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Nitrogen Fertilization in Blackberry

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Abstract

Nutrition studies for blackberry crop are scarce worldwide. This chapter presents several aspects of nitrogen (N) in blackberry (*Rubus* spp.) nutrition. Soil characteristics that can influence nitrogen fertilization are the large discrepancies in the rates recommended in the literature, forms and times of application, sources of nitrogen, differences between cultivars and the main symptoms of N deficiency. The impact of moderate and severe nitrogen deficiency on vegetative growth and yield of 'Tupy' blackberry is also presented. In addition, a nitrogen fertilization recommendation system is proposed, based on the organic matter content of the soil, the age of the plants, and the expected productivity of the cultivars.

Keywords: *Rubus* spp., nutritional requirements, cultivar differences, nutritional deficiency, soil organic matter, fertilization recommendation

1. Introduction

Nitrogen (N) is the mineral element that plants generally need in greater quantity, since they serve to form components of plant cells, such as amino acids and nucleic acids, besides participating in the chlorophyll molecule [1]. N deficiency rapidly reduces plant growth, as it causes reduction of cell division and expansion, leaf area, and photosynthesis [2].

In blackberry (*Rubus* spp.), N is the most abundant element and plays a major role in its growth, development, and productivity [3–6]. The optimum leaf content required for a satisfactory performance of blackberry varies from 2.2 to 3.0% of the dry matter of the leaves [7, 8].

The need for N supply may vary according to soil organic matter (SOM) content, yield, growth habit, age, and cultivar [8, 9]. The N rates recommended in the literature vary widely, mainly due to differences between cultivars and soil characteristics, but another important factor is the age of the plants. In the first years, the productive capacity of the plants is smaller, and therefore the demand for nitrogen is also lower. High N rates in the first 2 years can reduce fruit quality and increase disease incidence. On the other hand, low rates from the third year make it difficult to obtain high yield.

Nitrogen fertilization provides immediate effect (same season) and residual (next season). The immediate effect is mainly on the productive capacity of the

floricans and the size of the fruits. Already in the following season, the greatest influence is on the growth and formation of primocanes and floral buds [10].

Considering the N importance to blackberry, this chapter aims to review the dynamics of nitrogen fertilization and present a recommendation proposal.

2. Soil characteristics

The recommended soil pH for blackberries is 5.5 to 6.5 [7, 8, 11]. The availability of N from fertilizers mainly depends on the fertilizer source [12] and the method of application [13]. Soil pH affects nitrification, with ammonium-N sources converted more rapidly to nitrate-N at a pH of 6.0 than at 5.5 [8].

Another issue that must be observed in relation to pH is the presence of aluminum (Al^{3+}) in the soil. In these cases it is essential that the pH is raised to values close to 6.0 through liming, avoiding problems with phytotoxicity by aluminum.

The ideal soil organic matter content is around 2.0 to 4.5% [3, 14, 6]. However, what is observed is that the blackberry is a rustic species, which can be cultivated in soils with a wide range of SOM levels. The difference is that in soils with low levels, less than 2%, there is a need for special care in relation to nitrogen fertilization. On the other hand, when the content of SOM is high, more than 4.5%, the vigor of the plants is driven in a way that increases the frequency and intensity of pruning, as well as decreases the need for N fertilization.

Some studies indicate a lack of effect of fertilization on yield in soils with a SOM content of 3.9%, while in soil with a SOM content of 1.1%, there was a linear increase of the yield in response to increasing rates of N [4, 15]. These results suggest an important influence of SOM on the response of blackberry to fertilization with N.

3. Nitrogen fertilizer rate

There are significant variations in the nitrogen rates recommended by the literature, with values ranging between 0.0 and 200 kg ha⁻¹. Such differences may be related to factors such as soil characteristics, climate, and genotypes [3, 5].

Some authors recommend the application of 34–56 kg ha⁻¹ in the first year, regardless of growth habit, and in the following years, the dose would be from 56 to 78 kg ha⁻¹ for training and semi-erect cultivars and from 56 to 90 kg ha⁻¹ for cultivars of erect habit [8].

Other indications for semi-erect and erect cultivars are 25–45 kg ha⁻¹ at the establishment and 45–70 kg ha⁻¹ in subsequent years [16, 17]. The recommendations for training cultivars are between 25 and 45 kg ha⁻¹ in the year of establishment and between 45 and 60 kg ha⁻¹ in the following seasons [17].

Considering that Tupy and Xavante has semi-erect and erect growth habit, respectively, there was an inversion of the logic indicated in the recommendations of the literature. In this case, probably the greatest nutritional need of the cultivar Tupy may come as a result of its greater yield and export of nutrients, about 40% higher than that obtained with Xavante.

Another feature that diverges between these two genotypes is the presence of thorns. There is a need for new studies in order to verify if there is a possible relationship of this characteristic with the nutritional need.

The amount of nutrients applied in blackberry cultivation can also vary with the age of the plants. The application of N in the year of establishment of the crop is controversial; there are authors who do not recommend the application, due to the risk of damages to the vegetative buds and others that, although emphasizing

that the application is less necessary than in the subsequent years, suggest the application of up to 56 kg ha^{-1} [8, 14]. On the other hand, in a study carried out in the south of Brazil, in an area with a 1.1% SOM content, the maximum productive efficiency rate was 109 kg ha^{-1} in the first harvest after planting and increased up to 155 kg ha^{-1} at the third crop [4]. Thus, these results indicate that there is a need for differential fertilization strategy, depending on the age of the plants.

4. Nitrogen fertilizer application

The N application is usually done in granular form while planting directly in the row but can be carried out during crop development, via fertigation or foliar fertilization [14, 17]. In a study comparing the application methods, it was concluded that the granular fertilization in the spring had a better result than the drip fertigation, mainly due to the higher leaching observed in the drip method [13]. Although it can be used, foliar fertilization has not presented satisfactory results [8], which is justified by the high demand that the plant has in relation to this nutrient.

About the N sources, blackberry responds satisfactorily to several, but ammonium nitrate, urea, and ammonium sulfate are the most commonly used sources [3, 17]. In Brazil, the ammonium sulfate is currently recommended, as blackberries also demand important sulfur amount (about 3 kg per ton of fruit and pruning material removed) [7, 14].

However, research results indicate that after 3 years of using ammonium sulfate as N source, there is a significant reduction of pH (**Figure 1a**) and increase of Al^{3+} content (**Figure 1b**) in the soil, which may have a negative impact on the productivity (**Figure 1c**). In this specific case, when the soil pH was lower than 4.7 and the Al^{3+} content was higher than $0.66 \text{ cmol}_c \text{ dm}^{-3}$, blackberry production decreased. However, further studies on different soil types should be carried out in order to confirm this relationship. Therefore, when using ammonium sulfate as N source, the pH and Al^{3+} content of the soil should be monitored.

As for the time of application, N should be applied in the spring and after harvest [7, 14, 18]. Fertilization carried out at the end of winter or early spring aims to provide fruit production and the growth of primocanes, new stems that will be responsible for fruit production in the following year.

N has an important role in the formation of “primocane” numbers since it stimulates budding of crown buds, thus impacting the number of stems and the yield of the next season [3]. Maintaining the proper number of stems over the years is important. There is a positive correlation between the number of stems and the

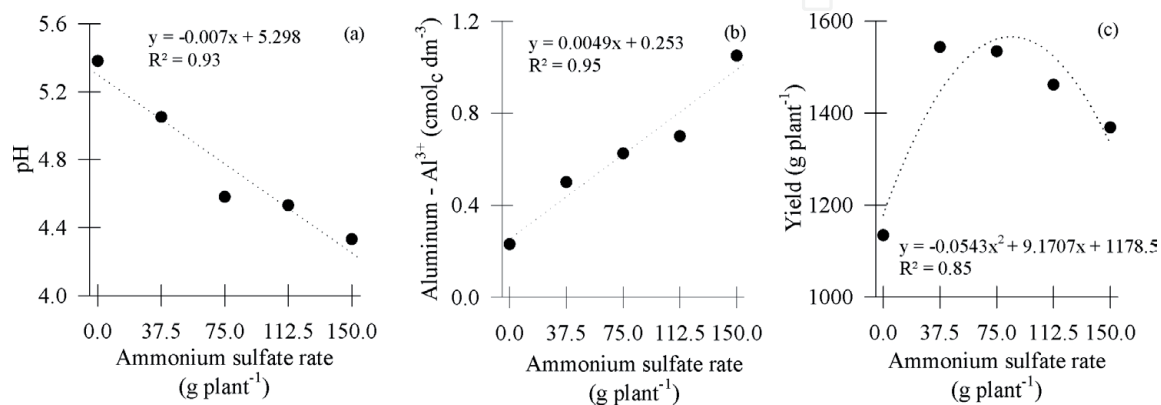


Figure 1. Influence of ammonium sulfate rates on pH (a), aluminum (Al^{3+}) concentration (b), and blackberry ‘Tupy’ productivity (c) [9].

yield of the blackberry, that is, the larger the number of stems (up to 12 stems m^{-1}), the greater the productivity [19].

On the other hand, postharvest fertilization, usually performed after post-harvest pruning, has the function of stimulating the development of primocanes, inducing the formation of vigorous stems and thus capable of supporting high yields and larger fruits in the next season. In blackberry cultivation, there is a significant correlation between stem diameter and fruit size, and more vigorous stems have potential for larger fruit production [19, 20].

5. Nutritional differences between cultivars

It has been observed in the literature that blackberry cultivars present important differences in relation to their nutritional requirements [4, 5, 8, 17]. Some authors recommend fertilization for groups of cultivars with the same growth habit [8, 17]. In addition, there are research results that also indicate differences between cultivars with and without thorns [5, 21]. But, in general, the greatest difference between demands of each cultivar is actually related to their productive capacity, that is, more productive cultivars export larger quantities of N and therefore also demand higher rates of fertilizer. For this reason, the tendency is that fertilization recommendations incorporate the expected productivity as a criterion to define the most adequate N rate.

6. Nitrogen deficiency

Compared to blackberry plants with no N deficiency (**Figure 2a**), N deficiency in leaves is characterized by foliar chlorosis (**Figure 2b**), and in severe deficiency situations, reddish patches may appear distributed throughout the leaf blade (**Figure 2c**). In addition to the leaves, the stems may also exhibit reddish pigmentation, and the greater the deficiency, the greater the intensity of the red (**Figure 2e and f**), being this type of pigmentation originated from the anthocyanin accumulation [21]. N deficiency appears on old leaves and progresses to the younger ones. This is due to the fact that N is easily translocated and redistributed within the plant [21]. Therefore, when the nutrient supply in the roots is insufficient, the nutrient of the older leaves is mobilized for the younger ones.

The vegetative growth is the major aspect affected by the deficiency of N, being the foliar chlorosis the first visible symptom. This happens because N-deficient plants present a lower chlorophyll leaf concentration, which can be verified by the lower SPAD (soil plant analysis development) index in leaves of nitrogen-deficient plants (**Figure 3a**), which is an indirect measure of the foliar chlorophyll content. It is noted that the SPAD index was not able to identify differences between moderate and severe deficiency. However, the method clearly identified N deficiency even in a moderate situation. In this way, it is possible that through calibration studies, the SPAD index can be used as a rapid method to evaluate the N leaf content in blackberry plants.

In general, when foliar chlorosis is identified, vegetative growth has generally been compromised. Among the main growth parameters that may indicate N deficiency problems in the blackberry are the length of internodes and the length of the stems. In **Figure 3b**, it is possible to observe the average reduction of 15% in the length of the internodes in plants with moderate N deficiency. However, the length of the stems is further reduced. In plants with moderate deficiency, the reduction in stem length was 35%, whereas in plants with severe deficiency, the reduction was 52% (**Figure 3c**).

N deficiency also causes a reduction in the number and in the mass of blackberry fruits. **Figure 3c** shows a reduction of 63% in the number of fruits produced

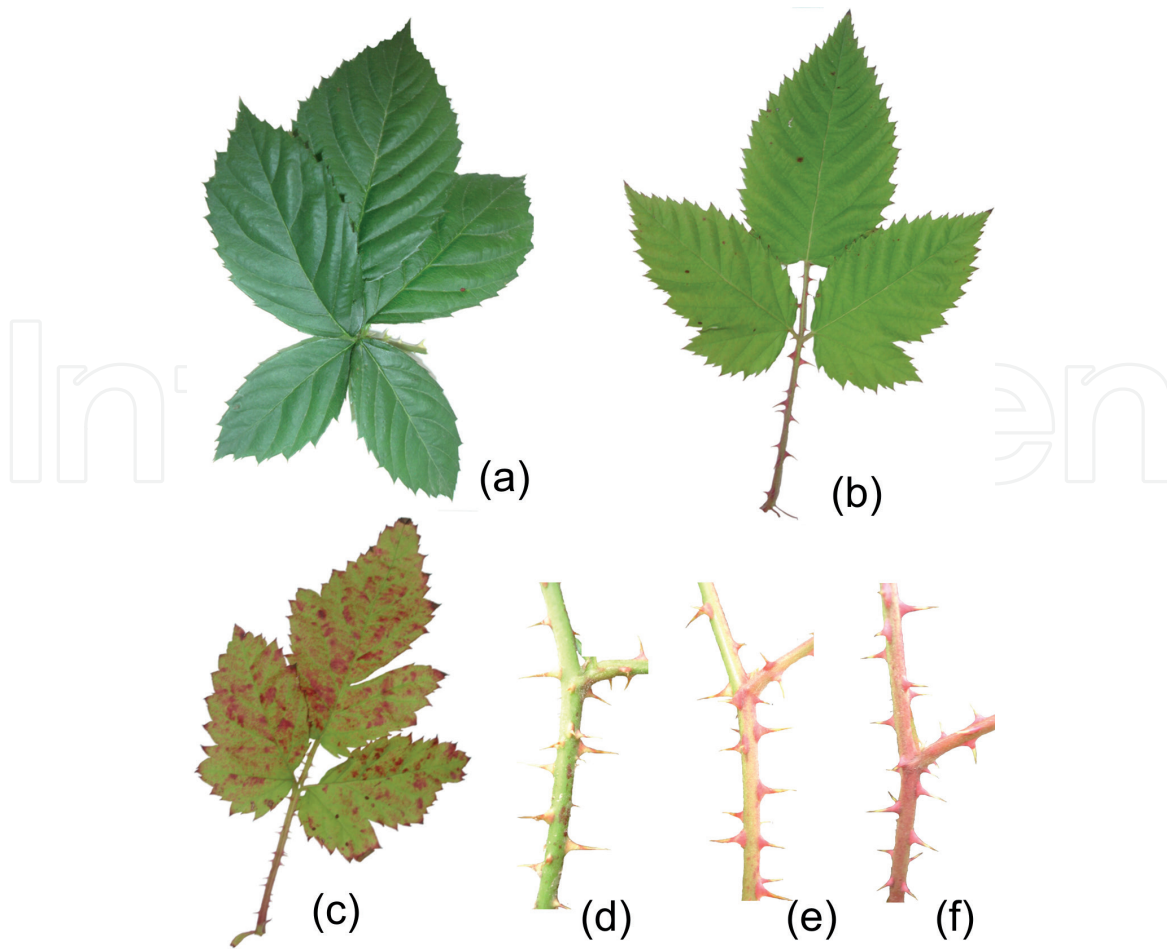


Figure 2. Leaf superior surface with normal aspect, no deficiency symptoms (a), with moderate (b) and severe nitrogen deficiency (c) in Tupy cultivar. Besides stems without deficiency symptoms (d) and with moderate (e) and severe nitrogen deficiency (f) [9].

in blackberry plants with moderate N deficiency and 65% in plants with severe deficiency. Regarding the fruit mass, the reduction was 52% in plants with moderate deficiency and 60% when the deficiency was severe (**Figure 3d**).

The increase in fruit size is the main effect of nitrogen fertilization on the fruit quality of blackberries [22]. In general, nitrogen fertilization induces the formation of vigorous stems which, in turn, provide the formation of larger fruits [20]. In terms of sensory quality, the effects are varied. Nitrogen fertilization performed at the recommended amount increases soluble solids concentration but has little effect on attributes such as pH, acidity, sugar/acid ratio, and firmness [23, 24]. On the other hand, the excess of N can cause reduction of soluble solids, increase acidity and pH, and also decrease fruit firmness.

The accumulation of negative effects caused by N deficiency on vegetative growth and fruit formation in blackberry plants had a catastrophic impact on plant productivity. It was observed a reduction of 71% in the productivity of plants with moderate deficiency and 75% in plants with severe deficiency (**Figure 3f**).

The results presented in **Figure 3** demonstrate that in many aspects there are no significant differences in vegetative growth or fruit yield between plants with moderate and severe N deficiency. This shows that even when N deficiency is moderate, the crop yield is extremely impacted.

Excess of N is characterized by excessive plant vigor, long internodes, thinner stems, dark green leaves, low yield, low quality of fruits, less conservation potential, and greater risk of diseases [8, 14, 21]. In addition, very high rates of N may result in a decrease in the foliar content of manganese (Mn), potassium (K),

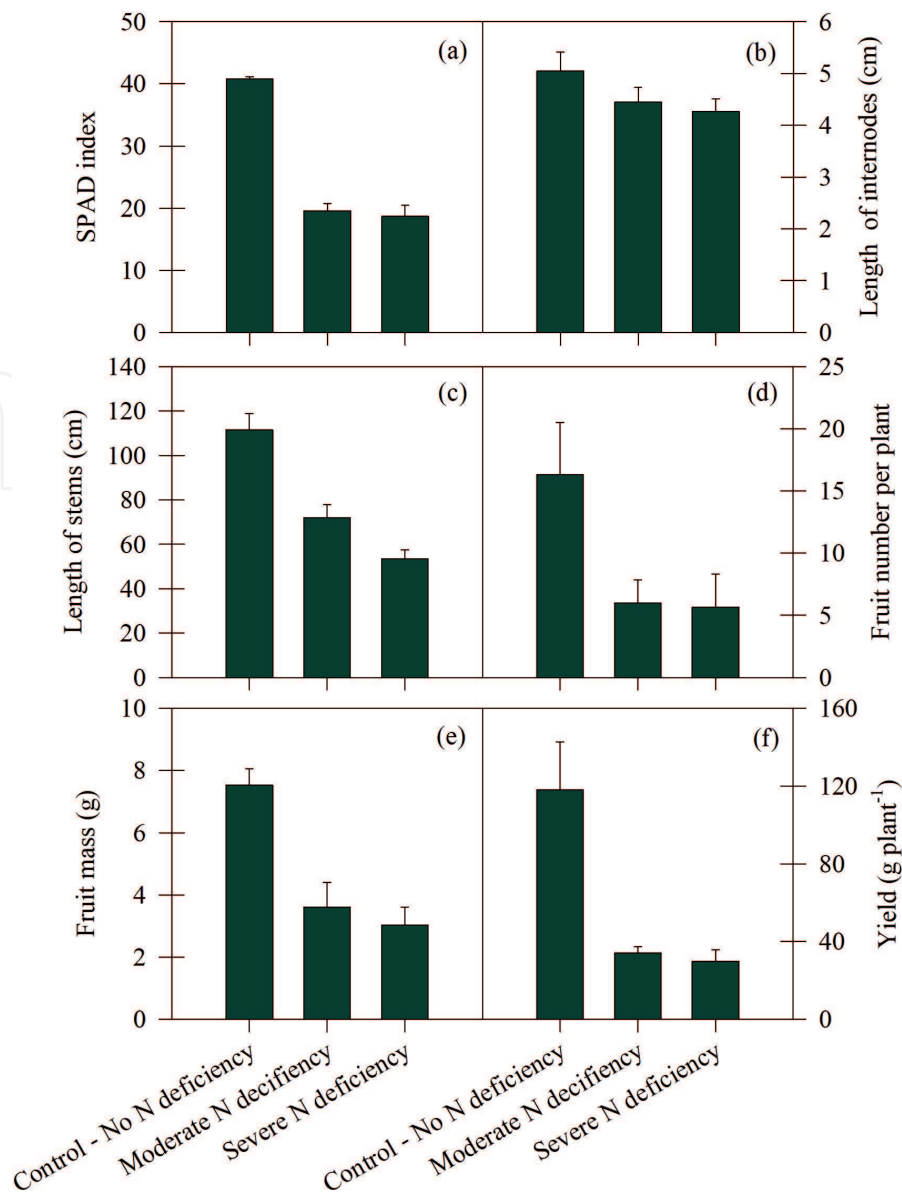


Figure 3. Effects of different levels of nitrogen (N) deficiency on the SPAD index (a), length of internodes (b), length of stems (c), fruit number per plant (d), fruit mass (e) and yield (f) of 'Tupy' blackberry. Deficiency levels: control or no N deficiency; moderate deficiency, and severe deficiency.

calcium (Ca), and magnesium (Mg) and increase of copper (Cu). On the other hand, the reduction of fertilization with N reduces the iron content (Fe) and may reduce production due to nutritional imbalance [4, 25]. The reduction of other nutrients can be attributed to two main factors, competition for the same binding sites and the dilution effect, since N stimulates vegetative growth [4].

7. Nitrogen recommendation fertilization

The fertilization recommendation is divided into **fertilization of preplanting** and **production fertilization** [7]. The preplanting fertilization aims to correct soil problems, as in the case of N, low levels of organic material, and must be carried out during soil preparation, before planting of seedlings, while the production fertilization has the objective to restore to the soil the quantities of N exported by the production of fruits (considers the expectation of production) and natural losses, as, for example, by leaching.

7.1 Preplanting fertilization

Nitrogen fertilization of preplanting is recommended in soils with organic matter content of less than 2.5%. In these cases, it is recommended to apply 40 kg ha⁻¹ of N, and it is preferable to use organic sources, such as compost from manure.

7.2 Production fertilization

Production fertilization begins in the year following to planting of the seedlings and takes into account soil organic matter content, plant age, and production expectation (Figure 4).

The N rate applied in the spring should be divided into three times: the first application should be made at the beginning of the budding; the second, 30 days

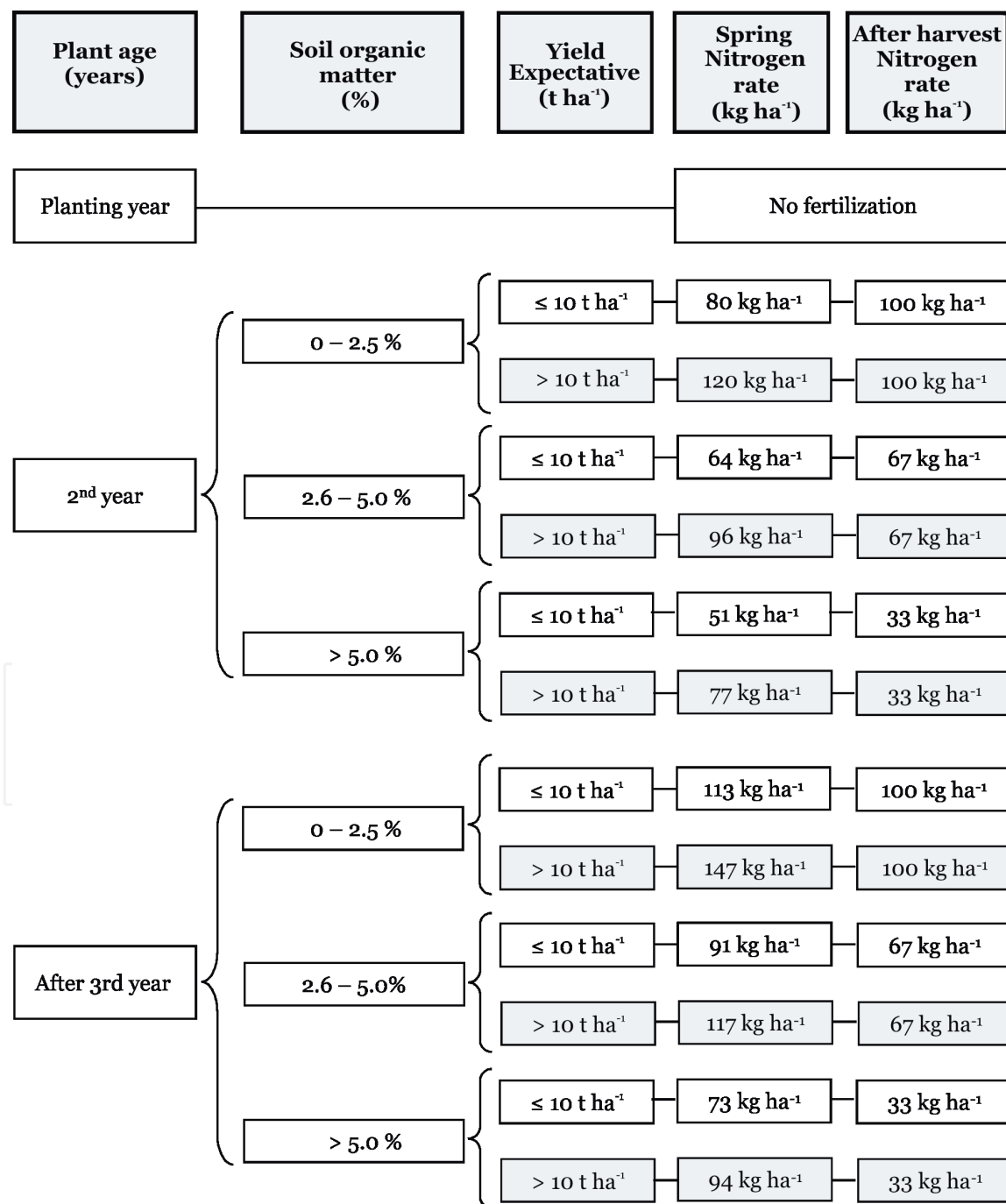


Figure 4.
 Recommendation of nitrogen production fertilization.

Class	Nitrogen content (%)
Insufficient	<2.20
Normal	2.30–3.00
Excessive	>3.00

Table 1.

Tissue N concentration from sampling after harvesting the primocane's leaves [8].

after; and the third, at 60 days after the first application. The application postharvest can be applied in a single rate.

The N may be applied in the form of urea (45% of N), calcium nitrate (14% of N), ammonium nitrate (32% of N), or ammonium sulfate (20% of N). Ammonium sulfate is preferably recommended because the blackberries require sulfur. However, the consecutive use of ammonium sulfate can significantly reduce soil pH, being necessary to monitor this parameter. An alternative to supply the sulfur demand with little impact on soil pH may be the use of agricultural gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), which also provides calcium and can be applied at a rate of 34–45 kg ha⁻¹ to supply possible S deficiencies of blackberries [8].

The N source application should be performed at the soil surface, along the planting row, approximately 15 cm away from crown of plants.

7.3 Leaf N concentrations

In contrast to other species, in blackberry, leaf analysis is applied to evaluate the nutritional status after harvest, aiming the elaboration of a fertilization program for the next productive cycle (**Table 1**). For this reason, sampling is performed after harvesting the primocane's leaves. Sampling is performed on the 6th completely expanded leaf from the stem apex.

8. Conclusion

Nutrition studies for blackberry crop are scarce worldwide. However, as presented in this chapter, nitrogen fertilization is one aspect of crop management that has the greatest impact on vegetative growth, fruit yield, and quality. It has been demonstrated in this chapter that even under conditions of moderate N deficiency, there can be significant impacts on blackberry yield. Nitrogen-deficient plants tend to form weak, low-yielding stems. In this way, the application of adequate rates for each type of soil and cultivar is fundamental for satisfactory productivities.

In addition, there are important differences in the demand of N between cultivars, probably due to productive capacity, that is, cultivars that provide higher yields also export larger amounts of N and therefore need larger amount of nitrogen fertilizers.

In this way, a nitrogen fertilization program was proposed, based on SOM (indicator of N availability), plant age, and production expectation.

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