

# Calopogonium caeruleum (Benth.)

## Monograph



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# Preface

The following monograph presents a comprehensive study of *Calopogonium caeruleum*, which is a species of tropical legume that is sometimes used for its benefits for agriculture. The purpose of this work is to look at the species from multiple perspectives and do so with well made research.

The information in this document, as touched before, is mostly based on scientific literature, academic sources, and databases for the sake of accuracy and reliability. It hopes to provide a clear understanding of the role *C. caeruleum* plays in ecosystems and its significance in agricultural systems as can be seen its use as a cover crop.

Through this monograph the reader should gain insight into both the practical and theoretical aspects of *Calopogonium caeruleum*.

This monograph talks about:

- Taxonomy
- Ecoregion
- Origin/Fossil Record
- Soils/Geology
- Light, Temperature, and Water
- Chromosomes
- Life Cycle
- Anatomy
- Growth Habits
- Reproductive Biology
- Regeneration
- Propagation
- Plantings
- Management/Control
- Cultivation
- Fertilizing
- Growth Stages
- Harvesting
- Pruning/Re-planting
- Importance
- Market
- And it's Uses

On a personal level, it is surprising the lack of available sources, at least at an academic level, that talk about this species, making it a bit harder to research. In some sections information of its close relative, *Calopogonium caeruleum*, is used with notice. The reason for the flexibility is due to both the lack of information on some topics and the extreme similarity between both species, with several articles discussing both as if they were a singular.

# Taxonomy

## Section 1

### Subsection I

#### Taxonomical History

*Calopogonium caeruleum* (Benth.) was first described by the 19th century English botanist George Bentham, though it would be later on when American botanist Charles Wright formally transferred the species into the genus *Calopogonium*. *C. caeruleum* belongs to the Kingdom *Plantae* which encompasses multicellular photosynthetic organisms with cells made of cellulose. (Rothwell, 2025) Within this kingdom it is placed in the subkingdom of *Tracheobionta*. This means that it is a vascular plant that has specialized conductive tissues, xylem and phloem, allowing a more efficient transportation of nutrients and water. Furthermore it belongs to the *Spermatophyta* superdivision which is characterized by producing seeds from fertilized ovules.

Moreover the plant is categorized as *Magnoliophyta* (flowering plants) which produce flowers and enclosed seeds. It is in the class of *Magnoliopsida/Dicotyledons* which is composed of plants with two embryonic seed leaves, a netlike leaf venation and flowering parts typically in groups of 4 or 5. (APG IV, 2016)

Additionally it belongs to the Rosidae which is a large “clade” that includes the order *Fabales*. Members of this order share fruit in the form of legumes (pods) and often have root nodules housing nitrogen-fixing bacteria. The family in which it is part of, being *Fabaceae*, is characterized by papilionaceous flowers and that some have the ability to fix nitrogen, though the ones of the *Caesalpinioideae* sub family tend to not have this nitrogen ability. (APG IV, 2016) (ILDIS, 2014) (Arvind, 2018)

Finally the genus *Calopogonium* consists of climbing or twining perennial legumes native to tropics of the America's, they have trifoliolate leaves, racemose inflorescences, and often vivid flowers (these traits aid their climbing habit). Specifically *C. caeruleum* is a woody twining climber that roots from nodes, bearing three-part leaves and elongated racemes of papilionaceous flowers that are typically blue, white or lavender.

## Subsection 2

### Taxonomic Classification of *Calopogonium caeruleum*

<b>Taxonomic Rank</b>	<b>Classification</b>	<b>Explanation</b>
Accepted Scientific Name	<i>Calopogonium caeruleum</i> (Benth.) Suav.	Scientific name with botanical authority; Bentham first described it, later transferred to <i>Calopogonium</i> by George Bentham.
Common Names	Jicama cimarrona, Bejuco Peludo, Frijolillo	Vernacular names used in different regions of Latin America.
USDA PLANTS Symbol	CACA42	Unique identifier used by the USDA PLANTS database.
Kingdom	Plantae	All multicellular, photosynthetic organisms with cellulose in their cell walls.
Subkingdom	Tracheobionta	Vascular plants with xylem and phloem for nutrient transport.
Superdivision	Spermatophyta	Seed-producing plants.
Division (Phylum)	Magnoliophyta	Flowering plants (angiosperms).
Class	Magnoliopsida	Dicotyledons, plants with two embryonic seed leaves.
Subclass	Rosidae	Large clade of dicots including legumes.
Order	Fabales	Plants producing legumes, often associated with nitrogen fixation.
Family	Fabaceae Lindl.	Pea family; papilionaceous flowers and potential nitrogen-fixing symbiosis.
Genus	<i>Calopogonium</i> Desv.	A genus of climbing legumes native to the tropical Americas.
Species	<i>C. caeruleum</i> (Benth.) Suav.	A woody, twining climber with trifoliolate leaves and blue to lavender flowers.

# Ecoregion and climate

## Section 2

### Subsection I

#### Ecoregion and Climate

*Calopogonium caeruleum* is native to the neotropical region and is recorded in the seasonally dry tropical biome. (Plants of the World Online) Because of this native range it is most suited for tropical and subtropical biomes rather than a temperate or true desert ecoregions. Within that ecoregion context, when observing toposequence, the plant can inhabit riparian corridors, secondary forest zones and the understorey of plantation. These types of ecoregions provide a broad setting that has let it expand across the tropics and subtropical regions.

*C. caeruleum* prefers tropical humid to seasonally dry climates, the species performs optimally in tropical and subtropical climate rather than temperate or even arid desert climate.(Tropical Forages, n.d.) The climate factors that favour *C. caeruleum* are as follows:

- Rainfall: The species is adapted to 1000-3000 mm in annual rainfall for optimum range. Though it will still persist at lower rainfall, that being of around 700 mm, although growth is hampered. (Tropical Forages, n.d.)
- Temperature: Typical temperatures of 18-25°C are optimal, with limits recorded are 10°C for minimum to 32°C maximum. (Tropical Forages, n.d.)
- Shade/lighting: Due to its use in under plantation canopy it exhibits good shade tolerance, maintaining growth even when light transmission is reduced. (Tropical Forages, n.d.)

### Subsection 2

#### Topoquence and Factors of Growth

*C. caeruleum* is commonly found or used in forest zones or plantation understorey rather than desert or arid savanna zones. It is frequently used as a cover crop under mature rubber or oil palm plantations, where it is placed

below the canopy. (Feedipedia, n.d.) In a riparian zone context *C. caeruleum* shows tolerance of moist soil contact would suggest that it could also occupy forest floor or edge zones along streams. (Tropical Forages, n.d.) It is not well adapted to desert zones or open savanna in its native range, that is when rainfall is extremely low or shade is negligible. Rather its successful performance in forest zone understory or shaded plantation systems, or forest edges within the tropical ecoregion.

The growth and performance of *C. caeruleum* are integrally linked to three related factors these being: the ecoregion in which the plant is experimentally or naturally grown, the toposequence location, and finally the prevailing climate regime.

# Fossil Record, Origin, Current Distribution

## Section 3

### Subsection I

#### Fossil Record and Origin

There is no known fossil record of *Calopogonium caeruleum* ever recorded. However, there have been analyses of Fabaceae family that indicate the tribe Phaseoleae, to which *Calopogonium caeruleum* belongs to, diverged approximately 25-30 Million years ago during the late Oligocene to early Miocene (Lavin et al., 2005; Koenen et al., 2020). This time period was known for the expansion of tropical forest across South America, this would suggest that the ancestors of *Calopogonium caeruleum* evolved under warm humid conditions of Neotropical rainforests of the area.

Paleoclimatic reconstructions support this. The Miocene was, in part, characterized by increased rainfall and forest connectivity in Central and South America which most likely facilitated ancestors of *Calopogonium* with help in dispersal throughout modern Latin America before the full formation of the Isthmus of Panama (Pennington et al., 2015). Thus, while there is no fossil remains the evolutionary lineage is well known thanks to genetic and geological evidence.

Genetic analysis within the tribe Phaseoleae suggests that *Calopogonium* shares a close evolutionary relationship with *Mucuna* and *Centrosema* which then similarly adapted to climbing and having a Nitrogen fixation (Egan et al., 2016). Because of this it is no surprise that *Calopogonium caeruleum* is indigenous to the tropical Americas, specifically Mexico, Central America, the Caribbean, and South America. (Cook et al., 2005; Heuzé et al., 2017).

## Subsection II

### Current Distribution

Research compiled by the Global Biodiversity Information Facility confirmed natural occurrences of *Calopogonium caeruleum* in from Mexico to Paraguay and Brazil. It tends to be distributed across low to mid elevation zones, approximately 0-800 m.a.s.l., where there is high humidity and moderate shade (GBIF, 2024).

Since its Neotropical origin *C. caeruleum* spread due to human mediated introduction in the 19th and 20th centuries. It was exported as a cover crop and green manure legume to Africa, Southeast Asia, Pacific Islands and Australia due to its shade tolerance, rapid soil cover, and nitrogen-fixing capacity (Cook et al., 2005). By the mid 1900s *C. caeruleum* had become naturalized across humid tropical regions worldwide particularly in Malaysia, Indonesia, Papua New Guinea, the Philippines and Northern Queensland. (FAO, 2022). In these ranges molecular barcoding shows low intraspecific variations in comparison to native populations supporting the claims of a recent anthropogenic expansion (Egan et al., 2016). Various attempts for greater introduction have failed outside the tropics and sub-tropical areas due to its high moisture requirements.

Ecologically *C. caeruleum* has sustained its niche, preferring shaded, moist habitats, but that has expanded globally due to its use in cultivations. This clearly shows an example of neotropical plant domestication and secondary naturalization with human usage extending the species general reach.

# Soils and Geology

## Section 4

### Subsection I Soils and Geology

The soil and any geological material at play are central to determining the nutrient availability, moisture balance and rooting environment for *Calopogonium caeruleum*. This tropical species develops optimally in slightly acidic solids, typically deprived from weathered tropical parent materials such as basalt, shale or lateritic formations rich in iron and aluminum oxides Cook et al., 2005). These geologies produce highly leached Ferralsol and Acrisols, which are commonly found across tropical lowlands and humid forest zones (FAO, 2022).

Because these soils are naturally low in phosphorus and exchangeable bases such as  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$  *C. caeruleum* depends on efficient nutrient recycling and a symbiotic nitrogen fixation to thrive. Its root nodules, which contain *Rhizobium calopogoni* and other related species, transform atmospheric  $\text{N}_2$  into ammonium which helps fuel amino acid and chlorophyll synthesis. Phosphorus becomes plant available through organic acid exudation from *C. caeruleum* roots, which is a critical adaptation in P-deficient tropical soils (Vance et al., 2003).

Lastly Calcium and Magnesium typically originate from parent rocks weathering, while Potassium and micronutrients derive from clay minerals and decomposing organic matter. *C. caeruleum* maintains great growth when these elements are presented in balanced proportions, helping to support structural stability, enzyme activation and reproductive success.

### Subsection II Soil properties and Plant Growth

*Calopogonium caeruleum* grows ideally in loamy or clay loam soils with a moderate structure and high water holding capacity (Heuzé et al., 2017). Fine textured soils allow stable nodulation and prevent rapid moisture

loss, while good aggregation helps to promote aeration that is necessary for root and rhizobial respiration. In compactor or poorly drained soils oxygen deprivation limits nodule activity and root extension.

The species contributes substantially to the creation of organic matter accumulation through leaf litter and root turnover. In seriatim high organic matter levels enhance cation exchange capacity which then improve nutrient retention and sustain beneficial microbial communities that help with phosphorus solubilization (FAO, 2022).

Solid reaction, as in pH, has a profound effect on nutrient solubility for *C. caeruleum*. It can tolerate moderate levels of acidity but growth tends to decline below a pH of 4.5, where aluminum toxicity interferes with root elongation (Cook et al., 2005). At near neutral pH availability of molybdenum, which is essential for nitrogenase activity, increases which leads to an improvement in N<sub>2</sub> fixation efficiency. Liming acid soils with a pH of 5.5-6.0 can therefore enhance plant vigor and biomass production.

In practice the process of integrating *C. caeruleum* into cropping systems improves soil nutrient statuses through biological nitrogen fixation and organic matter accumulation. Over time these effects can potentially counteract the natural infertility of highly weather tropical soils and stabilize the ecological productivity of forest zones or plantation landscapes. Though it is crucial to note the *C. caeruleum* can also behave like a weed and kill off other plants by blocking sunlight.

# Light, Temperature and Water

## Section 5

### Subsection I

#### Light, Temperature and Nutrients

Temperature has profound effects on *C. caeruleum*, with its optimal growth occurring between 18°C and 25°C. Photosynthesis declines sharply below 15°C or above 32°C (Cook et al., 2005). Within this thermal range enzymatic activity for carbon fixation, respiration and nitrogen assimilation operates efficiently, while excessive heat accelerates respiration leading to carbon loss while low temperatures restrict enzyme kinetics reducing growth.

Furthermore high temperature coupled with low humidity increases transpiration demand, *C. caeruleum* mitigates this through partial leaf folding and osmotic adjustments (Nicodemo et al., 2015).

*C. caeruleum* thrives in moderate to high shade tolerance, thriving under partial canopy cover (Nicodemo et al., 2015). When growth beneath oil-palm or rubber plantations it maintains efficient photosynthesis under light intensities of 30%-60% full sunlight, primarily thanks to a larger lamina area and higher chlorophyll a/b ratio, enhancing the light capture efficiency (Wong, 1985). Spectral light quality also affects development, a higher red:far-red ratio promotes compact growth and higher chlorophyll synthesis in comparison to low ratios under deep canopy that induce elongation but maintain carbon assimilation capacity (Li et al., 2021). *C. caeruleum* follow the C<sub>3</sub> photosynthetic pathway which is typical for tropical legumes. Although C<sub>3</sub> plants are less efficient than C<sub>4</sub> plants under high light and heat. *C. caeruleum* compensates through shade adapted chloroplast distribution and efficient photorespiration control (Taiz et al., 2015).

*Calopogonium caeruleum* like other tropical legumes depends on a balanced repository of macronutrients such as Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulfur. While also using micronutrients such as Iron, Manganese, Zinc, Boron and Molybdenum for optimal growth and nitrogen fixation. In tropical soil *C. caeruleum* form symbioses with *Rhizobium spp* that help enable atmospheric Nitrogen fixation, supplying its own nitrogen while improving soil fertility (Cook et al., 2005). Phosphorus from the soil minerals are vital for root elongation and nodule function which facilitate energy transfer via ATP during nitrogen fixation (Vance et al., 2003). Potassium regulates stomatal opening and osmotic balance directly influencing drought resistance and photosynthesis efficiency. Calcium and Magnesium, which are derived from weathered parent material and organic matter help in cellular strength and chlorophyll formation. The uptake of these nutrients depends on soil texture and water availability. In well drained tropical loams with sufficient organic matter, nutrients mobility is optimized supporting robust vegetative growth and rapid ground cover (Heuzé et al., 2017).

## Subsection II

### Water Requirements and Physiological Needs

Water availability greatly affects nutrient transportation, turgor maintenance and stomatal behavior in *Calopogonium caeruleum*. Its optimal conditions are that of 1000-3000 mm of annual rainfall, tolerating intermittent dry periods but not prolonged drought (Heuzé et al., 2017). Moistened soils nodulation and nitrogen fixation rates are maximized, meanwhile under water stress nodules since limiting Nitrogen supply and reducing leaf area (Sinclair & Serraj, 1995).

During the dry season it exhibits partial dormancy with reduced stomatal conductance and leaf expansion, lower water loss, while carbohydrate reserves in roots and stolons ensure regrowth when rainfall resumes. This water use strategy reflects adaptation to seasonally dry tropical climates where alternation between wet and dry phases is common.

### Subsection III

#### Integration of Nutrient, Light, Temperature and Water Factors

The usage of nutrients, light, temperature and water form and integrate physiological network. Proficient macronutrient supply supports robust chlorophyll synthesis and enzymatic activity, which enables efficient use of moderate light intensities typical of shaded tropical environments. Optimal temperatures sustain metabolic balance while adequate war ensures continuous nutrient uptake and turgor. Finally when any factor becomes limiting both nitrogen fixation and photosynthetic efficiency decline emphasizing the need for synchronized environmental and soil management to sustain productivity in a tropical ecoregion.

# Chromosome

## Section 6

### Subsection I

#### Chromosome complement

Though a direct study on the basis of chromosomes is not available for the public, or more likely simply does not exist, its composition can be inferred using the members of the immediate or close family. Individuals such as *Calopogonium sericeum* which has a chromosome number  $2n = 22$  (Espert et al., 2008). This would imply that *C. caeruleum* has an extremely similar chromosome composition to the rest of the *Calopogonium* genus.

# Life cycle and phenology

## Section 7

### Subsection I

#### Flowering and Reproduction

In its native environment *Calopogonium caeruleum* begins reproductive development after reaching full growth, it creates an elongated raceme of flowers that are papilionaceous and violet in color. It then proceeds to flower indefinitely through the wet season, with it sometimes continuing into dry season in climates with extended rainfall. Due to it being a perennial legume *C. caeruleum* does not suffer from strict seasonal triggers for flowering, instead its flower production overlaps with vegetative growth. This makes *C. caeruleum* a preferred pollination for insects as long as climate conditions remain favourable. This indeterminate flowering habit means that reproductive and vegetative phases are not strictly separated in time and seed production can occur concurrently with ongoing vine expansion. (Tropical Forages, n.d.)

## Subsection II

### Seed Maturation and Dormancy

Once the flowers are pollinated *Calopogonium caeruleum* develops linear oblong pods containing 4 to 8 seeds, which mature within the plant and are released as the pods dehisce. *C. caeruleum* is capable of producing moderate amounts of seed in the establishment year and seed maturity often overlaps with end of the wet season and early dry season in tropical environments. Seeds are primarily dispersed by gravity and passive release. Sadly, there is no truly detailed published research on the dormancy of *C. caeruleum* seeds, but it can be assumed as with other tropical legumes that its seeds can remain viable in the soil, enabling germination with the onset of favourable moisture and temperature condition at the beginning of subsequent wet season. (Tropical Forages, n.d.)

## Subsection III

### Long Term Growth and Persistence

*Calopogonium caeruleum* is a perennial vine that persists across multiple growing seasons by combining continuous vegetative growth with episodic seed production. The stem can grow several meters and root at nodes in contact with moist soil, this allows the plant to spread laterally and maintain ground cover without having to solely rely on seed regeneration. This propagation contributes to persistence in perennial cover crop systems. The plant's tolerance of shade and ability to grow under canopies allows it to persist as a cover crop or green manure in humid tropical plantations over several years of growth. (Tropical Forages, n.d.)

## Subsection IV

### Senescence and Turnover

Once established *Calopogonium caeruleum* develops individual shoots and leaves undergo continuous senescence and renewal, with older foliage senescing and falling as new stems and leaves develop. Although the overall plant remains perennial, individual parts have a finite lifespan and are replaced through ongoing vegetative

growth and node rooting. This turnover contributes to a steady supply of biomass, which is why it is valued as green manure. In less favourable conditions, such as prolonged dry periods or heavy shading beyond the plant's tolerance, portions may decline, but due to it having a large combined seed bank and vegetative spreading capacity, it generally allows for regeneration once favorable conditions return.

# Anatomy and Growth Habits

## Section 8

### Subsection I General Anatomy

As can be seen below, *Calopogonium caeruleum* is a twining perennial legume in the family Fabaceae that can produce stems several meters long which can become woody as it ages and are even capable of rooting at nodes when in contact with most soil (*Caeruleum Calopo (Calopogonium caeruleum) | Feedipedia, n.d.*). The species has trifoliolate leaves borne on long petioles, up to around 16cm, with leaflets that are elliptical to ovate or rhomboid ovate in shape, with lateral leaflets often broader and covered with hair above and below (Tropical Forages, n.d.). Its inflorescence are elongate racemes that can reach up to 50 cm, with many papilionaceous flowers with a bell shaped calyx and blue violet corolla approximately 1 cm long (Tropical Forages, n.d.). Finally, it has a linear oblong dehiscent pod that typically contains 4 to 8 seeds per pod, with the seeds being roughly 4 to 5 mm in diameter. (Tropical Forages, n.d.)

### Subsection II Growth Habits

*As a perennial climbing legume Calopogonium caeruleum* grows by twining and trailing over supports or the ground, forming a ground cover beneath tree canopies or amongst other plants. (*Caeruleum Calopo (Calopogonium caeruleum) | Feedipedia, n.d.*). It has adapted to humid tropical climates where annual rainfall

generally ranges from about 1m to 3m, though it can grow in environments with rainfall as low as 700 mm. (Tropical Forages, n.d.). It can tolerate a wide range of soil textures and even acidic soils with pH as low as 4.0, as long as it's well drained, and responds positively to liming fertile soils (Tropical Forages, n.d.). Unlike many cover legumes, it is highly shade tolerant and capable of maintaining productivity under significant canopy cover and even shows relatively steady growth at light transmissions between 60%-100% (Tropical Forages, n.d.). It is important to note however that *C. caeruleum* takes more time to establish than other tropical legumes often requiring extended time to achieve full soil cover. (Tropical Forages, n.d.).

# Reproductive Biology

## Section 9

### Subsection I

#### Reproductive Biology

*Calopogonium caeruleum* produces flowers indeterminately through the wet season, with flower formation commencing in the first appropriate rainy period after establishment and continuing into the early dry season when moisture allows for it (Tropical Forages, n.d.). Its flowers are adapted for insect pollination, a trait typical of papilionaceous legumes, though specific pollinators for this plant are not detailed sources. The species is capable of producing moderate amounts of seeds even in the establishment year and mature pods dehisce so as to release seeds into the environment for potential germination (Tropical Forages, n.d.). Field reports note that *C. caeruleum* can produce viable seed in its first year which contributes to population persistence alongside its widespread vegetative growth. (Tropical Forages, n.d.)

# Pests and Diseases

## Section 10

### Subsection I

#### Pests and Diseases

*Calopogonium caeruleum* is most affected by fungal diseases such as the Cercospora leaf spot, Anthracnose and Rhizoctonia foliar blight. All identified on the species growing in Colombian environments, this indicates susceptibility to common legume leaf disease under humid conditions (*Calopogonium caeruleum*, n.d.). Although there are no extensive lists of pests specifically for *C. caeruleum*, global plant pest records suggest that insects such as whiteflies (*Bemisia tabaci*) are recognized hosts on *Calopogonium* taxa and may contribute to stress or vector born pathogen transmission (*Bemisia Tabaci (BEMITA)[Overview]* | EPPO Global Database, n.d.). Closely related *Calopogonium* species have been shown to harbor legume viruses and be susceptible to insect feeding, this demonstrates that virus infections can occur in the genus and should be considered potential risks in tropical agronomic settings (Chatzivassiliou, 2021).

# Regeneration

## Section 11

### Subsection I

#### Natural Regeneration

*Calopogonium caeruleum* is capable of natural vegetative regeneration through rooting stems. Its stems root at nodes when they come in contact with moist soil, which allows new plants to develop without seed production. (Chemiseed, n.d.)

This type of growth pattern allows it to spread across the ground surface as a creeping or climbing perennial vine, forming dense cover over time. (CIFOR-ICRAF, n.d.)

Its vegetative rooting enables it to do rapid recolonization of disturbed soil and helps maintain persistent ground cover once it's established.

*C.caeruleum*'s natural regeneration also occurs through sexual reproduction via seeds, in an extremely similar way to its relative *Calopogonium mucunoides*. *C. caeruleum* produces seeds that can be used for establishment and regeneration in plantations (PlantUse, n.d.). Seeds often exhibit high proportions of hard, this can delay germination until conditions are favorable (PlantUse, n.d.). Though *C. mucunoides* and *C. carauleum* are indeed similar their main difference is that the former is more dependent on environments and seasonal conditions, while the latter is at growth and sexual reproduction via seeds year round.

When it comes to regeneration and persistence through perennial growth, *C. caeruleum* supports long term persistence in ecosystems. It is described as a perennial woody vine capable of surviving multiple growing seasons. (CIFOR-ICRAF, n.d.) Growth is initially slow but becomes vigorous between approximately 20 months and 5 years of age, this allows already established stands to persist and expand. (CIFOR-ICRAF, n.d.). Its perennial growth ensures that populations can regenerate annually from existing plants without needing new seed recruitment.

There are also cases of biological symbioses that can enhance regeneration and establish in *C. caeruleum*. For instance, *C. caeruleum* form nodules with rhizobia bacteria that fix nitrogen improving plant growth and establishment in soils. (Robson & Loneragan, 1983)

Furthermore, inoculation experiments show that certain rhizobial strains can increase shoot yield and nitrogen content, showing the importance of symbiotic nitrogen fixation for plant growth. (Robson & Loneragan, 1983)

## Subsection II

### Vegetative Regeneration

The most important natural vegetative regeneration mechanism in *Calopogonium caeruleum* is rooting at stem nodes. It has twinning stems that produce roots when nodes contact moist soil, this allows the new plant to develop from existing stems. (Feedipedia, n.d.).

These rooted nodes can form independent root systems, which enables the plant to spread across the surface of the soil. This nodal rooting allows a single plant to gradually produce many connected individuals, forming a dense cover in tropical ecosystems.

Vegetative regeneration can also occur through stoloniferous growth. *C. caeruleum* can spread via stolons, horizontal creeping stems, under favorable conditions. (Chemiseed, n.d.) These stolons allow the plant to expand laterally across the ground while continuing to generate new rooted nodes. (Chemiseed, n.d.). This stolon growth facilitates rapid ground coverage, which is why the species is frequently used as a cover crop in plantations such as rubber and oil.

Finally, vegetative regeneration may also occur when stem fragments containing nodes root in soil, again its relative the *Calopogonium mucunoides* can help us understand it better. Segments of the plant that include at least one node can be planted and develop into new plants, as long as the soil remains moist. (Botanikks, n.d.)

However, direct establishment of cuttings inserted into soil may sometimes have relatively poor success rates. This indicates that natural rooting is usually the more effective method. (PlantUse, n.d.)

# Propagation

## Section 12

### Subsection I

#### Seed Propagation

Propagation of *Calopogonium caeruleum*'s seed is usually from seed rather than vegetative material in nurseries and plantations. The species propagates more successfully from seeds than from cutting, with cutting having very low survival rate of around 5%. (Feedipedia, n.d.) Seeds are therefore the optimal and standard propagation material in nurseries and forage establishment systems. (Feedipedia, n.d.). Seed propagation is preferred because it results in higher establishment success and is easier to scale.

Nursery or field propagation typically begins with preparing a suitable seedbed. Seeds are mostly sown in a cultivated seedbed at the beginning of the rainy or wet season to ensure the best moisture for germination. (Feedipedia, n.d.) Recommended sowing methods include drilling in rows or broadcasting seed across the soil surface, while when broadcasting the seedbed may be rolled or lightly compacted to improve seed to soil contact and establishment. (PlantUse, n.d.)

Seeds often require pretreatment because they possess a high proportion of hard seed, which is similar to *C mucunoides*. Newly harvested seed may contain more than 75% hard seed which reduces immediate germination. (PlantUse, n.d.). To improve germination several scarification methods are recommended, such as mechanical scarification, hot water treatment (put for several minutes in water at 75°C), and soaking it for 30 minutes in Sulfuric acid. (PlantUse, n.d.)

Recommended seed rates are relatively low because the plant spreads after establishment. Typical seeding rates are about 1 to 3 kg of seed per hectare when planted in plantations or forage systems. (PlantUse, n.d.). Seeds can be planted alone or mixed with other tropical legumes used as cover crops. (Feedipedia, n.d.).

Furthermore establishment can be relatively slow and weed control can be necessary during early growth. (Feedipedia, n.d.). Fertilization with phosphorus or lime can improve establishment. (Tropical Forages, n.d.).

## Subsection II

### Vegetative Propagation and Cuttings

*Calopogonium caeruleum* can be propagated vegetatively using stem cuttings, although this method is not the most efficient. It can be established from stem cuttings but propagation is usually done from seeds instead. (Tropical Forages, n.d.). Cuttings may root and new plants when replaced in soil under appropriate conditions. (Botanikks, n.d.). Even though it's feasible, propagation by cuttings is a second hand option in comparison to seed propagation.

The main limitation of this type of propagation for *C. caeruleum* is the very low establishment rate. Only around 5% of stem cuttings typically establish successfully when planted directly in soil. (PROSEA, n.d.)

If cutting is going to be used then it is recommended to cut off around the older stem section located about 50cm or more from the growing tip. (PROSEA, n.d.). Cutting should be taken from a healthy, actively growing plant, preferably from softwood or semi hardwood stems. But, even when successfully established it can take up to 20 months to form a complete ground cover. (Tropical Forages, n.d.).

# Plantings

## Section 13

### Subsection I

#### Planting Methods

*Calopogonium caeruleum* is typically planted by direct seeding into prepared soil rather than by transplanting seedlings. The species is usually established from seeds sown into a cultivated seedbed, typically at the beginning of the wet season to ensure adequate moisture for germination and early growth. (Tropical Forages, n.d.).

Direct sowing is preferred because the plant propagates more successfully from seed than from cuttings. (Feedipedia, n.d.)

*C. caeruleum* tends to use two primary planting methods. The first method is Row drilling, in which seeds are drilled in rows in prepared soil that allow for easier management and weed control during early establishment. (PlantUse, n.d.). In plantation systems seed can be planted in V shaped drills approximately 2.5 cm deep between tree rows. The second method is Broadcasting, particularly in forage systems or when establishing cover crops. (PlantUse, n.d.). After broadcasting the seedbed is often rolled or compacted to improve seed to soil contact. (PlantUse, n.d.).

Recommended seeding rate vary depending on planting systems. When planted alone, seeding rates are typically about 2-3kg of seed per hectare. (Chemiseed, n.d.). In oil palm plantations lower rate of 1-1.5kg/ha are commonly used when the species is planted with other cover legumes. (Tropical Forages, n.d.).

Planting time is important for a successful establishment. Seeds are usually sown at the start of the rainy season which provides sufficient moisture for germination and early growth (Tropical Forages, n.d.). In some cropping systems the species can also be broadcast into upland rice fields after the final weeding functioning as a green manure crop (Tropical Forages, n.d.).

It can also be seen being mixed with other tropical legumes. For instance, it can be sown in mixture with species such as tropical kudzu (*Pueraria phaseoloides*), *Centrosema pubescens*, and *Desmodium Ovalifolium*. (Feedipedia, n.d.). Mixed planting helps combine different growth rates and shade tolerances, improving ground cover and soil protection. (Feedipedia, n.d.).

# Management and Control of Pests and Diseases

## Section 14

### Subsection I

#### Major Diseases

*Calopogonium caeruleum* is generally considered relatively resistant to pests and diseases. The species is usually pest and disease resistant but may occasionally be affected by insects or fungal pathogens. Several fungal diseases can affect the general *Calopogonium* genus. Root rot can occur due to soil borne fungi such as *Fusarium* and *Rhizoctonia* especially in poorly drained soils. (Botanikks, n.d.). Symptoms include yellowing leaves, wilting, stunted growth, and eventual plant death (Botanikks, n.d.). It's recommended to plant in well drained soil and avoid excessive irrigation, reduce waterlogging, and apply fungicides in severe cases. (Botanikks, n.d.). Finally, *Cercospora* fungi can cause leaf spot diseases characterized by small brown or yellow lesions on leaves (Botanikks, n.d.). Other potential fungal diseases include anthracnose, rust, and powdery mildew. (Botanikks, n.d.). The best management methods for these fungal diseases is to remove and destroy infected plant material, improve air circulation and avoid overcrowding, and finally apply appropriate fungicides when disease pressure is high (Botanikks, n.d.).

Certain viral diseases can significantly affect the crop. A yellow mosaic disease caused by some type of sobemovirus has been reported to infect *Calopogonium*, reducing its usefulness as a forage legume in tropical regions. (FAO, 1995). The virus can be transmitted mechanically or by insect vectors such as the beetle *Diabrotica balteate* (FAO, 1995). The best way to deal with this is to remove and

destroy the infected plant to prevent spread, while at the same time control insect vectors that transmit the virus (Botanikks, n.d.).

Several insect pests may attack *Calopogonium* plants. Aphids feed on plant sap causing leaf curling, yellowing, and reduced plant vigor. (Botanikks, n.d.). They can also transmit plant viruses such as mosaic viruses. (Botanikks, n.d.). To Aphids it recommended to apply insecticidal soap or neem oil, encourage natural predators such as ladybugs, and the use of water sprays to remove them from plant surfaces. (Botanikks, n.d.).

Other insect pests include: Spider mites, Caterpillars, Thrips, Whiteflies, and Nematodes.

Generally the best pest and disease strategies are:

- Cultural practices such as proper spacing, soil drainage, and weed control.
- Biological control using natural predators of insect pests.
- Chemical control, including fungicides or insecticides when necessary.
- Regular crop monitoring to detect problems early.  
(Botanikks, n.d.).

# Cultivation

## Section 15

### Subsection I

#### Cultivation Information

Successful cultivation of *Calopogonium caeruleum* is dependent on tropical climate conditions and suitable soils. The species is well adapted for humid tropical environments with annual rainfall between 1000-3000mm, although it can still persist in areas receiving as little as 700mm of rainfall. (Tropical Forages, n.d.). Optimal temperatures stand between 18-25°C with tolerance limits ranging from 10°C to 32°C. (Tropical Forages, n.d.). It can also grow in a wide range of soil textures and tolerates acidic soils with pH values as low as 4.0 (Tropical Forages, n.d.).

It is considered one of the best shade tolerant tropical legumes, allowing it to thrive beneath rubber or oil palm canopies.(Feedipedia, n.d.). The plant can maintain relatively stable productivity at 60-70% light transmission and can grow well under tree coverage. (Tropical Forages, n.d.).

*C. caeruleum* is usually established from seed sown into a cultivated seedbed at the beginning of the rainy season. (Tropical Forages, n.d.). Early weed control is necessary because the plant establishes slowly during its initial growth stages. (Tropical Forages, n.d.). Although it is tolerant to poor soils, the plant responds to fertilization. Growth and establishment can improve by applying phosphorus fertilizer and lime in acidic or infertile soils. (Tropical Forages, n.d.). As a legume the species can form symbiotic relationships with rhizobia bacteria that fix atmospheric nitrogen, which improves soil fertility. (Robson & Loneragan, 1983).

It is commonly cultivated within mixed cropping systems or plantations. It is widely grown as a cover crop in rubber, coconut, and oil palm plantations due to its ability to suppress weeds and protect against soil erosion. (Tropical Forages, n.d.). It can also be planted in mixture with other legumes such as *Pueraria phaseoloides* or *Centrosema pubescens*. (Feedipedia, n.d.).

Despite its advantages, cultivation of the species is troublesome. The plant establishes slowly and may require up to 20 months to produce complete ground cover in some systems. (Tropical Forages, n.d.). It is generally unpalatable to grazing livestock which then limits its use as a forage crop. (Feedipedia, n.d.). Without proper management it can dominate pasture areas due to its vigorous growth. (Tropical Forages, n.d.).

# Fertilizing

## Section 16

### Subsection I

#### Soil Fertility and Nutrient Management

*Calopogonium caeruleum* generally has low fertilizer requirements because it's a leguminous plant capable of fixing atmospheric nitrogen through symbiotic rhizobia bacteria. As a legume it can contribute to soil fertility by fixing nitrogen and adding organic matter through leaf litter and plant residues. (PlantUse, n.d.). Because of this nitrogen fixing ability heavy nitrogen fertilization is unnecessary in most systems. (PlantUse, n.d.).

Instead, the fertilization programs focus mainly on phosphorus and soil amendment rather than nitrogen. The species responds very well to phosphorus fertilizer particularly in infertile or acidic tropical soils. (Tropical Forages, n.d.). A fertilizer of 20kg N + 60kg P + 30kg K per hectare has been suggested for improved productivity. (Ibañez n.d.).

Although *C. caeruleum* can tolerate acidic soils, changes to said soil can improve growth. The plant can tolerate soil pH as low as 4 but it performs better when soil acidity is corrected with lime. (Tropical Forages, n.d.). In experiments on infertile acidic soil healthy growth was achieved with 10.8t/ha of lime combined with 315 kg/ha of triple superphosphate. (Tropical Forages, n.d.).

# Growth Stages

## Section 17

### Subsection I

#### Developmental Stages

The first stage of growth being in seed germination and early seedling development. *C. caeruleum* is usually established from seed sown into cultivated seedbeds at the beginning of the rainy season, this allows seeds to germinate under adequate soil moisture. (Feedipedia, n.d.). During the early seedling stage it establishes relatively slowly and weed control is often required to ensure successful establishment. (Feedipedia, n.d.).

Following seedling emergence the plant entered an establishment phase. The plant spreads through creeping or twining stems that root at nodes when they contact moist soil (Kudzu Seeds Trading, n.d.). However it can also remain relatively slow growing for the first months to years after planting. (CIFOR-ICRAF, n.d.).

Once established it entered a period of extensive vegetative growth. It can eventually produce dense vegetative growth and extensive ground cover. (Feedipedia, n.d.). In some systems the species covers most or all the soil surface within about 10--14 weeks after sowing depending on environmental conditions. (Feedipedia, n.d.).

After early growth the plant develops into full maturity. After establishment growth becomes extensive and may continue strongly from around 20 months up to 5 years of age. (CIFOR-ICRAF, n.d.).

The final stage of growth involves reproductive development and seed production. In humid tropical climates it flowers during the wet season and continues producing seeds into the dry season. (Tropical Forages, n.d.). The plant is self pollinated and capable of producing moderate amounts of seed during establishment year. (Tropical Forages, n.d.).

After reproductive growth the plant may experience aging or decline though the population then persists through regeneration. Some members of the *calopo* species are short lived, with a life span of 1-2

years, but still maintaining populations through recruitment from new seedlings. (PlantUse, n.d.). Regeneration may occur through seed germination or vegetative rooting of stems (Kudzu Seeds Trading, n.d.).

# Fruiting

## Section 18

### Subsection I

#### Fruit and Seed Development

The “fruit” of *Calopogonium caeruleum* is a legume pod that is typical for the *Fabaceae* family. *C caeruleum* produces linear oblong pods that are slightly curved and covered in hairs. (Tropical Forages, n.d.). These pods typically are 4-8cm long and 0.8cm wide. (Tropical Forages, n.d.). Each fruit contains several seeds, usually 4 to 8 seeds per fruit (Tropical Forages, n.d.). And due to the fact that the pod is constricted between the seeds it produces visible indentations along the fruit. (Tropical Forages, n.d.).

The seeds are shiny brown and somewhat circular. (Tropical Forages, n.d.). Individual seeds measure approximately 4-5mm in diameter. (Tropical Forages, n.d.). *C caeruleum* can produce about 20000-50000 seeds per kilogram of seed material. (Tropical Forages, n.d.).

An important factoid is that fruit develops from a fertilized ovary after flowering. The flowers are produced on elongated racemes that can reach up to 50 cm long, each containing multiple flowers. (Tropical Forages, n.d.). After pollination and fertilization the ovary develops into an elongated seed pod that is characteristic of the species. (Tropical Forages, n.d.). Over time the mature pod becomes firm and dry as seeds develop inside (Tropical Forages, n.d.). The pods will eventually open to release seeds. (Tropical Forages, n.d.).

# Harvesting

## Section 19

### Subsection I

#### Cutting and Forage Use

*Calopogonium caeruleum* can be either grazed directly by animal or cut and fed as fresh forage (Feedipedia, n.d.). Or, similarly to *Calopogonium mucunoides*, by manually harvesting by hand where it's rarely used for hay or silage. (PlantUse, n.d.). For forage production it can be harvested at intervals of 9 to 12 weeks after establishment (Feedipedia, n.d.). For seed harvesting it's recommended to do so after the pods are fully matured and dried on the plant. (PlantUse, n.d.). Finally for grazing it's recommended to give it rest periods of about 9 to 12 weeks. (Feedipedia, n.d.). Though it should be noted that it has a relatively low palatability, therefore livestock may graze it less than other forage plants.

# Pruning and Re-Planting

## Section 20

### Subsection I

#### Pruning Management

The usage of pruning is sometimes used to control excessive vegetative growth and maintain healthy plant structure. The *Calopogonium* species produce dense vine-like growth and regular pruning can help control plant size and improve overall health. (Botanikks, n.d.). The removal of overgrown stems allow better air circulation and light penetration into the canopy. (Botanikks, n.d.). The pruning is recommended during the dry season, late winter, or early spring before active growth begins. (Botanikks,

n.d.). Particularly, doing pruning during the dry seasons helps reduce the risk of disease and water related damage to plant tissues. (Botanikks, n.d.).

Several pruning techniques are used to manage plant growth. Some of these are:

- Cutting back excessive or overcrowded stems.
  - Reducing the plant canopy by around 30%
  - Removing dead, damage, or diseased branches.
- (Botanikks, n.d.).

It is key to note that regular slashing or cutting of it is necessary to prevent the vines from overgrowing young plantation trees or other plant life.

# Importance

## Section 21

### Subsection I

#### Ecological and Agronomic Role

One of the most important roles of *Calopogonium caeruleum* is how it contributes to soil fertility through nitrogen fixation. As a legume it can form symbiotic relations with rhizobia bacteria that fix atmospheric nitrogen into forms more usable for plants which then improves soil nutrient status (Ikram, 1983). Furthermore due to its spread habits it can provide continuous soil cover that reduces the impact of rainfall and prevents soil loss (Tropical Forages, n.d.).

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*C. caeruleum* is widely used as a cover crop in tropical plantations. It is most commonly grown under crops such as rubber, oil palms, and coconut to protect soil and improve conditions for the main crop (Tropical Forages, n.d.). Additionally, it forms a dense cover that reduces weed growth and protects the surface of the soil (Feedipedia, n.d.).

It is also highly effective at suppressing weeds. It has a vigorous growth rate which allows it to cover and outcompete many weed species for light and nutrients, this dense canopy reduces light reaching the surface of the soil which limits weed germination and growth (Tropical Forages, n.d.).

Due to it being a shade tolerant tropical legume it allows it to thrive under tree crops, which is why it's used in agroforestry systems (Feedipedia, n.d.). It contributes to sustainable plantation management by improving soil fertility and reducing erosion (Tropical Forages, n.d.).

It significantly improves soil properties, large amounts of its plant residue contributes to accumulation of organic matter in soil. Increased organic matter enhances soil structure, water retention, and microbial activity (Ikram, 1983).

It is considered relatively unpalatable to livestock which makes it more restrictive for a grazing plant (Feedipedia, n.d.). Finally, *C. caeruleum* plays an important role when it comes to helping the environment thanks to its ability to reduce erosion and improve soil fertility (Tropical Forages, n.d.).

# Market

## Section 22

### Subsection I

#### Commercial Distribution and Seed Trade

The primary commercial market for *Calopogonium caeruleum* is the sale of seeds as a cover crop. It is usually offered as part of a cover crop seed mixture for plantations. The species market presence is spread across humid tropical regions, such as Asia, Africa, and Latin America (Feedipedia, n.d.).

It is often used in mixtures with other legumes such as *Pueraria phaseoloides* and *Centrosema pubescens* (Feedipedia, n.d.).

# Uses

## Section 23

### Subsection I

#### Agricultural and Environmental Uses

The most important use of *Calopogonium caeruleum* is as a cover crop in tropical plantation systems. It is commonly grown as a cover crop under oil palm and rubber plantations, particularly in humid tropical climates (Feedipedia, n.d.). It forms a dense ground cover that protects soil and improves growing conditions for the main crop (FAO, n.d.).

Through symbiosis with rhizobia bacteria, it enriches the soil with nitrogen (FAO, n.d.). It creates a lot of biomass, or leaf litter, which decomposes and enriches the organic materials in the soil (Feedipedia, n.d.). Because of its dense, expansive nature, it can suffocate weeds (FAO, n.d.). Additionally, it has allelopathic effects on *Imperata cylindrica* and other weeds (Feedipedia, n.d.).

Because of the constant soil cover provided by its high vegetation, erosion from rainfall and runoff is minimised (FAO, n.d.). Root systems enhance soil structure and stabilise the soil (FAO, n.d.). Although it is not very useful, it is occasionally used for grazing (Feedipedia, n.d.). Animals tend to avoid this species since it is not very appealing to livestock (Feedipedia, n.d.). It is appropriate for integrated systems because of its great shade tolerance, which enables it to grow beneath tree crops (Feedipedia, n.d.). By enhancing soil and inhibiting weeds, it increases plantation yield (FAO, n.d.).

It can be used to restore weak or disturbed soils because of its quick spread and biomass production (FAO, n.d.). It improves soil structure and adds to the accumulation of organic matter in the soil (Feedipedia, n.d.). Because of its flowers, it can be utilised as an ornamental plant, however it is frequently seen to be too aggressive (Feedipedia, n.d.). Although these are not well-documented or commonly used, several sources mention food-related and therapeutic use (Selina Wamucii, n.d.).

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