yielding plant with significant nutrient requirements. Hop plants are extremely efficient about taking nutrients from the surrounding topsoil; therefore, monitoring and replacing depleted nutrients each season is crucial. Ensuring that the plants have adequate nutrition improves both quality and yield. Selecting the right combination of fertilisers and timing the application of those fertilisers, is crucial to optimal plant development. Testing and monitoring hops plant fertility is an important part of hop farm management. Fertiliser and nutrition regimes are complicated and an expert should be consulted to determine what is best for the location and varietals. This guide compiles research and ideas from a wide array of sources and publications, including material from Michigan State University Extension, the University of Vermont Extension, and Oregon State University Extension, among many others. A full list of references is available at the end of the document.

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Soils Testing

Soils testing is an important part of hop garden establishment and ongoing maintenance. Testing the soils ensures that all nutrients are in the optimum range and alerts you to any amendments that need to be made. Large amounts of nutrients are removed from the soil each year during the hop harvest, and need to be replaced. Figure 1 is a snapshot of a soils test, showing the type of information you may find on a typical soils test. Soils should be routinely tested for pH levels and nutrients, to ensure the plants have the available nutrition they need at each stage of the growth cycle.

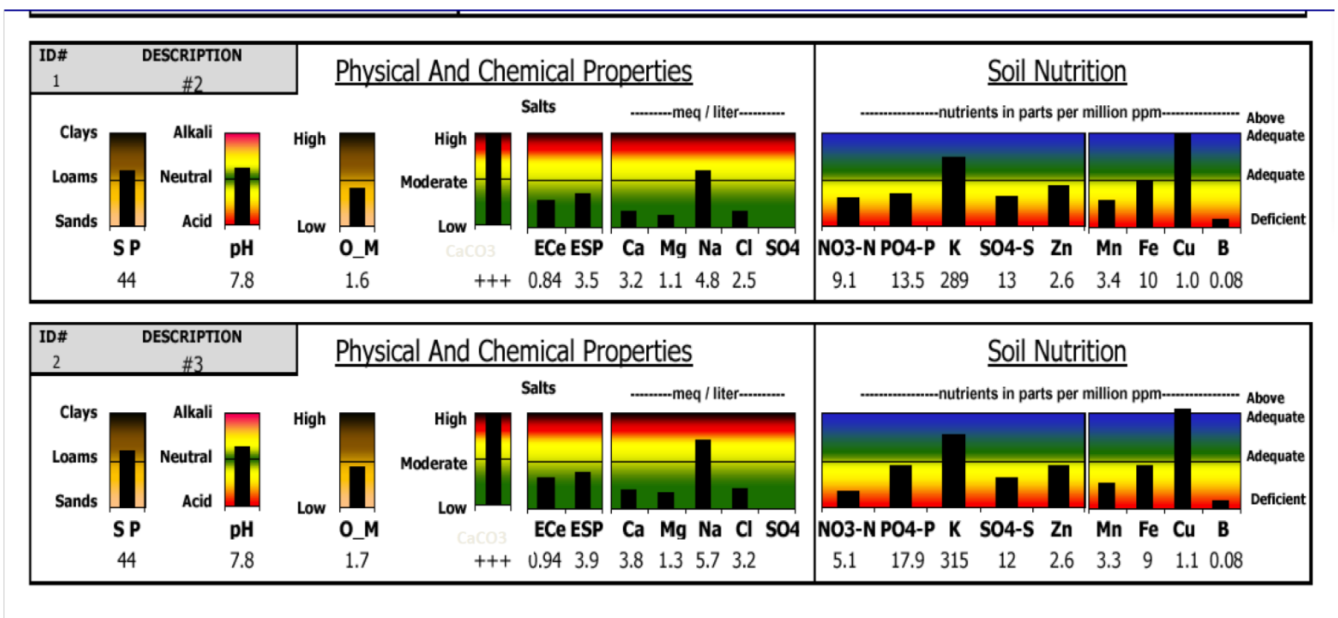


Figure 1 [i]

Conducting a Soils Test

The first step to determining the nutrient needs of your crop is to test the soil. Soil samples should be taken from around the hill for routine analysis. A core should be taken from the soil surface to a depth of 30cm in 15-20 locations throughout the hop garden.[ii] Soil samples can be taken at any time of the year, but should be taken at the same time each year for comparison year to year.

In addition to routine testing, a onetime sample should be taken in the hop garden to determine the soil type and makeup. The sample should be taken at 1.5m-2m depth, ideally prior to establishing a hop garden, or if that is not possible, samples should be taken between rows.[iii] Soils are often made up of layers of different types of soil, so testing will reveal valuable information about the makeup of the soil, and allow you to optimize fertiliser and irrigation.

Pre-Planting Soils Testing

Soils should be tested prior to planting to make sure all nutrients are present in the optimum range. Soil amendments, such as adding organic matter, should be done prior to planting. Ideally, the pH of the soil should be between 6.2 and 6.5. Lime can be used to correct soil pH the season before.[iv]

Spring Testing

Testing at this time, gives a good baseline of the general levels of nutrients and soil pH. This should be completed prior to any spring cultivation so that amendments to the soil can be made.

Mid-Season Testing

Mid-season testing should be conducted just prior to bine side arm initiation. Testing at this time is conducted specifically to ensure that the nutrients potassium, zinc, and boron are present in sufficient quantities for the plants to set burrs and cones, ensuring maximum yield. Amendments can be done at this time to correct any deficiencies.

Post-Harvest Testing

Post-harvest testing is important because it shows what nutrients have been removed, what nutrients are left in the soil, and what nutrients need to be replaced prior to the plants entering dormancy. Levels of phosphorus, potassium, and organic matter should be checked at this stage. If soil pH or compaction issues are identified, corrections can be made at this time.

Soil pH

Soil pH is important because of its effect on plant nutrient availability. Soil pH is a method of measuring soil acidity or alkalinity levels by measuring the electrical charges present in the soil. All soil minerals and nutrients carry either positive, cations or negative anions. When a soil pH is in electrical balance all the nutrients and minerals are available to the plant. When soil pH is too high (+) or too low (-) a variety of processes and nutrients become blocked, and are therefore less available to the plant. Microbial activity and organic matter decomposition rates are slowed when soil pH is incorrect, significantly impacting growth.[v]

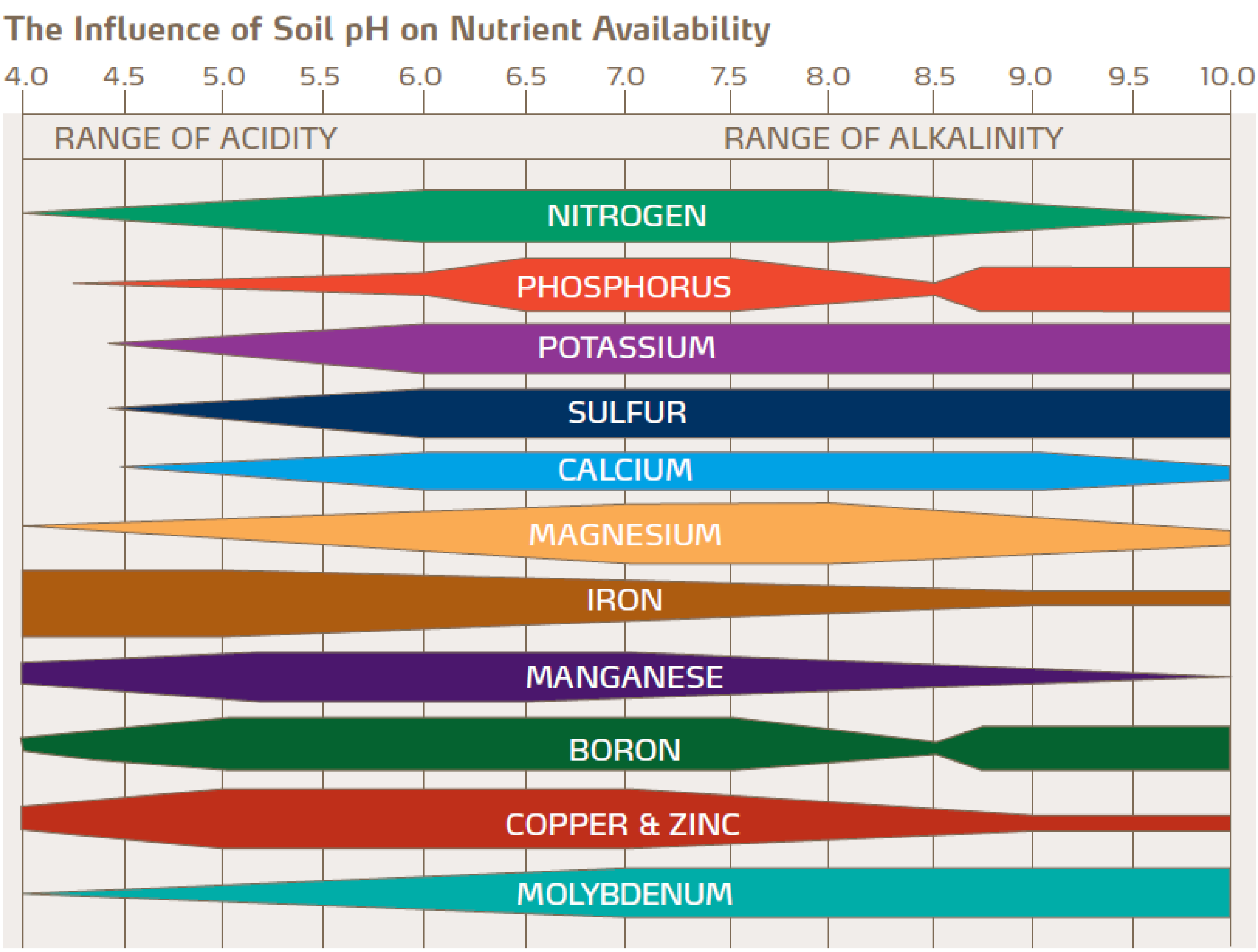


Figure 2 [vi]

Soil pH affects the amount of microorganisms in the soil, which is important because microbes are important to the cycling of nutrients in the soil.[vii] This makes critical nutrients less available to the plant, consequently affecting growth and overall plant health. Figure 2 illustrates the effect of soil pH on nutrient availability for plants. The majority of hop varieties prefer a slightly acidic soil, somewhere between 6.2 and 6.8. Soil pH varies seasonally, with the lowest pH usually occurring in late summer or early autumn.[viii]

Raising Soil pH

Raising soil pH is not as simple as applying lime, a specialist should be consulted to determine the proper rates of application of lime and/or gypsum to ensure that the levels of calcium, magnesium and sodium are kept in balance. Over application of lime and gypsum can cause deficiencies in magnesium, potassium, boron, zinc and copper.[ix]

Lowering Soil pH

Sulfur is used to lower soil pH; however, sulfur is hard on fine tip roots and fine feeder roots so it is best to do sulfur applications in multiple small doses. Additionally, the best time to apply sulfur is post-harvest. Heavy sulfur applications should be avoided during periods of active new root growth.[x]

Effect of Fertilisers on Soil pH

Soils will acidify over time with normal farming practices so monitoring soil pH each year is important so adjustments can be made. Lime can be used to correct soils with low pH. Dolomitic lime also adds Calcium and Magnesium. Low soil pH can lead to Aluminum toxicity and Phosphorus deficiency.[xi] Figure 3 shows the types of affects that fertilisers can have on soil pH.

Effect of fertilizers on soil pH

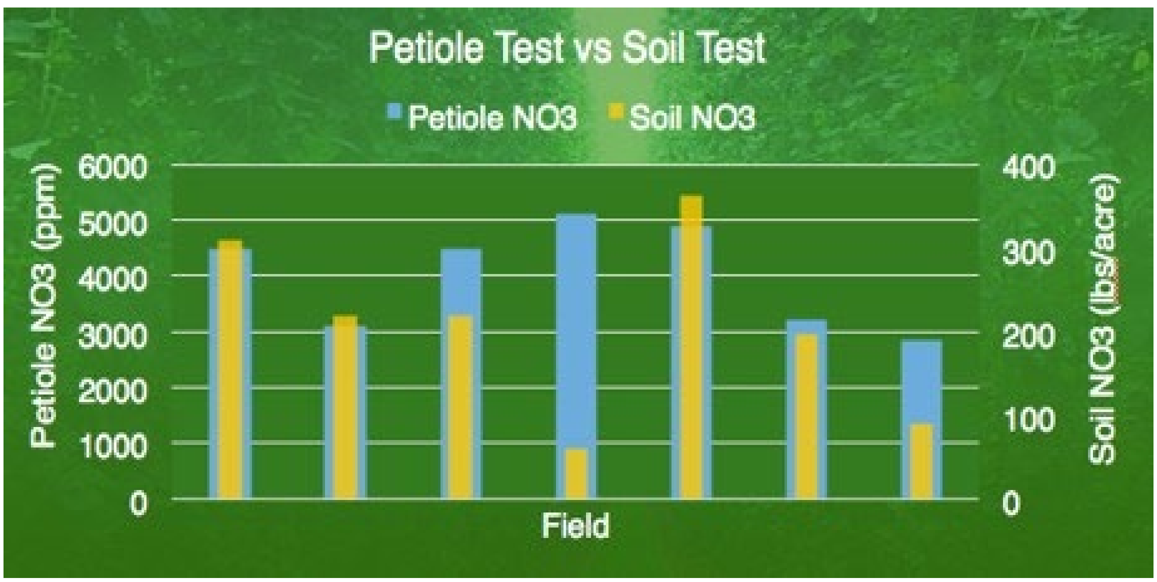
- Ammonium (NH4+) or ammonium forming fertilizers (ex. urea) will cause a decrease in soil pH over time.
- Nitrate (NO3-) sources carrying a basic cation should be less acid-forming then NH4+ fertilizers.
- The presence of Ca, Mg, K, and Na in the fertilizer will slightly increase or cause no change in soil pH.
- Elemental sulfur, ammonium sulfate, and compounds such as iron can reduce the soil pH

Figure 3 [xii]

Tissue (Petiole/leaf) Testing

While soils testing is needed to ensure that all nutrients are present in the soil in the optimum range, tissue (or petiole/leaf) testing is important for determining plant nutrient needs. Tissue testing allows you to optimize plant nutrition, growth and yield. The petiole is the stalk that attaches the leaf to the plant stem. Petiole testing provides an indication of nutrient uptake by the plant and in addition to soils testing, and should performed annually to compare with plant growth and yield from year to year. As shown in Figure 4, the nutrient levels in the soil can vary from the nutrient uptake of the plant.

Figure 4 [xiii]



Petiole testing is used to monitor plant nutrient levels, determine plant nutrient needs and identify deficiencies in a given year.[xiv] Petiole testing can be used to evaluate current year fertiliser applications in the hop garden when compared to samples taken annually. If deficiencies are identified, foliar treatments can be applied or adjustments can be made by other methods throughout the year.[xv]

Tissue samples should be taken from petioles and leaves in around 30 locations. Petiole samples should be taken from mature plants, just prior to reaching the wire, and should be taken from the main stem, 1.5m-2m from the ground.[xvi] Samples should be sent to a tissue testing

laboratory for nutrient analysis. Samples should be analysed for both macronutrients and micronutrients.

Essential Plant Nutrients

There are a variety of essential plant nutrients that hop plants require to properly grow and complete their lifecycle. Hops need larger amounts of some nutrients and only trace amounts of others. For example, hop plants require substantial amounts of nitrogen for growth, however only trace amounts of boron, zinc and magnesium for optimal growth. These trace elements; however, are crucial to plant growth and deficiencies have a large impact on the overall health and plant growth. Figure 5 shows a list of essential nutrients required for hops.

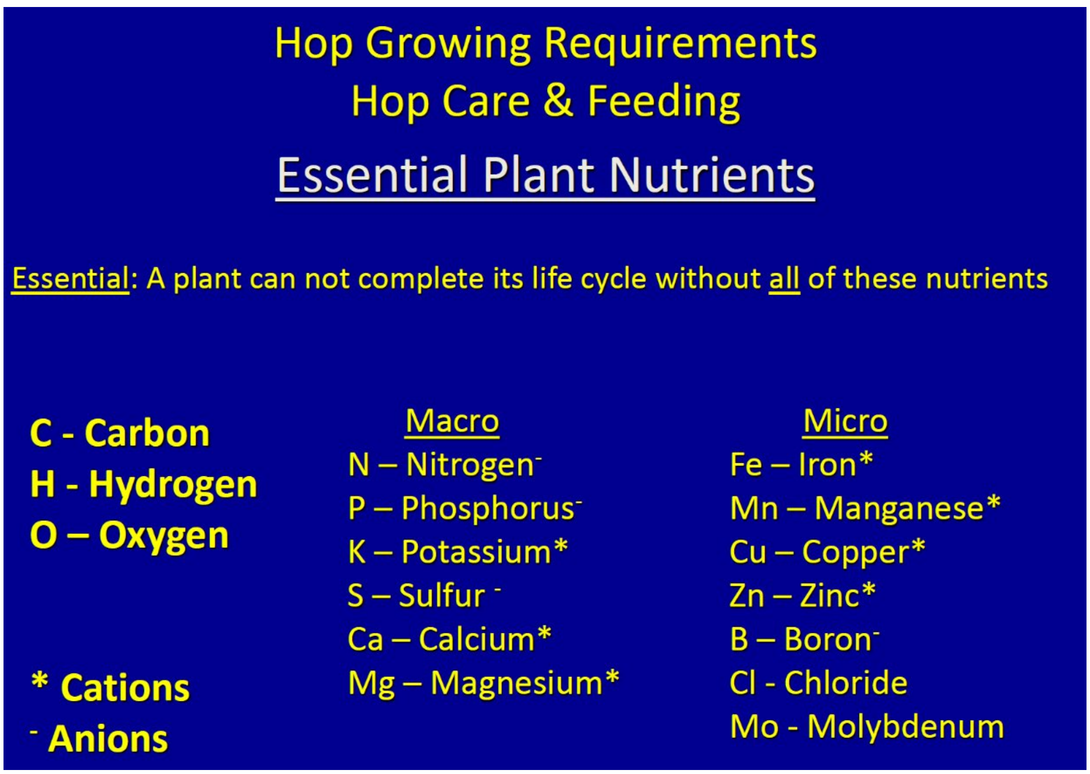


Figure 5[xvii]

Estimating crop and plant nutrient removal helps determine the fertiliser needs of the hop garden. Mature crops remove more nutrients from the soil because they have a larger biomass than younger plants. Although nutrient requirements vary slightly between varietals, hops plants generally have the following macronutrient requirements: 3% nitrogen, 2% phosphorus, and 0.50% potassium.[xviii] Hop nitrogen requirements are based on plant uptake of nitrogen, calculated from yields. The whole plant biomass for hops contains approximately 3% nitrogen.

Multiplying the whole plant biomass weight by 3% will indicate how much nitrogen has been removed from the soil. Cone yields are important because indicate the level of nutrients being removed from the soil. Since the whole plant biomass is not generally known, it can be estimated from cone yields. Cone yields, make up approximately 1/3 of the whole plant biomass.[xix] With this information, cone yields are used to estimate the whole plant biomass, and then the nitrogen and other nutrient requirements are calculated from those estimates.

Hops are a perennial crop, therefore it is important to select fertilisers that are slow to volatilize from the soils surface. Nitrogen and other nutrients can be delivered to the plants using commercial synthetic fertilisers and compost or other organic amendments. Plowing a cover crop into the hop garden is another way to supply nitrogen to the soil. It is important to test the nutrient levels in compost to determine what nutrients are being added and how much.[xx]

Macronutrients

Nitrogen (N)

Nitrogen is an essential nutrient and is required for optimal cone production.[xxi] Hops plants produce a substantial amount of biomass in for the form of bines, leaves and cones. Hop plants therefore, require a significant amount of nitrogen to satisfy their growth needs. Sufficient

nitrogen is vital for strong canopy growth; a high yielding hop garden can remove 110-170 kgs of nitrogen per hectare each harvest season.

Figure 6 [xxii]

Higher yielding plants require even more nitrogen per acre for optimal growth and development.[xxiii] With the biomass of an entire hops plant around 3% nitrogen, and the cones making up approximately 1/3rd of the plants biomass, a substantial amount of nitrogen is required.[xxiv] The best time to apply nitrogen is during the vegetative growth stage when bine elongation and lateral formation occurs. Nitrogen should not be applied after the plant has flowered, as it can result in unwanted vegetative growth.[xxv] The availability of nitrogen is limited any time microbial activity is reduced. Common signs of nitrogen deficiency are poor growth, along with stunting and yellowing of the leaves, particularly in older leaves.

In general, the cones on nitrogen deficient plants are smaller.[xxvi] Care should be used to determine the correct amount of nitrogen for the plant's needs because nitrogen deficiencies, as well as over fertilizing with nitrogen, can encourage disease and pests. For example, large amounts of nitrogen, especially if applied late in the season, can encourage outbreaks of spider mites, and there is also evidence that nitrogen deficiency can induce spider mite outbreaks.[xxvii] Excessive levels of nitrogen are known to induce zinc, sulfur and copper deficiencies, and can burn out organic matter and soil microbes. Additionally, nitrogen combines with sulfur to leach calcium out of the soil[xxviii]

The amount of fertiliser nitrogen the plants require is calculated by subtracting the amount of nitrogen returned to the soil from manure, organic matter, and cover crops, from the nitrogen requirement for the garden. Nitrogen use efficiency is depended on soil quality and management practices; however, it is thought to be around 65%, suggesting that about 35% of actual Nitrogen applied is lost to the environment through leaching and volatilization, and is not taken up by the plant.[xxix] Typical first year nitrogen requirements are 85 kgs of nitrogen per hectare, and increase to 110-170 kgs of nitrogen per hectare in subsequent years.[xxx] Nitrogen can be supplied to the hop garden using commercial fertiliser, soil organic matter, manure, cover crops, and returned bines.[xxxi] Application of nitrogen should be reduced when manure or other

organic materials are used.[xxxii] Nitrogen from commercial synthetic fertilisers is considered to be 100% available to the plant, although caution should be used with synthetic fertilisers as they can lower the microbial levels in the soil.[xxxiii]

Phosphorus (P)

Hop plants have minimal phosphorus needs compared to their nitrogen and potassium requirements. Studies have found that hops have a fairly low phosphorus requirement, only removing an average of 20-35 kg per hectare. Around 25-30% of the phosphorus is found in the leaves, so returning bines and leaves to the hop garden greatly reduces the need for an additional phosphorus application after each harvest.[xxxiv] The availability of phosphorus to the plant is restricted in soil with a lower pH and high level of aluminum, iron and zinc.[xxxv] Excessive phosphorus levels in the soil blocks zinc and copper uptake, and can also lead to zinc deficiency.[xxxvi] Symptoms of phosphorus deficiency include, thin, weak bines, brown discoloration on cones, and down-curved dark green leaves lower down on the plant that have a dull appearance.[xxxvii] Some studies have shown a decrease in yield when the plants have a phosphorus deficiency, even if symptoms are not visible. It is however, important not to over

fertilise with phosphorus, as this not only has negative environmental impacts, but can induce zinc deficiency.

Figure 7 [xxxviii]

Potassium (K)

Potassium is important for bine growth as well as leaf and cone development. Plants remove about 90-170 kg per hectare each season, with one quarter of the potassium found in the cones and three quarters in the bines and leaves.[xxxix] If bines and leaves are returned to the hop garden, much of the potassium is recycled, reducing the need for further fertiliser applications. Potassium uptake can be blocked by excessive levels of calcium, magnesium and sodium in the soil.[xl] Potassium deficiency causes weak bine growth and reduced burr formation, and may reduce nitrogen efficiency. Over fertilization with potassium may induce magnesium deficiencies. Excessive levels of potassium block boron, calcium and manganese uptake.[xli] Symptoms of potassium deficiency include bronzing between the veins on the leaves, that then become ash grey. Leaves may shed prematurely.[xlii]

Figure 8 [xliii]

Micronutrients

Boron (B)

Boron is essential for creating new plant cells and is used with calcium in cell wall synthesis. Boron deficiency reduces the normal expansion and growth of cell walls and inhibits root elongation. A plants boron needs are much higher during the reproductive growth phase.[xliv] Plants also need adequate levels of boron to ensure effective sugar translocation within the plant, and boron is necessary for optimal nitrogen conversion. Boron leaches easily and generally needs to be replaced annually.[xlv] Symptoms of boron deficiency include delayed emergence of shoots, small, distorted chlorotic leaves, shortened internodes, and lots of buds on the crown at ground level.[xlvi] In addition, plants will exhibit stunted growth, and yellowing or whitening of leaves between veins.[xlvii] Boron can easily become toxic with over fertilization and plant damage can occur if boron is applied excessively or in too high concentrations.[xlviii] Boron deficiencies are most common in acidic and sandy soils.[xlix] A typical application of boron, is 1-2 kg per hectare.[l] A soil test is necessary to determine if there is a boron deficiency, if less than 1.5ppm, apply 1.1-1.7 kg per hectare, if greater than 1.5ppm no need to apply fertiliser.[li]

Calcium (Ca)

Calcium loosens most soils, making nitrogen more available; however, in too high levels, calcium blocks most nutrients, particularly magnesium, potassium, boron, zinc and copper.[lii] Calcium

deficiency exhibits similar symptoms to boron deficiency, with yellowing of growing points, reduced leaf development, and yellowing and death of leaf margins.[liii] As an amendment, when exchangeable calcium is below 5 meq/100g of soil, lime is recommended.[liv]

Iron (Fe)

Iron rapidly becomes unavailable to the plant in soils with a high pH.[lv] Iron deficiency is most common in alkaline soils and can be induced in highly acidic soils, with high manganese accumulation. Iron deficiency is first exhibited on young leaves as a yellowing between veins, while the veins themselves remain green.[lvi]

Magnesium (Mg)

Magnesium deficiencies are most common in acid soils where potassium has been applied. Symptoms include yellowing between veins of older leaves, while the veins themselves remain green, followed by defoliation and sometimes death in these areas.[lvii] The two most common amendments for low soil magnesium are dolomite lime and magnesium sulfate.[lviii] If the soil test for magnesium is below 1 meq/100g, dolomite can be applied at a rate of about 2,200kg per hectare.[lix]

Manganese (Mn)

Manganese is important because it helps the plant set and hold cones.[lx] Manganese is an essential element, but can become toxic to the plant when accumulated beyond the its needs. Manganese accumulation in plant tissues increases as soil pH decreases.[lxi] Manganese becomes limited in high pH or alkaline soils. Manganese accumulation interferes with iron uptake and can lead to iron deficiencies. Symptoms of manganese deficiency are yellowing of young leaves and white speckling.[lxii]

Molybdenum (Mo)

Hop plants require trace amounts of molybdenum for growth. Molybdenum deficiencies are often confused with nitrogen deficiencies because the plants exhibit similar symptoms. Symptoms first appear in the older leaves as yellowing and white speckling, and plants have a general yellowing. Deficiencies occur in acidic soils with a pH of 5.7 or less.[lxiii]

Sulfur (S)

Sulfur helps in the microbial breakdown of organic matter, and in excess lowers soil pH.[lxiv] Sulfur is commonly deficient in acidic, coarse soil, and in soils with a high leaching potential. Sulfur combines with and leaches out calcium and magnesium from the soil. Symptoms of sulfur deficiency are stunted growth, spindly stems, and yellowing of younger leaves.[lxv] Sulfur applications are recommended for optimum production of most crops, and although there is currently no reliable test for prediction of sulfur levels in hops, applications are generally 33-44 kg per hectare.[lxvi]

Zinc (Zn)

Hop plants require zinc for optimal growth and cone production. Zinc aids plant growth hormones and the enzyme system. It is necessary for starch formation, root development, and the formation of chlorophyll and carbohydrates.[lxvii] Zinc levels should always be higher than copper levels.[lxviii] Hops are sensitive to zinc deficiency, and symptoms include chlorotic leaves, weak lateral and bine growth, poor cone production, leaves that are small, misshapen, yellow, curl upwards and become brittle. In severe cases the plants can even die.[lxix] Zinc deficiencies occur when soil pH is above 7.5. Fertiliser should be applied when the soil test is above 1ppm at a rate of 11.2-13.5 kg per hectare for broadcast applications and 3.3-4.4 kg per hectare for banded applications. A foliar application of zinc sulfide (.15-.18%) could also be applied.[lxx]

Hop Plant Growth

Hop plants have varying nutritional needs at different stages of their growth cycle, and some nutrients are critical at specific points in the growth cycle. Phosphorus is important in early spring for new root development, at burr onset, and for rebuilding energy going into winter. Nitrogen is critical during the climbing and sidearm stage, and is an essential nutrient for optimal cone development. Trace elements, Zinc and Boron are critical for burr initiation. Fertiliser is most effective during phase 1, 2, and 3 of the growth cycle and should be complete by the time flowers become visible, stage 5 of the growth cycle.[lxxi] Figure 9 shows details of the first three stages of the growth cycle. A table showing all growth stages can be found at the end of this document.

Principal growth stage 1: Leaf development	
11	First pair of leaves unfolded
12	2nd pair of leaves unfolded (beginning of twining)
13	3rd pair of leaves unfolded
1 .	Stages continuous till . . .
19	9 and more pairs of leaves unfolded
Principal growth stage 2: Formation of side shoots	
21	First pair of side shoots visible
22	2nd pair of side shoots visible
23	3rd pair of side shoots visible
2 .	Stages continuous till . . .
29	Nine and more pairs of side shoots visible (secondary side shoots occur)
Principal growth stage 3: Elongation of bines	
31	Bines have reached 10% of top wire height
32	Bines have reached 20% of top wire height
33	Bines have reached 30% of top wire height
3 .	Stages continuous till . . .
38	Plants have reached the top wire
39	End of bine growth

Figure 9 [lxxii]

Appendix

Hop Rossbauer et al., 1995

Phenological growth stages and BBCH-identification keys of hop
(*Humulus lupulus* L.)

Code	Description
Principal growth stage 0: Sprouting	
00	Dormancy: rootstock without shoots (uncut)
01	Dormancy: rootstock without shoots (cut)
07	Rootstock with shoots (uncut)
08	Beginning of shoot-growth (rootstock cut)
09	Emergence: first shoots emerge at the soil surface
Principal growth stage 1: Leaf development	
11	First pair of leaves unfolded
12	2nd pair of leaves unfolded (beginning of twining)
13	3rd pair of leaves unfolded
1 .	Stages continuous till . . .
19	9 and more pairs of leaves unfolded
Principal growth stage 2: Formation of side shoots	
21	First pair of side shoots visible
22	2nd pair of side shoots visible
23	3rd pair of side shoots visible
2 .	Stages continuous till . . .
29	Nine and more pairs of side shoots visible (secondary side shoots occur)
Principal growth stage 3: Elongation of bines	
31	Bines have reached 10% of top wire height
32	Bines have reached 20% of top wire height
33	Bines have reached 30% of top wire height
3 .	Stages continuous till . . .
38	Plants have reached the top wire
39	End of bine growth
Principal growth stage 5: Inflorescence emergence	
51	Inflorescence buds visible
55	Inflorescence buds enlarged

Hop Rossbauer et al., 1995

Phenological growth stages and BBCH-identification keys of hop

Code	Description
Principal growth stage 6: Flowering	
61	Beginning of flowering: about 10% of flowers open
62	About 20% of flowers open
63	About 30% of flowers open
64	About 40% of flowers open
65	Full flowering: about 50% of flowers open
66	About 60% of flowers open
67	About 70% of flowers open
68	About 80% of flowers open
69	End of flowering
Principal growth stage 7: Development of cones	
71	Beginning of cone development: 10% of inflorescences are cones
75	Cone development half way: all cones visible, cones soft, stigmas still present
79	Cone development complete: nearly all cones have reached full size
Principal growth stage 8: Maturity of cones	
81	Beginning of maturity: 10% of cones are compact
82	20% of cones are compact
83	30% of cones are compact
84	40% of cones are compact
85	Advanced maturity: 50% of cones are compact
86	60% of cones are compact
87	70% of cones are compact
88	80% of cones are compact
89	Cones ripe for picking: cones closed; lupulin golden; aroma potential fully developed
Principal growth stage 9: Senescence, entry into dormancy	
92	Overripeness: cones yellow-brown discoloured, aroma deterioration
97	Dormancy: leaves and stems dead

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