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L'impact des pratiques agricoles pour la production de bleuets sauvages sur la fertilité du sol.

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RÉSUMÉ

Les pratiques agricoles sont couramment utilisées pour améliorer la croissance des plants et le rendement en fruits dans la culture du bleuet sauvage. Cependant, la façon dont la méthode de taille, l'application d'engrais et de fongicides affectent la fertilité du sol au cours d'une saison de croissance dans les champs de bleuet n'a pas été clairement établie. Nous avons donc étudié la réponse de la dynamique de l'azote (N) et du phosphore (P) du sol après 6 années de pratiques agricoles pendant une saison de croissance simulée en incubation aérobie. Nous avons également caractérisé le pH du sol, la matière organique du sol et la dynamique des nutriments (P, K, Ca, Mg, Fe et Al), qui sont importants pour la fertilité du sol dans la culture du bleuet. Par comparaison aux engrais organiques, les engrais minéraux ont permis d'augmenter de 74 kg ha^{-1} la quantité de N-NH$_4$ minéralisé. La quantité de N-NH$_4$ minéralisé était 5,5 fois plus élevée que la quantité de N-NO$_3$ minéralisé. Pour la dynamique du P, la fertilisation minérale et organique ont permis d'augmenter la quantité de P minéralisé de 116 kg ha^{-1} et 161 kg ha^{-1} respectivement. La fauche thermique a eu tendance à diminuer de 6% la matière organique du sol, de 15% l'azote total et de 33% la quantité de NO$_3$-N minéralisé. En conséquence, moins d'azote organique a été minéralisé en NH$_4$-N et ensuite en N-NO$_3$ par les micro-organismes du sol suite à cette pratique. Cette étude a permis de mettre en évidence l'impact des pratiques agricoles sur les processus de minéralisation de l'N et du P dans le sol et sur différents indices de fertilité du sol, pouvant avoir un impact sur la résilience du système de production sur le long terme.

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Le Saguenay-Lac-Saint-Jean représente 80% de la superficie des bleuetières au Québec, ce qui en fait une région propice pour la recherche sur le bleuet nain sauvage (*Vaccinium angustifolium* Aiton). La Bleutière d'Enseignement et de Recherche (BER) est une infrastructure d'enseignement et de recherche à cœur ouvert, avec plus de 80 ha disponible pour étudier différentes modalités de productions. Face aux nombreux défis agronomiques, ce projet de recherche porte sur l'impact des pratiques agricoles sur la fertilité des sols des cultures de bleuets sauvages. Le mémoire se compose d'un chapitre écrit sous forme d'un article scientifique en anglais, portant sur l'influence de la technique de fauche, de l'application de fertilisants et de fongicides sur la dynamique de minéralisation de l'N et du P au cours d'une saison de croissance. Cette étude porte également sur l'influence de ces pratiques agricoles sur la matière organique du sol, les nutriments et le pH du sol au niveau de la couche organique et minérale du sol.

INTRODUCTION GÉNÉRALE

1. Le bleuet nain sauvage et le bleuet en corymbe : deux espèces différentes

Le bleuet est un fruit riche en antioxydants du genre *Vaccinium.* En Amérique du Nord, on trouve principalement le bleuet nain sauvage (*Vaccinium angustifolium* Aiton et *Vaccinium myrtilloides* Michaux) et le bleuet en corymbe (*Vaccinium corymbosum* L.) (Lareau et Urbain 2008). Bien que ces deux espèces soient de la famille des Éricacées, elles présentent tout de même des différences morphologiques importantes. Premièrement, le bleuet nain sauvage, comme son nom l'indique, est une espèce qui se retrouve à l'état sauvage typiquement en forêt boréale, car il n'est pas planté contrairement au bleuet en corymbe. Dans les productions de bleuets en corymbe, les buissons sont plantés en rang. Concernant les productions de bleuets sauvage, les bleuetières sont établies dans des zones où ils sont naturellement présents en talles ou en colonies (Lareau et Urbain 2008). De plus, le bleuet sauvage est un petit arbuste ne dépassant pas les 40 cm de haut, contrairement au bleuet en corymbe qui peut mesurer jusqu'à 2 m de hauteur (Lareau et Urbain 2008). Ces deux espèces diffèrent également par la taille de leurs fruits et les rendements à l'hectare. Les bleuets en corymbes donnent des fruits trois à cinq fois plus gros que le bleuet nain sauvage (Lareau et Urbain 2008). La production de bleuet nain sauvage se concentre essentiellement au Québec, dans les provinces maritimes et dans le Maine, aux États-Unis, tandis que la production de bleuet en corymbe s'étend de la Nouvelle-Écosse au Wisconsin, jusqu'au Texas en passant par la côte Ouest américaine.

2. Le bleuet sur le marché

Première culture fruitière au Canada en termes de valeur à la ferme, le bleuet est un véritable petit trésor économique pour le Canada. En effet, en 2020, le bleuet (bleuet nain et bleuet en corymbe) avait une valeur annuelle à la ferme de 274 millions de dollars, et le bleuet sauvage représentait 41% de cette valeur (MAPAQ 2022). De plus, le bleuet est la principale culture fruitière exporté par le Canada (5$^{\text{ème}}$ plus grand exportateur de bleuet dans le monde) et représente 43.8% du volume totale de fruit exportés au pays. Au Canada, le bleuet se commercialise principalement sous deux formes : frais ou surgelé. Sous forme de fruits frais, le bleuet en corymbe est l'espèce majeure de bleuet exporté et représente 75.1% du volume totale de bleuet frais exporté. Sur le marché du surgelé, le bleuet sauvage est la principale espèce de bleuet exporté et représente trois cinquièmes des volumes de bleuets sous forme congelé (Agriculture et agroalimentaire Canada 2021). En effet, après la récolte, près de 95% des bleuets sauvages récoltés sont surgelés ou transformés (ex. : tartes, yaourts, confitures, etc.) avant d'être commercialisés dans plus de 22 pays à travers le monde. Concernant les importations, le Canada est le deuxième plus gros importateur de bleuets frais au monde, bleuets importés majoritairement hors saison des États-Unis (MAPAQ 2022).

3. La production de bleuet sauvage au Canada

Au Canada, les bleuetières sont caractérisées par deux espèces de bleuets sauvages, à savoir *Vaccinium angustifolium* Aiton et *Vaccinium myrtilloides* Michaux (Fournier *et al.* 2020). En termes de superficies, le bleuet sauvage est de loin la première culture fruitière du Canada avec plus de 65 000 hectares dédiés à cette culture (Agriculture et agroalimentaire Canada 2021). Le bleuet sauvage représente 49% de la production canadienne de bleuet contre 51% pour le bleuet en corymbe (MAPAQ 2022). À l'échelle provinciale, c'est la province du Québec qui détient le leadership dans la production de bleuet sauvage. En effet, la province concentre 48% de la production canadienne de bleuet sauvage contre 21% pour la Nouvelle-Écosse, 18% pour le Nouveau-Brunswick et 12% pour l'Île-du-Prince-Édouard (Agriculture et agroalimentaire Canada 2021). Au Québec, le bleuet sauvage représente 97% de la production de bleuet contre 3% pour le bleuet en corymbe (MAPAQ 2022), ce qui en fait un véritable petit trésor économique. Les bleuetiers sauvages se retrouvent soit en forêt où il pousse à l'état sauvage ou en bleuetières commerciales où sa production est contrôlée par différents traitements agricoles tels que la fauche et la fertilisation. À l'heure actuelle, 98% des bleuets sauvages que l'on retrouve sur le marché proviennent des bleuetières commerciales (MAPAQ 2022). De plus, l'industrie du bleuet sauvage est une source de revenu pour de nombreuses personnes, puisqu'elle ne génère pas moins de 5 800 emplois (ex. : récolte, transformation et production) au Québec (Gagnon 2020).

4. Le bleuet sauvage dans la région du Saguenay-Lac-Saint-Jean

Présent depuis longtemps dans la région, le bleuet a connu une expansion suite aux grands feux de 1870. Suite à ces feux, de nombreuses terres brûlées de la région du Saguenay-Lac-Saint-Jean se sont retrouvées être des superficies propices à la culture et au développement du bleuet (Tremblay 2016). La région du Saguenay-Lac-Saint-Jean est une importante région productrice de bleuet sauvage au Québec avec plus de 80% des superficies cultivées (MAPAQ 2022). Ainsi, au Saguenay Lac-Saint-Jean, on retrouve 77% des producteurs de bleuet sauvage de la province (Gouvernement du Québec 2022). Connu également sous le nom de « perles bleue », le bleuet sauvage constitue la deuxième activité agricole la plus importante de la région, tout juste derrière la production laitière (Gagnon 2020).

5. Condition de culture du bleuet sauvage

Généralement, les bleuetières sont caractérisées par des sols sableux, bien drainés, pauvres en éléments nutritifs et acides, dont les valeurs de pH oscillent entre 4.2 et 5.2 (Argall *et al.* 1998). Ces sols, qualifiés de sols Podzoliques (Soil Classification Working Group 1998), sont définies notamment par une fine couche de matière organique peu décomposée en surface (Blatt et Hall 1989; Lafond et Ziadi 2013). Toutefois, bien que cette couche de matière organique soit de faibles profondeurs (entre 1 et 5 cm d'épaisseurs), elle est la principale source d'éléments nutritifs pour les bleuetiers ce qui en fait une ressource précieuse à conserver afin de maintenir un système de production durable et résilient (Lafond 2014a). En bleuetières commerciales, les sites sont « entretenus » afin de limiter le développement d'autres espèces végétales notamment de mauvaises herbes qui pourraient venir concurrencer le bleuet pour les éléments nutritifs du sol (Yarborough 2004).

6. Optimisation de la culture du bleuet sauvage au Saguenay-Lac-Saint-Jean

Afin d'améliorer les rendements, diverses pratiques agricoles sont utilisées en bleuetières commerciales telles que la fertilisation minérale et/ou organique, la fauche mécanique et/ou thermique, l'emploi de fongicides et d'herbicides (Eaton *et al.* 2004; Yarborough 2004; Lafond 2010; Lafond et Ziadi 2011; Lafond 2014b; Marty *et al.* 2019). Une autre pratique couramment utilisée par les producteurs afin d'optimiser la pollinisation et donc la mise à fruit, est l'utilisation d'insectes pollinisateur (e.g., quads, ruches, etc.) (Desjardins et De Oliveira 2006).

Plusieurs études ont montré l'effet de ces pratiques agricoles sur la croissance et les rendements en fruits du bleuet sauvage (Percival et Sanderson 2004; Yarborough 2004; Lafond 2014b; Marty *et al.* 2019; Paré *et al.* 2022). Concernant la fertilité du sol en bleuetières, les études sont moins nombreuses. Pourtant, étant donné que le bleuet sauvage peut assimiler l'azote du sol sous forme organique grâce notamment à la symbiose avec des champignons mycorhiziens éricoïdes (Cairney et Meharg 2003; Mitchell et Gibson 2006; Abbey *et al.* 2021), un sol pauvre en matière organique et donc en éléments nutritifs peut impacter la croissance végétative et en conséquence la productivité de la culture. Certaines études ont montré un impact de la fertilisation (organique ou minérale) et de la fauche mécanique et/ou thermique sur l'horizon organique et notamment la disponibilité en éléments nutritifs du sol (Smith et Hilton 1971; Hanson *et al.* 1982; Warman 1987; Penney *et al.* 1997; Sanderson et Eaton 2008; Warman *et al.* 2009; Lafond 2019). Toutefois, les études sur les indicateurs de la fertilité du sol se sont limitées jusqu'à maintenant qu'à la fertilité chimique des sols, à savoir aux simples contenus ponctuels en éléments nutritifs. En effet à ce jour, aucunes études ne portent sur le potentiel de minéralisation de l'azote (N) et du phosphore (P) du sol. Pourtant, ces deux nutriments (N et P) sont essentiels à la croissance et au développement du bleuet sauvage et leur disponibilité dépend notamment de la matière organique du sol (Lafond et Ziadi 2013). Ainsi, en déterminant l'N et le P potentiellement minéralisables du sol, cela pourrait permettre de prédire les quantités d'azote et de phosphore organiques transformées en formes inorganiques ($N\text{-}NH_4^+$; $N\text{-}NO_3^-$; $P\text{-}PO_4^{3-}$) au cours d'une période de croissance et ainsi mieux comprendre et prédire les besoins en fertilisation du bleuet sauvage (Ros *et al.* 2011). Par conséquent, en ayant connaissance de ces valeurs cela permettrait de mieux gérer l'azote et le phosphore en bleuetières.

7. Objectif et hypothèses

L'objectif général de ce projet est de caractériser la fertilité de l'horizon organique (5-0cm) et minéral (0-10cm) des sols en bleuetière afin de déterminer quelle(s) pratiques ou quelle(s) combinaison de pratiques agricoles sont les plus propices à maintenir un niveau de fertilité du sol élevé. Ainsi, il sera question de l'influence de la fauche mécanique et/ou thermique, de la fertilisation (minéral, organique ou sans) et du fongicide ©Proline (prothioconazole) (avec et sans) sur la dynamique de minéralisation de l'azote et du phosphore du sol et la dynamique du flux de CO_2 du sol de bleuetière sur une saison de croissance. Il sera également question de la caractérisation des sols en évaluant leur pH, leur teneur en éléments nutritifs et matière organique, leur ratio C/N et leur indice de saturation en phosphore selon les différentes pratiques culturales testées. Les hypothèses suivantes ont été émises :

(1) La technique de fauche n'affectera pas de manière significative les teneurs en matière organique du sol, la dynamique de l'azote et du phosphore ou les teneurs en éléments nutritifs du sol ;

(2) Les applications de fongicide n'affecteront pas les indices de fertilité du sol ;

(3) Les applications d'engrais minéral et organique augmenteront la minéralisation du P, l'indice de saturation en P du sol et la teneur en éléments nutritifs du sol, mais l'engrais organique aura un effet plus important que l'engrais minéral. L'engrais organique augmentera les teneurs en matière organique du sol. L'engrais minéral augmentera la nitrification du sol, mais pas la quantité de NH_4-N minéralisée. Le pH du sol diminuera avec l'apport d'engrais minéral et augmentera avec l'apport d'engrais organique.

CHAPTER 1: THE IMPACT OF AGRICULTURAL PRACTICES FOR WILD BLUEBERRY PRODUCTION ON SOIL FERTILITY IN SAGUENAY–LAC–SAINT–JEAN

1.1 Abstract

Agricultural practices are commonly used to improve the growth of the plant and fruit yield in wild lowbush blueberry (WLB) crops. However, it remained unclear how the pruning method and the fertilizers and fungicide applications affect soil in WLB field fertility. Here, we study the response of soil nitrogen (N) and phosphorus (P) dynamics to these agricultural practices during a simulated growing season in laboratory aerobic incubation. We also characterized the soil pH, the soil organic matter (SOM) and the nutrient dynamics (P, K, Ca, Mg and Fe), which are essential for soil fertility in WLB production. Mineral fertilizer compared to organic fertilizer allowed to increase by 74 kg ha^{-1} the quantity of NH_4-N mineralized, and the NH_4-N mineralized was 5.5 times higher than the quantity of NO_3-N mineralized. For the P dynamic, mineral and organic fertilizers allowed to increase the quantity of P mineralized by 116 kg ha^{-1} and 161 kg ha^{-1}, respectively. Thermal pruning tends to decrease by 6% SOM, by 15% the total N, and by 33% the quantity of NO_3-N mineralized. As a consequence, less organic N is mineralized to NH_4-N and then to NO_3-N by soil microorganisms. This study highlights how agricultural practices impact the N and P mineralization process in soil and the soil fertility index, which can potentially impact the soil nutrients reservoir in the long term.

1.2 Introduction

Wild lowbush blueberry (WLB) (*Vaccinium angustifolium* Ait.) is a perennial plant of the Ericaceae family that is native to North America (Vander Kloet 1978). WLB fruits are produced commercially in eastern Canada. About 80% of the WLB lands in the province of Quebec are located in the Saguenay Lac-Saint-Jean region (MAPAQ 2022). Although the WLB crop grows naturally, the fruit yield of commercial fields can be increased with several agricultural practices such as mowing, disease control with fungicides and fertilization. These practices affect the WLB growth and several plant traits such as stems or leaves (Yarborough 2004; Paré et al. 2022), but little is known about soil properties.

WLB production is generally harvested on a 2-year production cycle (Appendix A). During the first year, called the pruning or vegetative year, plant shoots (new stems) emerge from the buds located on the rhizome, and grow. WLB spreads primarily through an underground organ called the rhizome, which forms roots that allow the plant to colonize new areas. Their growth is stimulated by pruning the plants (Gagnon *et al.* 2015). Pruning causes the plant to allocate photosynthates and other resources to vegetative growth and flower bud formation in the first year. During this first year, no fruit is harvested. The flower buds open in late May and early June in the next growing season. The flowers are pollinated by insects, and the fruits development may occur. Consequently, the fruit are harvested at the end of this second year (namely harvesting year) in late August or early September. In late autumn, about 2 months after fruit harvesting, stems are mechanically and/or thermally mowed at the ground level and the cycle rebegin (Chiasson et Agrall 1996; Gagnon *et al.* 2015).

Thermal or mechanical pruning needs to be performed adequately. Properly used, mechanical pruning (i.e < 1 cm above ground level), has the same effect as burning (i.e., performed at low temperature) for the regeneration of WLB plants (Moreau 2014). Pruning (thermal or mechanical), is known to not affect fruit yield (Eaton et Nams 2006), but the combination of mechanical and thermal pruning, can be a good issue as it may increase fruit yield, nitrogen (N) and phosphorus (P) concentrations in leaf tissues, stem height, density, biomass, and mycorrhizal colonization while reducing weed competition and plant diseases (Black 1963; Smith et Hilton 1971; Ismail *et al.* 1981; Hanson *et al.* 1982; Warman 1987; Penney *et al.* 1997).

However, in the case of thermal pruning, the intensity of the fire needs to be controlled to minimize the soil organic matter (SOM) losses. In the short term (1 burn cycle), thermal pruning as compared to mechanical pruning has no impact on oxidized SOM and total SOM concentrations and depths (Hanson *et al.* 1982; Morvan *et al.* 2022). In the long term, repeated burning may however reduce the depth of the soil's organic horizons and cause a net loss of soil nutrients (Smith et Hilton 1971). However, nutrient losses can be offset by adding significant quantities of SOM before pruning such as straws (Smith et Hilton 1971). Although thermal pruning is more expensive than mechanical pruning, greater available soil P concentrations following thermal mowing occur due to the P released from combusted plant residues (i.e., ash) (Morvan *et al.* 2022). Mechanical pruning leaves chopped plant residues on the soil surface, and these residues decompose very slowly throughout the years (Warman 1987). Moreover, WLB fields are perennial no-till systems, which means a limited amount of soil C is lost through decomposition and erosion compared to annual cropping systems. Currently, there are no reports in the literature on how thermal pruning in commercial WLB fields impacts soil fertility by altering the potentially mineralizable N and extractable P concentrations in both organic and mineral soil horizons.

Fungal disease treatments are another agricultural intervention that occurs in commercial WLB fields. In Quebec, growers can choose to apply fungicides during the pruning years to control these pests, but there are environmental and user health consequences associated with fungicides. Therefore, using fungicides to control and prevent fungal diseases, while minimizing their impact on the environment, is a challenge for growers (MAPAQ 2021). Fungal diseases such as septoria leaf spot (*Septoria lycopersici*) and sclerotinia rot (*Monilinia vaccinii-corymbosi*) can diminish the fruit yield of WLB (Abbey *et al.* 2021). In the Saguenay Lac-Saint-Jean region, the fungicide Proline© is the most used fungicide in order to control fungal diseases (Bellemare *et al.* 2012). There is no information on how fungicides applied to WLB affect soil chemical or physical processes. However, Lloyd et al. (2021) showed that prothioconazole applications stimulated the presence of some fungi (i.e, Clavariaceae) associated with the ericoid mycorrhizal association. Since prothioconazole (© Proline) is a systemic broad-spectrum triazole fungicide, it blocks the synthesis of sterols in fungi, more precisely ergosterol (essential for the maintenance of the fungus cell), leading to the death of the fungus (Crop Science Bayer 2022). Lloyd et al. (2021) also found that prothioconazole applications may also decrease several soils fungi. As a consequence, dead fungal cells are lysed by soil organisms, which may release soil nutrients. Lack of information regarding the soil biological processes following fungicide applications to commercial WLB fields is a critical research need.

WLB plants have relatively low nutrient requirements relative to annual crops such as oat, barley and canola (Lafond 2014a). Nevertheless, the application of fertilizers (N, P, K, Ca, Mg, and B) at the beginning of the pruning year is beneficial for WLB crops. In Quebec, 50 kg N ha^{-1} application are recommended in WLB fields to obtain the best fruit yield (Lafond 2019). When < 50 kg^{-1} N ha^{-1} is applied, there is no need to provide P fertilizer. When the N fertilizer rates are ≥ 50 kg^{-1} N ha^{-1}, applying P fertilizer at a rate of 20 kg^{-1} P_2O_5 ha^{-1} is recommended. No more than 30 kg^{-1} K_2O ha^{-1} is recommended for WLB (Lafond 2019).

Mineral or organic fertilizers application are known to improve WLB growth, development, and fruit yield (MAPAQ 2016; Lafond 2019) when weeds are controlled (Ismail *et al.* 1981; Eaton 1994; Penney et McRae 2000). Fertilizers can be used to modify the pH of the soil, because mineral fertilizers are known to have an acidifying effect (Sanderson et Eaton 2008; Lafond 2019), while organic fertilizers are known to have a slight liming effect (Whalen *et al.* 2000). Moreover, as pruning method, fertilization needs to be performed adequately. Repeated application of P fertilizer results in an accumulation of P in the soil due to the crop's low need for this element (Warman 1987; Sanderson et Eaton 2008).

Since mineral fertilizers are highly water-soluble, nutrients from mineral fertilizers are rapidly available for the plants. On the contrary, only a portion of the nutrients in organic fertilizers are available for the crop and the rest are released slowly as the organic material decomposes. The timing of organic and mineral fertilizer application depends upon the synchrony of nutrient release from the fertilizer in relation to the crop nutrient demands (MAPAQ 2016). Repeated applications of organic fertilizers improve many soil properties (e.g., moisture retention, structure, biological activity, etc.) that are beneficial for soil fertility (Marty *et al.* 2019), and increase soil P, K and Ca contents (Warman *et al.* 2009). However, organic fertilizers have a more significant residual effect than mineral fertilizers. Nutrients in organic compounds (e.g., proteins, cell walls, etc.) must be biologically transformed via mineralization into plant-available nutrient ions (e.g., NH_4^+, NO_3^-, $H_2PO_4^-$) for plant uptake, so it may take several months for the organic nitrogen and phosphorus in an organic fertilizer to become available for plants (N'Dayegamiye *et al.* 2004; Tremblay *et al.* 2010). Currently, there is no study about the impacts of fertilization (organic or mineral) on N and P dynamics in WLB soils. As nitrogen and phosphorus are major soil nutrients that undergo soil mineralization processes, it remains crucial to know and understand how agricultural practices impact their dynamics during a complete growing season.

In this study, we investigated the N and P mineralization dynamics in response to the pruning technique (mechanical and/or thermal pruning), the use of fungicide (with or without ©Proline), and the type of fertilization (mineral or organic or control), in a commercial WLB field from Saguenay-Lac-Saint-Jean region (Québec, Canada). This study aims to understand how these agricultural practices influence the dynamics of selected nutrients as well as extractable nutrients (P, K, Ca, Mg, Fe and Al), which are essential for soil fertility in WLB production. It is hypothesized that:

(1) The pruning method will not significantly affect SOM levels, N and P dynamics or soil nutrient contents;

(2) Fungicide applications will not affect soil fertility index;

(3) Application of mineral and organic fertilizers will increase P mineralization, soil P index and soil nutrient content, but organic fertilizer will have a greater effect than mineral fertilizer. Organic fertilizer will increase SOM levels. Mineral fertilizer will increase soil nitrification but not the quantity of NH_4-N mineralized. Soil pH will decrease with mineral fertilizer and increase with organic fertilizer.

1.3 Materials and methods

1.3.1 Field site

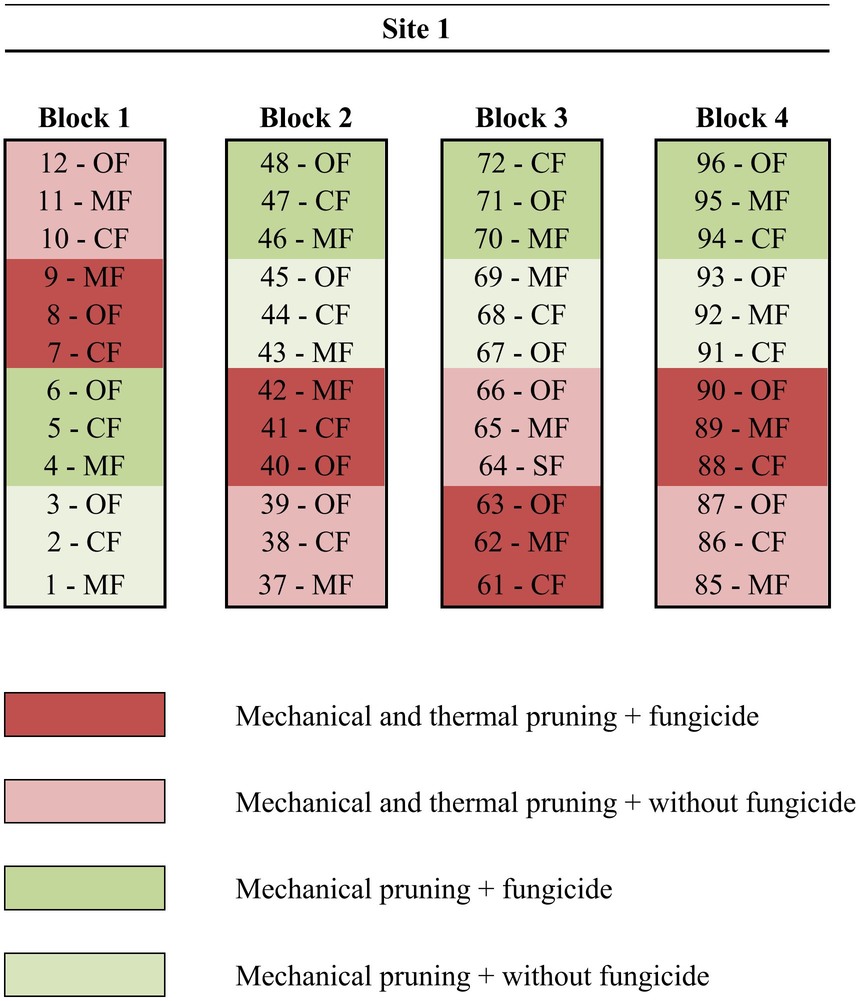
The study was located at the Bleuetière d'Enseignement et Recherche (BER) in Normandin, Quebec, Canada (48°49′35″N; 72°39′35″W) (Appendix B). The region has a continental climate with an average air temperature of 14.9°C and 340 mm of rainfall from May to September (Environnement Canada 2021). WLB are grown on infertile acidic soils of the Podzolic Order derived from deposits of fine sands of fluvioglacial (i.e., deltaic) origin (Raymond *et al.* 1965). The soil is classified as a Parent and L'Afrique soil series, containing about 86% sands, 13% silts and less than 1% of clay (Raymond *et al.* 1965). The soil has a thin layer of organic matter at the surface, from one to several centimetres thick. The organic layer contains 226 g organic matter kg^{-1}, an order of magnitude more than the underlying mineral soil with 14.5 g of organic matter kg^{-1}. The WLB field in this study has been under commercial production since 2008, and used for research since 2016. General soil chemical properties are reported in Table 1.

Table 1. Soil chemical properties in the organic layer (0–5 cm) and mineral layer (5–20 cm) under WLB when the BER in Normandin, Quebec, Canada was established in fall 2016.

Soil depth (cm)	**pH**	**P**	**K**	**Ca**	**Mg**	**Fe**	**Al**	**OM**	**C/N ratio**
		mg kg^{-1}							
0-5	4.57	19	103	953	109	157	503	226	30
5-20	4.59	19	8	34	4	215	1460	14.5	23

1.3.2 Experimental design

A factorial split-split split-plot experiment was established at the site in the fall of 2016. The factorial (Pruning x Fungicide x Fertilizer) treatments were combinations of two pruning methods [mechanical (M) or/and thermal pruning (T)], two fungicide regimes (with or without (w/o) and three types of fertilizer application [mineral (MF) or organic (OF) or w/o fertilizer (CF)], for a total of 12 factorial treatments (Fig 1). This experiment design includes 48 experimental units measuring 15 x 22 m, distributed in 4 blocks, of 12 plots (i.e., 12 treatments). Each plot (i.e., experimental units) was minimally separated by a 3 m buffer to reach spatial independence (Pelletier et al. 2023).



Site 1

Block 1	Block 2	Block 3	Block 4
12 - OF	48 - OF	72 - CF	96 - OF
11 - MF	47 - CF	71 - OF	95 - MF
10 - CF	46 - MF	70 - MF	94 - CF
9 - MF	45 - OF	69 - MF	93 - OF
8 - OF	44 - CF	68 - CF	92 - MF
7 - CF	43 - MF	67 - OF	91 - CF
6 - OF	42 - MF	66 - OF	90 - OF
5 - CF	41 - CF	65 - MF	89 - MF
4 - MF	40 - OF	64 - SF	88 - CF
3 - OF	39 - OF	63 - OF	87 - OF
2 - CF	38 - CF	62 - MF	86 - CF
1 - MF	37 - MF	61 - CF	85 - MF

🟥 Mechanical and thermal pruning + fungicide

▨ Mechanical and thermal pruning + without fungicide

🟩 Mechanical pruning + fungicide

▨ Mechanical pruning + without fungicide

Figure 1. Experimental design for WLB research at the BER site in Normandin, Quebec, Canada. Each block has twelve experimental units (15 x 22 m) separated by a 3-meter buffer. The twelve

factorial treatments in each block are combinations of 2 pruning, 2 fungicide and 3 fertilizer treatments. M, mechanical pruning; MT, mechanical and thermal pruning; OF, organic fertilizer (poultry manure); MF, mineral fertilizer; CF, without fertilizer (control).

All plots (n=48) were mowed mechanically during the bud dormancy period in the fall with a blueberry mower (model TB-1072, JR Tardif, Rivière-du-Loup, Canada). Exceptionally, plots were mowed after snowmelt in spring 2017 while the plants were still dormant due to logistic issues in fall 2016. Thermal pruning occurred after mechanical pruning on half of the plots (n=24 plots) using a homemade propane gas burner towed by a tractor. The gas burner has four individual propane burners at the height of 10 cm above the soil surface and burns the vegetation with an intensity of 6,580 MJ ha^{-1} (Paré *et al.* 2022). Thermal pruning increased the soil temperature raised by <10°C on average (Vincent *et al.* 2018; Paré *et al.* 2022).

Fungicide was applied during the pruning year only, in mid-July (summer) when WLB was in its vegetative growth phase (Table 2). A broad-spectrum fungicide Prothioconazole (©Proline) was used according to the manufacturer's recommended procedure (0.315 L ha^{-1} of proline 480 SC dissolved with 0.250 L ha^{-1} of AG Surf adjuvant). ©Proline controls several fungal diseases, including rust, Septoria leaf spot, anthracnose, phomopsis and phytophthora (Crop Science Canada 2020). The effect of the fungicide (n=24 plots) was compared to an unsprayed control (n=24 plots), which did not receive fungicide treatment.

Table 2. Application dates of the treatments on the sampled plots (n=48).

Year	2016	2017	2018	2019	2020	2021
Mechanical pruning		15 May	9 October	-	7 and 8 October	-
Thermal pruning	7 November	-	7 and 8 November	-	6, 9 and 10 November	-
Fungicide application	-	13 July	-	July	-	15 July
Fertilizer application	-	13 June	-	6 June	-	28 May

In early June (spring) of pruning years, fertilizers were applied to the soil surface (Table 2) with a small broadcast spreader before stem emergence. These included mineral fertilizer, organic fertilizer or an unfertilized control (Appendix C). Plots that received mineral fertilizer (n=24) had a broadcast application of mixed fertilizers, namely ammonium sulfate (50 kg N ha^{-1}), triple superphosphate (30 kg P_2O_5 ha^{-1}), potassium sulfate (20 kg K_2O ha^{-1}) and borate (1 kg B ha^{-1}). The organic fertilizer was 1,000 kg ha^{-1} of granulated chicken manure (Pure Hen Manure 5-3-2, Acti-Sol Inc., Notre-Dame-du-Bon-Conseil, Canada). Organic fertilizer provided an equivalent amount of N, P and K as the mineral fertilizer. To balance the fertilizer application, we also broadcast borate with organic fertilizer at a of 1 kg B ha^{-1} rate. Furthermore, organic fertilizer provided 70 kg Ca ha^{-1} and 710 kg organic matter ha^{-1}.

1.3.3 Soil sampling and analysis method

1.3.3.1 Soil sampling

Soil was sampled from each plot on 23 September 2021. Soil samples were collected with a soil sampling probe (ø 20 mm) from the organic layer (approximately 5–0 cm) and the mineral layer (starting at 0 cm and ending 15 cm below the soil surface). One sample was the composite of 15–20 sub-samples per plot. The thickness of the organic layer varied from 1 to 5 cm thick, depending on the sampling location. The 0–15 cm depth was sampled for the miner soil layers corresponds to the soil horizons where most of the WLB roots are found (Eaton et Patriquin 1990). The soil samples were air-dried in the greenhouse (temperature around 18°C) for 3 weeks, homogenized, and then sieved (<2 mm) prior analysis.

1.3.3.2 Soil analysis

1.3.3.2.1 Chemical analysis

Soil pH – Soil pH was measured in deionized water and 0.01 *M* $CaCl_2$ solution with an AR25 pH meter (Fisher Scientific, Pittsburgh, PA, USA). The soil:solution ratio was 1:10 for the organic soil and 1:2 for the mineral soil (Hendershot *et al.* 2007).

Plant-available nutrients – Plant-available nutrients were extracted from soil with Mehlich-3 solution at a 1:5 soil:extractant ratio according to Sen et Ziadi (2007). The P concentration was determined by colorimetry (with molybdate and ascorbic acid) (Murphy et Riley 1962), while the K, Ca, Mg, Fe and Al concentrations were determined by inductively coupled plasma mass spectrometry (ICP-MS) (Agilent 7700x, Agilent Technologies Inc., Santa-Clara, California, USA). The ICP-MS also detected other trace elements (Na, Mn, Si, Sr, Pb, Ba) in the soil extracts reported in supplementary materials (Appendix O).

Total soil C and N – Dry soil samples were individually ground to fine powder with a rotary tumbler (75RT, Diamond Pacific Tool Corp., Barstow, CA, USA) and stainless-steel ball bearings. Then, soil samples (60 to 70 mg) were wrapped in small aluminum capsules. Afterwards, total carbon (C) and total nitrogen (N) were determined by dry combustion using a Thermo Finnigan Flash EA 1112 CN Analyzer (Carlo Erba, Milan, Italy). The total C was assumed to be equivalent to organic C because Podzols do not contain significant amounts of inorganic C. The total carbon content divided by the total nitrogen content was the C:N ratio for each soil sample.

Organic matter content - The organic matter (OM) content of the soil was calculated as according to Angers et al. (2010) as:

$$\text{OM (\%)} = \text{organic C} \times 1.724 \qquad (1)$$

Soil P saturation index – This index was the ratio of:

$$\left[\frac{P}{(Al+\gamma Fe}\right]_{M3} \tag{2}$$

where, P, Al and Fe are in mg kg^{-1}, γ = 1 for mineral soil horizons and γ = 5 for organic soil horizons (Khiari *et al.* 2000; Guérin *et al.* 2007).

1.3.3.2.2 Physical analysis

1.3.3.2.2.1 Estimation of potentially mineralizable nitrogen and phosphorus

Potentially mineralizable nitrogen and phosphorus were determined with aerobic incubations following Campbell et Curtin (2008) procedure, modified from the technique of Stanford et Smith (1972). Incubation lasted for 20 weeks (wk), approximately corresponding to the growing season at the study site. Soils were moistened to 60% of field capacity because mineralization is optimal when the soil moisture is between 50 and 70% of field capacity (Halvin *et al.* 1999). The incubation temperatures were adjusted according to the average soil temperature during a 20-wk period at the study site from June 2018 to August 2020 (Fig 2.).

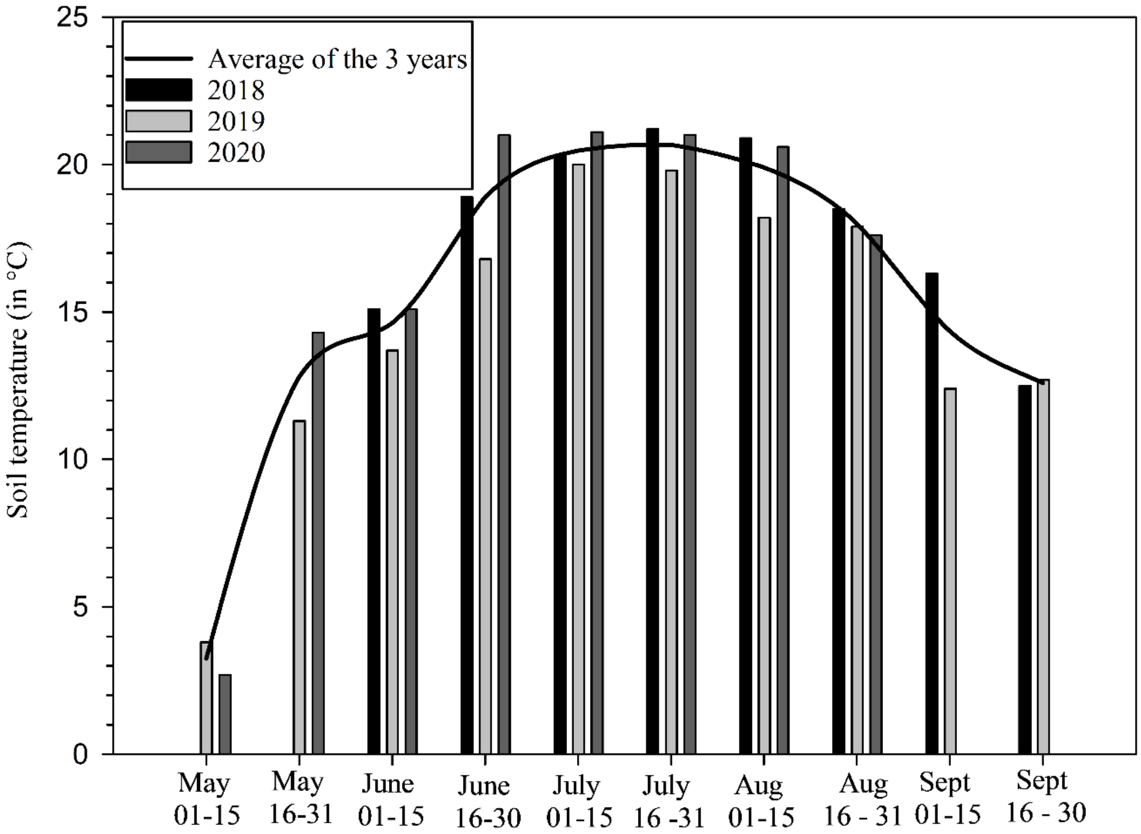


Figure 2. Average soil temperature of the organic layer (≈0–3 cm depth) under WLB at the BER site in Normandin, Quebec, Canada from June 2018 to August 2020.

For incubation, dry soil (4.5–6 g for organic soil and 11 g for mineral soil) was placed in 20 mL scintillation vials, rewetted to 60% of the field capacity and the scintillation vials were placed in Mason jars (500 mL, each Mason jar contained 4 scintillation vials). A total of 768 scintillation vials (96 samples x 8 incubation periods (2, 4, 6, 8, 10, 12, 16, 20 weeks)) and 192 Mason jars (768/4) were used. At each sampling date, 96 scintillation vials were randomly removed (1 per mason jar) from the incubator (Fisherbrand Isotemp BOD Refrigerated Incubator, Fisher Scientific, Waltham, MA, USA). The soil in each vial was extracted with 0.01 *M* $CaCl_2$ solution (1:8 soil: extractant), then filtered through filter paper (Quantitative Grade 2 filter paper circles, Fisherbrand). Soil filtrates were kept frozen (-20°C) until analysis.

Nitrogen as nitrate (NO_3-N) and as ammonium (NH_4-N) was determined colorimetrically using a modified indophenol blue technique (Sims *et al.* 1995). The orthophosphate ($H_2PO_4^-$) concentration was determined colorimetrically with the malachite green method (Ohno et Zibilske 1991) at 600 nm, using a Bio-Tek Model EL 309-microplate reader (Bio-Tek Instruments, Winooski, Vt.). We converted the mg N L^{-1} value to mg N kg^{-1} and the mg P L^{-1} value to mg P kg^{-1} as follows:

$$mg\ N\ kg^{-1} = \frac{mg\ N\ L^{-1}\ x\ V_{CaCl2\ (0.01M)}}{M_{dry\ soil}} \tag{3}$$

where $V_{CaCl2\ (0.01M)}$ in L corresponds to the volume of $CaCl_2$ used for the extraction (0.025 L for the organic layer and 0.05 L for the mineral layer) and $M_{dry\ soil}$ in kg is the weight of dry soil extracted.

Soil dry mass was confirmed by placing a subsample of the incubated soil in an oven for 24 h at 105°C, on each sampling date. Assuming that results can be linearly interpolated to a field scale, we used a multiplication factor to convert the mg N/kg value to kg N/ha and mg P/kg value to kg P/ha. For the organic layer, the factor used was 0.255 and for the mineral layer the factor used was 2.04, based on Duguet (2005) procedure.

We could not determine the potentially mineralizable nitrogen (mg N kg^{-1}) and potentially mineralizable phosphorus (mg P kg^{-1}) by using first-order kinetics after the 20-wk incubation because the curves were linear (Appendices D to H). Instead, we determined the cumulative N mineral (NO_3-N and NH_4-N) and P mineral mineralized according to linear regression (zero order) (Appendices D and E for NH_4-N; Appendices F and G for NO_3-N; Appendix H for P) model according to Griffin et Honeycutt (2000), and Griffin *et al.* (2005):

$$N_{min} = b(t) + a \tag{4}$$

$$P_{min}=b(t)+a \tag{5}$$

where N_{min} is the cumulative N mineralized between 0 and 20 wk (in mg N $kg^{-1}season^{-1}$), P_{min} is the cumulative P mineralized between 0 and 20 wk (in mg P $kg^{-1}season^{-1}$), *a* is the intercept, *b* is the slope that corresponds to the rate of mineralization (in mg N kg^{-1} wk^{-1} or mg P kg^{-1} wk^{-1}), and *t* is the time (in wk). For the P mineralization, no curves were done for the soil mineral horizon as there were no trace of P in this soil horizon. The N and P mineralized during the first 2 weeks were not included because they were affected by the initial microbial growth upon soil rewetting, which could result in immobilization or mineralization of N and P.

Net N mineralized (Net N_{min}) was the difference between the cumulative N mineralized (N_{min}) after 20 wk and the initial mineral N ($N_{initial}$).

$$Net\ N_{min=} N_{min\ (20wk)} - N_{initial} \tag{6}$$

Net P mineralized (Net P_{min}) was the difference between the cumulative P mineralized (P_{min}) after 20 wk and the initial mineral P (I_{nitial}).

$$Net\ P_{min=} P_{min\ (20wk)} - P_{initial} \tag{7}$$

We also determined the net nitrification rate (N_{nit}, measure as mg NO_3-N kg^{-1} $season^{-1}$) and the amount of net NH_4-N mineralized (Net NH_4-N_{min}) in mg NH_4-N kg^{-1} $season^{-1}$, below:

$$N_{nit} = NO_3{-}N_{min\ (20\ wk)} - NO_3{-}N_{initial} \tag{8}$$

$$Net\ NH_4{-}N_{min} = NH_4{-}N_{min\ (20\ wk)} - NH_4{-}N_{initial} \tag{9}$$

1.3.3.2.3 Estimation of soil CO_2 production

CO_2 flux was measured throughout the 20-wk incubation on the jars (i.e., 96 Mason jars). These jars were tightly sealed with a lid fitted with a septum, allowing gas collection from the headspace. At each sampling time (1, 2, 4, 6, 8, 10, 12, 16, and 20 wk), the headspace gas was mixed by withdrawing and reinjecting the gas 3 times without removing the 20 mL syringe with needle (25 gauge). Then a 20 mL gas sample was removed and injected into a previously evacuated, marked 12 mL vial (Labco, Wycombe, UK). Once the headspace was sampled, the jar lid was removed for 15 min to replenish the oxygen in the jars and maintain the incubation under aerobic conditions before re-sealing the jar to allow gas accumulation for the next sampling time

The CO_2 in headspace gas samples was measured with a flame ionization detector (FID) on a gas chromatograph 450-GC System (Bruker Corp., Bremen, Germany). Soil CO_2 production was determined in two steps. First, the CO_2 concentration was converted from ppm to mass concentration by volume (g CO_2-C L^{-1}) according to the ideal gas equation (Holland et al. 1999):

$$C_m = \frac{C_v \times M \times P}{R \times T} \tag{10}$$

where C_v is the headspace CO_2 concentration in ppm, M is the atomic mass of carbon (12 g C mol^{-1}), P is the atmospheric pressure (1 atm), R is the universal gas constant (0. 0820575 L atm K^{-1} mol^{-1}) and T the incubation temperature in K (week 1, 2, 4: 285.45 K; week 6, 8: 289.95 K; week 10, 12: 293.75 K; week 16: 292.05 K; week 20: 286.65 K).

Then, the amount of CO_2 (g CO_2-C kg^{-1} soil) produced was calculated according to Yanni *et al.* (2011):

$$\text{g } CO_2 \text{ - C } kg^{-1} \text{ soil} = \frac{Cm - C \times V}{W} \tag{11}$$

where V corresponds to the headspace volume (in L) and W is the weight of dry soil used (in g).

We determined the cumulative CO_2-C produced in 20-wk according to a quadratic equation. As the incubation temperature changed during the 20 wk period, cumulative CO_2-C production was expressed as g CO_2-C kg^{-1} $soil^{-1}$ $season^{-1}$.

1.3.3.2.4 Soluble organic carbon and dissolved organic nitrogen in soil extracts

Soluble organic C was determined in the soil filtrates (0.01 *M* $CaCl_2$) with a Shimadzu TOC-L analyzer (Shimadzu Corp., Kyoto, Japan). Soluble total nitrogen was measured on the same instrument with the TN module (TNM-L, Shimadzu). Beforehand, the samples were diluted 1:30 for the organic soil filtrates and 1:3 for the mineral soil filtrates in 40 mL acid-washed vials closed with a septa cap.

As the data were in mg L^{-1}, they have been converted into mg kg^{-1} and in kg ha^{-1} by making the same assumptions as for nitrogen and phosphorus mineralization rates. Then we have determined the cumulative soluble organic carbon (Soluble C) and cumulative soluble total N (Soluble total N), during the 20-wk of incubation. From this data, we estimated the quantities of soluble total N (mg soluble total N $kg^{-1}season^{-1}$) and soluble organic C (mg soluble organic C $kg^{-1}season^{-1}$) during incubation according to a linear regression for the soluble total N and according to a quadratic equation (second-degree polynomial function) for the soluble organic C.

$$\text{Soluble total N} = b(t) + a \tag{12}$$

$$Soluble\ organic\ C = a + b(t) + c(t^2) \tag{13}$$

where, *a* is the intercept, *b* is the slope which correspond to the rate of mineralization (in mg soluble total N or soluble organic C kg^{-1} $season^{-1}$), and *t* is the time (in wk).

The amount of soluble total N and soluble organic C was calculated as the difference between the cumulative soluble total N (soluble total N) or soluble organic C (soluble organic C) after 20-wk and at time 0 according to the linear regression and quadratic equation respectively.

$$Soluble\ total\ N = soluble\ total\ N_{(20wk)} - Soluble\ total\ N_{initial} \tag{14}$$

$$Soluble\ organic\ C = Soluble\ organic\ C_{(20wk)} - Soluble\ organic\ C_{initial} \tag{15}$$

1.3.4 Statistical analysis

Before analysis of variance, data normality was analysed graphically by looking at the distribution as a histogram of the data. Shapiro-Wilk's normality was also performed to see if the data followed normal distribution. Homoscedasticity was evaluated by residue analysis and Levene's test to see if the data variance was homogenous or not. These tests indicated that all variables needed transformation to meet normality criteria except one variable (total N). Data were transformed according to the Box-Cox transformation (Box et Cox 1964), summarized in Appendix I. Seven (7) plots (n°70 to 72 and 93 to 96) were removed for the statistical analyses because these plots were flooded 1 year out of 2, due to a beaver dam.

Analysis of variance of the normalized data was done with a linear mixed model (mixed model procedure) using JMP 17 software (SAS Institute Inc., Cary, NC, USA). Agricultural practices (pruning, fungicide and fertilizer) were fixed factors and blocks were random factors. Three-way analysis of variance (ANOVA) shows if there were significant differences in N and P dynamics, pH, organic matter levels, extractable nutritive elements and other trace metallic elements due to pruning method (mechanical and/or thermal), fungicides regimes (with or without), fertilizers application (MF, OF or CF) and the interaction term (Pruning x Fungicide; Pruning x Fertilizer; Fungicide x Fertilizer; Pruning x Fungicide x Fertilizer). For significant ($p<0.05$) treatment results on soil fertility indexes, post hoc multiple comparison tests (Tukey's HSD $\alpha = 0.05$) were performed to compare the mean values. Data presented in the tables and figures are the untransformed means (± standard errors). Pearson correlation was also performed to test the relationship between soil fertility index (Appendix J).

1.4 Results

1.4.1 SOM content, soil C/N ratio and soil pH

Although not significant, thermal pruning tended to decrease SOM content in the organic horizons (5-0 cm) by about 5%, whereas utilizing mineral and organic fertilizers tended to increase SOM by 8 and 4%, respectively (Table 3). The soil C/N ratio was affected by pruning, the pruning × fungicide interaction, and the pruning × fungicide × fertilizer interaction in the organic horizons (5-0 cm) (Appendix K). Soil C/N ratio increased by 4 units with thermal pruning (Table 3). Thermal pruning with added fungicide had a 13% lower C/N ratio compared to no fungicide (Table 3). The pruning × fungicide × fertilization inconsistently affected the C/N ratio, and the highest C/N ratio of

49 was achieved with thermal pruning, no fungicide and mineral fertilizer or without fertilizer. The mechanical pruning without fungicide and mineral fertilizer combination had the lowest C/N ratio of 36 (Table 3). There was also a significant ($P<0.001$) effect of fertilization on soil pH_{water} (Appendix K). As hypothesized, mineral fertilizer decreased soil pH_{water} by 0.2 unit and organic fertilizer increased pH_{water} by 0.3 unit, compared to the unfertilized control (Table 3). Furthermore, pH_{water} was influenced significantly ($P<0.001$) by the pruning method (Appendix K). Mechanical pruning slightly increased soil pH_{water} by 0.1 unit compared to thermal pruning (Table 3). Soil pH_{CaCl2} was also significantly impacted by fertilization as soil pH_{water} (Appendix K).

In mineral soil horizons (0-15 cm), fungicide and pruning × fungicide affected the SOM content (Appendix K). There was 2.7 times less SOM in plots receiving fungicide compared to those without fungicide (Appendix L). Thermal pruning without fungicide had 4.1 times higher SOM compared to thermal pruning with fungicide (Appendix L).

Table 3. Soil organic matter (SOM), total N, Soil C/N ratio and soil pH of the organic layer, as affected by pruning, fungicide, fertilizer application and their interactions.[1].

Significant factors and interactions			SOM (g kg^{-1})	Total N (g kg^{-1})	C/N ratio	pH$_{water}$
Pruning						
Mechanical pruning			325 (17) a	4.64 (0.21) a	41 (1) b	4.4 (0.1) a
Thermal pruning			308 (17) a	4.04 (0.23) a	45 (1) a	4.3 (0.1) b
Fertilizer						
Mineral fertilizer			326 (22) a	3.99 (0.33) a	-	4.1 (0.0) c
Organic fertilizer			316 (18) a	4.26 (0.32) a	-	4.6 (0.1) a
w/o fertilizer (control)			303 (18) a	4.61 (0.20) a	-	4.3 (0.1) b
Pruning x Fungicide						
Mechanical pruning	w/ fungicide		-	-	43 (2) ab	-
	w/o fungicide		-	-	40 (1) b	-
Thermal pruning	w fungicide		-	-	42 (1) b	-
	w/o fungicide		-	-	47 (2) a	-
Pruning × Fungicide × Fertilizer						
Mechanical pruning	w/ fungicide	Mineral	-	-	47 (3) ab	-
		Organic	-	-	41 (2) ab	-
		w/o fertilizer	-	-	41 (2) ab	-
	w/o fungicide	Mineral	-	-	36 (1) b	-
		Organic	-	-	44 (1) ab	-
		w/o fertilizer	-	-	40 (2) ab	-
Thermal pruning	w/ fungicide	Mineral	-	-	40 (2) b	-
		Organic	-	-	41 (3) ab	-
		w/o fertilizer	-	-	42 (2) ab	-
	w/o fungicide	Mineral	-	-	49 (3) a	-
		Organic	-	-	44 (3) ab	-
		w/o fertilizer	-	-	49 (1) a	-

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[1] Interactions between pruning x fertilizer, fertilizer x fungicide did not impact soil organic matter levels and thus is not shown in the table (Appendix A). Mean values were compared with a Tukey's post-hoc test at α = 0.05.

1.4.2 N, P and C dynamics

1.4.2.1 NH_4-N and NO_3-N mineralizations

In the organic horizons (5-0 cm), fertilization and pruning significantly affected the N dynamics (Appendix K). Adding mineral fertilizer significantly increased NH_4-N mineralization compared to the unfertilized control and the organic fertilizer. Indeed, the NH_4-N mineralization was about 2.5 times higher with mineral fertilizer compared to organic fertilizer or no fertilizer (Table 4). However, adding organic fertilizer increased nitrification by 77% compared to the unfertilized control. In addition, the net NO_3-N mineralized was 5.3 times higher with organic fertilizer compare to mineral fertilizer (Table 4). The pruning method significantly influenced the soil nitrification processes (Appendix K). Compared to mechanical pruning, thermal pruning reduced by 28 kg ha^{-1} the net NO_3-N mineralized (Table 4). There was a significant fertilization × pruning interaction (Appendix K). First, combining thermal pruning with mineral fertilizer had the lowest NO_3-N mineralization rates (Table 4). In the mineral soil horizon (0-15 cm), pruning, fungicide or fertilizer had no significant effect on soil N dynamics (Appendix K).

Table 4. Soil nitrogen mineralization, nitrification, and phosphorus mineralization of the organic soil layer, as affected by pruning, fertilizer application and their interactions.[2]

Significant factors and interaction		**Net NH_4-N min** (kg ha^{-1})	**Net NO_3-N min** (kg ha^{-1})	**Net P min** (kg ha^{-1})
Pruning				
Mechanical pruning		-	85 (14) a	-
Thermal pruning		-	57 (11) b	-
Fertilizer				
Mineral fertilizer		122 (12) a	23 (5) c	150 (38) a
Organic fertilizer		48 (6) b	121 (14) a	195 (36) a
w/o fertilizer (control)		45 (8) b	70 (13) b	34 (13) b
Pruning x Fertilizer				
Mechanical pruning	Mineral	-	28 (9) b	-
	Organic	-	120 (25) a	-
	w/o fertilizer	-	111 (15) a	-
Thermal pruning	Mineral	-	18 (7) b	-
	Organic	-	121 (18) a	-
	w/o fertilizer	-	30 (7) b	-

1.4.2.2. P mineralization

In the organic soil horizons (5 to 0 cm), the P mineralization was significantly affected by fertilizer application (Appendix K). Both fertilizer applications increased P mineralization (Table 4). P mineralization was 4.5 times higher with mineral fertilizer and 5.8 times higher with organic fertilizer compared to the unfertilized control (Table 4). In the mineral soil horizon (0-15 cm), there was no difference in the P mineralization due to fertilizer, pruning or fungicide application (Appendix K).

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[2] Fungicide application did not impact the soil N dynamics and thus is not shown in the table (Appendix A). Mean values were compared with a Tukey's post-hoc test at α = 0.05.

1.4.3 Soil C dynamics

The pruning method significantly affected the soluble organic C (<2 μm) ($SOC_{<2\ \mu m}$) in the organic soil horizons (5-0 cm) (Appendix K). The $SOC_{<2\ \mu m}$ was 14% greater with thermal pruning compared to mechanical pruning (Appendix M). Although pruning × fungicide × fertilization had a significant interactive effect on the CO_2 flux (Appendix K), no significant differences were detected among treatments using the Tukey post-hoc test (Appendix K). In the mineral soil horizon (0-15 cm), management practices (fertilizer, pruning, fungicide application) had no impact on the $SOC_{<2\ \mu m}$ or the soil CO_2 fluxes (Appendix K).

1.4.4 Soil nutrient content

In the organic soil horizons (5-0 cm), pruning method, fertilization and fungicide all affected soil nutrient contents (Appendix K). Thermal pruning decreased soil Mn content by 44% (Appendix K). Compared to unfertilized control, adding organic fertilizer significantly increased P, K, Ca contents by 76%, 50% and38% respectively (Appendix N) and soil Na content by 80% (Appendix O). Adding mineral fertilizer significantly decreased soil Mg and Ca (Appendix N) contents compared to unfertilized control and the organic fertilizer. Mineral fertilizer decreased soil Ca content by 42% and soil Mg content by 56% compared to unfertilized control (Appendix N). On the other hand, organic fertilizer increased soil Ca content by 38% compared to unfertilized control (Appendix N). Soil Mn content decreased with both fertilizers compared to the control (Appendix O). Moreover, fungicide application significantly affected soil Fe and Mn contents. Applying fungicide reduced soil Fe (Appendix N) and Mn (Appendix O) contents by 12% and 37%, respectively. Moreover, there was a significant pruning x fungicide interaction on soil Mn content (Appendix K). When mechanical pruning was performed with no fungicide, soil Mn content was twice higher than mechanical pruning with fungicide or thermal pruning without fungicide (Appendix O). Both fertilizers increased the soil P saturation index compared to unfertilized plots (Appendix N).

In the mineral soil horizon (0-15 cm), fertilization and pruning affected soil nutrient contents (Appendix K). Adding organic fertilizer increased K by 25% significantly compared to unfertilized control (Appendix L). The pruning method had a significant effect of on soil Ca and Al contents. Thermal pruning decreased by 18% the soil Ca content and increased by 16% the soil Al content compared to mechanical pruning (Appendix L).

1.4.5 Soil trace elements

In organic soil layers (5-0 cm), fertilizer, pruning, fungicide and interaction effects of pruning x fungicide influenced some of the soil trace elements (Appendix K). Adding mineral fertilizer decreased soil Sr and Ba contents by 40% and 33%, respectively (Appendix O). Thermal pruning decreased soil Ba content by 27% (Appendix O). Moreover, there was a significant ($P<0.001$) pruning x fungicide interaction on soil Ba content. When mechanical pruning was combined with no fungicide, soil Ba content was 37% higher compared to mechanical pruning combined with fungicide or thermal pruning without fungicide (Appendix O).

The pruning method affected the soil Sr and Ba content in the mineral soil horizon (0-15 cm) (Appendix K). For both elements, thermal pruning increased their contents by 18% for the Sr and by 15% for the Ba compared to mechanical pruning (Appendix L).

1.5 Discussion

As expected, after five growing seasons of treatments, soil fertility indexes in the organic soil horizons (5-0 cm) were more impacted compared to the mineral soil horizons (0-15 cm), which agrees with our fourth hypothesis. The pruning method affected soil C/N ratio, soil pH and nitrification, which is not in agreement with our first hypothesis. Regarding fungicide application, this management technique affects SOM content in the mineral soil horizon (0-15 cm), so our second hypothesis is rejected. Finally, mineral and organic fertilizers applications increased both P and N dynamics, which only partially accept our third hypothesis.

1.5.1 Pruning method

In our study, thermal pruning tended to decrease SOM content but these results were not significant, as only three cycles of pruning have been performed on this site. Previous studies have shown that thermal pruning did not significantly impact the thickness of the soil surface organic horizons (or SOM contents) after four to five cycles of spring burnings (Penney *et al.* 1997) or one cycle of fall burning (Morvan *et al.* 2022) (Hanson *et al.* 1982; Warman 1987; Penney *et al.* 1997).However, other studies found that repeated burnings reduced the thickness of the organic layer in commercial sites from Maine (Trevett 1956), Ontario (Smith et Hilton 1971), Quebec (Bouchard 1986), and Nova Scotia (Hayman *et al.* 2003). On the other hand, several studies observed that mechanical pruning increased the thickness of the SOM compared to thermal pruning (Argall *et al.* 1998; Hayman *et al.* 2003; Eaton *et al.* 2009b). Indeed, mechanical pruning generates plant debris (e.g., blueberry leaves and stems), which decompose slowly at the soil surface, and add numerous and various organic compounds to the soil surface (Argall *et al.* 1998; Eaton *et al.* 2009b). On the contrary, our field observations suggest that thermal pruning burns most of the flammable leaves and contributes less to global biomass inputs and subsequently, the thickness of the soil surface organic horizons.

In general, the soil C/N ratio is affected by management practices that increase the input of new and labile OM like plant residues to soil (Retamales et Hancock 2012; Sumiahadi et Acar 2020) and/or by organic C and N losses (e.g., by volatilization, erosion, leaching/runoff, etc.) (Allen 1964; Smith 1970). Plant residues (i.e., leaves, stems, etc.) contain large amounts of C and N. Moreover, leaves are more flammable than stems and have a lower C/N ratio than the stems. The burn of plant residues richer in N (i.e., leaves) is not without consequence on the soil C/N ratio. Our results show that thermal pruning increased the soil surface layer C/N ratio by 4 units compared to mechanical pruning (Table 3). In a grassland, Fynn *et al.* (2003) also reported that the soil C/N ratio was lower in the unburned plots compared to burned plots, due to greater loss of volatile soil N compounds during burning. Inconsistent interactions between thermal pruning, fungicide, and fertilizer applications suggest that fungicide and fertilizer applications had minimal impacts on soil C/N ratio (Table 3).

Although the pruning method have significantly influenced soil pH, the small decrease of soil pH indicates that this change is irrelevant. This observation agreement with others studies that found no influence of pruning technique (mechanical or thermal) on the soil pH in WLB crops (Hanson *et al.* 1982; Warman 1987). Moreover, after thermal pruning, Morvan *et al.* (2022) did not observe a significant change in soil pH, but some studies (Smith et Hilton 1971; Wein et MacLean 1983) reported that thermal pruning temporarily increased the soil pH immediately after the treatment, which dissipates in few months following the pruning event. However, mechanical pruning can also cause a temporary change in soil pH because it adds OM that buffers H^+ exchange (i.e., adsorbing H^+ to negatively charged colloids in the short-term and releasing H^+ as OM decomposes) (Neina 2019). As our sampling occurred 11 months after the last thermal pruning, it is still possible that we did not capture this short-term soil pH fluctuation.

Although it is now well-known how thermal pruning decreases SOM contents (Trevett 1956; Smith et Hilton 1971; Bouchard 1986; Hayman *et al.* 2003; Gumbrewicz 2021), our study is the first that highlights thermal pruning effect on key soil N dynamics such as N mineralization and N nitrification processes. The presence of ammonium ions influences the nitrification process in soil. The availability of ammonium ions, in turn, depends on the SOM, more particularly the SOM C/N ratio. A high soil C/N ratio results in the immobilization of ammonium, limiting its accessibility for nitrifying organisms (Tisdale et Nelson 1970; Verstraete et Focht 1977; Sahrawat 1996; Sahrawat 2008). In our experiment, thermal pruning tended to decrease by 6% SOM (not significant) compare to mechanical pruning and increased soil C/N ratio, which may explain lower nitrification rates after thermal pruning (Table 3).

Soluble organic C ($SOC_{<2\ \mu m}$) increased with thermal pruning in our experiment, but there is scant information in the literature to predict the effect of the pruning method on soluble organic C in soil and even less in WLB production. However, several studies observed an increased level of dissolved organic carbon (DOC) following wildfires for various types of vegetation covers in Montana (Mast et Clow 2008) and in Alberta (McEachern *et al.* 2000). Furthermore, Revchuk et Suffet (2014) observed that wildfires release additional organic carbon that would not otherwise leach from unburned vegetation. Indeed, the combustion of the vegetation cover releases soluble organic compounds into the soil, and considerable amount of particulate organic matter. In our study, pruning by burning increased $SOC_{<2\ \mu m}$ due to the combustion of flammable plant debris (i.e., leaves and stems) on the soil surface. Moreover, Neary *et al.* (1999) emphasized that wildfires can substantially alter organic carbon by reducing larger organic particles into smaller, more labile forms. In our study, thermal pruning reduced (non-significantly) SOM content (Table 2). Burning may have reduced large sizes of organic molecules into smaller molecules, and explain why thermal pruning increased the $SOC_{<2\ \mu m}$.

Several other factors such as the duration of the study and the burning intensity may explain the variation in our results. First, the duration of the study, some are conducted on long terms (Penney *et al.* 1997), and others on short terms (Smith et Hilton 1971; Hanson *et al.* 1982; Warman 1987; Penney *et al.* 1997; Hayman *et al.* 2003; Morvan *et al.* 2022). Field management history and the number of years of commercial operation before establishing of the experimental design are also factors that can affect soil properties. Second, burning can be done by using different types of fuels such as oils (Smith et Hilton 1971; Hanson *et al.* 1982; Warman 1987; Hayman *et al.* 2003), propane (Morvan *et al.* 2022; Paré *et al.* 2022), or/and straw (Penney *et al.* 1997). Third, burning can be done in the late fall (Smith et Hilton 1971; Hanson *et al.* 1982; Hayman *et al.* 2003) or early spring (Warman 1987; Penney *et al.* 1997; Hayman *et al.* 2003; Morvan *et al.* 2022). All these parameters should to be considered when comparisons are done between studies, hence, explaining some differences among the study's conclusions.

1.5.2 Fungicide application

To our knowledge, no prior reports about how fungicide influences soil nutrients and soil nutrient dynamics in WLB fields. Overall, our results showed minimal effect of fungicide applications on our measured soil properties (Appendix K). In sandy soils, SOM plays key role in permanently adsorbing propiconazole (our fungicide active ingredient) (Conde-Cid *et al.* 2019). This adsorbing mechanism may, in terms, form less mobile organic molecules that are less subject to leaching, explaining our lower SOM contents in deeper mineral soil horizons (0-15 cm) following fungicide applications. Regarding lower concentrations of Fe observed in the surface soil horizons (5-0 cm), propiconazole may also have formed complexes with Fe, hence reducing Fe availability in the soil (Conde-Cid *et al.* 2019). Since Proline® fungicide is now repeatedly and widely used by many WLB growers, propiconazole effect on both SOM and Fe will definitely need furthers investigation.

1.5.3 Fertilizer application

Both fertilizers (mineral and organic) tended to increase SOM content in the organic surface horizons (5-0 cm), but these increases were not significant. Warman (1987) found that chicken manure and NPK fertilizers did not impact SOM, which is consistent with our results. As Warman (1987), our study has been led from a mid-term perspective, and the organic and mineral fertilizers may not yet have contributed enough to detect significant changes in the SOM accumulation. Nevertheless, from a long-term perspective, repeatedly applying fertilizers will likely lead to a substantial increase in SOM contents. Eaton *et al.* (2009b) reported that after 8 years of repeated NPK fertilizer application, SOM content increased in WLB production in Nova Scotia. Moreover, mineral fertilizers are known to increase vegetative biomass strongly (Lafond et Ziadi 2011; Fournier 2020) compared to chicken manure (Paré *et al.* 2022). So, pruning plots fertilized with chicken manure will leave fewer plant residues (i.e., leaves, stems) at the soil surface compared to mineral fertilized plots. This explains why mineral fertilizer tends to increase the SOM content more than organic fertilizer.

Therefore, our results are in accordance with the fact that management practices favouring plant biomass will also likely improve SOM contents and soil carbon sequestration.

Soil pH has been influenced by fertilizer application in the organic horizon (0-5 cm). Poultry manure increased soil pH due to the liming effect of manure amendment (Whalen *et al.* 2000). This is in agreement with other studies that observed an increase in soil pH by 0.2 unit (no significant) following poultry manure (Warman 1987) and an increase by 0.8 to 1.2 units following manure amendment (Whalen *et al.* 2000). As cattle manure (Whalen *et al.* 2000), poultry manure buffers the acidity of the soil because this fertilizer is rich in calcium (i.e., calcium carbonate) (Bril et Salomons 1990).

Furthermore, nitrification increased with poultry manure amendment because of the pH of the poultry manure (i.e., pH ± 7.1), which creates microsites with high pH. These microsites favour the activity of nitrifying bacteria sensitive to soil acidity (De Boer et Kowalchuk 2001), so more NH_4-N have been converted to NO_3-N in soils amended with our alkaline poultry manure. According to Angers et al. (2010), amendments with a C/N ratio lower than 30 tend to decompose rapidly. As poultry manure applied to the soil had a low C/N ratio (i.e., poultry manure C/N ratio of 6), it decomposed rapidly which favoured the activity of nitrifying bacteria.

On the opposite, applying nitrogen fertilizer as ammonium sulfate reduces the soil pH because both ammonium and sulfate are known to lower soil pH (Sanderson et Eaton 2008; Lafond 2019). Several studies showed a 0.1 to 0.3 unit reduction in soil pH after its application (Warman 1987; Lafond et Ziadi 2013), while Warman *et al.* (2009) observed no significant change in soil pH 4 years after its first utilization (i.e., plots fertilized every 2 years). Several parameters can explain this variation among studies such as the dates of fertilizer application and soil sampling (Warman 1987; Warman *et al.* 2009; Lafond et Ziadi 2013). The rate of N application may also explain these study variations (Warman 1987; Warman *et al.* 2009; Lafond et Ziadi 2013). Moreover, the number of fertilization cycles before to soil sampling may also be an important factor on soil pH; longer ammonium sulfate application legacy will likely lead to lower even more soil pH.

As De Boer et Kowalchuk (2001), our results suggest that soil pH had an important influence on soil nitrate (NO_3-N) mineralization, since nitrification rates decrease as the soil pH becomes more acidic (Appendix J). Moreover, Eaton et Patriquin (1988) observed that nitrification was low in blueberry soil (soil pH from 4.5 to 5.5) compared to garden soil (soil pH 6.6). However, some studies reported that repeated N fertilizer applications under the form of ammonium sulfate stimulated the activity of autotrophic nitrifiers in the soil, and led to an increase in the nitrification process (Eaton et Patriquin 1988; Tabatabai *et al.* 1992; Hanson *et al.* 2002; Chantigny *et al.* 2007). Autotrophic nitrifying bacteria function optimally at a soil pH from 6.6 to 8 (Paul et Clark 1989). Still, in acidic soils, high nitrification is attributed to acid-tolerant autotrophic bacteria (De Boer *et al.* 1990) and/or nitrifying heterotrophic organisms (Stroo *et al.* 1986). Nevertheless, after 20-wk of laboratory incubation, our results showed that the net NH_4-N mineralized was 5.5 times higher compared to net NO_3-N mineralization. As the nitrification results of the transformation of ammonium to nitrate, it seems that soil ammonium is not easily converted to nitrate by autotrophic nitrifiers under our acidic soil conditions. At the BER (our research site), we still don't know which community of nitrifying bacteria are present and active in the soil since, along with soil pH, variation in soil nitrifiers community is likely a factor that can explain variation in soil nitrification (Sahrawat 2008; Li *et al.* 2018).

Our study shows a substantial increase of ammonium mineralization after mineral fertilizer application (Table 4). Several studies also observed that soil ammonium content increased during the first 1 to 3 months after fertilizer applications (Eaton et Patriquin 1988; Lafond 2010; Lafond et Ziadi 2013) and then started to decrease in the following months in late summer and in early fall. This late-season decrease of ammonium is commonly explained by both plant ammonium uptake and the migration of NH_4-N to the lower layers through soil N leaching (Eaton et Patriquin 1988; Lafond 2010). Furthermore, as we previously reported, mineral fertilizer increased SOM content in fertilized plots (Table 3). This higher concentration of SOM also increased the available substrate for ammoniating bacteria, which use the organic debris in the soil to transform them into ammonia.

Higher SOM content also increased the quantity of organic P, and thus the quantity of P mineralized by soil microorganisms during the 20-wk incubations (Table 4). Lafond et Ziadi (2013) observed that soil P content increased 1-2 months following mineral fertilization and then started to decrease the following months. Plant P uptake and soil P fixation (Al and Fe) likely explain this P content decrease, since no increase of P was detected in the underneath mineral soil layers. Regarding organic fertilizer, there are no prior reports, to our knowledge, about how they influenced the dynamics of P mineralization in WLB systems. In Spodosols (Podzols), Graetz et Nair (1995) found that long term dairy manure applications increased soil P content of the organic layers. In manure, P is present as inorganic (e.g., orthophosphates) and organic forms such as phospholipids or nucleic acids (Turner et Leytem 2004), which can be mineralized to inorganic forms by soil microorganisms. Since poultry manure contains organic P and inorganic P, our results showed that its utilization greatly increases both the P mineralization potential and P saturation index of the soils.

The extractable P concentration in soil has a variable response to mineral fertilization. According to Warman *et al.* (2009) and Lafond (2019), our results show that applying mineral fertilizers did not significantly increase the soil P concentrations. Still, other reports indicated that P fertilizer utilization increased the Mehlich-3 extractable P of the soil surface of many WLB fields from Maritime (Eaton *et al.* 1996; Sanderson et Eaton 2008; Eaton *et al.* 2009b) and Quebec (Lafond et Ziadi 2013) provinces. Specifically, Lafond et Ziadi (2018) found that the extractable P concentrations in soil increased one month after P fertilizer application and slightly decreased the following months. In acidic soils such as our study, likely a great proportion of the applied P is rapidly fixed by Fe and Al (hydr)oxides, which strongly reduce the P plant availability as well as the amount of extractable P (Khiari et Giroux 2010). In our study, as the soil has been fertilized three times in five years and we sampled the soil four months after the last fertilizer application, we were able to see a slight but not significant increase in soil P content, whereas the P saturation index significantly increased by 0.7% compared to unfertilized plots (Appendix N).

For organic amendment, Warman (1987) found that applying chicken manure (3 000 kg ha^{-1}) didn't increase the soil extractable P concentration in Nova Scotia WLB fields. In our study, three fertilization cycles were performed prior sampling, while Warman (1987) had two fertilization cycles before soil sampling. This may suggest that at least three fertilization cycles are needed to accumulate significant amount of nutrients, relative to unfertilized controls. Organic P mineralization likely contributed to the extractable P concentration later in the growing season. To our knowledge, no prior report about how organic fertilizers influence soil P saturation index in WLB soil systems exists. Podzolic soils (e.g., blueberry soils) are characterized by a high P fixation capacity, since their molar ratio P/(Fe + Al) is very low (Khiari *et al.* 2000; Lafond 2019). P saturation index varies among cropping systems (Guérin *et al.* 2007) and regions according to soil texture and soil pH (Pellerin *et al.* 2006; Benjannet *et al.* 2018). In British Columbia, Canada, for the highbush blueberry, Messiga *et al.* (2021) established a critical threshold for soil P saturation index at 18%, for soil with a pH not exceeding 4.7 and for a critical P_w value at 3.7 mg kg^{-1}. In the region of Saguenay-Lac-Saint-Jean, Quebec, Canada, for the WLB, Lafond et Ziadi (2013) established a critical threshold at 2.8% for a relative fruit yield of 74% in the horizon 0-10 cm (i.e., horizon organic, and Ae were mixed). This means that above this threshold, applying more P fertilizer has no advantages from an agronomic point of view. Our results showed that we reached this threshold value of 2.8%, but only when organic fertilizers were applied (Appendix N). When using mineral or no fertilizer, the P saturation index was significantly below this threshold.

Like phosphorus, applying organic fertilizer significantly increases soil K contents, whereas mineral fertilizer tended but did not significantly increase K in soil (Appendix N). In the past, it has been shown that mineral fertilizer applications did not increase the extractable K concentration in soil in some studies (Warman *et al.* 2009; Lafond 2019). On the other hand, others showed an increase in soil extractable K concentrations after fertilization (Warman 1987; Sanderson et Eaton 2004; Eaton *et al.* 2009a). Some differences are expected among studies that applied combined NPK fertilizers and those that made a separate application of each nutrient (i.e., individual N, P or K fertilizers). When only N (as ammonium sulfate) fertilizer was applied, the soil extractable K concentration tended to decrease, whereas this trend changed when K fertilizer was added (Lafond 2019). One explanation for this observation is the competition between NH_4^+ and K^+ ions on soil exchange sites (Penney *et al.* 2003). Indeed, excess ammonium may remove K^+ on exchangeable colloids, which may, in turn, increase K^+ leaching and losses.

No change in soil extractable K concentration was reported by Warman (1987) when WLB fields were fertilized with poultry and swine manures. However, similar to our study, increases in soil extractable Ca concentrations were observed after applying poultry manure. Indeed, poultry and chickens receive K, Na, Ca and Mg salts in their diet to maintain body osmotic balance, strong bones, and sustain egg production (Azeez et Van Averbeke 2012), explaining why we found that organic manure (i.e., poultry manure) increased the soil K, Ca (Appendix N) and Na concentrations (Appendix O). Moreover, the source of K used for the fertilization is important. Indeed, WLB roots have been reported to be susceptible to Cl damage due to the source of K fertilizer such as potash chloride (Bryla *et al*. 2021). In our study, K was under the form of potash hydroxide in the poultry manure (Acti-sol 2020) and under potassium sulfate for the mineral fertilizer. Under these two forms, no one reported any negative effect on blueberry roots.

We found that soil Ca and Mg concentrations decreased when blueberries received mineral fertilizer, which disagrees with other studies that mainly report any significant change in Ca and Mg soil concentrations after mineral applications (Warman 1987; Eaton *et al.* 2009a; Lafond 2019). However, a recent study from Schmitt (2023) showed that mineral fertilizers significantly increased the amount of Ca and Mg removed and exported out of the field through WLB fruit. As plant nutrient uptakes increase with mineral fertilizer, it depleted the soil extractable Ca and Mg concentrations in the upper layers of the soil, which highlights the importance of monitoring Ca and Mg nutrient status in the long terms.

1.5.4 Best management practices that improve soil fertility

Maintaining high levels of soil fertility is crucial for successful WLB production. From a mid-term perspective (after 3 cropping cycles), thermal pruning did not show any advantage. Indeed, our results showed that thermal pruning decreased SOM content, which is not desirable. In contrast, mechanical pruning leaves more plant debris that decomposed slowly over time and hence contributes significantly to the SOM built-up over time. Furthermore, thermal pruning reduced soil N and Ca contents, increased soil C/N ratio, and slowed N mineralization and cycling processes. As a result, compared to mechanical pruning, thermal pruning is not a good practice in order to maintain a high fertility level in WLB soils.

Our study also showed that using of the fungicide Proline® did not impact most of our measured soil fertility variables. However, more researches are needed to understand better the effect of propiconazole on SOM and soil Fe contents and dynamics. Since propiconazole may decrease SOM's mobility and/or solubility, a tight monitoring of SOM in subsoil horizons must be performed.

Since WLB plants prefer ammonium over nitrate, it is important to recommend to stakeholders management practices that favour the formation of ammonium instead of nitrate. In the Maine, Lloyd et al. (2021) found that fungicide application increases the abundance of an enzyme (i.e., nitronate monooxygenase) responsible to convert a nitrogenous organic compound into an inorganic plant-available nitrogen compound such as ammonium (Expasy 1993). However, in our study, we showed that fungicide applications did not impact soil N cycling processes.

Our study reveals that only mineral fertilizer application favors and promotes NH_4-N mineralization. However, it would be interesting to study in more detail what type bacteria are found in the soils at our research site, as the composition of root associated bacterial communities differs between managed and natural WLB fields (Yurgel et Lloyd 2017). Regarding the fungi community, in Nova Scotia *Ascomycota* have been found to be the most abundant fungal phylum in WLB soils, known to promote P and N uptakes (Yurgel et Lloyd 2017).

Mineral fertilizer also tends to increase the SOM content, a key soil fertility index that needs to be maintained and improved over the years. SOM plays an important role in soil fertility. A soil with a high content of OM increased soil water holding capacity, soil nutrients content, CEC and soil biology (i.e., microbes utilize the energy stored in SOM's chemical bonds for their growth and metabolism) (Quideau *et al.* 2021). A high content of SOM also improves soil structure and drought resistance, reduces the risk of erosion (Quideau *et al.* 2021), and contributes to mitigating the effect of climate change by sequestering more C (Sommer et Bossio 2014). Furthermore, mineral fertilizers help to keep soil pH below 4.5, which is suitable to maintain WLB's competitiveness against most of the weeds already present in commercial fields (Marty *et al.* 2019). However, since the soils begin to be depleted in Ca and Mg after only three cycles of mineral fertilization, non-liming alternatives such as calcium sulfate should be rapidly found for this crop.

In organic agriculture, repeated applications of poultry manure over the years could not be well adapted to WLB, as this management technique increase the soil pH above 4.5 and drastically increase soil nitrate mineralization and soil P saturation index. Combining poultry manure with elemental sulfur, authorized in organic farming, may help and be an excellent option to offset this unsuitable effect on soil pH.

1.6 Conclusion

This project successfully characterized the mineralization dynamics of N and P in the soil of WLB crop in the region of Saguenay-Lac-Saint-Jean based on pruning method, fungicide and fertilizer application. At the same time, soil samples were analyzed to characterize soil pH, nutrient content and OM. After 5 years of agricultural practices, it was found that the organic soil horizon (5-0 cm) was more influenced by these practices than the mineral soil horizon (0-15 cm), and characterized by higher levels of OM and nutrients, crucial for WLB. The study identified a significant interaction between mowing technique and fertilization on the dynamics of NO_3-N, with a more pronounced impact from fertilization. Since WLB preferentially take up nitrogen in the form of ammonium, it is preferable to choose a fertilizer that favors nitrogen in the ammonium form rather than in the nitrate form, for the good development of WLB. In testing both types of fertilization, mineral fertilization increased the quantities of NH_4-N mineralized over the course of a growing season, as opposed to organic fertilization. In addition, thermal mowing didn't influence the dynamics of NH_4-N and P but had a negative impact on the quantity of NO_3-N mineralized. Concerning fungicide application, Proline© was without impact on WLB soils, notably on the mineralization dynamics of N and P. It is therefore still recommended to apply fungicides to combat parasitic diseases and thus ensure good plant development. This short-term study provides initial insights into the impact of agricultural practices on soil fertility. However, long-term research is needed to further assess how the mowing technique and fertilizer application influence the dynamics of N and P mineralization over the course of a growing season, as well as soil OM, although the latter tends to be negatively impacted in the short term by the mowing technique.

CONCLUSION GÉNÉRALE

L’objectif général de ce projet a été atteint. La dynamique de minéralisation de l’N et du P selon les pratiques agricoles testées ont pu être caractérisées lors de l’incubation des sols sur une périodes de 20 semaines, ce qui correspond à une saison de croissance dans la culture du bleuet sauvage. En parallèle, l’analyse des échantillons de sols a pu permettre de caractériser le pH du sol, les teneurs en nutriments et en MO du sol selon la technique de fauche, le régime fertilisant et fongicide appliqués aux parcelles. Après 5 années de pratiques agricoles, il en est ressorti que l’horizon organique était plus impacté par les pratiques agricoles que l’horizon minérale et que les teneurs en MO et nutriments du sols étaient plus élevées dans l’horizon de surface. Cet horizon constitue le « garde-manger » des plants de bleuets. De ce fait, il nécessite d’être gérer de manière durable afin de maintenir des systèmes de productions durables et résilients.

Déterminer s’il existait des pratiques ou combinaison de pratiques agricoles qui étaient plus favorables à maintenir un niveau de fertilité de sol élevée faisait partie de l’objectif de ce projet. En étudiant les différentes combinaisons possibles, seule l’interaction de la technique de fauche et de la fertilisation s’est révélée significative sur la dynamique de l’$N-NO_3$, mais en y regardant de plus près le traitement fertilisant présentait un effet plus important. Étant donné que le bleuet prélève de manière préférentielle l’azote sous forme d’ammonium, il est préférable de choir un fertilisant qui favorise l’azote sous forme d’ammonium que sous forme de nitrate, pour le bon développement du bleuet. En testant les deux types de fertilisation, la fertilisation minérale a permis d’augmenter les quantités de $N-NH_4$ minéralisées au cours d’une saison de croissance par opposition à la fertilisation organique. Cela s’explique en partie par le pH du fertilisant utilisé, car les bactéries nitrifiantes du sol sont plus actives lorsque le pH du sol se rapproche de la neutralité. Étant donné que les sols des bleuetières sont caractérisés par des sols acides dont le pH oscille entre 4 et 5, il est normal que l’apport d’engrais NPK n’a pas stimulé la nitrification bien qu’il soit une source de substrat (i.e., ammonium sous forme de sulfate d’ammonium) pour les bactéries nitrifiantes du sol. Néanmoins, il serait intéressant d'étudier plus en détails quel types de bactéries nitrifiantes peuplent les sols de la BER, ce qui permettrait de comprendre davantage le processus de nitrification dans les sols en bleuetières. De plus, la fauche thermique n'a pas influencé la dynamique de minéralisation de l'N-NH_4 et du P, mais impacté négativement les quantités de N-NO_3 minéralisé. Cette étude a également apporté des précisions quant à l'impact des fongicides sur les indices de fertilité du sol. L'étude a montré que le fongicide Proline © était sans impact pour les sols des bleuetières, notamment sur la dynamique de minéralisation de l'N et du P. Il est donc toujours recommandé d'appliquer des fongicides pour lutter contre les maladies parasitaires et donc assurer le bon développement des plants.

Cette étude menée sur le court terme, donne une première orientation quant à l'impact de ces pratiques agricoles sur la fertilité du sol et plus particulièrement la dynamique de minéralisation de l'N et du P. La poursuite de recherche sur le long terme est nécessaire pour évaluer clairement comment la technique de fauche et l'application de fertilisants influencent la dynamique de minéralisation de l'azote et du phosphore au cours d'une saison de croissance, mais aussi la MO du sol, bien que celle-ci tend à être impacté négativement sur le court terme par la technique de fauche. La fertilisation minérale combinée à la fertilisation organique pourrait être une bonne idée car la fertilisation organique libère graduellement une partie des nutriments pour la plante et la fertilisation minérale permet de maintenir le sol dans des conditions acides et limite l'activité des bactéries nitrifiantes dans le sol et donc la conversion de l'N-NH_4 en N-NO_3.

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APPENDICES

APPENDIX A. DEVELOPMENT OF THE BLUEBERRY PLANT DURING A 2-YEAR PRODUCTION CYCLE.

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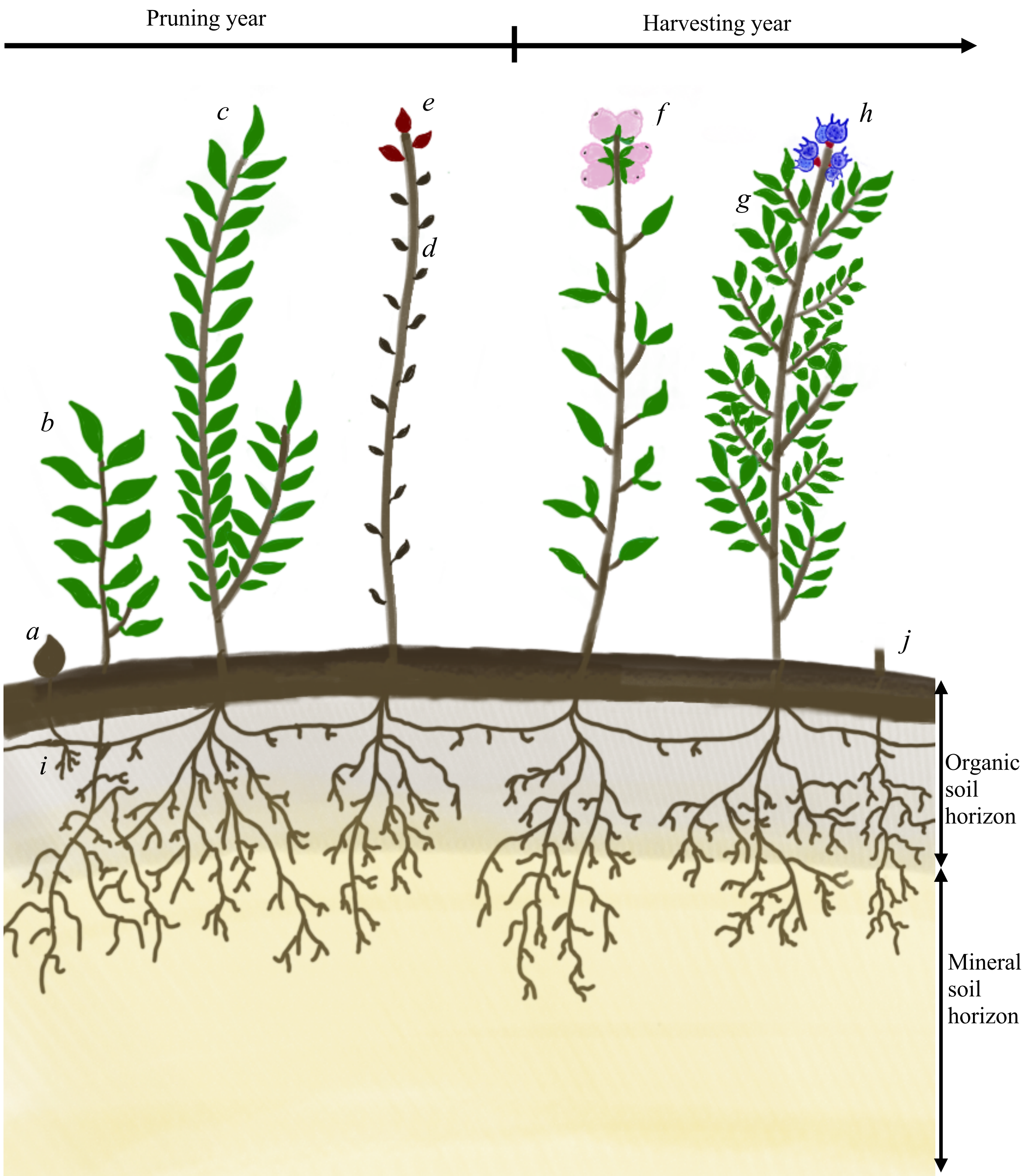
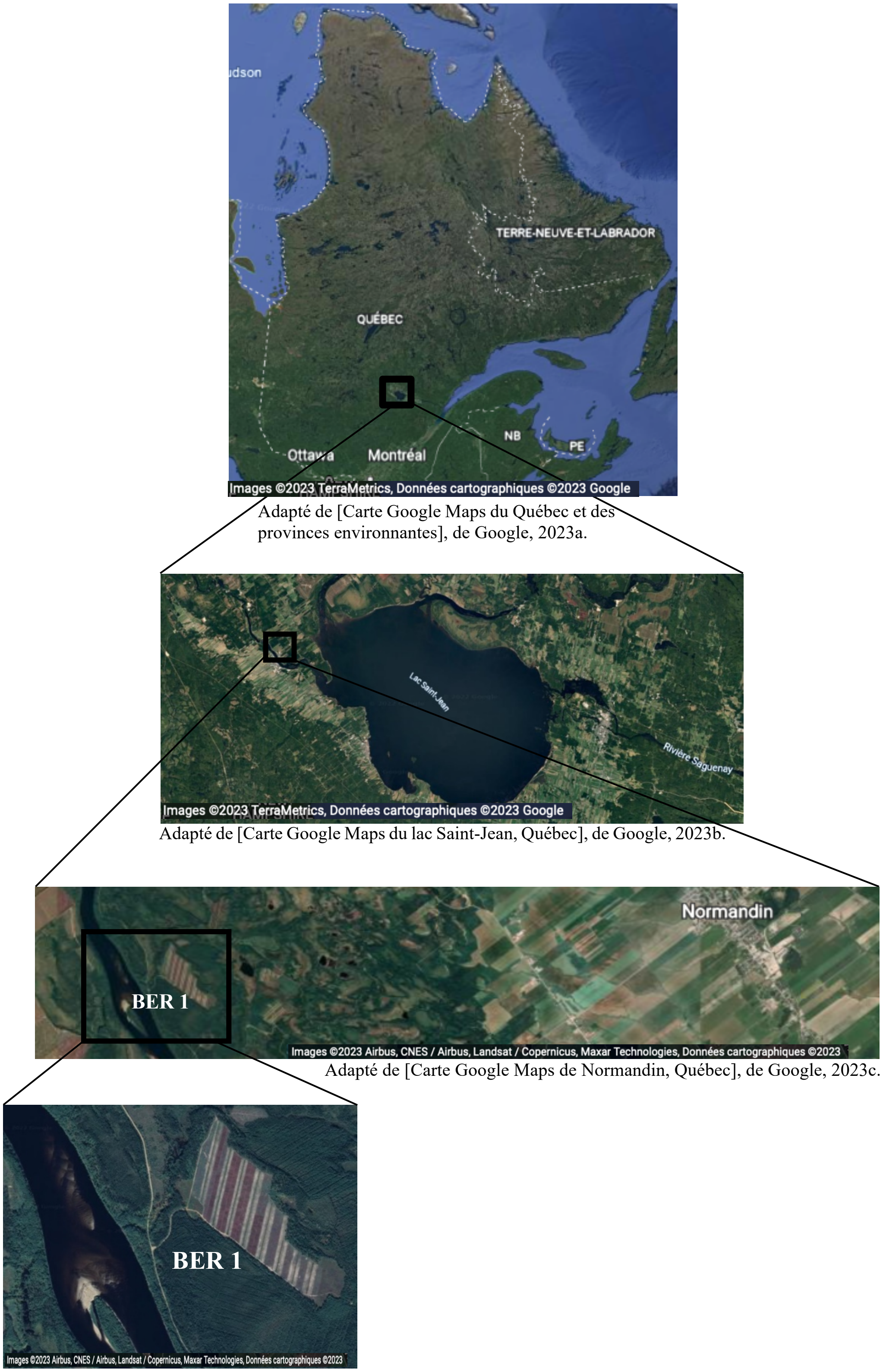


Appendix A. Development of the blueberry plant during a 2-year production cycle. The letters refer to components of the blueberry plants: a to the primary leaf bud, b to the leaves, c to the ramification, d to the leaf buds, e to the flower buds, f to the apical a and total flowers, *g* to the branches, *h* to the apical and total blueberries, *i* to the rhizome and *j* illustrates blueberry plants after pruning.

APPENDIX B. LOCALISATION OF THE BLUEBERRY STUDY SITE “BLEUETIÈRE D’ENSEIGNEMENT ET DE RECHERCHE » (BER) IN NORMANDIN, SAGUENAY-LAC-SAINT-JEAN, QUEBEC, CANADA.



Adapté de [Carte Google Maps du Québec et des provinces environnantes], de Google, 2023a.

Adapté de [Carte Google Maps du lac Saint-Jean, Québec], de Google, 2023b.

Adapté de [Carte Google Maps de Normandin, Québec], de Google, 2023c.

Adapté de [Carte Google Maps de la BER, Normandin, Québec], de Google, 2023d.

Appendix B. Localisation of the blueberry study site « Bleuetière d'Enseignement et de Recherche » (BER) in Normandin, Saguenay-Lac-Saint-Jean, Québec, Canada.

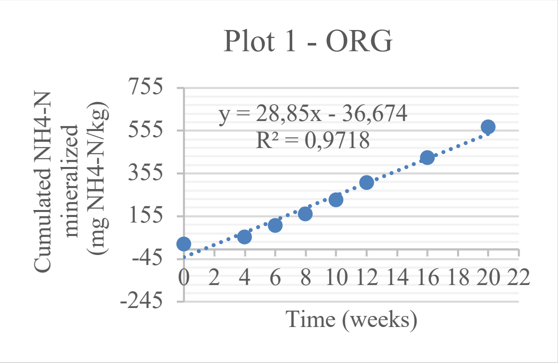
APPENDIX C. AGRICULTURAL PRACTICES APPLIED TO BLUEBERRY PRODUCED AT THE BER SITE, NORMANDIN, QUEBEC, CANADA.

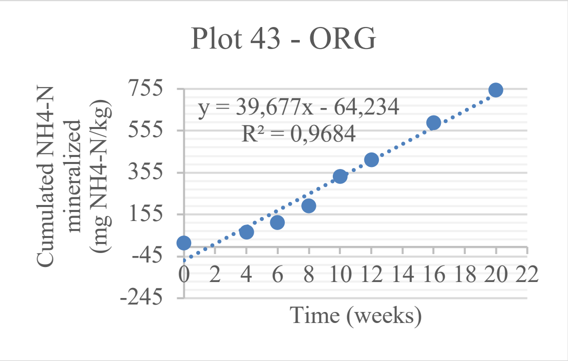
Appendix C. Agricultural practices applied to WLB produced at the BER site in Normandin, Quebec, Canada.

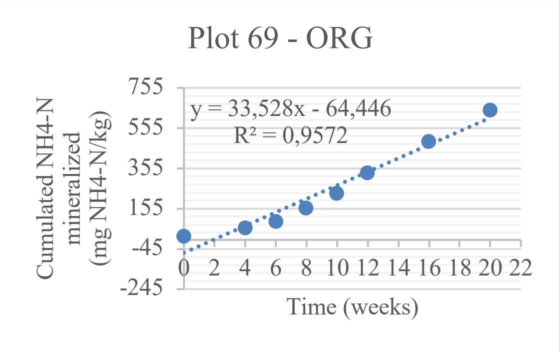
Treatment	Cycle	Pruning	Fungicide	Fertilization
1	2 years	Mechanical	Without	Mineral
2	2 years	Mechanical	Without	None
3	2 years	Mechanical	Without	Organic
4	2 years	Mechanical	With	Mineral
5	2 years	Mechanical	With	None
6	2 years	Mechanical	With	Organic
7	2 years	Mechanical and thermal	With	None
8	2 years	Mechanical and thermal	With	Organic
9	2 years	Mechanical and thermal	With	Mineral
10	2 years	Mechanical and thermal	Without	None
11	2 years	Mechanical and thermal	Without	Mineral
12	2 years	Mechanical and thermal	Without	Organic

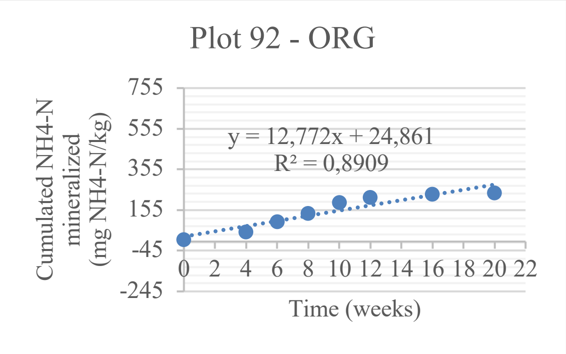
APPENDIX D. CURVES OF CUMULATED NH_4-N MINERALIZED IN THE ORGANIC (ORG) LAYER DURING A 20-WK AEROBIC INCUBATION ACCORDING TO DIFFERENT TREATMENTS (12 TREATMENTS).

Treatment 1: Mechanical pruning, no fungicide and with mineral fertilizer.

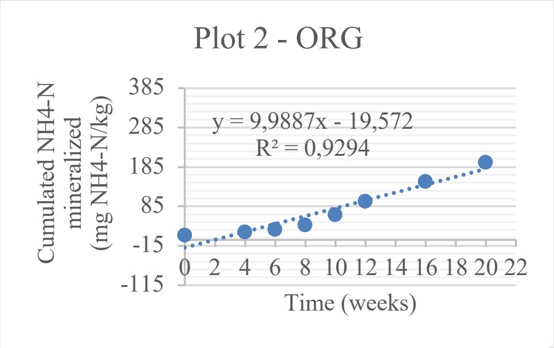


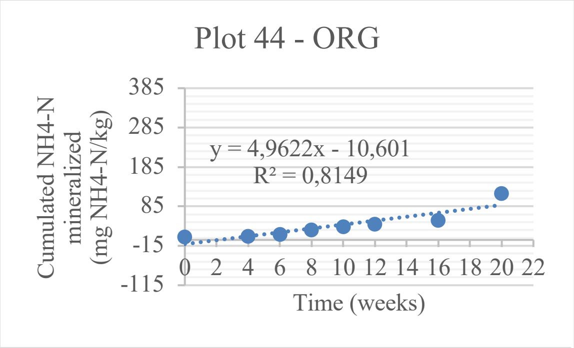


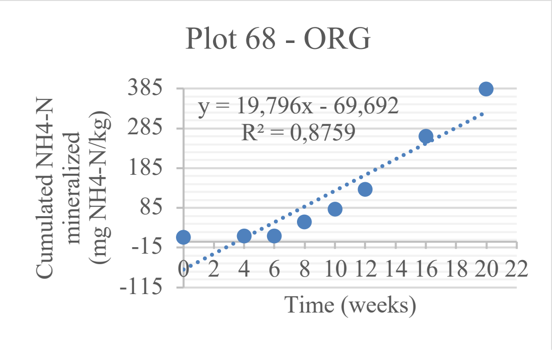


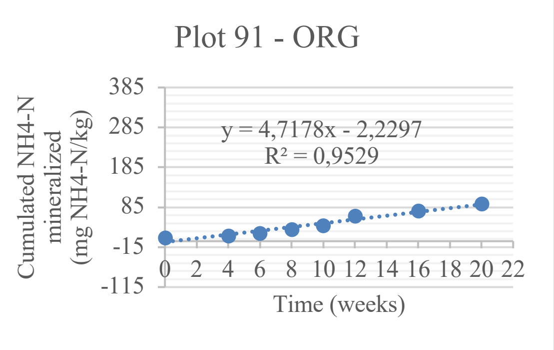


Treatment 2: Mechanical pruning, no fungicide and no fertilizer.

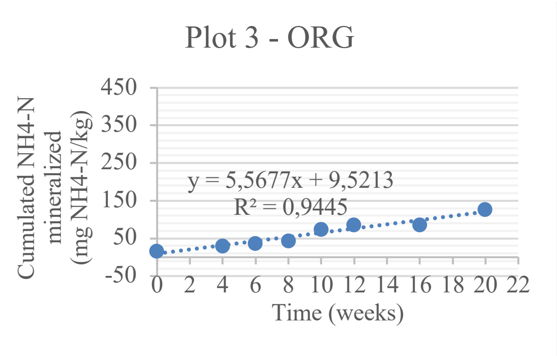


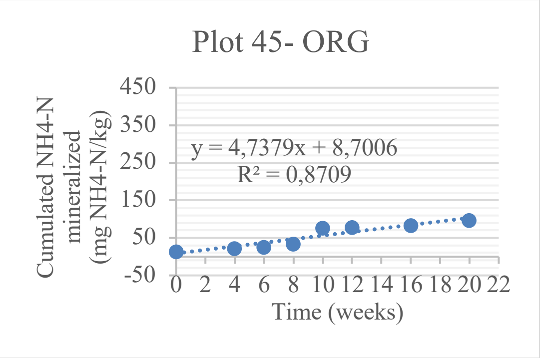


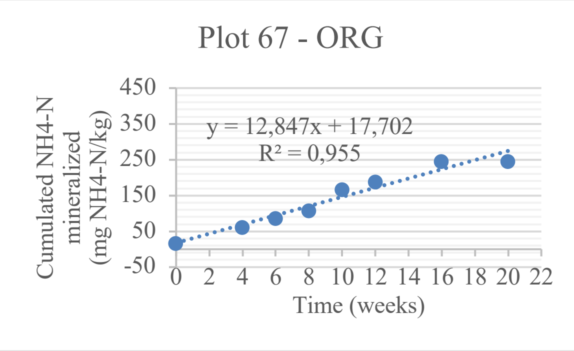


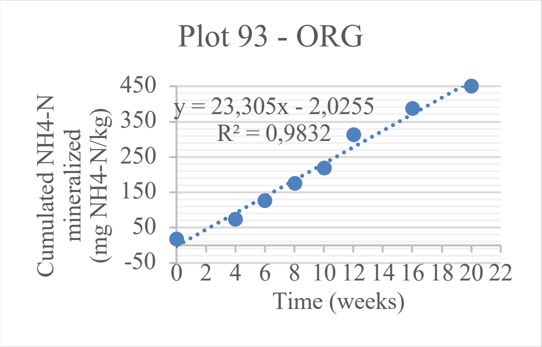


Treatment 3: Mechanical pruning, no fungicide and with organic fertilizer.

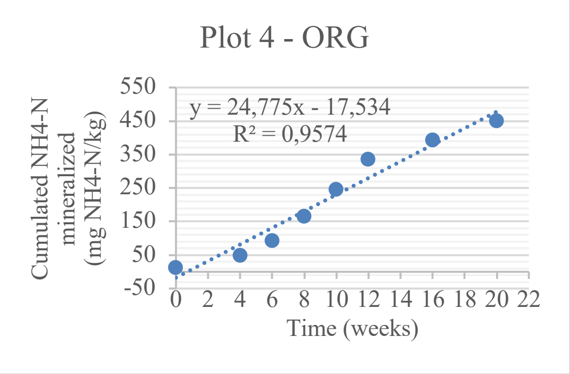


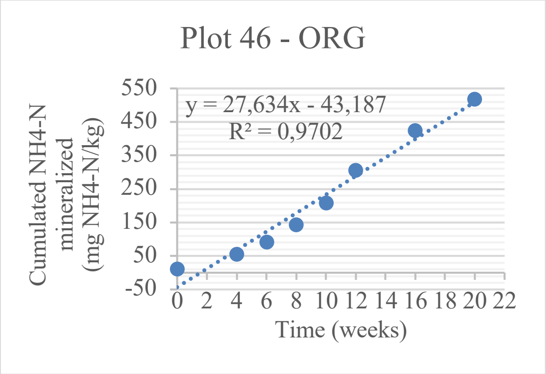


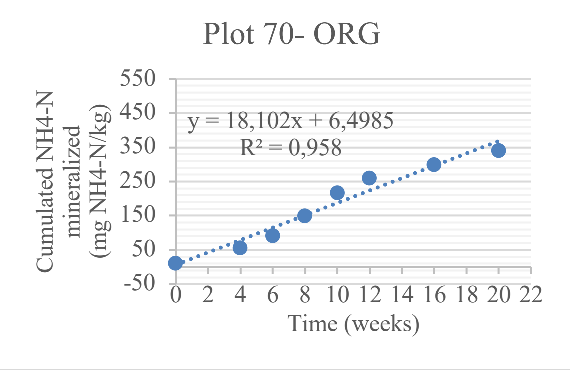


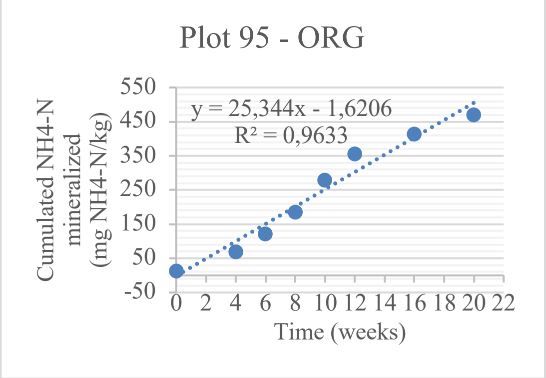


Treatment 4: Mechanical pruning, with fungicide and with mineral fertilizer.

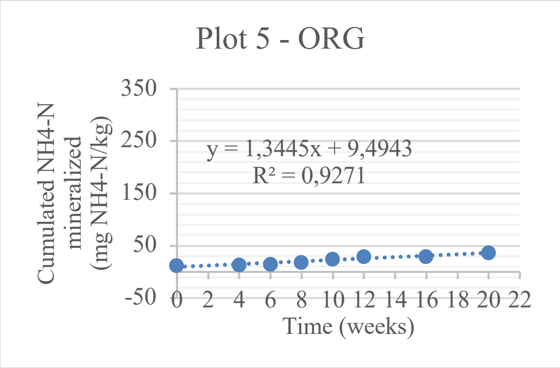


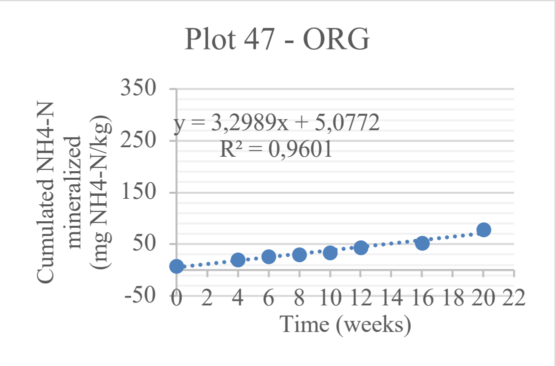


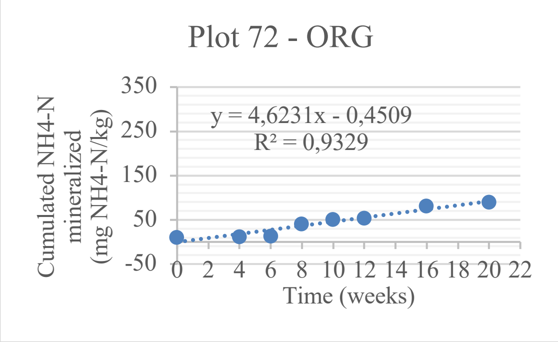


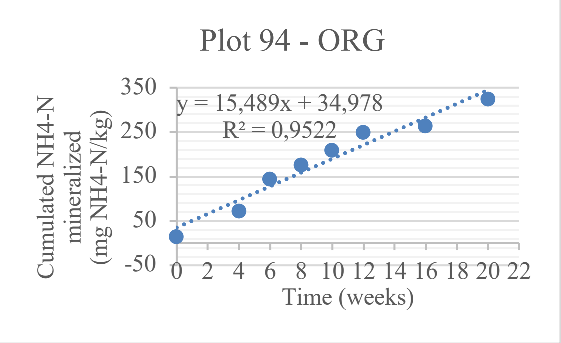


Treatment 5: Mechanical pruning, with fungicide and no fertilizer.

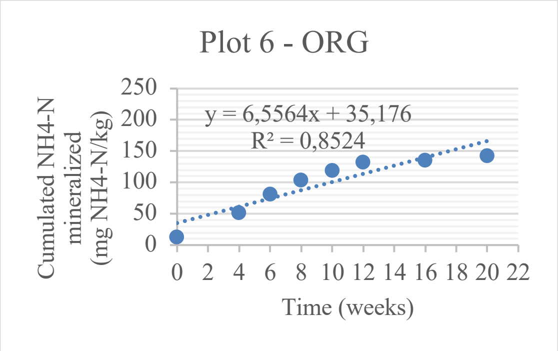


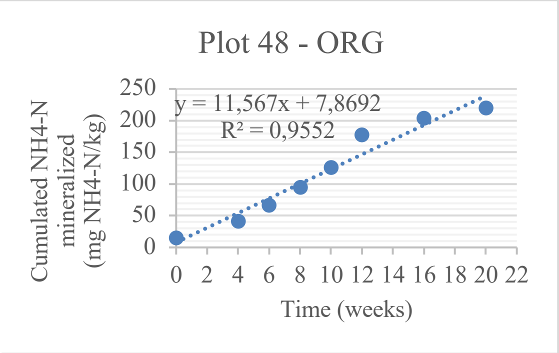


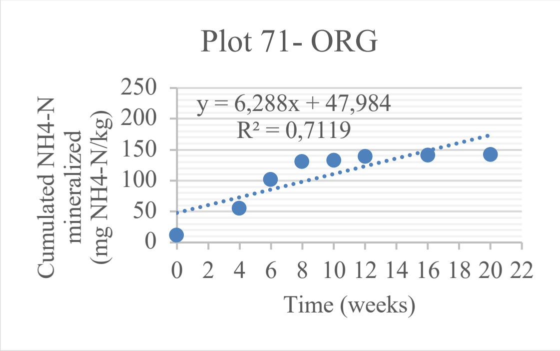


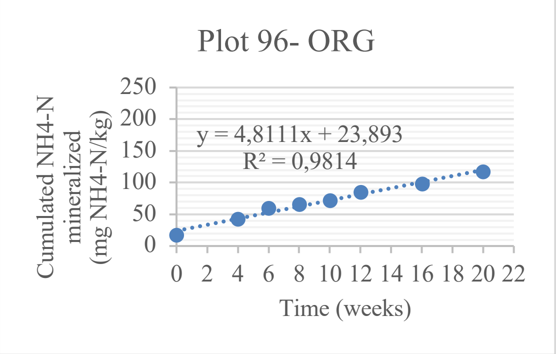


Treatment 6: Mechanical pruning, with fungicide and with organic fertilizer.

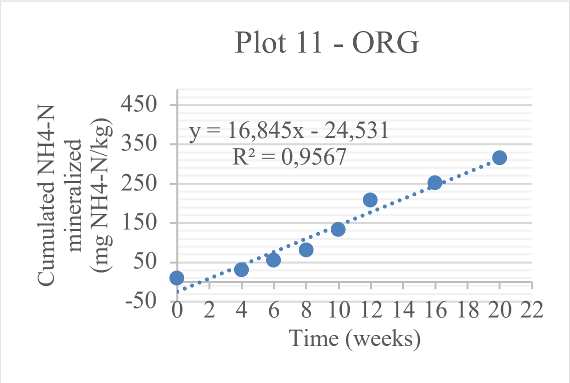


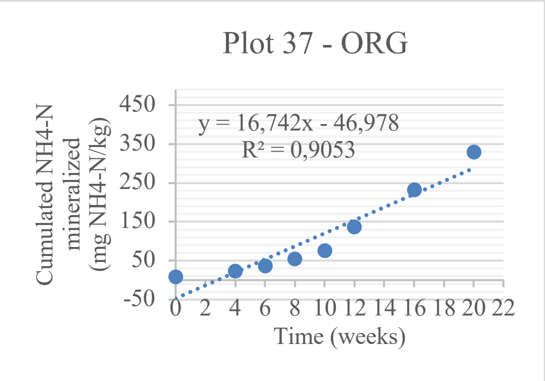


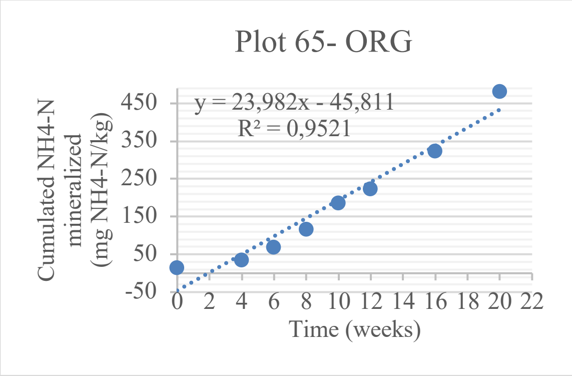


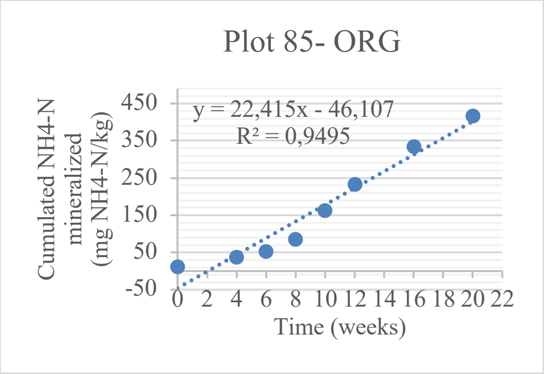


Treatment 7: Thermal and mechanical pruning, no fungicide and mineral fertilizer.

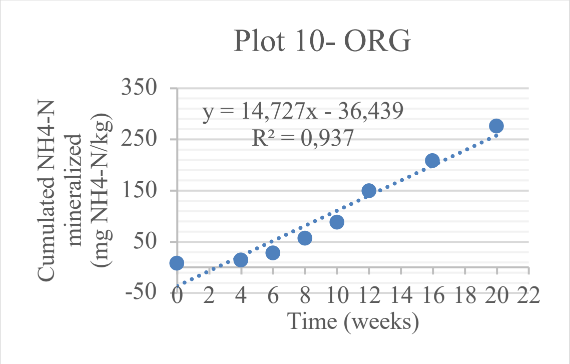


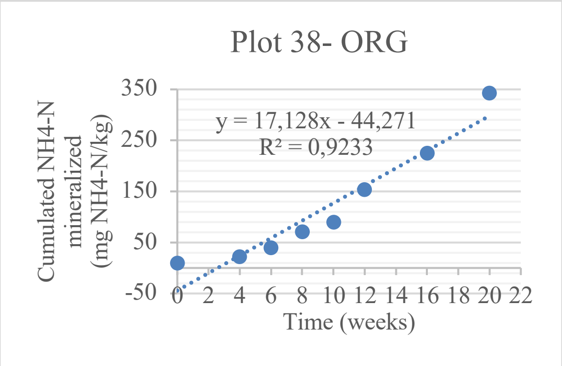


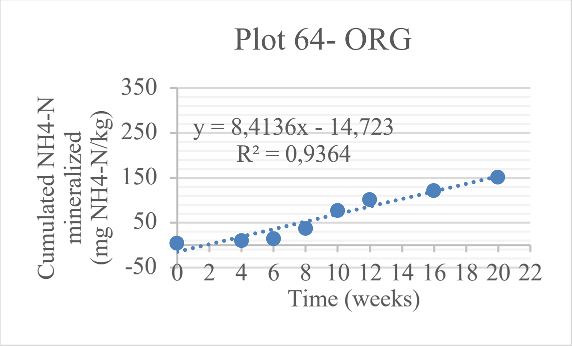


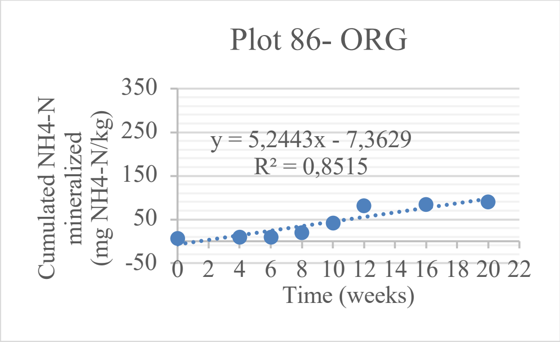


Treatment 8: Thermal and mechanical pruning, no fungicide and no fertilizer.

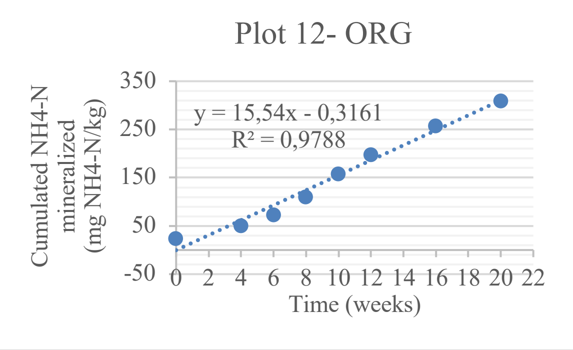


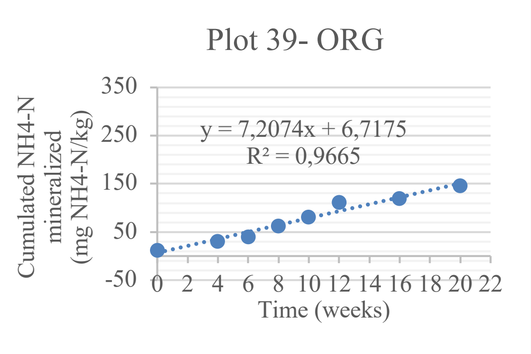


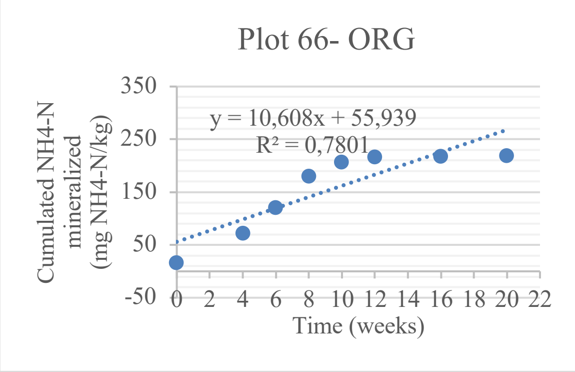


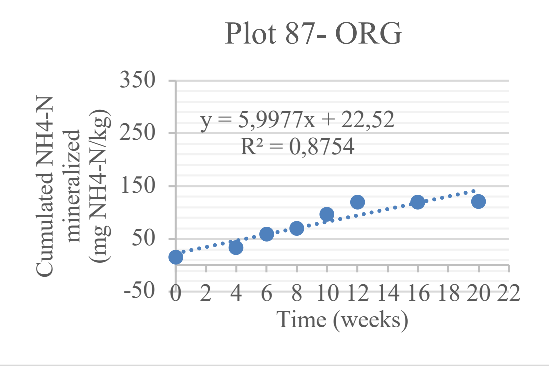


Treatment 9: Thermal and mechanical pruning, no fungicide and with organic fertilizer.

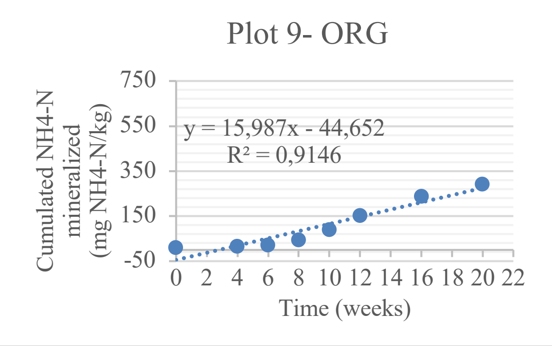


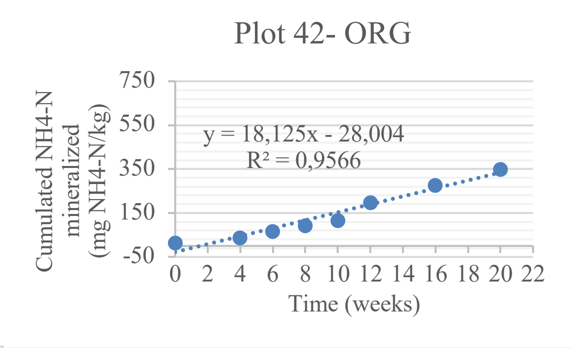


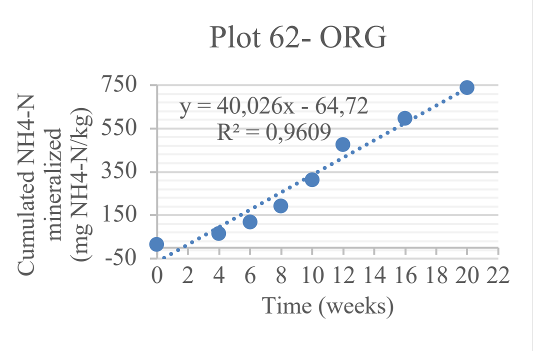


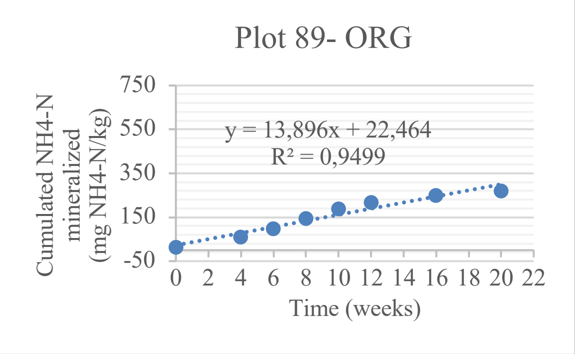


Treatment 10: Thermal and mechanical pruning, with fungicide and with mineral fertilizer.

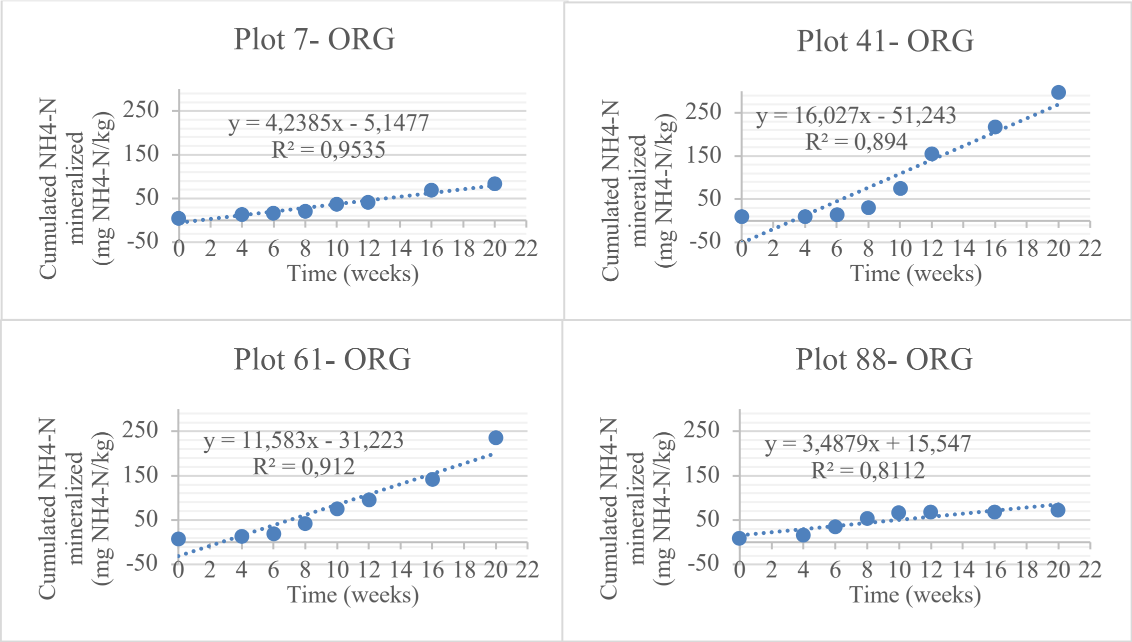




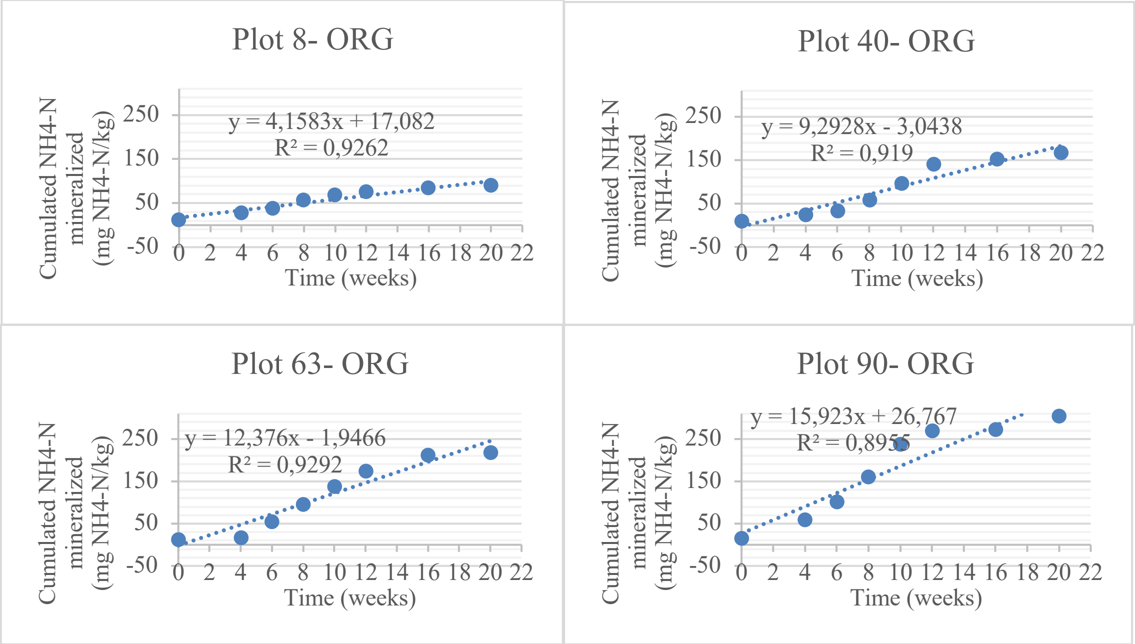




<u>Treatment 11:</u> Thermal and mechanical pruning, with fungicide and no fertilizer.



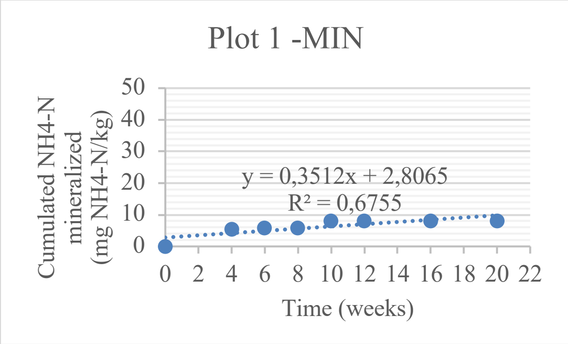
<u>Treatment 12:</u> Thermal and mechanical pruning, with fungicide and with organic fertilizer.

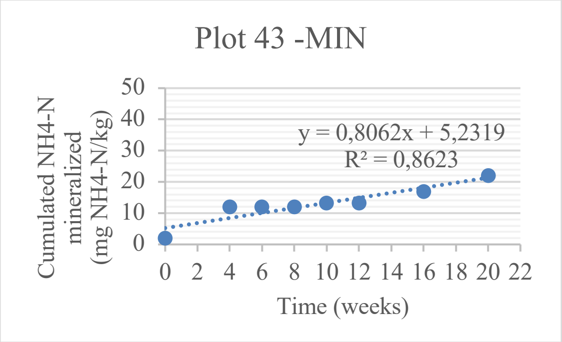


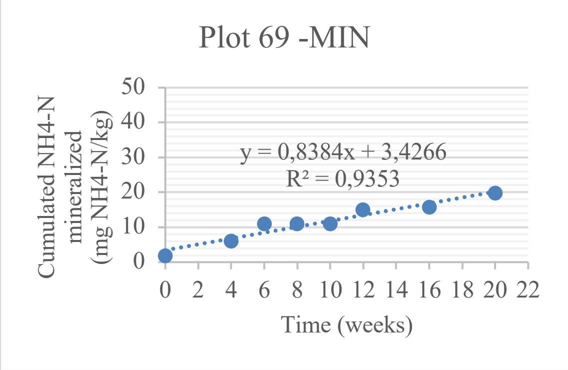
Appendix D. Curves of cumulated NH_4-N mineralized in the organic (ORG) layer during a 20-wk aerobic incubation according to different treatments (12 treatments). Each treatment consists of 4 plots (replicates). The NH_4-N mineralized during the first 2 wk was not use to make the curves as it represents the initial mineralization flux upon rewetting.

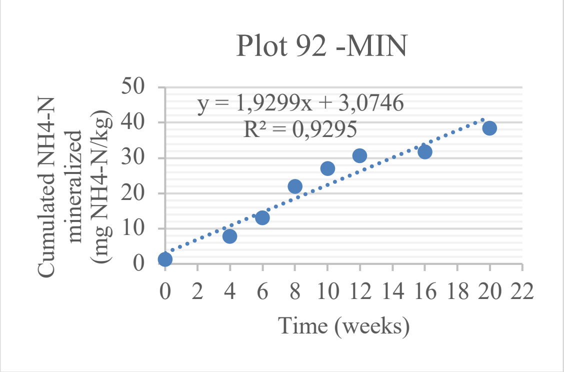
APPENDIX E. CURVES OF CUMULATED NH_4-N MINERALIZED IN THE MINERAL (MIN) LAYER DURING A 20-WK AEROBIC INCUBATION ACCORDING TO DIFFERENT TREATMENTS (12 TREATMENTS).

Treatment 1: Mechanical pruning, no fungicide and with mineral fertilizer.

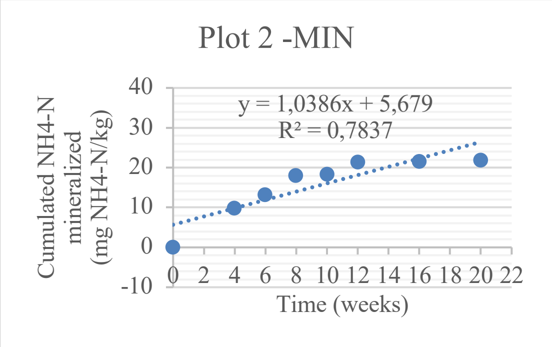


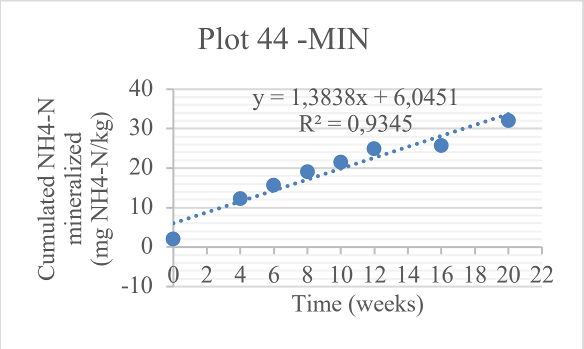


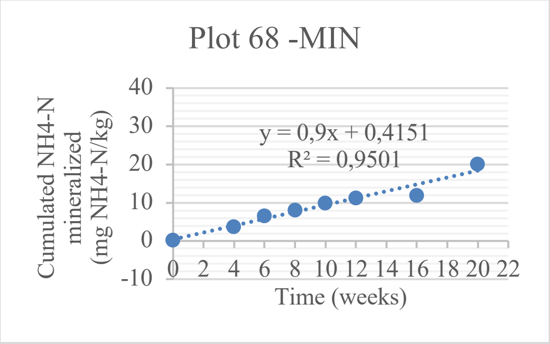


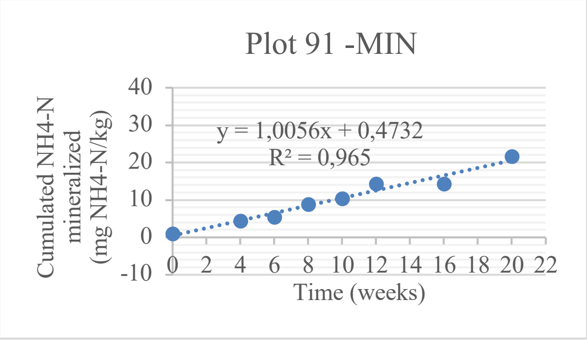


Treatment 2: Mechanical pruning, no fungicide and no fertilizer.

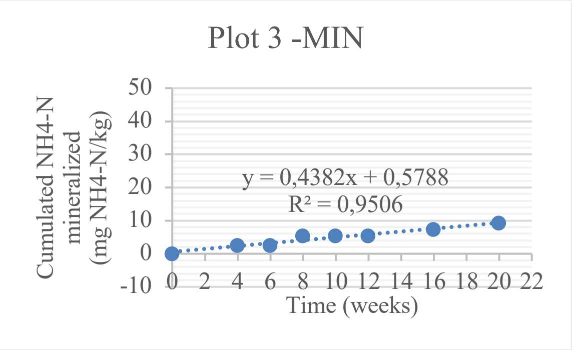


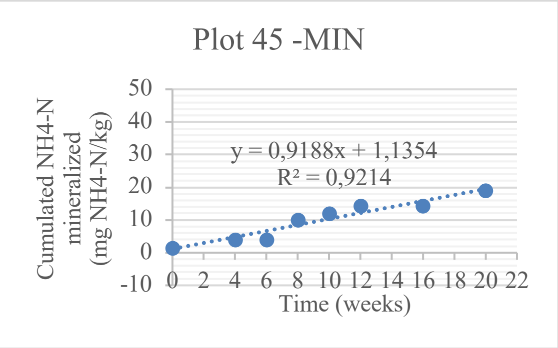


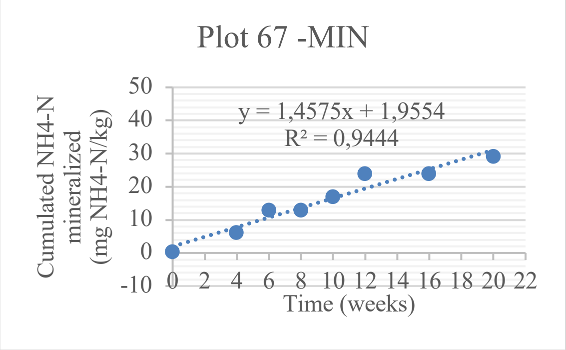


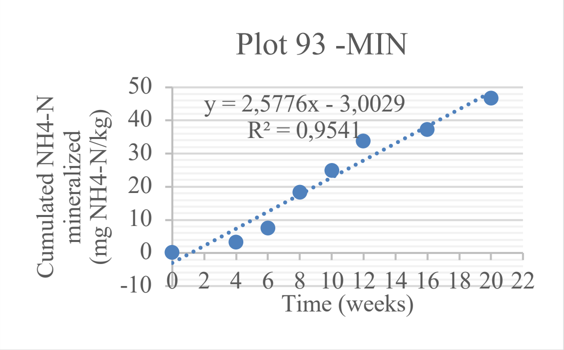


Treatment 3: Mechanical pruning, no fungicide and with organic fertilizer.

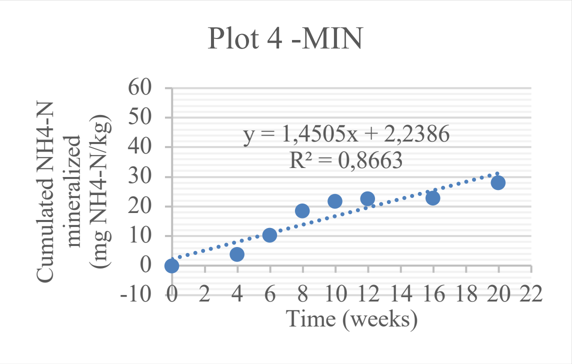


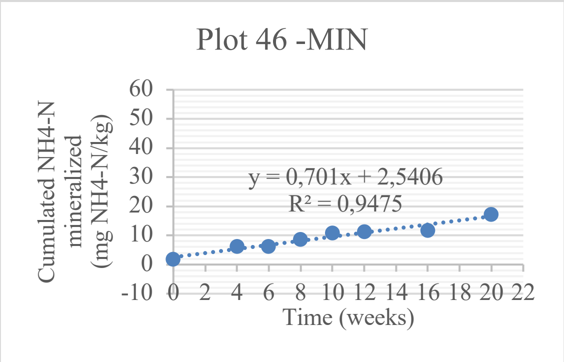


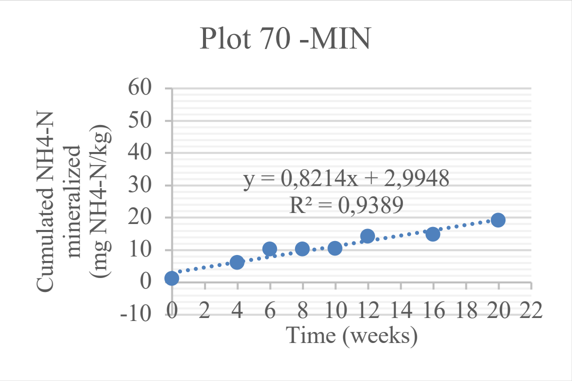


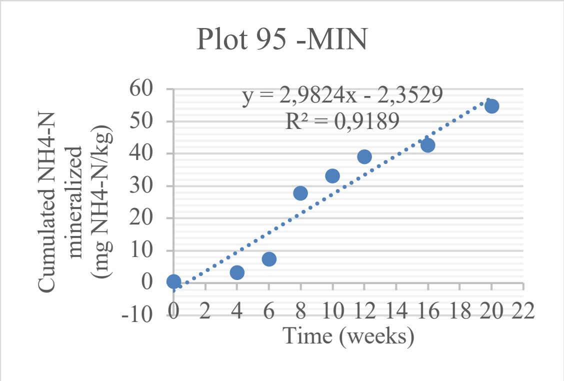


Treatment 4: Mechanical pruning, with fungicide and with mineral fertilizer.

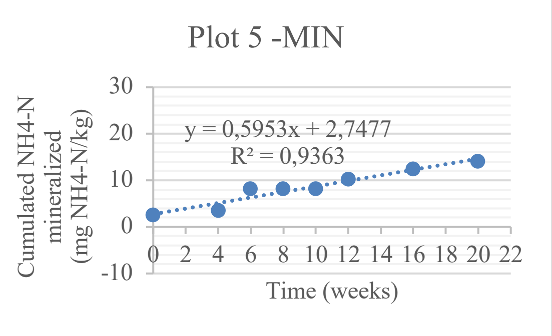


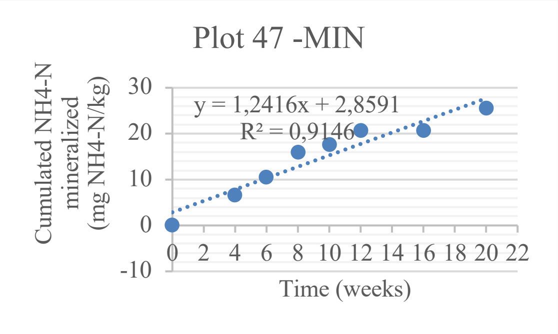


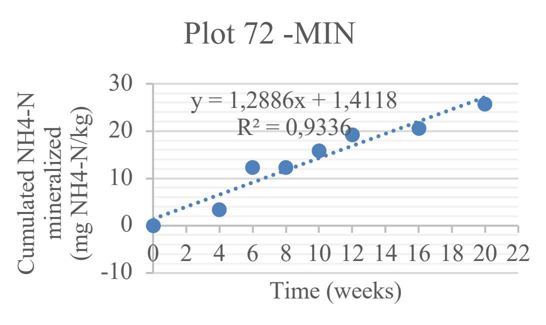


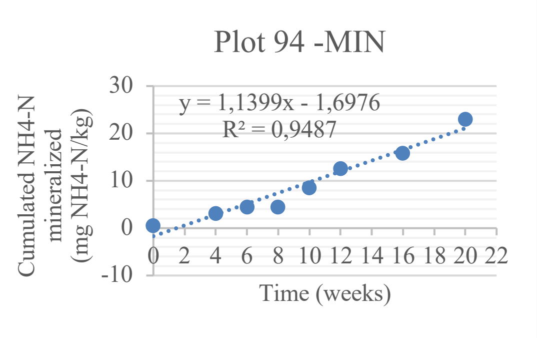


<u>Treatment 5:</u> Mechanical pruning, with fungicide and no fertilizer.

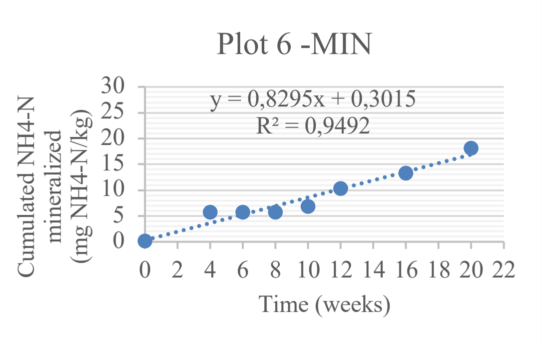


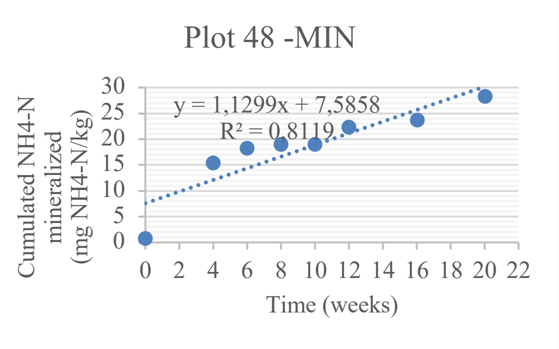


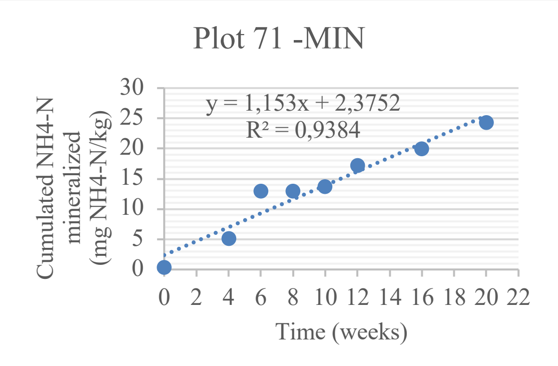


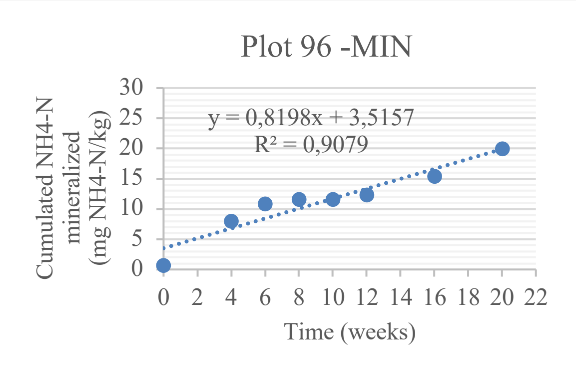


<u>Treatment 6</u>: Mechanical pruning, with fungicide and with organic fertilizer.

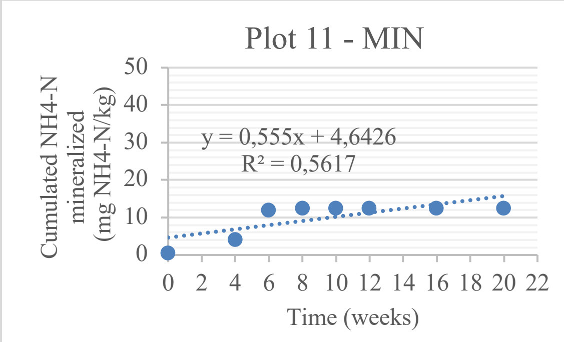


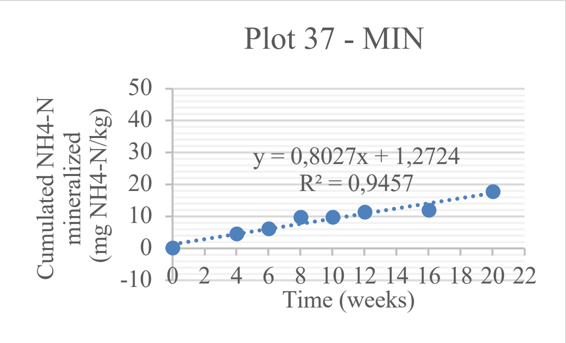


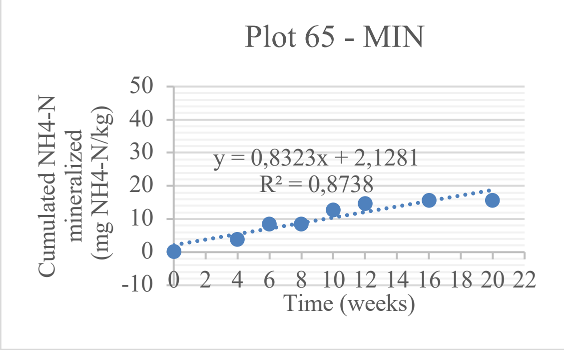


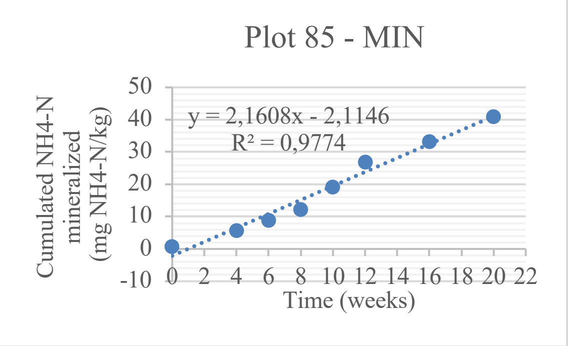


Treatment 7: Thermal and mechanical pruning, no fungicide and mineral fertilizer.

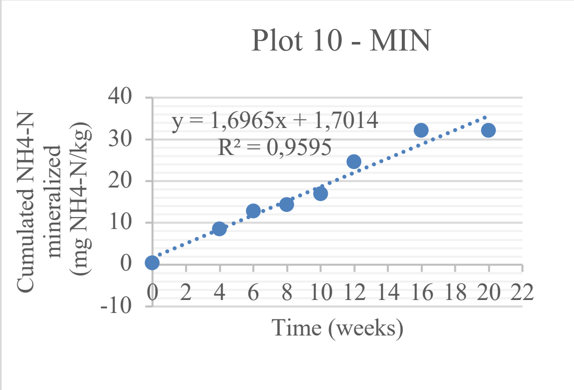


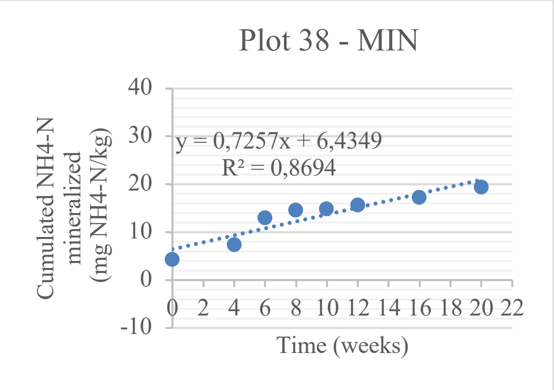


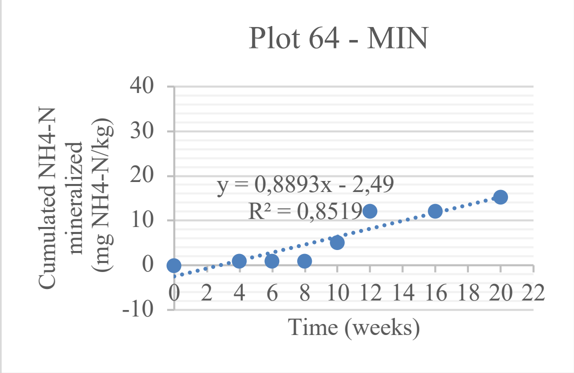


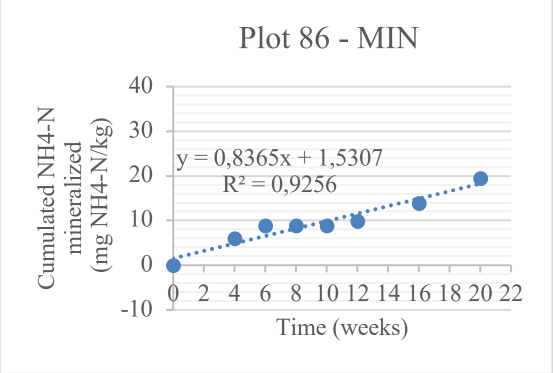


Treatment 8: Thermal and mechanical pruning, no fungicide and no fertilizer.

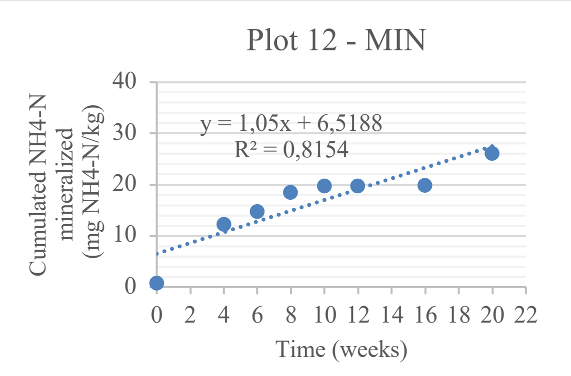


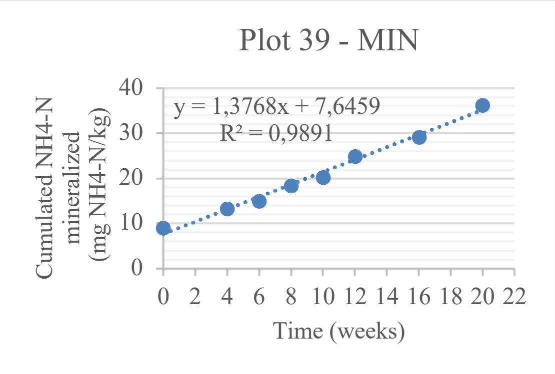


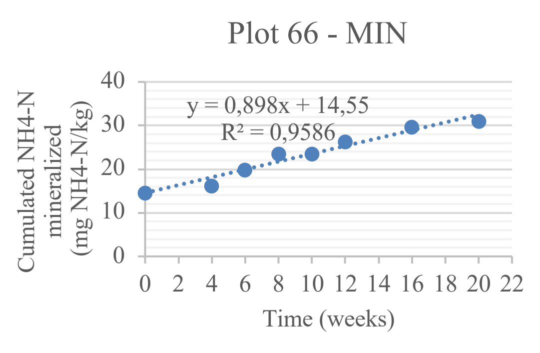


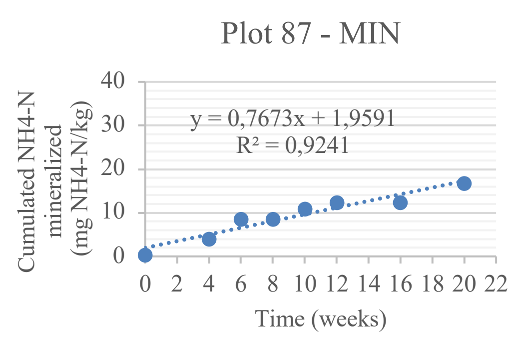


Treatment 9: Thermal and mechanical pruning, no fungicide and with organic fertilizer.

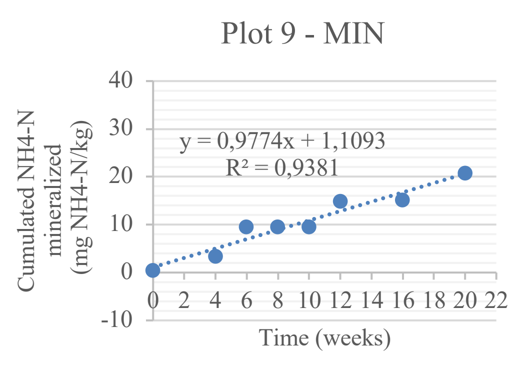


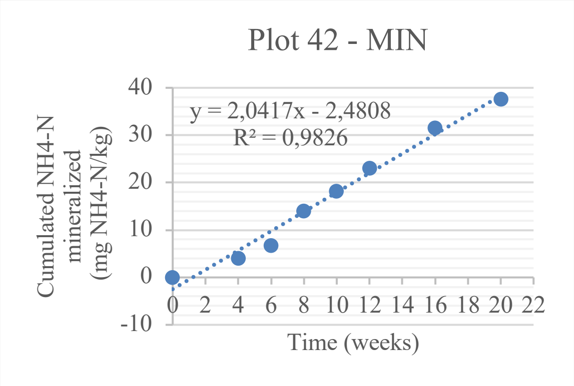


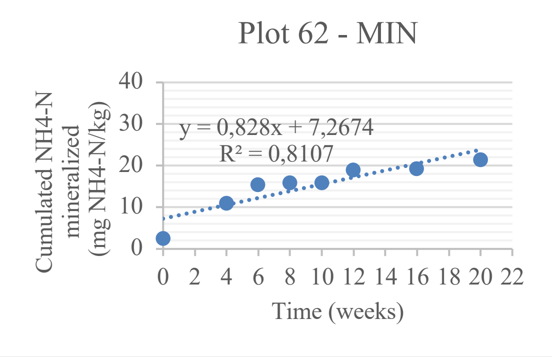


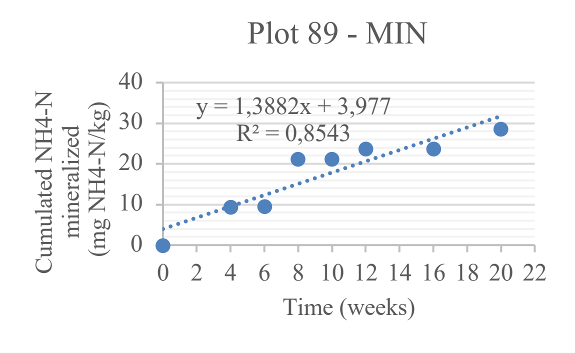


Treatment 10: Thermal and mechanical pruning, with fungicide and with mineral fertilizer.

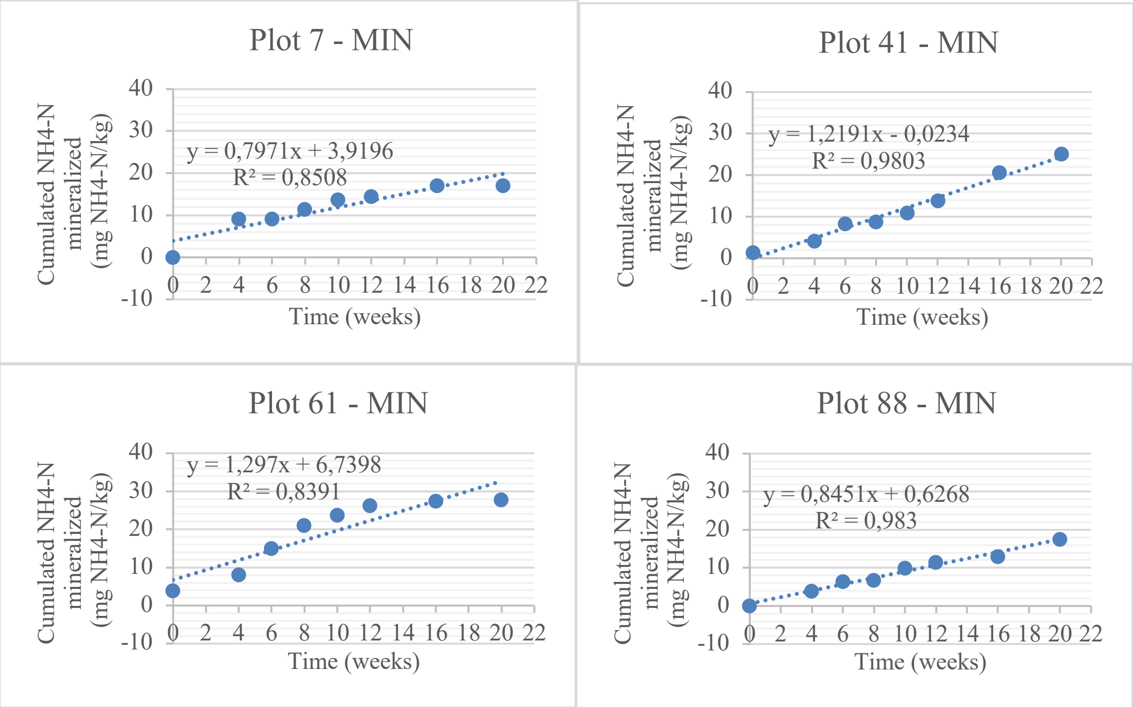




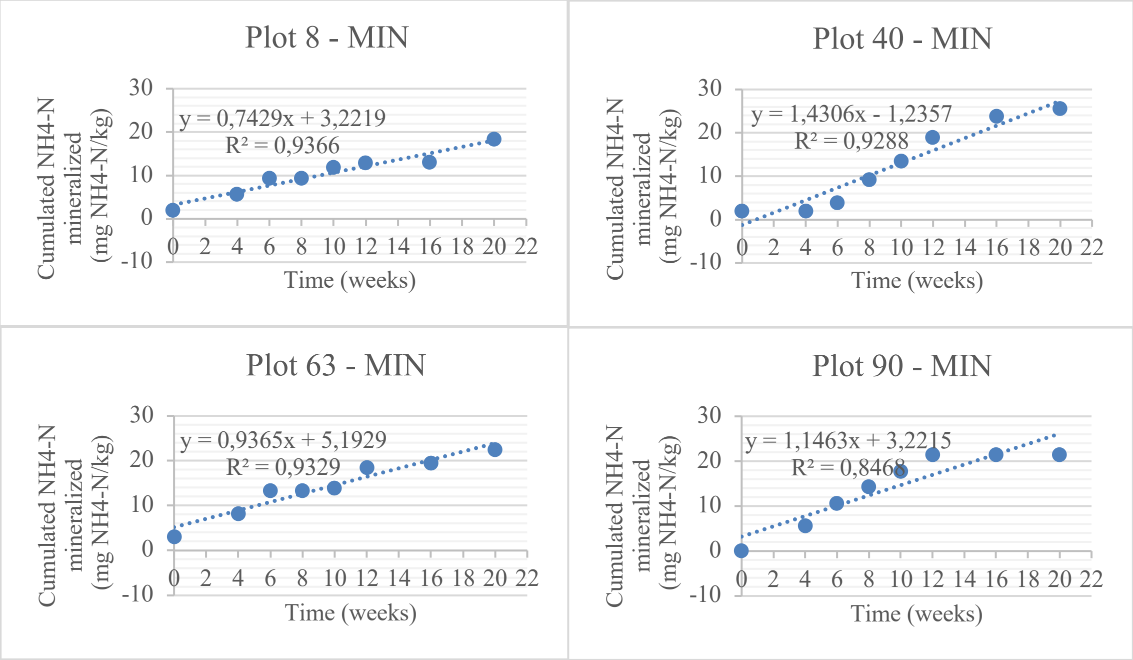




Treatment 11: Thermal and mechanical pruning, with fungicide and no fertilizer.



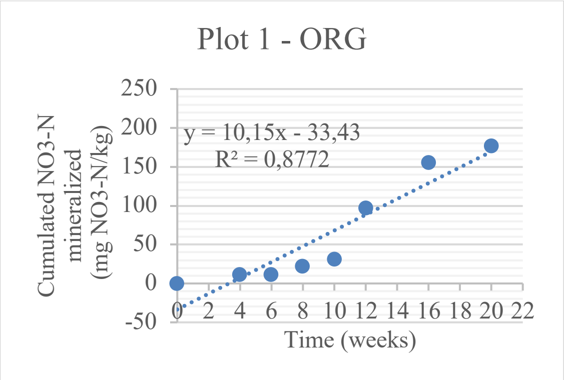
Treatment 12: Thermal and mechanical pruning, with fungicide and with organic fertilizer.

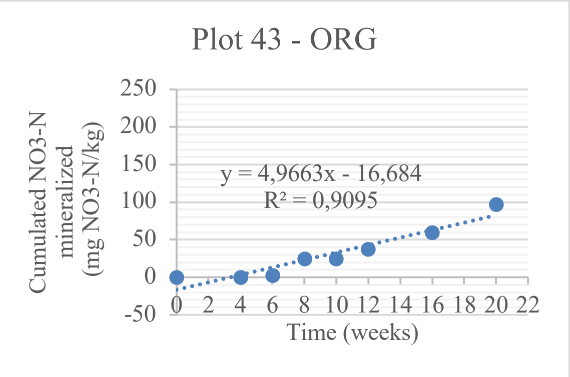


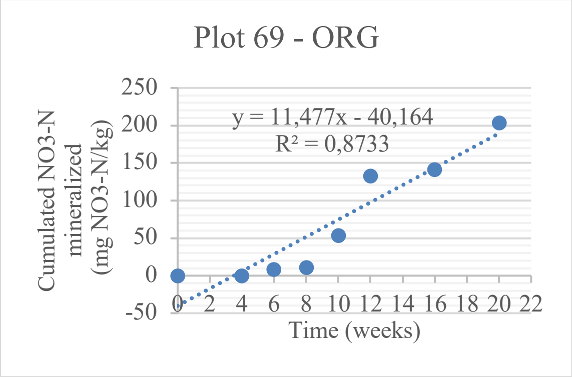
Appendix E. Curves of cumulated NH_4-N mineralized in the mineral (MIN) layer during a 20-wk aerobic incubation according to different treatments (12 treatments). Each treatment consists of 4 plots (replicates). The NH_4-N mineralized during the first 2 wk was not use to make the curves as it represents the initial mineralization flux upon rewetting.

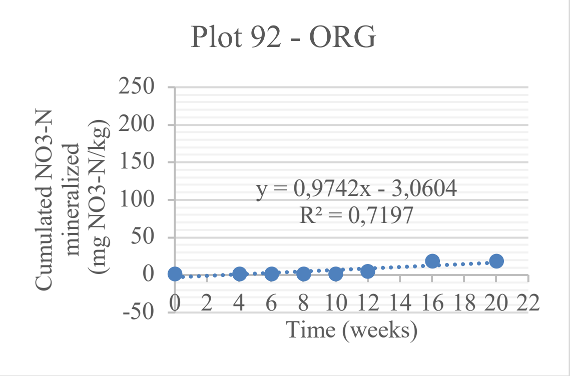
APPENDIX F. CURVES OF CUMULATED NO_3-N MINERALIZED IN THE ORGANIC (ORG) LAYER DURING A 20-WK AEROBIC INCUBATION ACCORDING TO DIFFERENT TREATMENTS (12 TREATMENTS).

<u>Treatment 1:</u> Mechanical pruning, no fungicide and with mineral fertilizer.

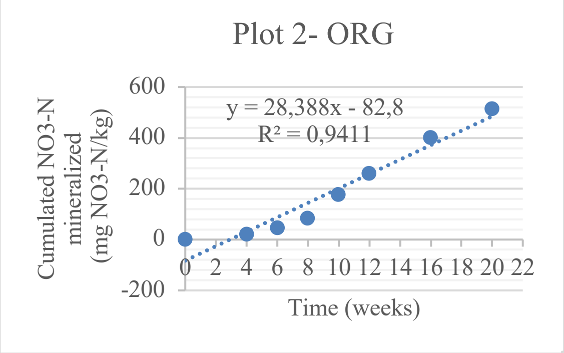


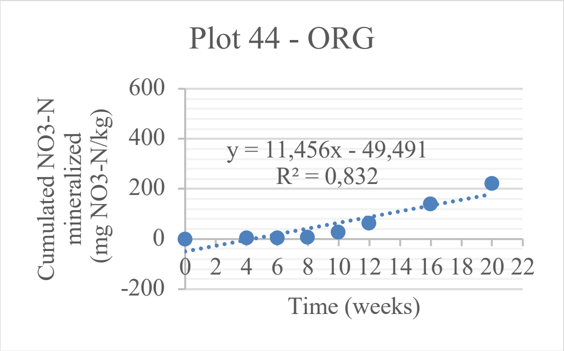


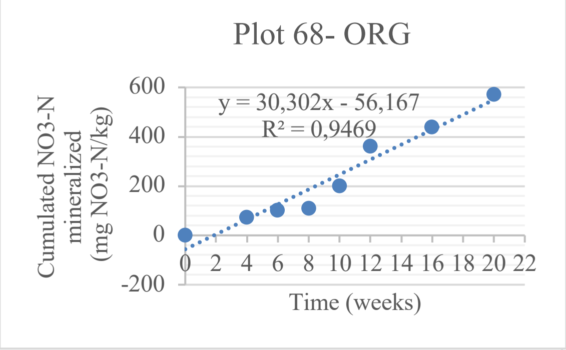


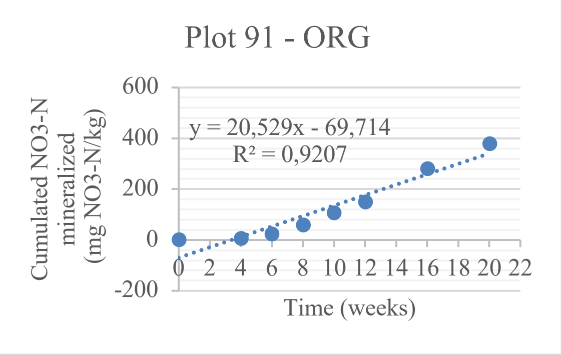


<u>Treatment 2:</u> Mechanical pruning, no fungicide and no fertilizer.

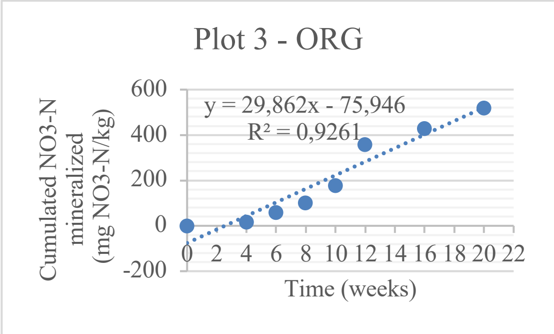


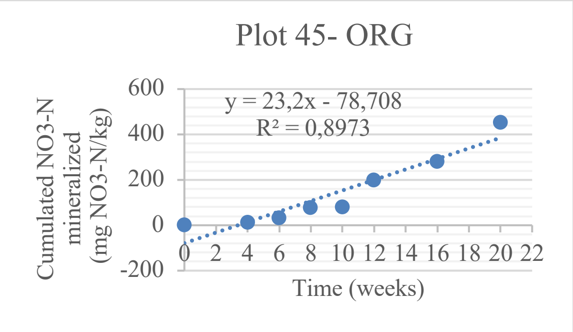


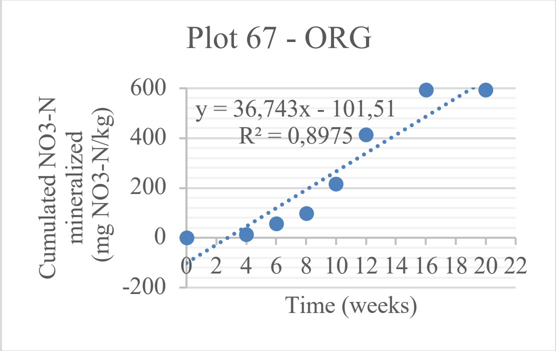


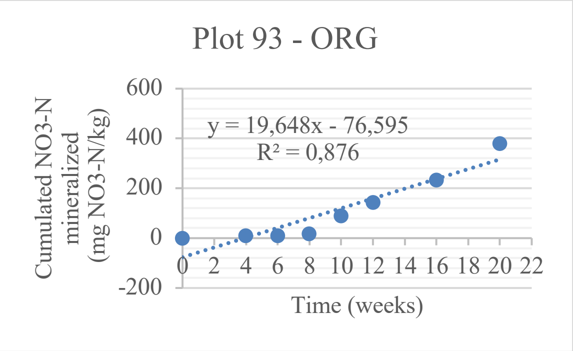


Treatment 3: Mechanical pruning, no fungicide and with organic fertilizer.

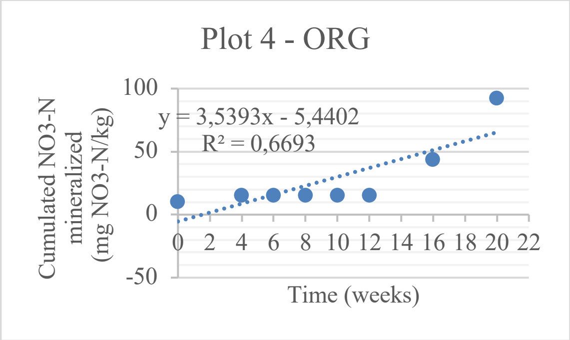


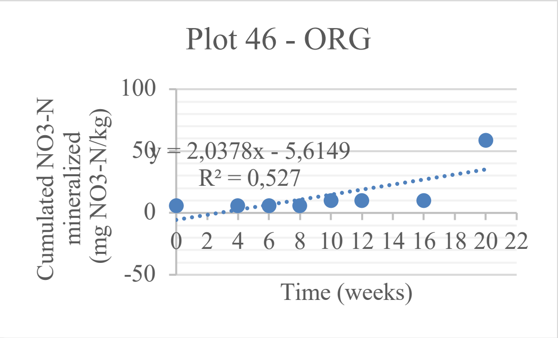


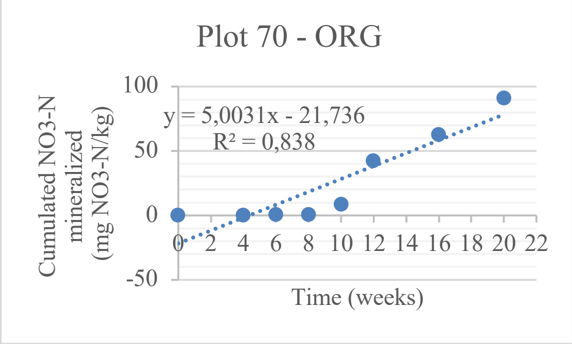


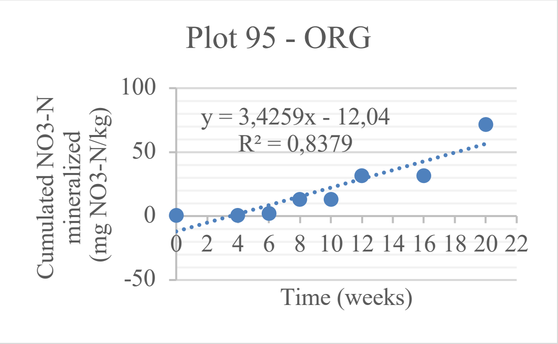


Treatment 4: Mechanical pruning, with fungicide and with mineral fertilizer.

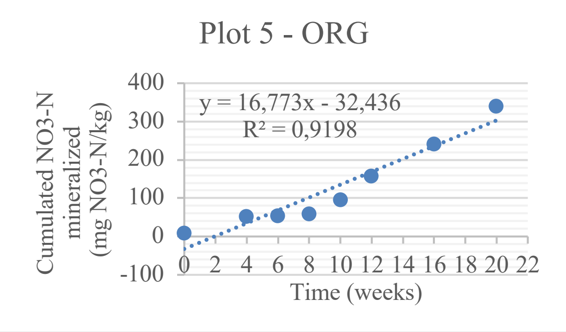


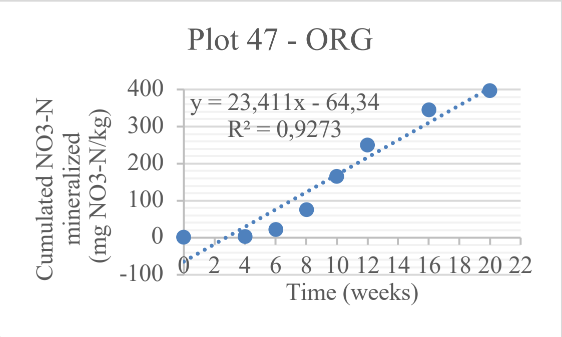


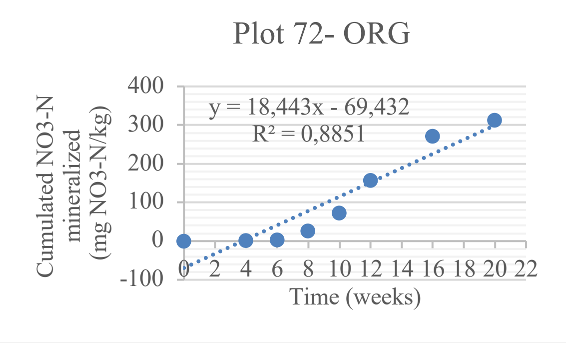


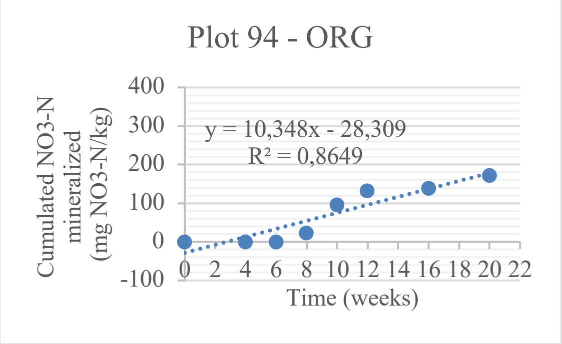


Treatment 5: Mechanical pruning, with fungicide and no fertilizer.

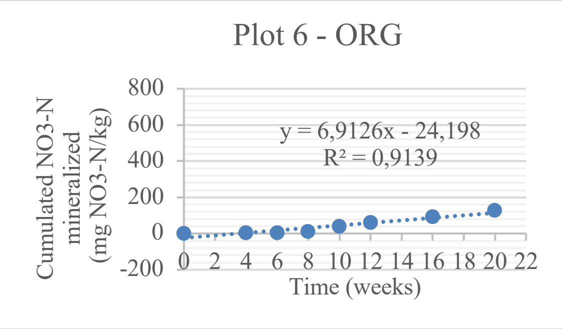


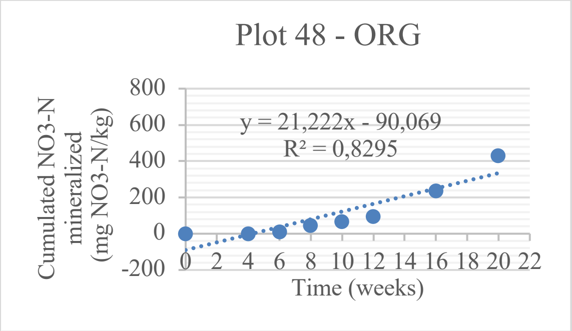


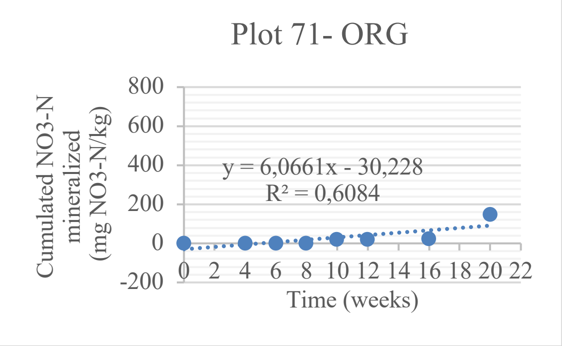


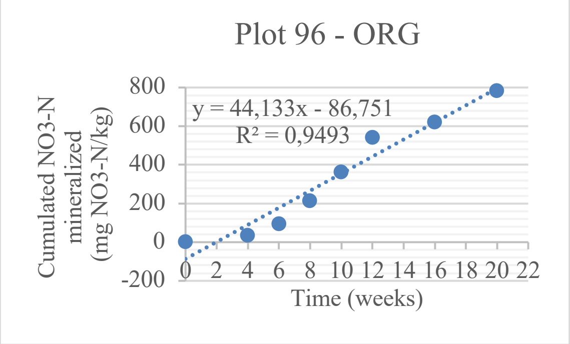


Treatment 6: Mechanical pruning, with fungicide and with organic fertilizer.

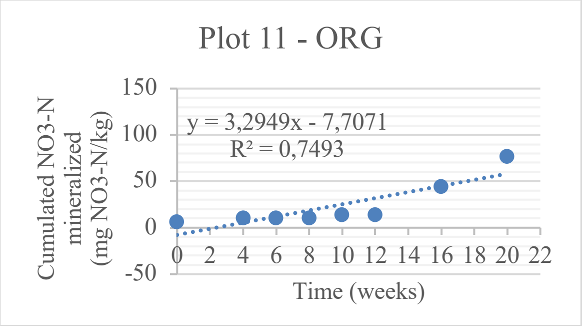


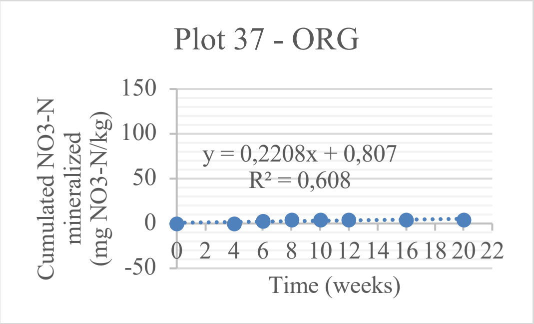


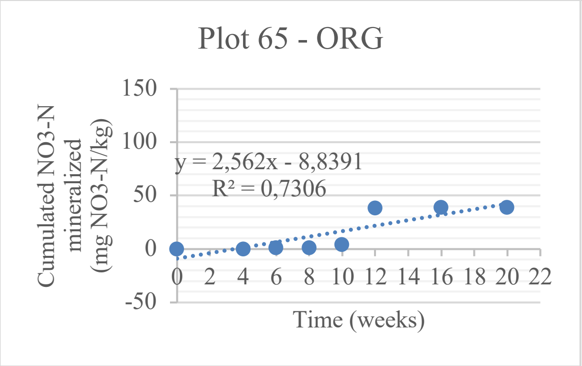


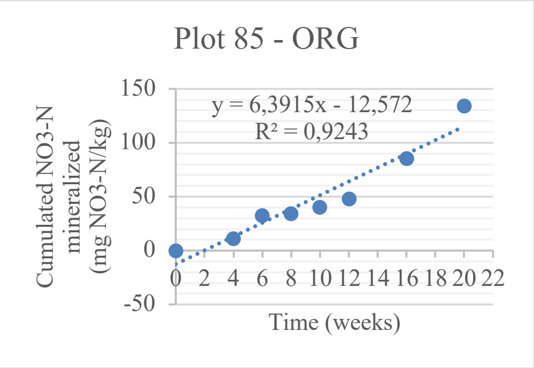


Treatment 7: Thermal and mechanical pruning, no fungicide and mineral fertilizer.

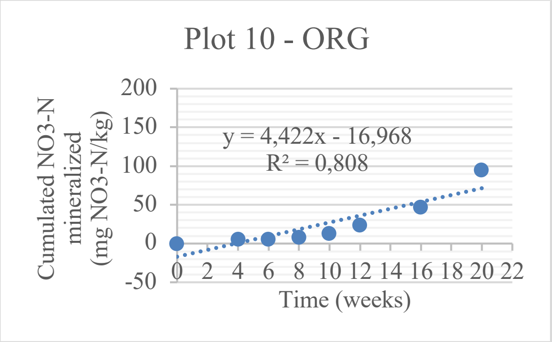

Plot 11 - ORG

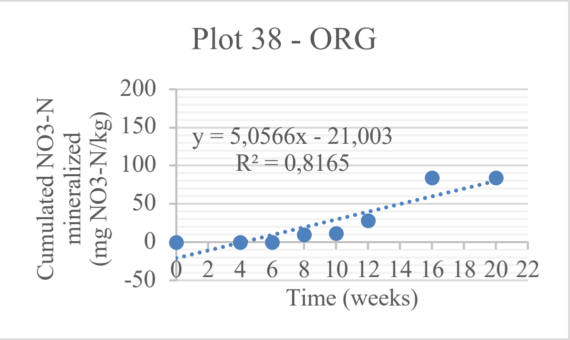

Plot 37 - ORG

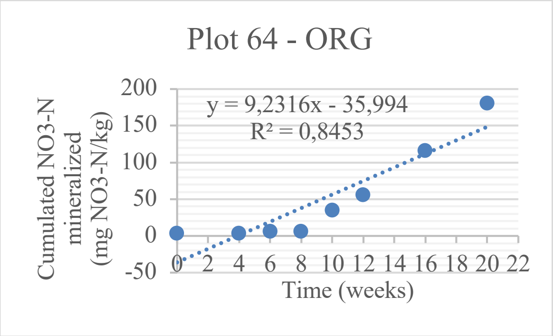

Plot 65 - ORG

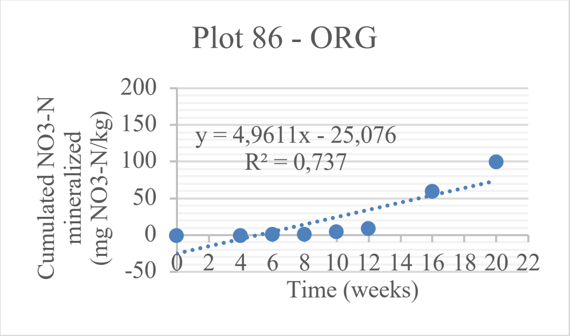

Plot 85 - ORG

Treatment 8: Thermal and mechanical pruning, no fungicide and no fertilizer.

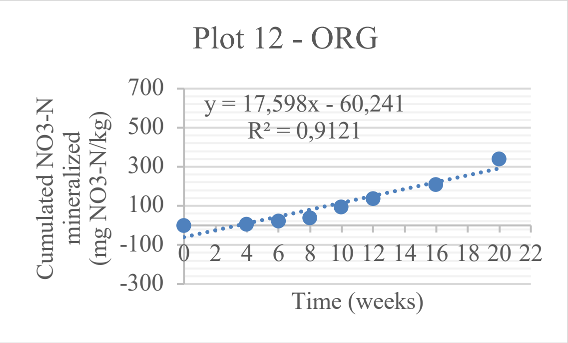

Plot 10 - ORG

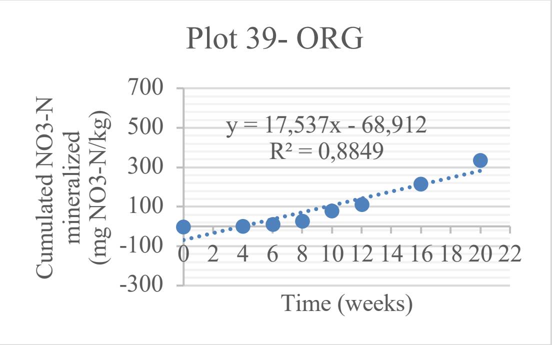

Plot 38 - ORG

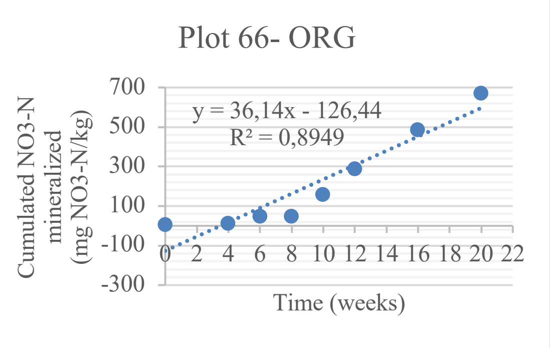

Plot 64 - ORG

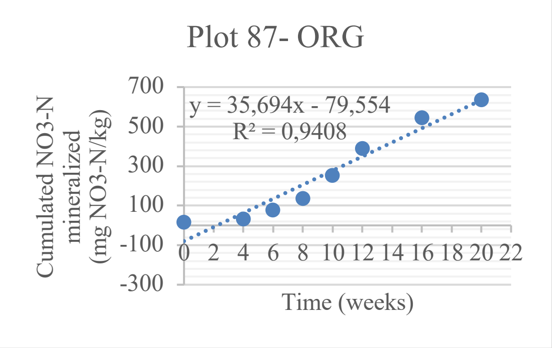

Plot 86 - ORG

Treatment 9: Thermal and mechanical pruning, no fungicide and with organic fertilizer.

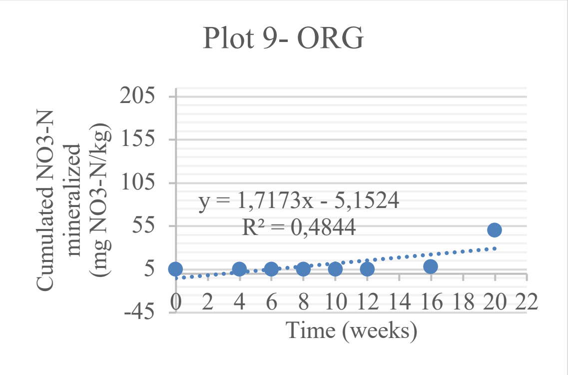


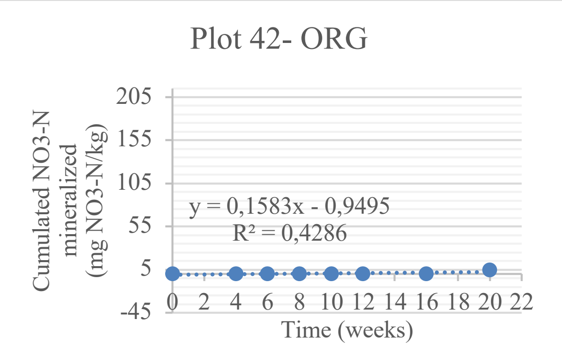


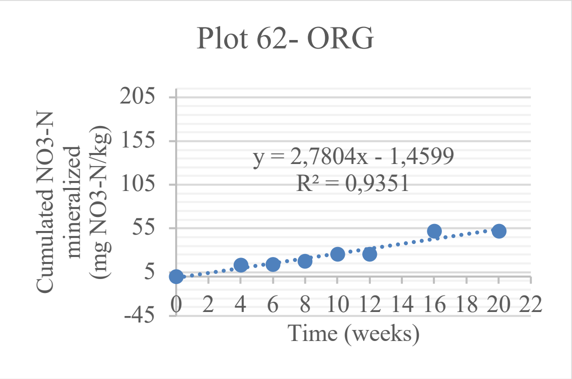


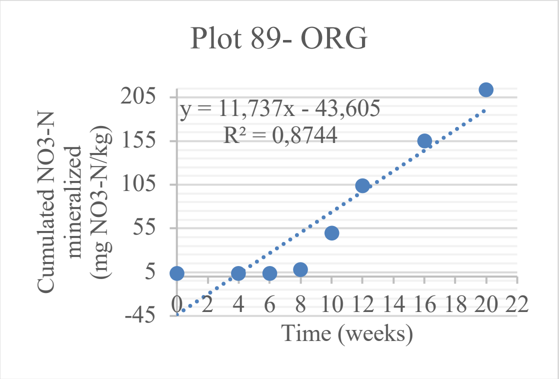


Treatment 10: Thermal and mechanical pruning, with fungicide and with mineral fertilizer.

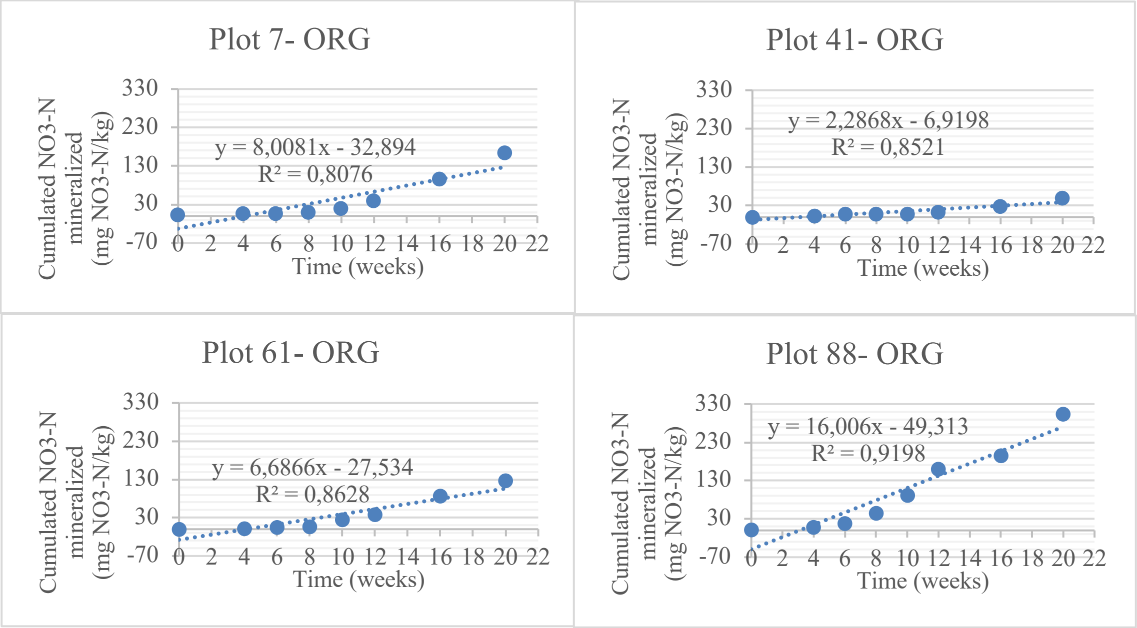




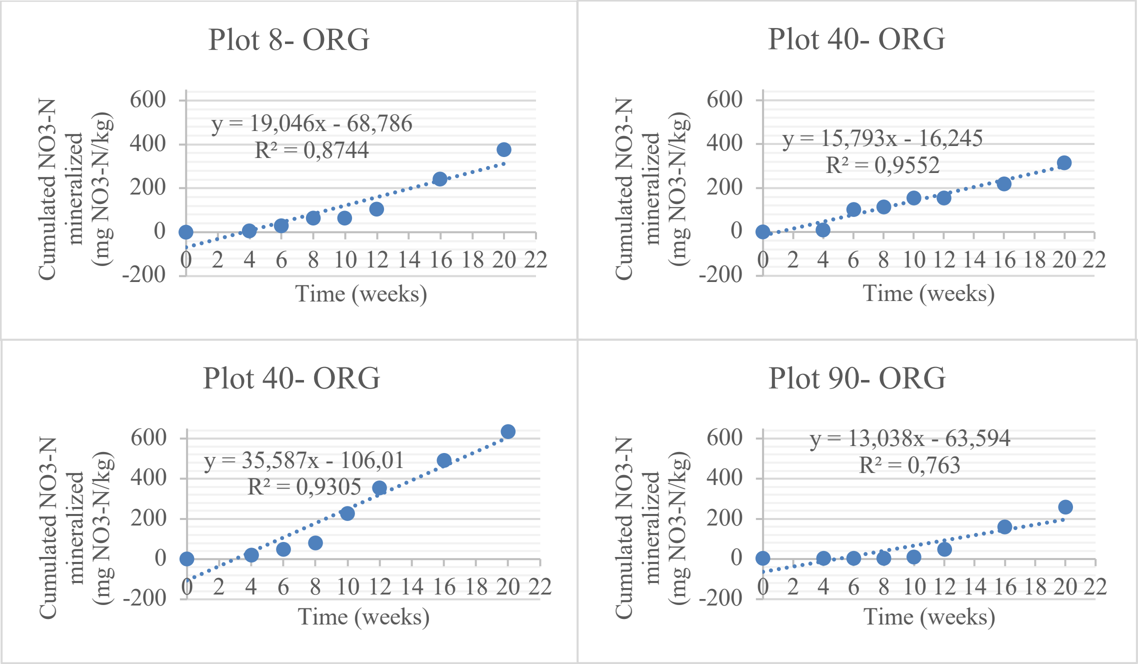




Treatment 11: Thermal and mechanical pruning, with fungicide and no fertilizer.



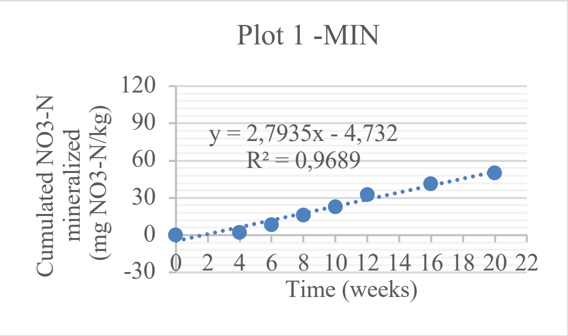
Treatment 12: Thermal and mechanical pruning, with fungicide and with organic fertilizer.

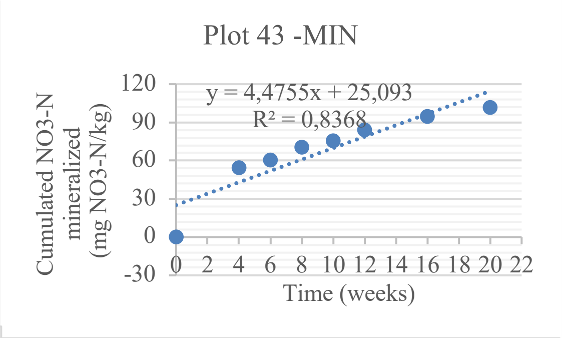


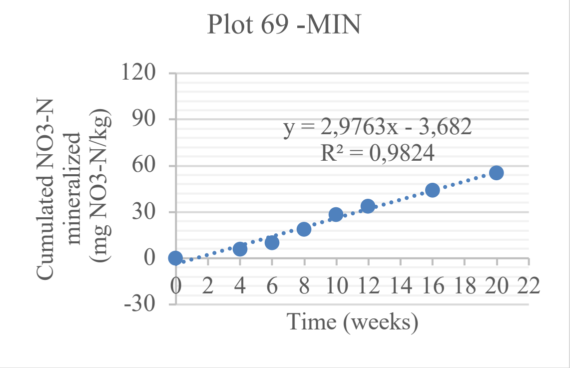
Appendix F. Curves of cumulated NO_3-N mineralized in the organic (ORG) layer during a 20-wk aerobic incubation according to different treatments (12 treatments). Each treatment consists of 4 plots (replicates). The NO_3-N mineralized during the first 2 wk was not use to make the curves as it represents the initial mineralization flux upon rewetting.

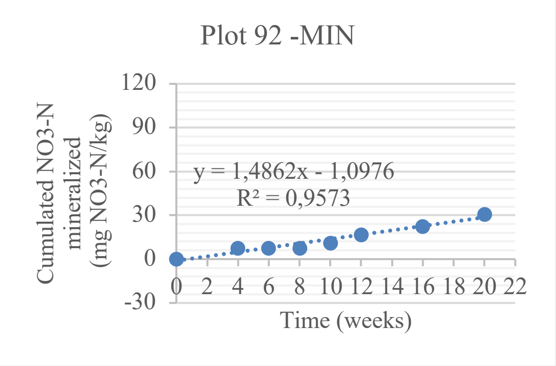
APPENDIX G. CURVES OF CUMULATED NO_3-N MINERALIZED IN THE MINERAL (MIN) LAYER DURING A 20-WK AEROBIC INCUBATION ACCORDING TO DIFFERENT TREATMENTS (12 TREATMENTS).

Treatment 1: Mechanical pruning, no fungicide and with mineral fertilizer.

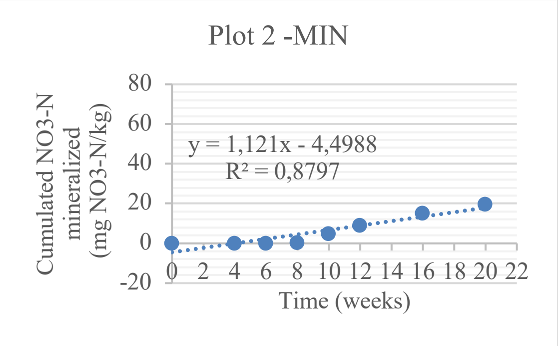


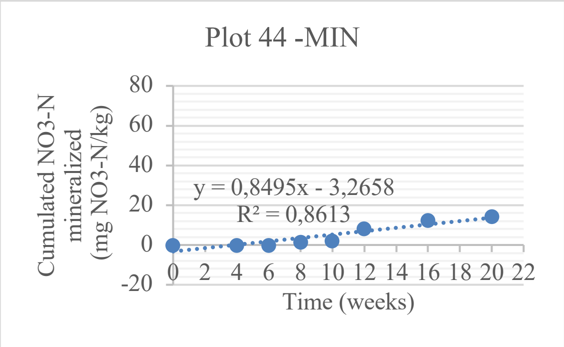


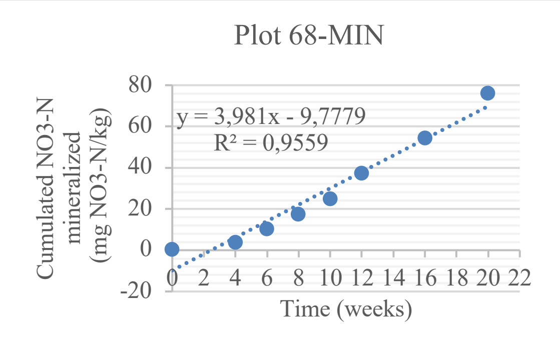


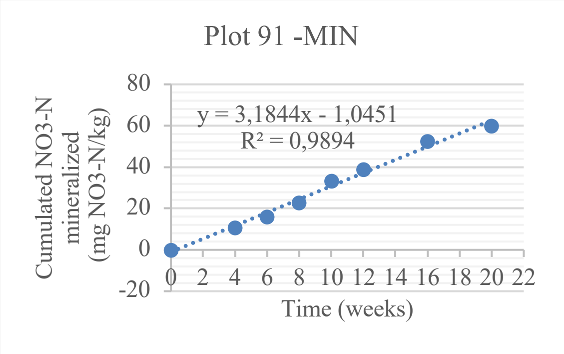


Treatment 2: Mechanical pruning, no fungicide and no fertilizer.

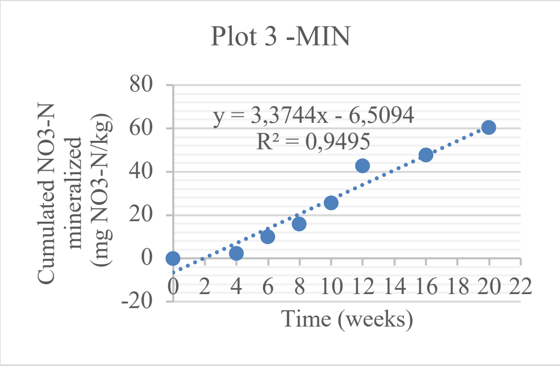


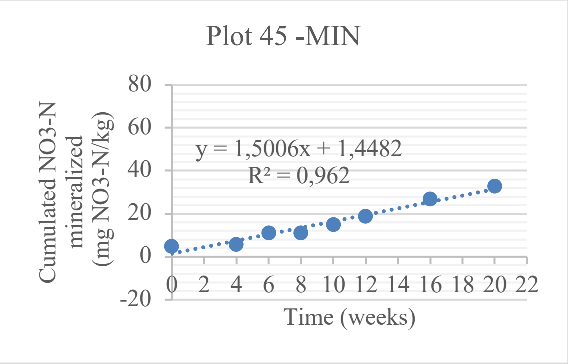


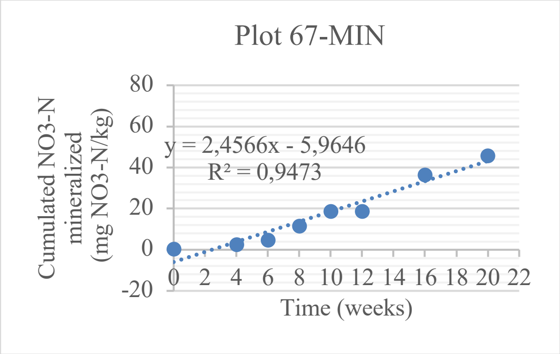


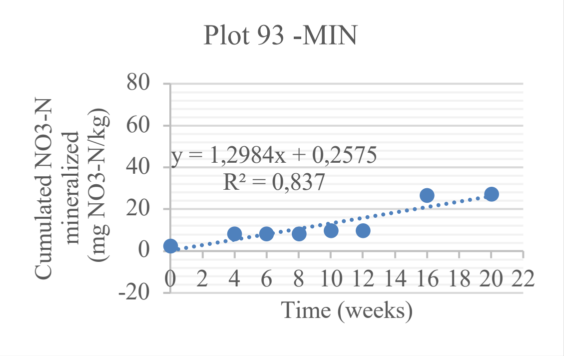


Treatment 3: Mechanical pruning, no fungicide and with organic fertilizer.

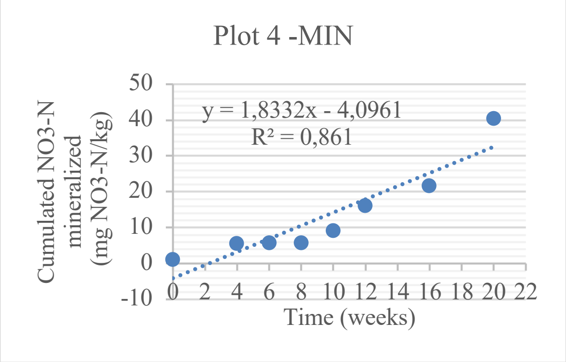


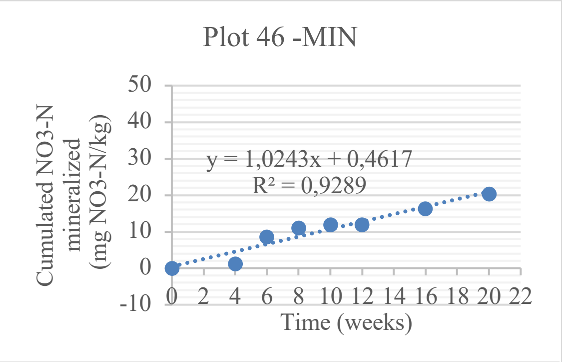


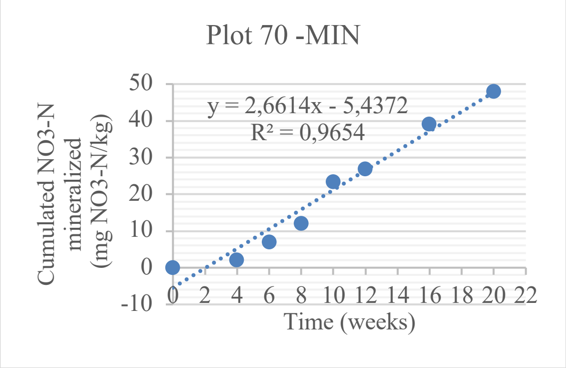


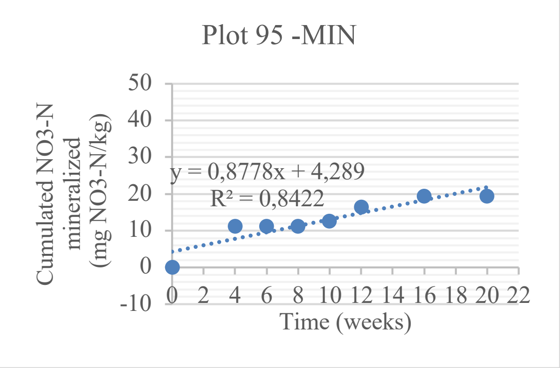


Treatment 4: Mechanical pruning, with fungicide and with mineral fertilizer.

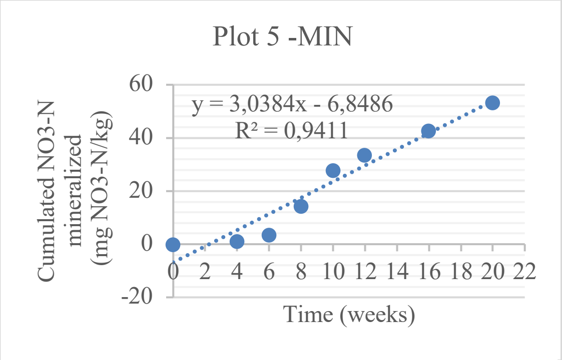


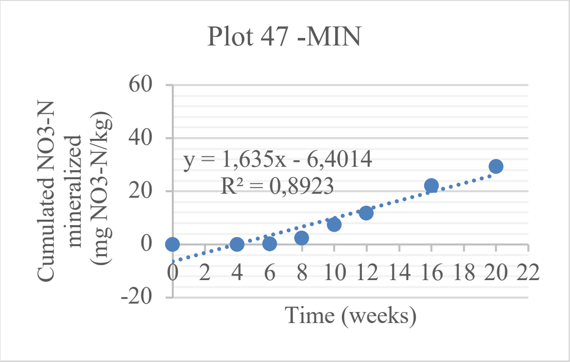


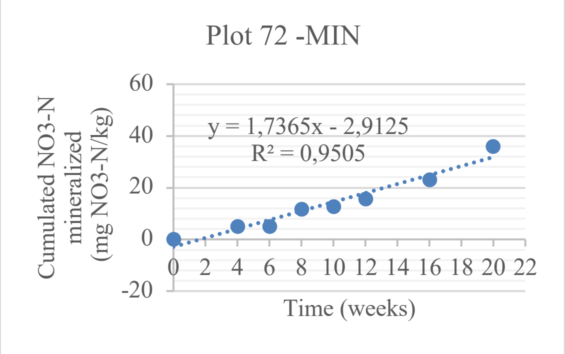


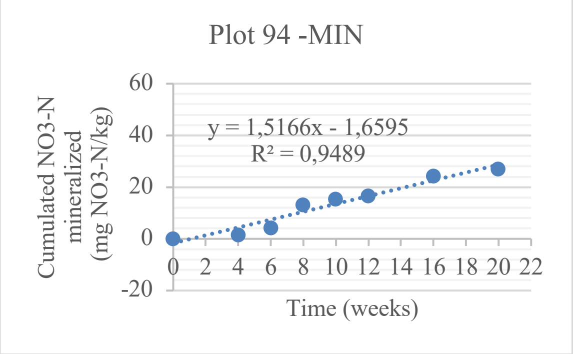


Treatment 5: Mechanical pruning, with fungicide and no fertilizer.

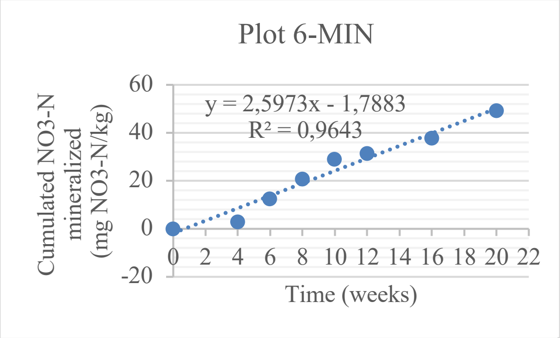


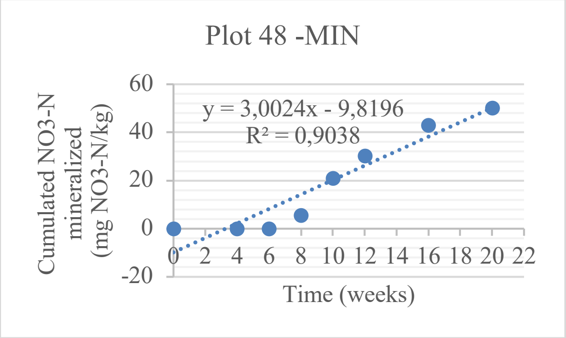


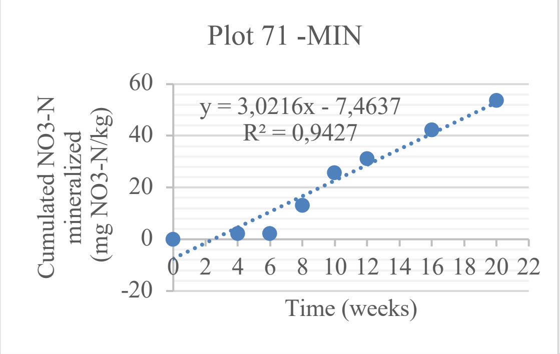


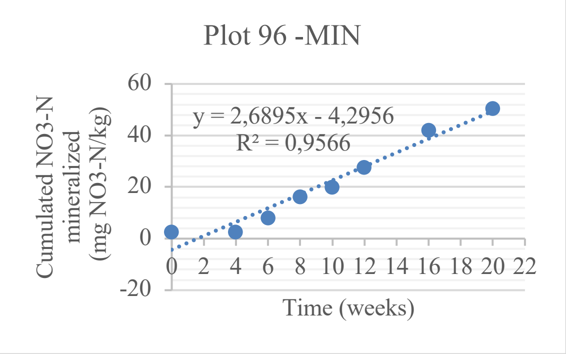


Treatment 6: Mechanical pruning, with fungicide and with organic fertilizer.

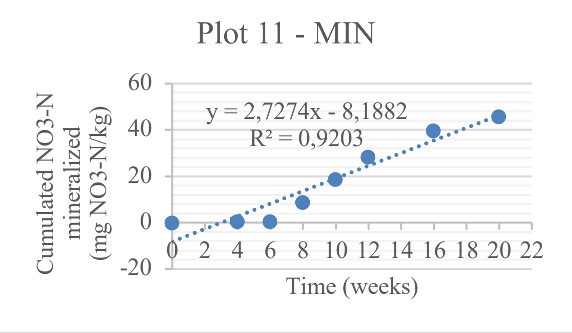


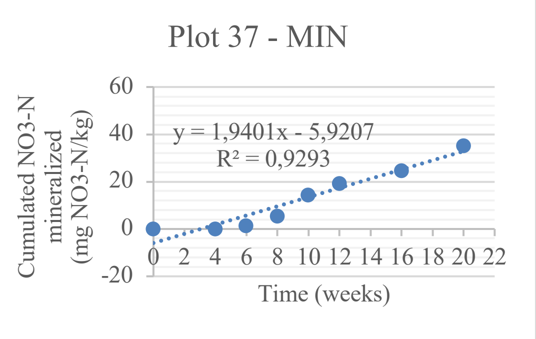


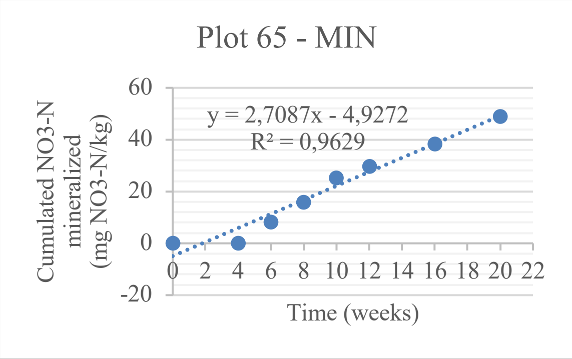


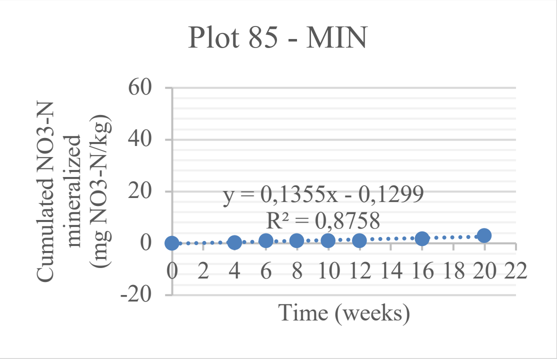


Treatment 7: Thermal and mechanical pruning, no fungicide and mineral fertilizer.

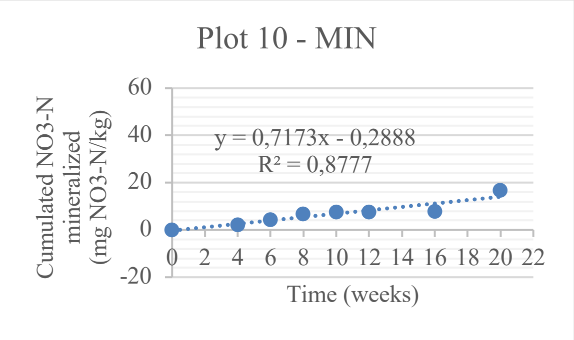


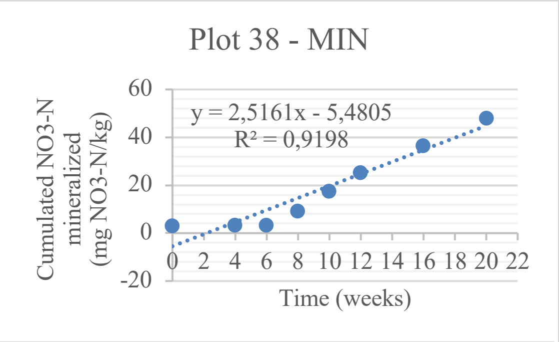


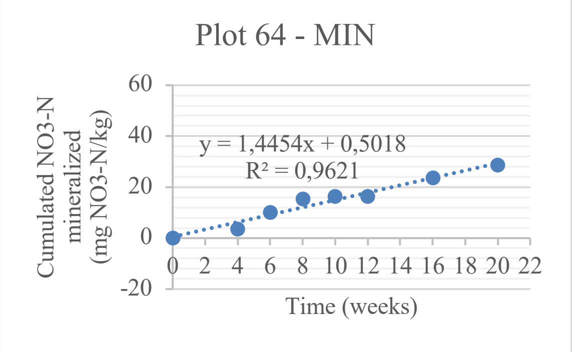


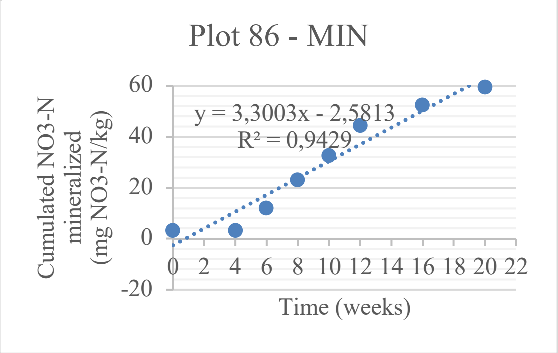


Treatment 8: Thermal and mechanical pruning, no fungicide and no fertilizer.

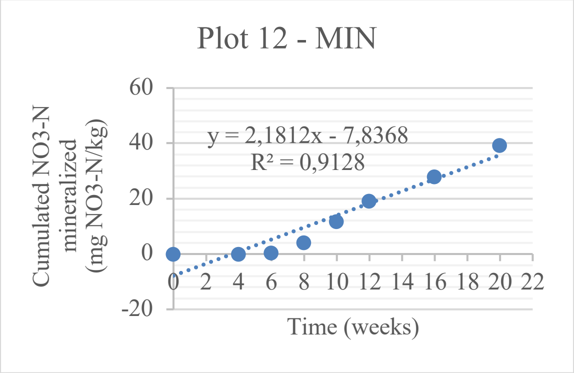


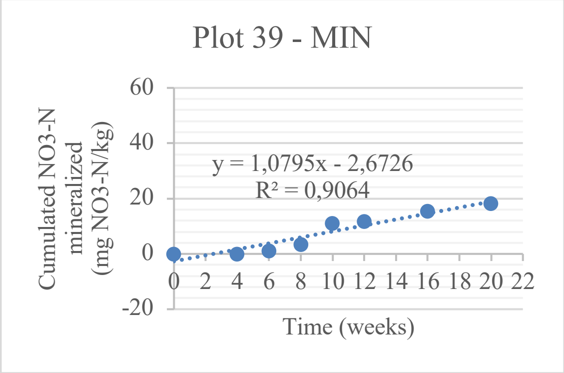


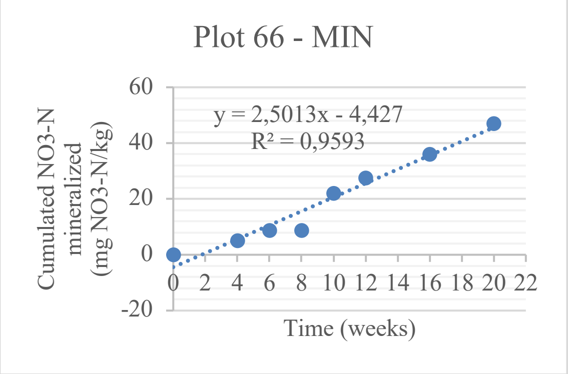


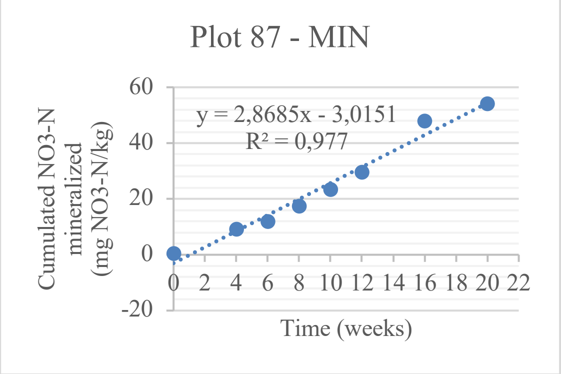


<u>Treatment 9:</u> Thermal and mechanical pruning, no fungicide and with organic fertilizer.

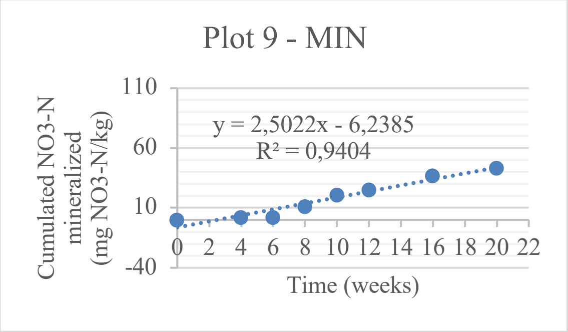


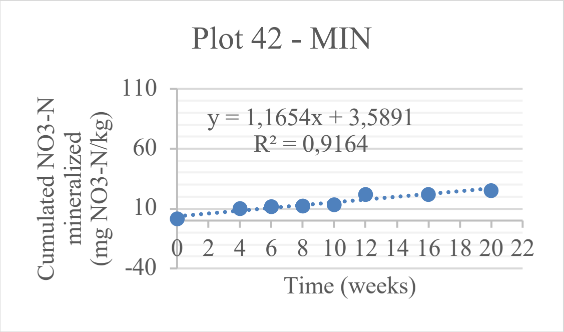


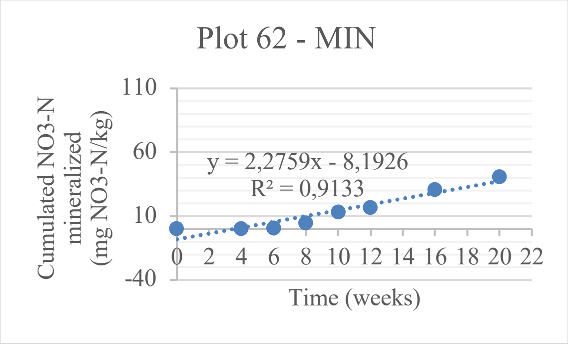


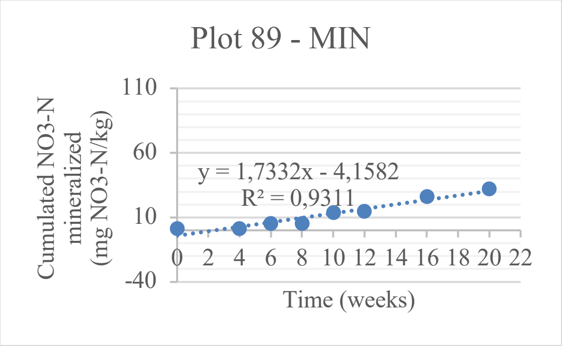


<u>Treatment 10:</u> Thermal and mechanical pruning, with fungicide and with mineral fertilizer.

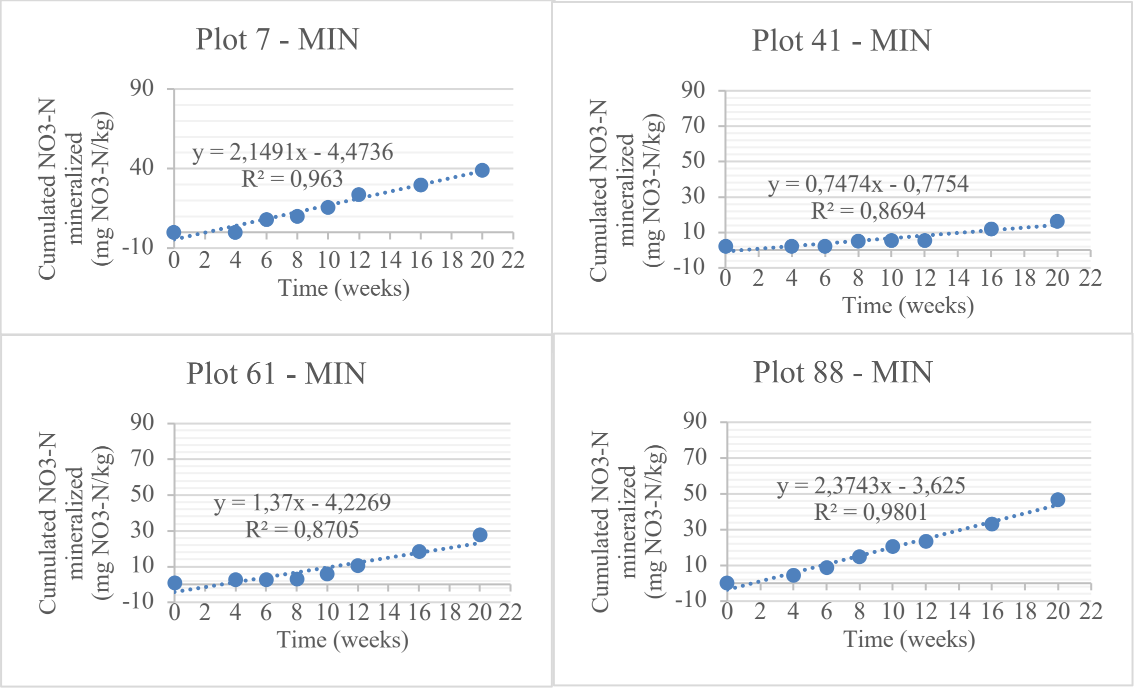




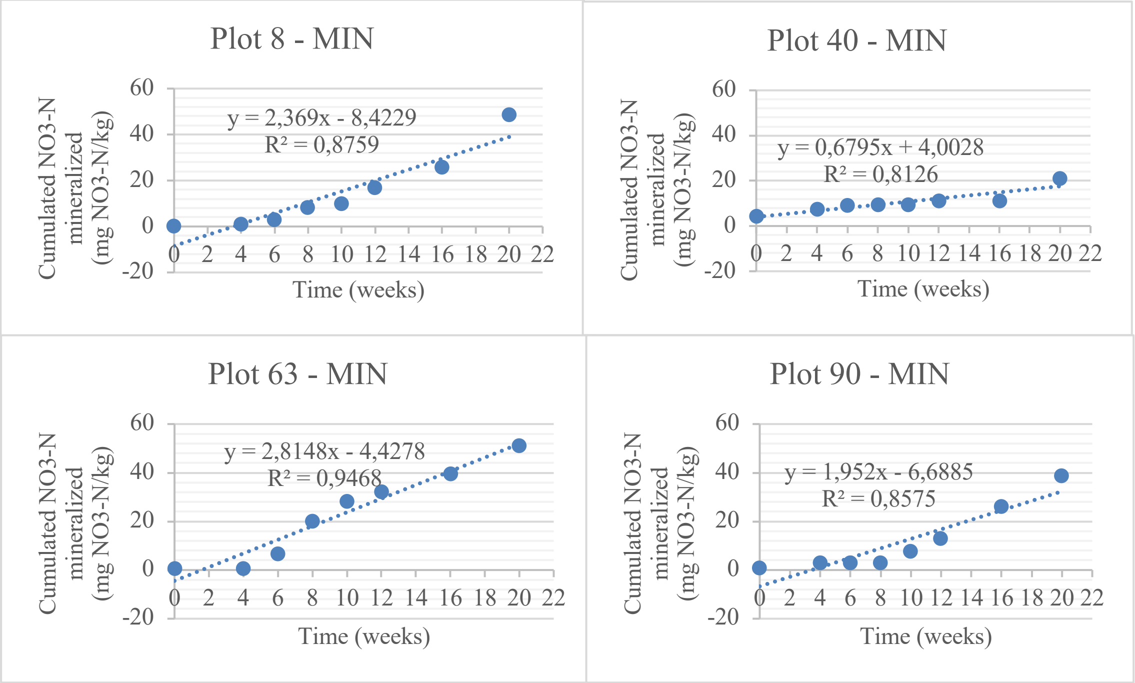




<u>Treatment 11:</u> Thermal and mechanical pruning, with fungicide and no fertilizer.



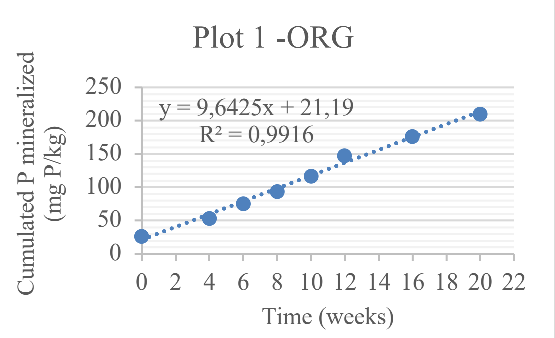
<u>Treatment 12:</u> Thermal and mechanical pruning, with fungicide and with organic fertilizer.

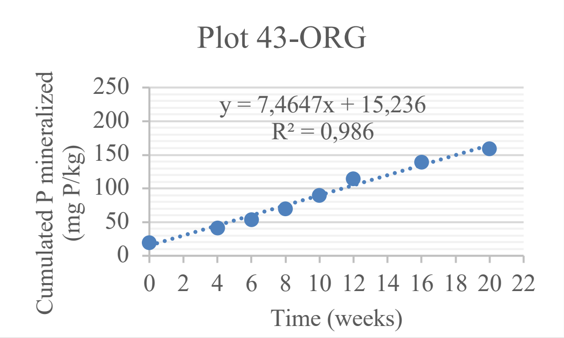


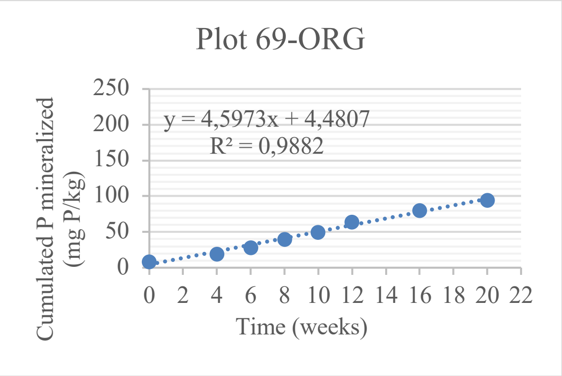
Appendix G. Curves of cumulated NO_3-N mineralized in the mineral (MIN) layer during a 20-wk aerobic incubation according to different treatments (12 treatments). Each treatment consists of 4 plots (replicates). The NO_3-N mineralized during the first 2 wk was not use to make the curves as it represents the initial mineralization flux upon rewetting.

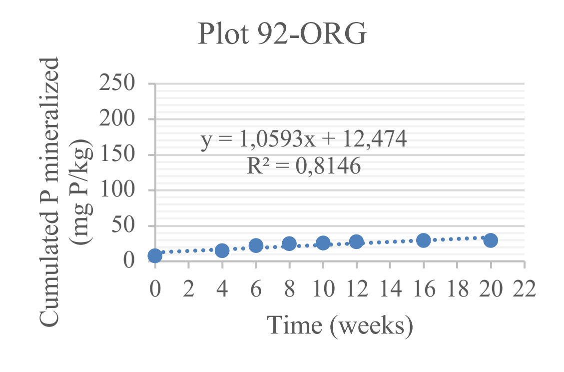
APPENDIX H. CURVES OF CUMULATED P MINERALIZED IN THE ORGANIC (ORG) LAYER DURING A 20-WK AEROBIC INCUBATION ACCORDING TO DIFFERENT TREATMENTS (12 TREATMENTS).

Treatment 1: Mechanical pruning, no fungicide and with mineral fertilizer.

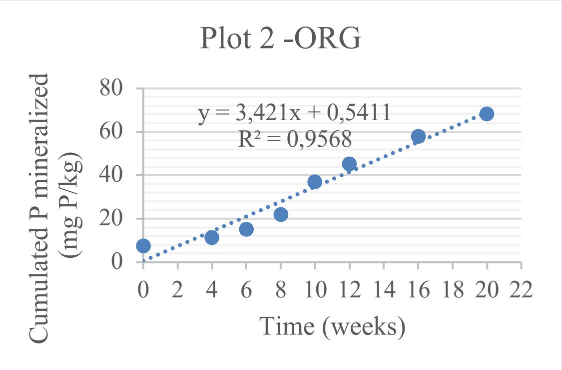


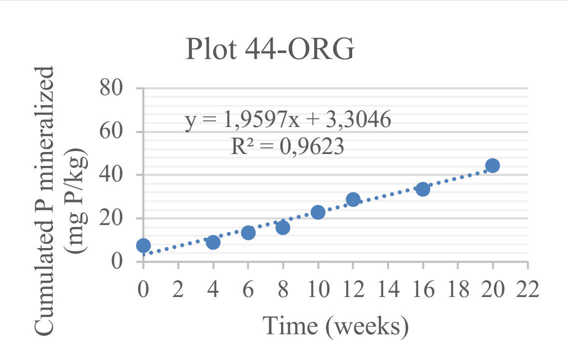


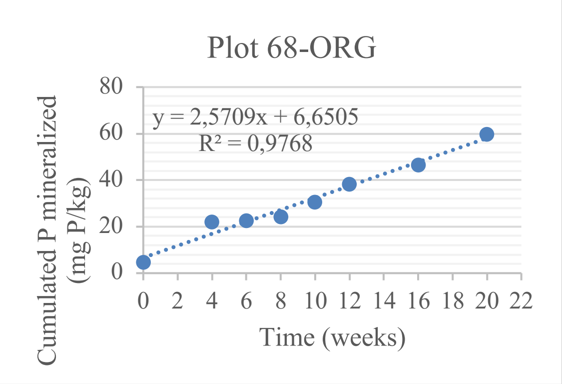


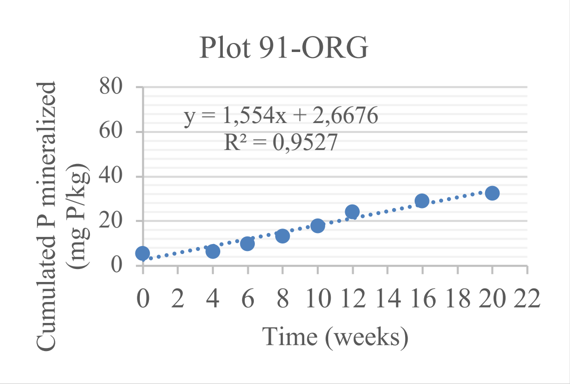


Treatment 2: Mechanical pruning, no fungicide and no fertilizer.

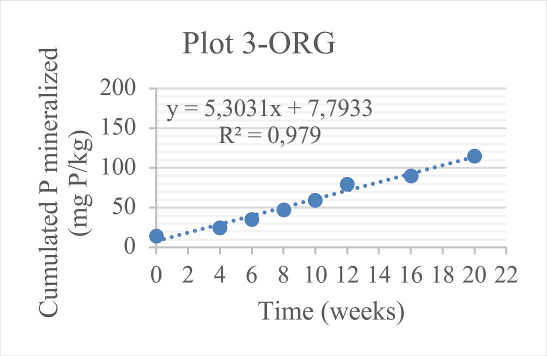


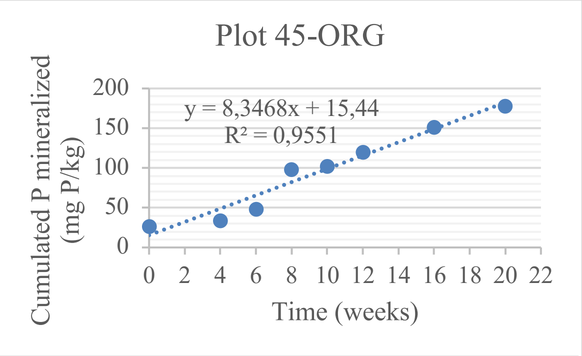


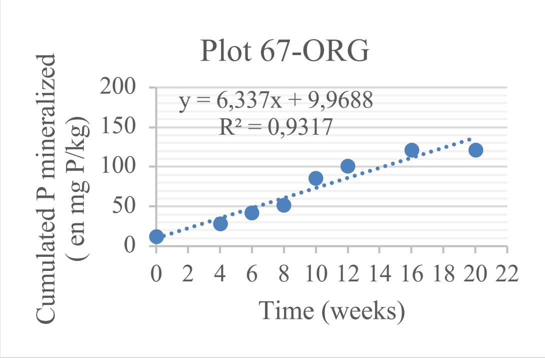


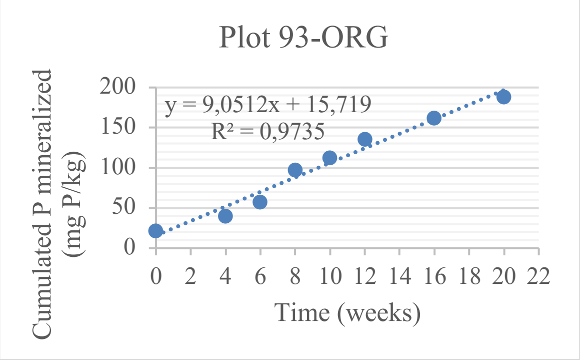


<u>Treatment 3:</u> Mechanical pruning, no fungicide and with organic fertilizer.

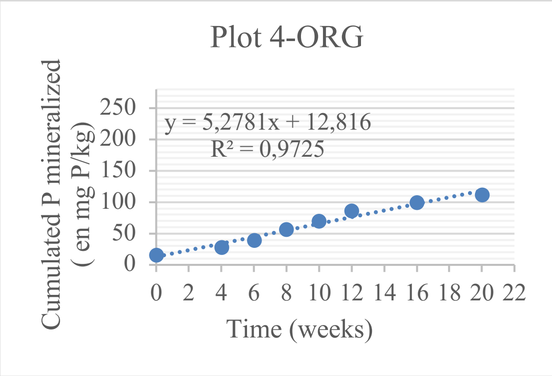


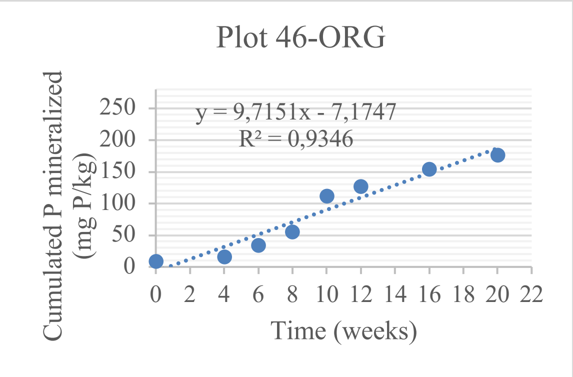


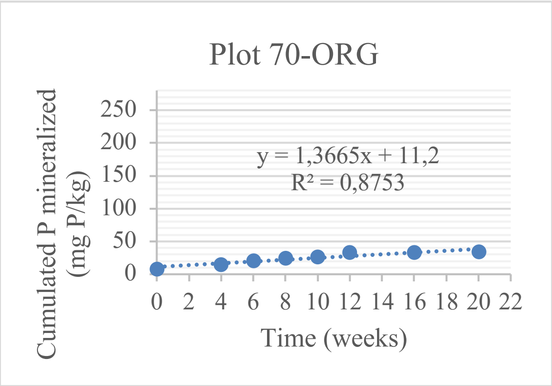


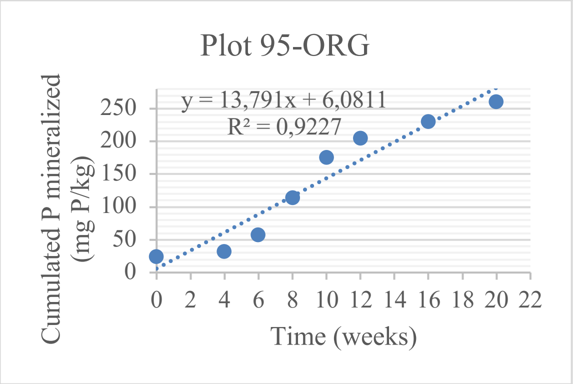


<u>Treatment 4:</u> Mechanical pruning, fungicide and with mineral fertilizer.

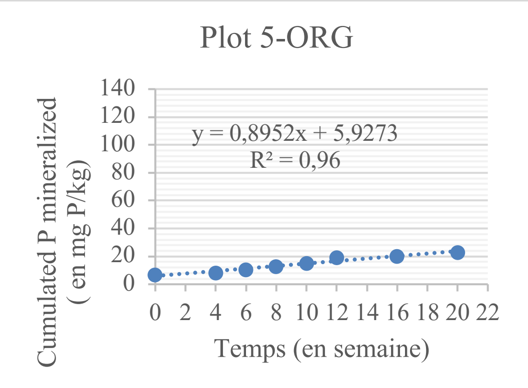


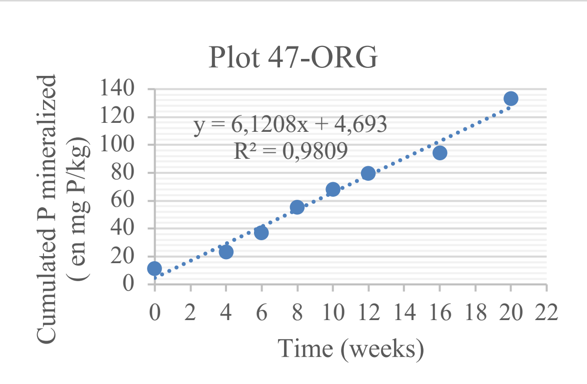


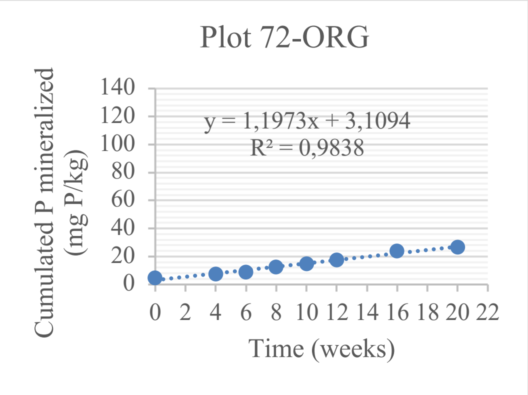


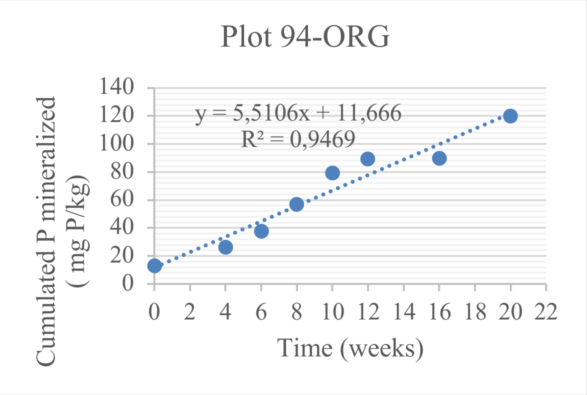


Treatment 5: Mechanical pruning, with fungicide and no fertilizer.

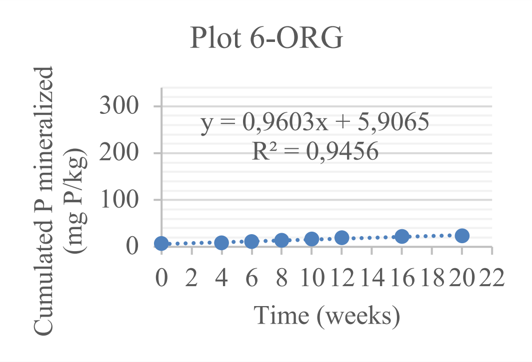


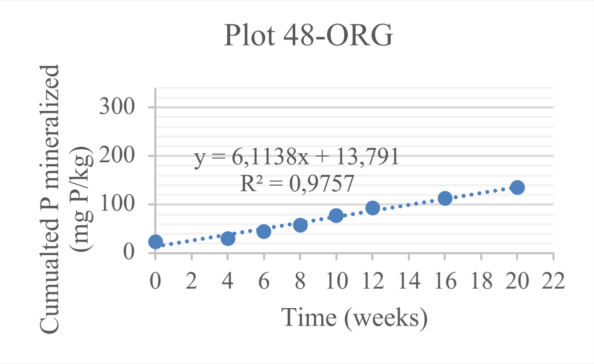


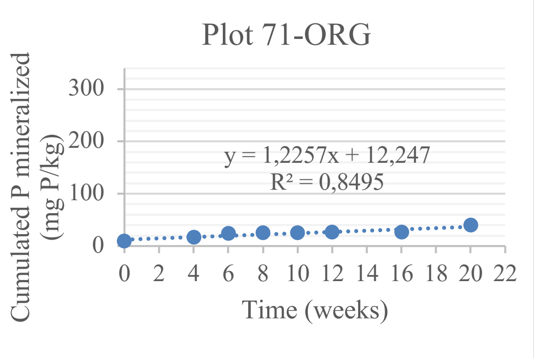


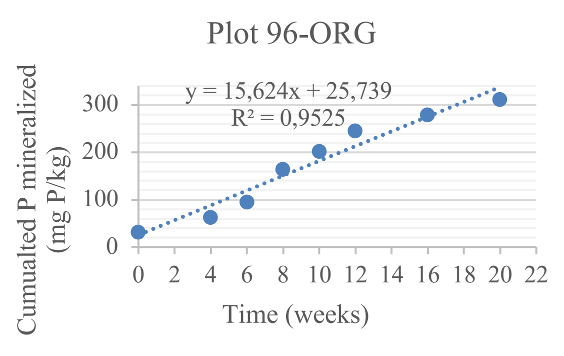


Treatment 6: Mechanical pruning, with fungicide and with organic fertilizer.

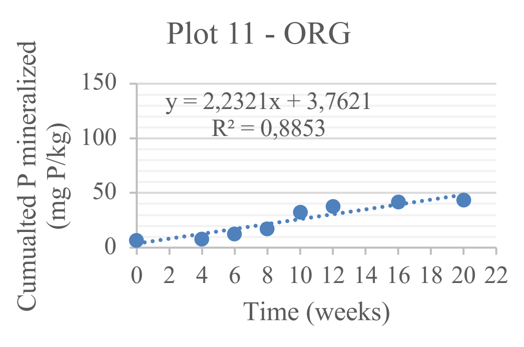


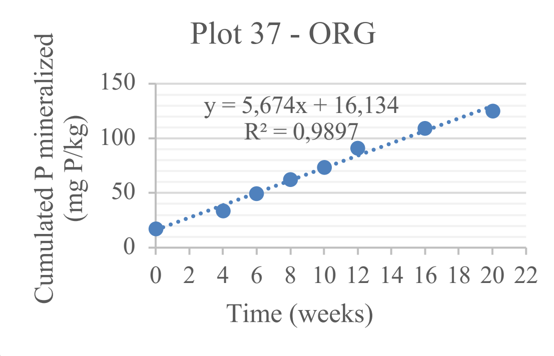


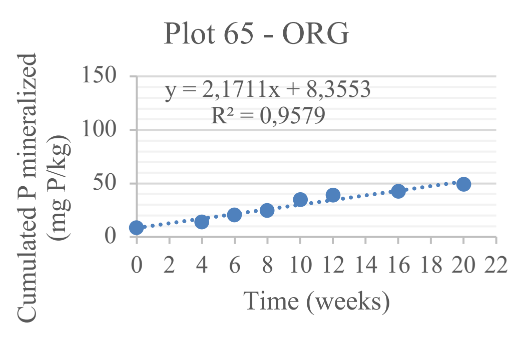


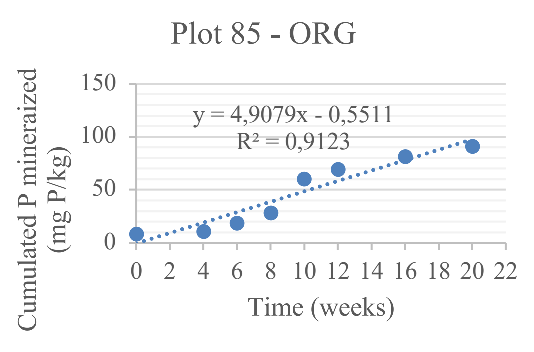


Treatment 7: Mechanical and thermal pruning, no fungicide and with mineral fertilizer.

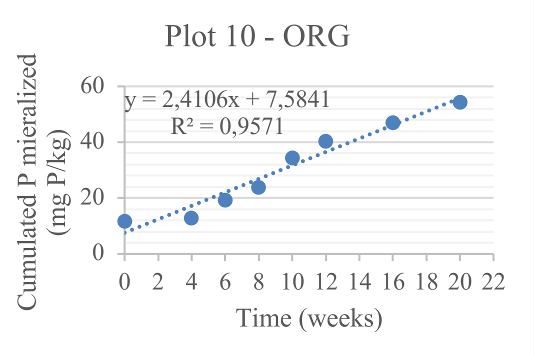


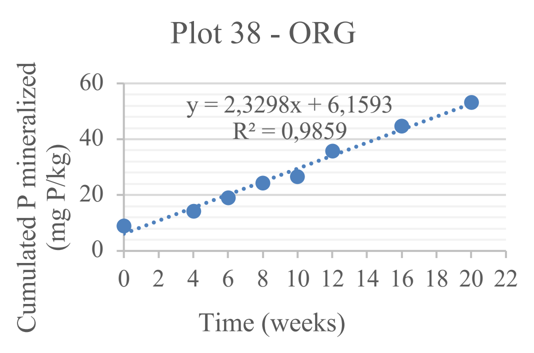


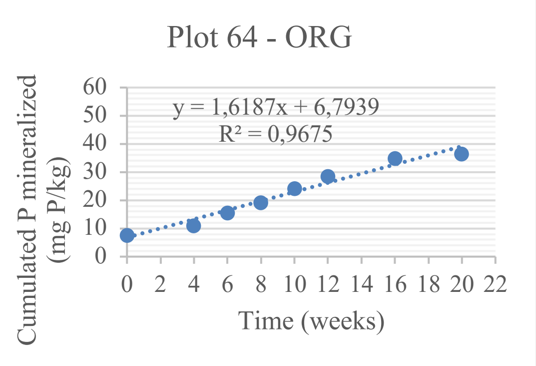


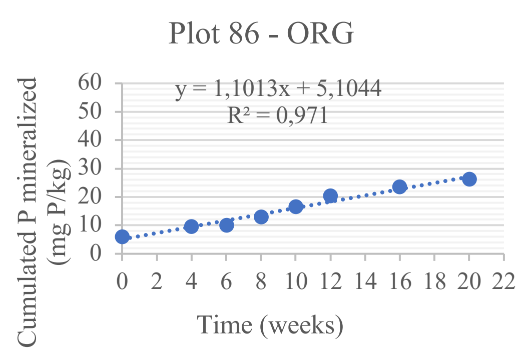


Treatment 8: Mechanical and thermal pruning, no fungicide and no fertilizer.

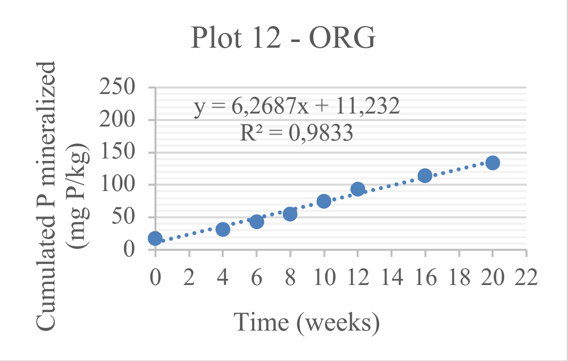


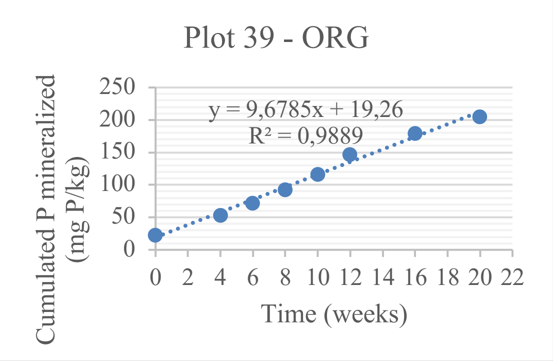


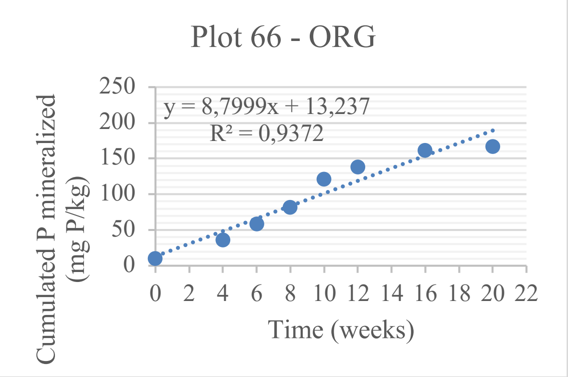


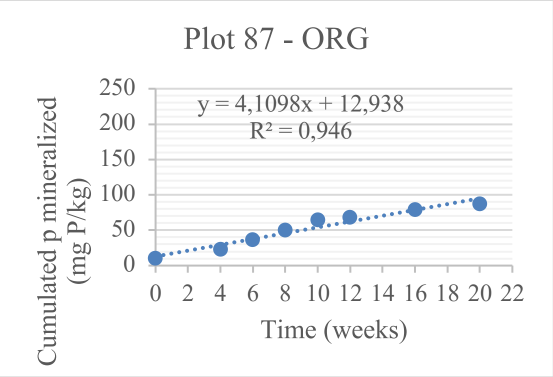


Treatment 9: Mechanical and thermal pruning, no fungicide and with organic fertilizer.

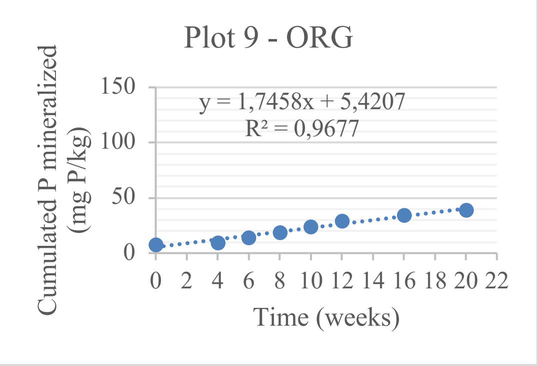


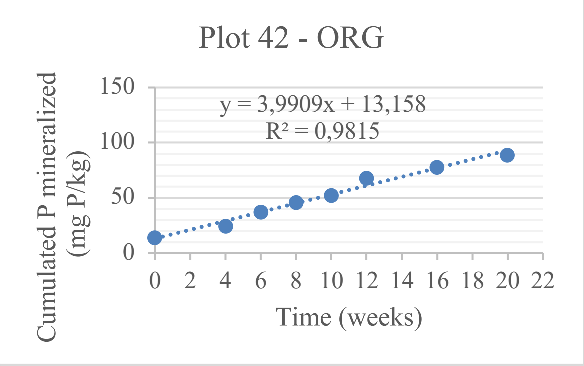


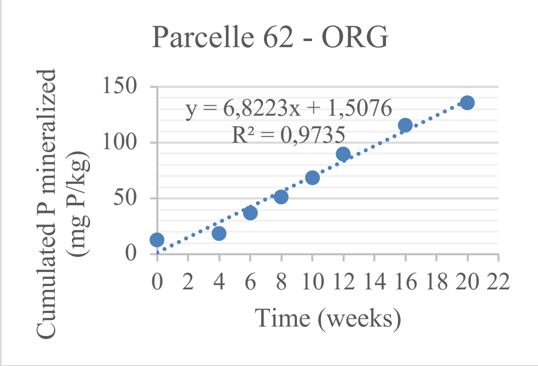


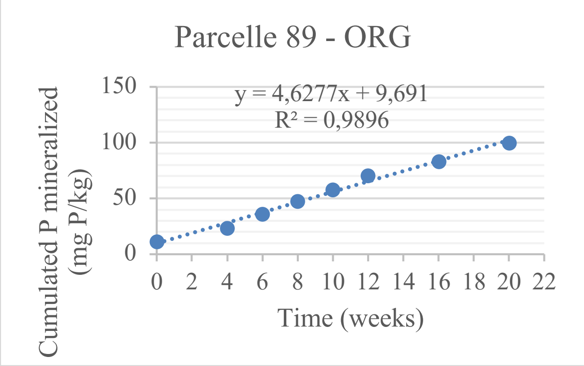


Treatment 10: Mechanical and thermal pruning, with fungicide and with mineral fertilizer.

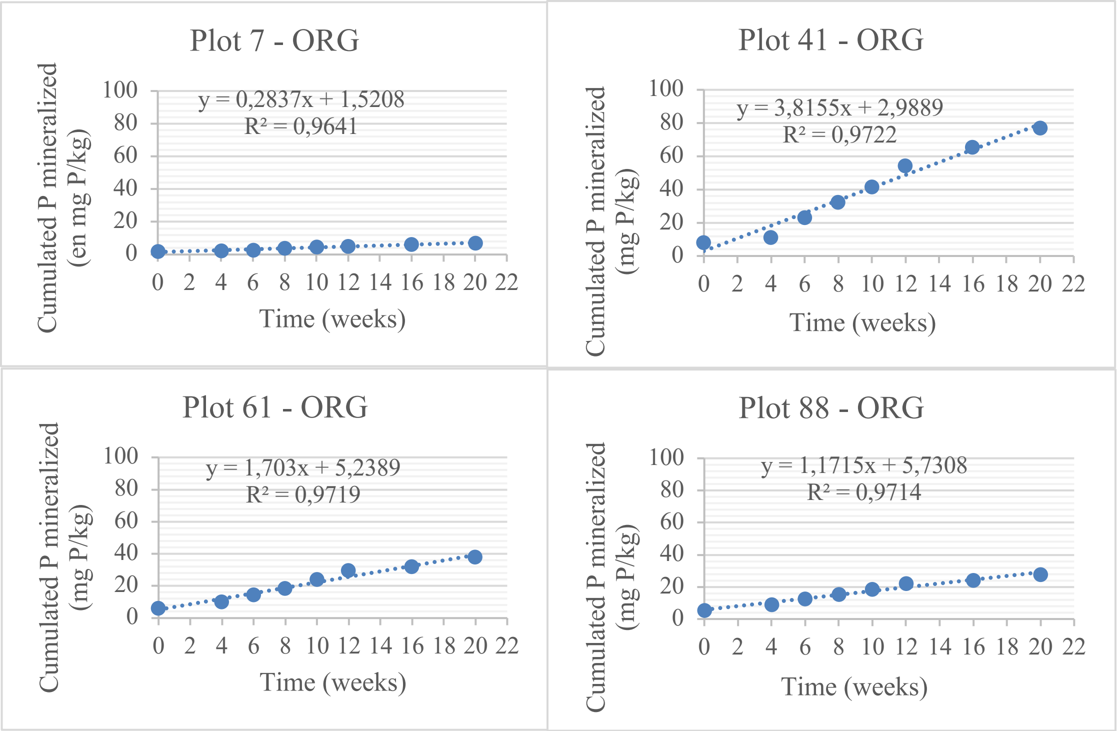




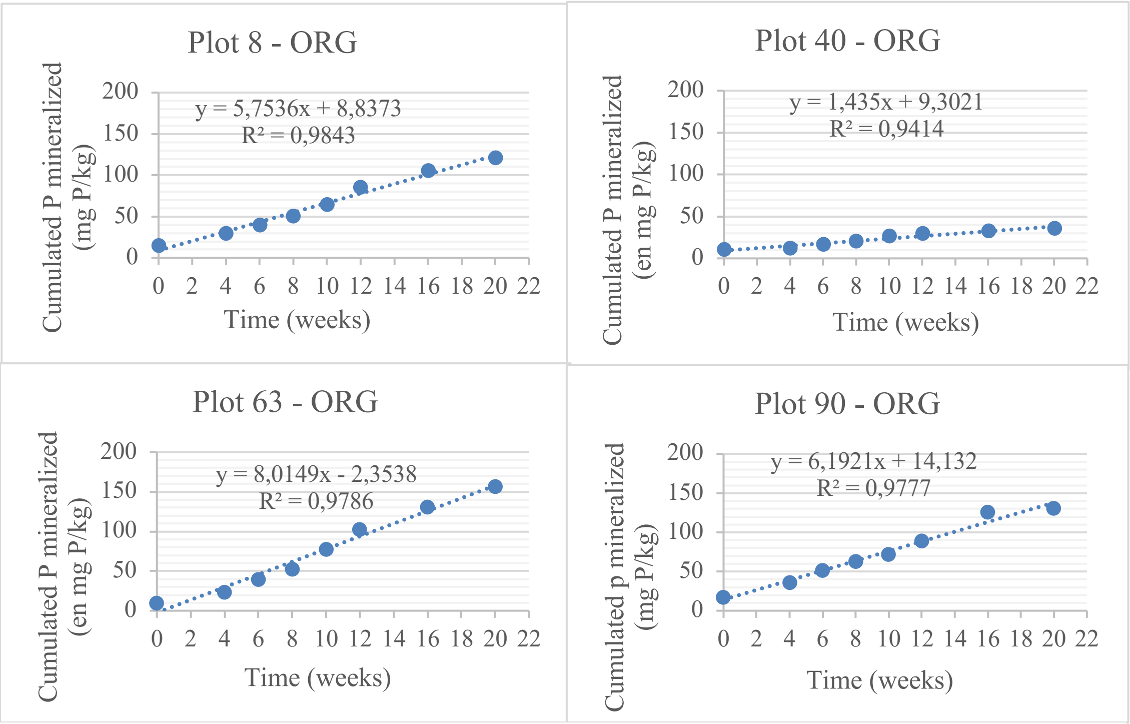




Treatment 11: Mechanical and thermal pruning, with fungicide and no fertilizer.



Treatment 12: Mechanical and thermal pruning, with fungicide and with organic fertilizer.



Appendix H. Curves of cumulated P mineralized in the organic (ORG) layer during a 20-wk aerobic incubation according to different treatments (12 treatments). Each treatment consists of 4 plots (replicates). The P mineralized during the first 2 wk was not use to make the curves as it represents the initial mineralization flux upon rewetting.

APPENDIX I. BOX-COX TRANSFORAMTION APPLIED TO THE DATA.

Appendix I. Box-Cox transformation applied to the data.

	Box-Cox transformation	
	Organic layer (5-0 cm)	**Mineral layer (0-15 cm)**
Net NH_4-N min	$\frac{Net\ NH4min^{0.326}-1}{0.326}$	Log (Net NH_4min)
Net NO_3-N min	$\frac{Net\ NO3min^{0.543}-1}{0.543}$	$\frac{Net\ NO3min^{1}-1}{1}$
Net N min	$\frac{Net\ Nmin^{0.109}-1}{0.109}$	$\frac{Net\ Nmin^{1.304}-1}{1.304}$
Net P min	$\frac{Net\ Pmin^{0.217}-1}{0.217}$	-
pH $CaCl_2$	$\frac{pHCaCl2^{-4.022}-1}{-4.022}$	$\frac{(pHCaCl2+2)^{4.565}-1}{4.565}$
pH_{water}	$\frac{pHwater^{-2.609}-1}{-2.609}$	$\frac{pHwater^{4.239}-1}{4.239}$
C/N ratio	$\log(\frac{C}{N}ratio)$	$\frac{\frac{C}{N}ratio^{-0.217}-1}{-0.217}$
Organic matter	$\frac{organic\ matter^{1.739}-1}{1.739}$	$\frac{organic\ matter^{-0.435}-1}{-0.435}$
Total N	No transformation	$\frac{Total\ N^{0.217}-1}{0.217}$
Soil P saturation index	$\frac{P\ saturation\ index^{-0.109}-1}{-0.109}$	$\frac{P\ saturation\ index^{-1}-1}{-1}$
P	$\frac{P^{0.543}-1}{0.543}$	$\frac{P^{-1}-1}{-1}$
Al	$\frac{Al^{1.848}-1}{1.848}$	$\frac{Al^{3}-1}{3}$
Fe	$\frac{Fe^{-0.109}-1}{-0.109}$	$\frac{Fe^{-1}-1}{-1}$
K	Log (K)	$\frac{K^{-0.326}-1}{-0.326}$
Ca	$\frac{Ca^{-0.326}-1}{-0.326}$	$\frac{Ca^{0.109}-1}{0.109}$

Appendix I. Suite

	Box-Cox transformation	
	Organic layer (5-0 cm)	**Mineral layer (0-15 cm)**
Mg	$\frac{Mg^{0.109}-1}{0.109}$	$\frac{Mg^{-3}-1}{-3}$
Mn	$\frac{Mn^{-0.435}-1}{-0.435}$	$\frac{Mn^{-0.652}-1}{-0.652}$
Na	$\frac{Na^{-0.761}-1}{-0.761}$	$\frac{Na^{-0.109}-1}{-0.109}$
Si	$\frac{Si^{-1-0.652}-1}{-0.652}$	$\frac{Si^{2.283}-1}{2.283}$
Sr	$\frac{Sr^{0.109}-1}{0.109}$	$\frac{Sr^{-0.326}-1}{-0.326}$
Pb	$\frac{Pb^{0.87}-1}{0.87}$	$\frac{Pb^{-0.326}-1}{-0.326}$
Ba	$\frac{Ba^{0.217}-1}{0.217}$	$\frac{Ba^{-1}-1}{-1}$
$SOC_{<2\ \mu m}$	$\frac{\mathrm{SOC} < 2\ \mu\mathrm{m}^{0.87}-1}{0.87}$	$\frac{\mathrm{SOC} < 2\ \mu\mathrm{m}^{1}-1}{1}$
CO_2 flux	$\frac{CO2\ flux^{0.652}-1}{0.652}$	$\frac{(CO2\ flux+5)^{0.326}-1}{0.326}$

APPENDIX J. PEARSON CORRELATION COEFFICIENT BETWEEN DIFFERENT SOIL PROPERTIES OF ORGANIC LAYER.

Appendix J. Pearson correlation coefficient between different soil properties of organic layer.

	pH$_{water}$	C/N ratio	Organic matter	Total N	P index
	Pearson correlation coefficient (probabilities)				
pH$_{water}$	-	-	-	-	-
C/N ratio	-0.2625 (0.0974)	-	-	-	-
Organic matter	**-0.3094** **(0.0490)**	0.0570 (0.7233)	-	-	-
Total N	0.0987 (0.5392)	-0.0106 (0.9475)	0.1101 (0.4583)	-	-
Soil P index	0.2597 (0.1011)	-0.0210 (0.8964)	0.0636 (0.6929)	0.0006 (0.9973)	-
P	0.1916 (0.2301)	0.0488 (0.7617)	0.0250 (0.8759)	0.0879 (0.5847)	**0.9252** **(<0.0001)**
K	-0.0757 (0.6379)	**0.3146** **(0.0452)**	0.0569 (0.7240)	0.2389 (0.1333)	**0.5136** **(0.0006)**
Ca	**0.3671** **(0.0182)**	0.2042 (0.2003)	-0.1218 (0.4481)	**0.4007** **(0.0094)**	**0.3618** **(0.0201)**
Mg	0.2476 (0.1186)	0.2621 (0.0978)	-0.1520 (0.3429)	**0.3930** **(0.0110)**	0.2496 (0.1155)
Fe	-0.1671 (0.2965)	0.1095 (0.4956)	-0.1043 (0.5164)	0.1314 (0.4129)	-0.3722 (0.0166)
Al	**-0.3254** **(0.0379)**	0.2817 (0.0744)	-0.0393 (0.8073)	0.1957 (0.2202)	0.0790 (0.6234)
Net NH$_4$-N min	**-0.5395** **(0.003)**	-0.0036 (0.9823)	0.2859 (0.0700)	0.0545 (0.7352)	0.1691 (0.2906)
Net NO$_3$-N min	**0.8006** **(<0.001)**	-0.1164 (0.4685)	**-0.3221** **(0.0400)**	0.3437 (0.0278)	0.3064 (0.0514)
Net N min	0.3043 (0.0531)	-0.1271 (0.4285)	-0.0355 (0.8258)	**0.4528** **(0.0030)**	**0.4897** **(0.0012)**
Net P min	0.0625 (0.6980)	0.0488 (0.7617)	0.1460 (0.3623)	**0.4064** **(0.0084)**	**0.5586** **(0.0001)**
SOC$_{<2\ \mu m}$	**0.3389** **(0.0302)**	**0.3752** **(0.0156)**	0.0673 (0.6758)	0.0757 (0.6382)	-0.0720 (0.6547)
CO$_2$ flux	-0.0320 (0.8425)	-0.0169 (0.9166)	0.1444 (0.3678)	-0.1730 (0.2794)	0.1679 (0.2940)

Appendix J. Suite

	P	K	Ca	Mg	Fe	Al
			Pearson correlation coefficient (probabilities)			
P	-	-	-	-	-	-
K	**0.6543** **(<0.0001)**	-	-	-	-	-
Ca	**0.5043** **(0.0008)**	**0.7589** **(<0.0001)**	-	-	-	-
Mg	**0.4344** **(0.0045)**	**0.7680** **(<0.0001)**	**0.9749** **(<0.0001)**	-	-	-
Fe	-0.0435 (0.7873)	0.1933 (0.2259)	0.1340 (0.4036)	0.2337 (0.1415)	-	-
Al	**0.3450** **(0.0272)**	**0.4362** **(0.0044)**	**0.4393** **(0.0041)**	**0.5415** **(0.0003)**	**0.3125** **(0.0467)**	-
Soil P index	**0.9252** **(<0.0001)**	**0.5136** **(0.0006)**	**0.3618** **(0.0201)**	0.2496 (0.1155)	**-0.3722** **(0.0166)**	0.0790 (0.6234)
SOC$_{<2\ \mu m}$	0.0976 (0.5437)	**0.2890** **(0.0668)**	**0.3130** **(0.0463)**	**0.3454** **(0.0270)**	0.2664 (0.0922)	**0.6394** **(<0.001)**
CO$_2$ flux	0.0974 (0.5445)	0.1408 (0.3798)	0.1157 (0.4715)	0.0823 (0.6089)	-0.2458 (0.1214)	**-0.0515** **(0.7492)**
pH$_{water}$	0.1916 (0.2301)	-0.0757 (0.6379)	**0.3671** **(0.0182)**	0.2476 (0.1186)	-0.1671 (0.2965)	-0.3254 (0.0379)
C/N ratio	0.0488 (0.7617)	**0.3146** **(0.0452)**	0.2042 (0.2003)	0.2621 (0.0978)	0.1095 (0.4956)	0.2817 (0.0744)
Organic matter	0.0250 (0.8769)	0.0569 (0.7240)	-0.1218 (0.4481)	-0.1520 (0.3429)	-0.1043 (0.5164)	-0.0393 (0.8073)
Total N	0.0879 (0.5847)	0.2384 (0.1333)	**0.4007** **(0.0094)**	**0.3930** **(0.0110)**	0.1314 (0.4129)	**0.1957** **(0.2202)**
Net NH$_4$-N min	0.1563 (0.3291)	0.2288 (0.1502)	-0.2316 (0.1451)	-0.2484 (0.1174)	0.1528 (0.3404)	**-0.0986** **(0.5395)**
Net NO$_3$-N min	**0.3239** **(0.0388)**	0.1623 (0.3107)	**0.5552** **(0.0002)**	**0.4621** **(0.0024)**	-0.0502 (0.7554)	-0.0174 (0.9140)
Net N min	**0.4781** **(0.0016)**	**0.3390** **(0.0302)**	0.3004 (0.0563)	0.1923 (0.2283)	0.0169 (0.9164)	-0.1105 (0.4914)
Net P min	**0.4724** **(0.0018)**	**0.4691** **(0.0020)**	**0.3211** **(0.0407)**	0.2103 (0.1868)	-0.2427 (0.1262)	-0.1886 (0.2377)

Appendix J. Suite

	Net NH_4-N min	Net NO_3-N min	Net N min	Net P min	$SOC_{<2\ \mu m}$
	Pearson correlation coefficient (probabilities)				
Net NH_4-N min	**-**	-	-	-	-
Net NO_3-N min	**-0.4492 (0.0032)**	-	-	-	-
Net N min	**0.4304 (0.0050)**	**0.5779 (<0.0001)**	-	-	-
Net P min	**0.4100 (0.0078)**	0.2544 (0.1085)	**0.6883 (<0.0001)**	-	-
$SOC_{<2\ \mu m}$	0.1254 (0.4347)	-0.0902 (0.5750)	-0.0416 (0.7962)	-0.1129 (0.4782)	-
CO_2 flux	0.0646 (0.6883)	0.0425 (0.7919)	0.1029 (0.5222)	0.1569 (0.3271)	0.1509 (0.3464)

APPENDIX K. MIXED MODEL ANALYSIS OF VARIANCE (ANOVA α = 0.05) OF SOIL FERTILITY INDEX OF ORGANIC AND MINERAL LAYERS ACCORDING TO THE FACTORS PRUNING, FUNGICIDE, AND FERTILIZER, AND THEIR INTERACTIONS.

Appendix K. Mixed model analysis of variance (ANOVA α = 0.05) of soil fertility index of organic and mineral layers according to the factors pruning, fungicide, and fertilizer, and their interactions.

		Organic layer (5-0 cm)				**Mineral layer (0-15 cm)**			
Factor	df	Net NH_4-N min	Net NO_3-N min	Net N min	Net P min	Net NH_4-N min	Net NO_3-N min	Net N min	Net P min
		F values (probabilities)							
Pruning method (Pru)	1	0.4601 (0.5030)	**5.2555** **(0.0293)**	2.1687 (0.1516)	0.9845 (0.3293)	0.6112 (0.4407)	1.4330 (0.0116)	1.4378 (0.2402)	-
Fungicide (Fu)	1	1.2511 (0.2725)	2.7328 (0.1091)	2.1875 (0.1499)	0.2916 (0.5933)	0.3051 (0.5849)	0.3999 (0.5321)	0.4521 (0.5067)	-
Fertilizer (Fe)	2	**22.3707** **(<0.0001)**	**27.2361** **(<0.0001)**	3.2794 (0.0520)	**7.4187** **(0.0025)**	0.0216 (0.9787)	0.5415 (0.5876)	0.5700 (0.5717)	-
Pru x Fu	1	2.3104 (0.1172)	2.0762 (0.1603)	1.4316 (0.2412)	0.0301 (0.8635)	0.0577 (0.8118)	0.0116 (0.9150)	0.1264 (0.7247)	-
Pru x Fe	2	2.3104 (0.1172)	**4.7700** **(0.0162)**	2.0072 (0.1526)	1.6305 (0.2133)	0.0740 (0.9288)	0.2219 (0.8023)	0.6053 (0.5527)	-
Fu x Fe	2	2.0718 (0.1442)	1.5198 (0.2357)	0.6597 (0.5246)	1.9385 (0.1621)	0.4497 (0.6422)	0.1910 (0.8272)	0.3658 (0.6968)	-
Pru x Fu x Fe	2	0.5357 (0.5909)	0.0972 (0.9076)	0.0482 (0.9530)	0.3903 (0.6803)	0.1397 (0.8702)	0.9714 (0.3905)	1.4412 (0.2531)	-

Appendix K. Suite

Factor	df	Organic layer (5-0 cm)				Mineral layer (0-15 cm)			
		pH$_{\text{CaCl2}}$	pH$_{\text{water}}$	C/N ratio	Organic matter	pH$_{\text{CaCl2}}$	pH$_{\text{water}}$	C/N ratio	Organic matter
		F values (probabilities)							
Pruning method (Pru)	1	4.0532 (0.0535)	**6.4601** **(0.0166)**	**4.3628** **(0.0456)**	**7.0660** **(0.0126)**	2.7122 (0.1104)	0.9168 (0.3462)	0.3872 (0.5386)	0.0353 (0.8522)
Fungicide (Fu)	1	0.6233 (0.4362)	0.0101 (0.9205)	0.8799 (0.3560)	0.0011 (0.9742)	0.6696 (0.4199)	0.0098 (0.9220)	0.4464 (0.5093)	**16.2084** **(0.0004)**
Fertilizer (Fe)	2	**28.2507** **(<0.001)**	**31.1573** **(<0.001)**	0.0429 (0.9580)	**5.4441** **(0.0098)**	**4.5958** **(0.0198)**	**30.4855** **(<0.0001)**	0.2524 (0.7786)	1.4056 (0.2614)
Pru x Fu	1	0.0583 (0.8110)	0.5873 (0.4496)	**8.5345** **(0.0067)**	**16.7421** **(0.0003)**	0.0121 (0.9133)	0.8777 (0.3566)	0.9614 (0.3349)	**6.3563** **(0.0174)**
Pru x Fe	2	1.1127 (0.3423)	1.2740 (0.2949)	0.2768 (0.7602)	1.4817 (0.2440)	1.4305 (0.2556)	1.6470 (0.2101)	0.2059 (0.8151)	1.4052 (0.2615)
Fu x Fe	2	1.2605 (0.2986)	0.8089 (0.4551)	0.8440 (0.4403)	1.6884 (0.2025)	0.1882 (0.8295)	0.9560 (0.3962)	0.0315 (0.9691)	0.2255 (0.7995)
Pru x Fu x Fe	2	1.0481 (0.3635)	0.1001 (0.9051)	**5.3165** **(0.0108)**	0.1202 (0.8872)	0.3040 (0.7402)	0.3928 (0.6787)	0.7113 (0.4994)	0.0933 (0.9112)

Appendix K. Suite.

Factor	df	Organic layer (5-0 cm) Soil P saturation index	Organic layer (5-0 cm) P	Organic layer (5-0 cm) Al	Organic layer (5-0 cm) Fe	Mineral layer (0-15 cm) Soil P saturation index	Mineral layer (0-15 cm) P	Mineral layer (0-15 cm) Al	Mineral layer (0-15 cm) Fe
		F values (probabilities)							
Pruning method (Pru)	1	0.0573 (0.8124)	0.1087 (0.7441)	0.9978 (0.3261)	0.1768 (0.6772)	0.4671 (0.4998)	0.7198 (0.4032)	**5.8053** **(0.0226)**	0.0446 (0.8342)
Fungicide (Fu)	1	0.0022 (0.9630)	1.0280 (0.3190)	0.0808 (0.7783)	**11.6871** **(0.0019)**	2.7335 (0.1091)	1.7471 (0.1966)	0.8343 (0.3686)	0.3206 (0.5756)
Fertilizer (Fe)	2	**22.1211** **(<0.0001)**	**12.4293** **(0.0001)**	1.9829 (0.1559)	1.5373 (0.2320)	0.0411 (0.9598)	0.2922 (0.7488)	0.0264 (0.9740)	0.5314 (0.5934)
Pru x Fu	1	0.0038 (0.9514)	0.1441 (0.7070)	0.1025 (0.7511)	2.1072 (0.1573)	0.0003 (0.9870)	0.0231 (0.8804)	0.0195 (0.8900)	0.0111 (0.9168)
Pru x Fe	2	0.8370 (0.4432)	0.6033 (0.5537)	0.1655 (0.8483)	1.0704 (0.3560)	1.4237 (0.2571)	2.3713 (0.1112)	1.2700 (0.2960)	0.1271 (0.8812)
Fu x Fe	2	0.2951 (0.7467)	0.4461 (0.6444)	0.2824 (0.7560)	0.6445 (0.5323)	0.2470 (0.7828)	0.2873 (0.7524)	0.0276 (0.9728)	0.1181 (0.8890)
Pru x Fu x Fe	2	0.0620 (0.9400)	0.0784 (0.9248)	0.2300 (0.7960)	0.1003 (0.9048)	2.5972 (0.0917)	1.5925 (0.2207)	1.0898 (0.3497)	0.4079 (0.6688)

Appendix K. Suite.

		Organic layer (5-0 cm)				Mineral layer (0-15 cm)			
Factor	df	K	Ca	Mg	Mn	K	Ca	Mg	Mn
					F values (probabilities)				
Pruning method (Pru)	1	0.7845 (0.3831)	0.0155 (0.9019)	0.2425 (0.6261)	**6.7807** **(0.0144)**	0.1845 (0.6707)	**5.8261** **(0.0223)**	1.8385 (0.1856)	2.5351 (0.1222)
Fungicide (Fu)	1	4.1318 (0.0513)	1.7901 (0.1913)	3.1338 (0.0872)	**9.4774** **(0.0045)**	0.2732 (0.6051)	0.9346 (0.3417)	0.0001 (0.9909)	0.2053 (0.6538)
Fertilizer (Fe)	2	**5.8624** **(0.0073)**	**21.7949** **(<0.0001)**	**15.2339** **(<0.0001)**	**6.4576** **(0.0048)**	**5.4001** **(0.0101)**	0.4369 (0.6502)	0.3691 (0.6945)	0.1501 (0.8613)
Pru x Fu	1	1.6274 (0.2122)	0.3121 (0.5807)	0.7993 (0.3787)	**5.6118** **(0.0247)**	0.0127 (0.9111)	0.3094 (0.5823)	0.0685 (0.7954)	1.1236 (0.2979)
Pru x Fe	2	1.0267 (0.3709)	1.7566 (0.1905)	1.2748 (0.2947)	1.4781 (0.2447)	0.1722 (0.8427)	1.8317 (0.1782)	0.3805 (0.6869)	0.4044 (0.6711)
Fu x Fe	2	1.0151 (0.3749)	1.1525 (0.3299)	0.9754 (0.3891)	0.3885 (0.6816)	1.6965 (0.2010)	0.6664 (0.5212)	0.1065 (0.8993)	0.2777 (0.7595)
Pru x Fu x Fe	2	0.0072 (0.9928)	0.1747 (0.8406)	0.1491 (0.8621)	0.5444 (0.5860)	0.1074 (0.8985)	0.6183 (0.5458)	0.0415 (0.9495)	0.0626 (0.9394)

Appendix K. Suite.

		Organic layer (5-0 cm)				Mineral layer (0-15 cm)			
Factor	df	Na	Si	Sr	Pb	Na	Si	Sr	Pb
		F values (probabilities)							
Pruning method (Pru)	1	0.8094 (0.3757)	0.6433 (0.4290)	0.0032 (0.9551)	1.4132 (0.2442)	4.0792 (0.0527)	2.992 (0.0939)	**7.2321** **(0.0117)**	0.1457 (0.7054)
Fungicide (Fu)	1	1.5965 (0.2165)	0.3083 (0.5830)	1.2641 (0.2701)	0.3934 (0.5354)	0.1756 (0.6786)	1.8651 (0.1825)	0.7065 (0.4075)	2.4929 (0.1252)
Fertilizer (Fe)	2	**9.4576** **(0.0007)**	0.2713 (0.7643)	**6.3385** **(0.0052)**	1.0629 (0.3585)	1.3479 (0.2756)	0.2789 (0.7586)	0.2236 (0.8010)	0.0518 (0.9497)
Pru x Fu	1	2.6281 (0.1158)	0.2232 (0.6401)	0.4117 (0.5261)	0.1671 (0.6587)	1.5498 (0.2231)	0.0010 (0.9754)	0.0664 (0.7985)	0.0481 (0.8279)
Pru x Fe	2	1.5108 (0.2376)	0.0283 (0.9721)	1.7612 (0.1897)	2.1704 (0.1323)	0.6960 (0.5067)	1.0147 (0.3750)	2.4188 (0.1068)	0.1995 (0.8203)
Fu x Fe	2	0.4488 (0.6428)	0.0269 (0.9735)	1.1270 (0.3370)	2.1374 (0.1362)	1.0901 (0.3496)	0.0676 (0.9348)	0.6661 (0.5214)	0.1417 (0.8685)
Pru x Fu x Fe	2	0.0875 (0.9165)	0.8475 (0.4388)	0.1642 (0.8494)	0.0948 (0.9099)	0.3002 (0.7430)	0.4419 (0.6471)	1.0480 (0.3635)	0.0986 (0.9064)

Appendix K. Suite.

		Organic layer (5-0 cm)				Mineral layer (0-15 cm)			
Factor	df	Ba	Total N	$\text{SOC}_{<2\ \mu m}$	CO_2 flux	Ba	Total N	$\text{SOC}_{<2\ \mu m}$	CO_2 flux
					F values (probabilities)				
Pruning method (Pru)	1	**9.0955** **(0.0053)**	2.4816 (0.1260)	**4.6155** **(0.0402)**	0.1038 (0.7496)	**6.5980** **(0.0156)**	0.3226 (0.5744)	0.0218 (0.8836)	2.6934 (0.1116)
Fungicide (Fu)	1	2.6447 (0.1147)	1.5893 (0.2175)	0.0271 (0.8704)	0.0417 (0.8396)	0.0062 (0.9376)	0.2161 (0.6455)	0.1014 (0.7524)	1.0593 (0.3119)
Fertilizer (Fe)	2	**5.4399** **(0.0099)**	1.3285 (0.2805)	0.8435 (0.4405)	1.4881 (0.2425)	1.3346 (0.2790)	0.3503 (0.7074)	0.0296 (0.9709))	0.1531 (0.8588)
Pru x Fu	1	**5.0777** **(0.0320)**	0.0562 (0.8142)	2.0408 (0.1638)	0.6254 (0.4355)	0.1809 (0.6738)	0.0027 (0.9587)	0.1014 (0.7524)	0.0784 (0.7815)
Pru x Fe	2	1.8338 (0.1779)	0.9228 (0.4088)	0.1094 (0.8967)	0.2190 (0.8046)	0.9451 (0.4003)	0.2598 (0.7730)	0.2658 (0.7684)	0.2664 (0.7680)
Fu x Fe	2	1.2873 (0.2913)	1.2140 (0.3117)	0.3834 (0.6849)	2.0086 (0.1524)	0.0329 (0.9677)	0.5333 (0.2923)	1.0401 (0.3662)	0.8205 (0.4502)
Pru x Fu x Fe	2	0.0732 (0.9296)	0.2625 (0.7709)	0.5194 (0.6003)	**6.4826** **(0.0047)**	0.1676 (0.8465)	0.9604 (0.3946)	0.4177 (0.6625)	0.5582 (0.5783)

APPENDIX L. SOIL PROPERTIES IN THE MINERAL LAYER (0-15 CM), AS AFFECTED BY PRUNING METHOD, FUNGICIDE AND FERTILIZER APPLCIATION AND THEIR INTERACTION.

Appendix L. Soil properties in the mineral layer (0-15cm), as affected by pruning method, fungicide and fertilizer application and their interaction.[3]

Significant factors and interaction		**Organic matter**	**K** (mg.kg^{-1})	**Ca** (mg.kg^{-1})	**Al** (mg.kg^{-1})	**pH$_{water}$**
Pruning						
Mechanical pruning		-	-	42.1 (2.1) a	1182 (68) b	-
Thermal pruning		-	-	35.7 (1.8) b	1371 (31) a	-
Fungicide						
w/ fungicide		21.5 (1.5) b	-	-	-	-
w/o fungicide		57.9 (8.8) a	-	-	-	-
Fertilizer						
Mineral fertilizer		-	21.6 (1.0) ab	-	-	4.9 (0.0) b
Organic fertilizer		-	23.5 (1.3) a	-	-	5.2 (0.0) a
w/o fertilizer (control)		-	18.7 (0.7) b	-	-	5.1 (0.0) a
Pruning x Fungicide						
Mechanical pruning	w/ fungicide	25.5 (0.7) ab	-	-	-	-
	w/o fungicide	36.5 (5.1) a	-	-	-	-
Thermal pruning	w/ fungicide	18.9 (2.0) b	-	-	-	-
	w/o fungicide	77.5 (14) a	-	-	-	-

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[3] Interactions not shown in the table were not significant in the ANOVA (Appendix A). Mean values were compared with a Tukey's post-hoc test at α = 0.05.

APPENDIX M. SOLUBLE ORGANIC C IN THE ORGANIC LAYER, AS AFFECTED BY PRUNING METHOD.

Appendix M. Soluble organic C (<2 µm) in the organic layer, as affected by pruning method. [4]

Significant factors and interactions			$SOC_{<2\ \mu m}$ (kg.ha^{-1})	CO_2 flux (g.kg^{-1})
Pruning				
Mechanical pruning			1770 (72) b	-
Thermal pruning			2005 (61) a	-
Pruning × Fungicide × Fertilizer				
Mechanical pruning	w/ fungicide	Mineral	-	2335 (598) a
		Organic	-	1271 (48) a
		w/o fertilizer	-	398 (310) a
	w/o fungicide	Mineral	-	837 (548) a
		Organic	-	1703 (278) a
		w/o fertilizer	-	1825 (296) a
Thermal pruning	w/ fungicide	Mineral	-	1398 (368) a
		Organic	-	1390 (287) a
		w/o fertilizer	-	1303 (264) a
	w/o fungicide	Mineral	-	1715 (486) a
		Organic	-	1065 (327) a
		w/o fertilizer	-	747 (202) a

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[4] Fungicide and fertilizer application did not impact the soil C dynamics and thus is not shown in the table (Appendix A). Mean values were compared with a Tukey's post-hoc test at α = 0.05.

APPENDIX N. SOIL P, K, Ca, Mg, Fe CONTENT IN THE ORGANIC LAYER, AS AFFECTED BY FUNGICIDE AND FERTILIZER APPLICATION.

Appendix N. Soil P, K, Ca, Mg, Fe content in the organic layer, as affected by fungicide and fertilizer application. [5]

Significant factors	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	Ca ($mg.kg^{-1}$)	Mg ($mg.kg^{-1}$)	Fe ($mg.kg^{-1}$)	P index (%)
Fungicide						
w/ fungicide	-	-	-	-	257 (7) b	-
w/o fungicide	-	-	-	-	288 (7) a	-
Fertilizer						
Mineral fertilizer	41.7 (3.2) b	215 (18) ab	900 (57) c	134 (9) b	-	2.1 (0.1) b
Organic fertilizer	55.7 (3.8) a	298 (29) a	1769 (108) a	251 (17) a	-	2.8 (0.2) a
w/o fertilizer (control)	31.6 (2.0) b	198 (15) b	1279 (84) b	209 (16) a	-	1.4 (0.1) c

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[5] Pruning method did not impact the soil C dynamics and thus is not shown in the table (Appendix A). Mean values were compared with a Tukey's post-hoc test at α = 0.05.

APPENDIX O. SOIL Mn, Na, Sr, Ba CONTENT IN THE ORGANIC LAYER (5-0 CM), AS AFFETED BY PRUNING METHOD, FUNGICIDE AND FERTILIZER APPLICATION AND THEIR INTERACTION.

Appendix O. Soil Mn, Na, Sr, Ba content in the organic layer (5-0 cm), as affected by pruning method, fungicide and fertilizer application and their interaction. [6]

Significant factors and interaction		**Mn** ($mg.kg^{-1}$)	**Na** ($mg.kg^{-1}$)	**Sr** ($mg.kg^{-1}$)	**Ba** ($mg.kg^{-1}$)	**pH$_{CaCl2}$** ($mg.kg^{-1}$)
Pruning						
Mechanical pruning		88.8 (9.5) a	-	-	19.2 (1.2) a	-
Thermal pruning		65.7 (3.9) b	-	-	15.4 (0.8) b	-
Fungicide						
w/ fungicide		64.1 (4.3) b	-	-	-	-
w/o fungicide		88.2 (7.7) a	-	-	-	-
Fertilizer						
Mineral fertilizer		69.8 (7.3) b	14.9 (3.2) b	6.36 (0.4) b	14.5 (1.4) b	3.1 (0.0) c
Organic fertilizer		64.8 (5.4) b	21.3 (1.9) a	9.04 (0.6) a	17.6 (0.9) ab	3.6 (0.1) a
w/o fertilizer (control)		97.4 (10) a	11.8 (1.3) b	8.94 (0.6) a	19.3 (1.2) a	3.3 (0.0) b
Pruning x Fungicide						
Mechanical pruning	w/ fungicide	65.7 (8.5) b	-	-	16.3 (1.1) ab	-
	w/o fungicide	110 (11) a	-	-	21.4 (1.5) a	-
Thermal pruning	w/ fungicide	63.4 (5.1) b	-	-	15.6 (1.0) b	-
	w/o fungicide	68.1 (6.2) b	-	-	15.2 (1.3) b	-

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[6] Interactions not shown in the table were not significant in the ANOVA (Appendix A). Mean values were compared with a Tukey's post-hoc test at α = 0.05.