EFFECT OF MINERAL AND ORGANIC N SOURCES ON GROWTH, NUTRIENT ACCUMULATION AND YIELD OF SILAGE MAIZE

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1 SUMMARY

The usage of chicken litter as fertilizer has increased during the last years. It is applied without any technical criteria to the soil, generating phosphorus (P) accumulation, as the demand for this nutrient is usually exceeded. The aim of this work is to estimate the effect of the addition of chicken litter on the growth, nutrient accumulation and yield of corn for silage as well as the differences between the phosphorus accumulation within the soil. This is achieved through testing out different factorial combinations of three doses of chicken litter (0, 180 and 360 Kg N ha^{-1}) and three of urea (0, 90 and 180 Kg N ha^{-1}). The different treatments were segregated in three repetitions completely randomized set in blocks across the land. The soil's initial and final fertility was studied through chemical parameters, along with the crop cycle, levels of N, P and foliar K. They were measured on the bloom and at harvest, as well as, the dry matter yield and the accumulation of nitrogen, phosphors and potassium. In four of the nine treatments, a 'growth test' was carried out. For this purpose, the plants were assayed across its entire cycle, determining the foliar area. In each sample, it was analyzed the dry matter, nitrogen, phosphorus and potassium concentration. The mineralization of the chicken litter during the study was lower than the expectation due to a hydric deficit during its period, altering the vegetal response. With this set of information, dry matter accumulation curves, as well as, for nutrients were determinate, allowing to estimate the growth rate and the crop's nutrient absorption. With the measurements, it was estimated the growth rate of the foliar area, its duration and the net absorption rate of the crop. The mineralization of the chicken litter during the period under study, was less than normal due to a period of lack of water, which affected the vegetal response. Nonetheless, it was possible to set the curve of the accumulation of dry matter, nitrogen, phosphorus, potassium and foliar area index reaching to the conclusion that the phonologic state V6 is critical for the nitrogen fertilization; this matches with the bibliography that was consulted, and with the usual soil management practices. At harvest, a relationship between the performance of the dry matter with the chicken litter and the urea was determined, in which urea in maximum dosage became negative. This relationship between two sources of nitrogen was not found when the N, P, or K were extracted. In the soil, it was concluded that the increase of phosphorus produced by the addition of chicken litters exponential and that the combination of chicken litter and urea reduces the phosphorus. It is probably that this is due to a bigger extraction of the nutrient by the plants as urea is added to the soil.

Key words: *chicken litter and urea, growing and absorption of nutrients curves, response curves, maize for silage, phosphorus in the soil.*

2 INTRODUCTION

2.1 CHICKEN LITTER

The production of chickens and hens (*Gallus gallus domesticus* L.) in the world has grown in the last decade, as has the waste generated by this industry (FAO, 2017). The rearing of chickens for meat is usually done in sheds with a floor composed of different organic materials, which after a certain number of broilers, together with chicken excreta and other waste or aggregates, are removed from the shed to form a waste commonly called "chicken litter" (Sims and Wolf, 1994).

Since the beginning of the millennium, Uruguay has experienced an increase in poultry production (Docampo, 2005). It is estimated that broiler chicken production generates approximately 48500 tonnes of chicken litter (dry basis) annually, generally composed of rice husks or, less frequently, pine sawdust. This in terms of nitrogen (N), phosphorus (P) and potassium (K) is equivalent to 4700 tonnes of urea, 4100 tonnes of calcium superphosphate and 1800 tonnes of K chloride (Moltini and Silva, 1981; Campelo et al, 1982; Docampo et al, 2005). When analysing chicken litter we found high levels of carbon (C) and water, to a lesser extent N and P, as well as traces of chlorine (Cl), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn) and arsenic (As) (Sims and Wolf, 1994; Barbazán et al, 2011; Rabuffetti 2014[*]).

This is why a fairly widespread use in many countries, and one that has traditionally been followed in Uruguay, is the use of this material as an organic soil amendment, particularly in the area where poultry production is concentrated, the

[*] [*] RABUFFETTI, A. (2014). Evaluación agronómica y de impacto ambiental en suelos y aguas, debido al uso de la cama de pollo como fertilizante o enmienda orgánica con diferentes grados de procesamiento. Internal document of the Facultad de Ciencias Agrarias, Universidad de la Empresa.

south of the country (del Pino et al, 2008). The value of poultry manure as a source of nutrients for crop, pasture, vegetable and fruit production has been known for a long time. In Uruguay, it is mainly used in horticultural production (Moltini and Silva, 1981; Campelo et al, 1982; Docampo et al, 2005). Poultry litter is also used to improve the physical condition of soils (aeration, water retention and cation exchange capacity). In this sense, its use is a management strategy to add C to degraded soils or soils under cropping systems in which all plant biomass is removed at harvest (Hochmuth et al, 2009; Barbazán et al, 2011), such as those traditionally cultivated in the department of Canelones (García de Souza et al, 2011). However, the high ratio of C to N in poultry litter makes it difficult to transfer and apply, as large volumes are required to meet the N requirements of crops (Barbazán et al, 2011).

N from poultry litter is found in various chemical forms which, when applied to the soil, are transformed by the action of bacteria, pH, humidity and the oxygen concentration of the medium. This results in N losses by volatilisation as ammonia and run-off as nitrates dissolved in water, generating a negative environmental impact (Sims and Wolf, 1994; Kelleher et al, 2002; Nahm, 2003). When amounts that significantly exceed the nutrient requirements of crops are frequently applied, in the medium term, not only can nutrient imbalances be caused by excessive accumulation of P, Cu and Zn, but the risk of environmental impact can be significantly increased (Kelleher et al, 2002). Even so, the benefits of using poultry litter as an amendment are sufficiently relevant for the maintenance of soil productivity under intensive production, so it is necessary to increase research efforts to generate technological information that allows the use of environmentally safe forms of it under Uruguayan production conditions.

For maize, a crop with a high nutrient extraction rate, low organic matter return to the soil and a long cycle, chicken litter is considered an exceptional fertiliser due to its gradual release of nutrients and the high yields recorded at the experimental level (Rasnake, 1998).

2.2 UREA

The use of urea as a nitrogen fertiliser has grown in recent years, being the most widely used in the world, mainly in maize and wheat (Heffer, 2013; Prasad, 2013; FAO, 2017). In Uruguay, its import has grown in the last decade, becoming the fertiliser with the largest volumes purchased in recent years (M.G.A.P., 2015).

Urea has a high concentration of N, which facilitates its transport and application to the soil, it has high solubility so that N is quickly available to plants and it is inexpensive. Disadvantages include potential N loss, reduced germination in case of localised fertilisation in dry conditions and high temperatures, and soil acidification if applied in high doses for a long time (Fernandez, 1984; Chen, 2006).

2.3 ENVIROMENTAL IMPACT

The risk of environmental impact from the use of poultry litter is the one that has caused most social controversy in recent years. It is associated with the excess P that is generated when a crop is fertilised with doses without any technical criteria. This promotes the eutrophication of the waters of ponds, lagoons and other watercourses due to the accumulation of N and P due to erosion and surface runoff. This results in an over-stimulation of aquatic vegetation development with consequent deterioration of fish habitat conditions, among other effects, due to reduced oxygen availability. Concentrations higher than 0.5 - 1.0 mg N l^{-1} and 10-100 µg P l^{-1} are already considered to have a high probability of inducing eutrophication of aquatic systems (Sims and Wolf, 1994; Mallarino et al, 2005; RAP-AL Uruguay, 2010).

Usually, microorganisms found in water need certain proportions of C, N and P for their correct development, the ratio C:N:P being 106:16:1. C is generally not a limiting factor in water for the development of micro-organisms, the limitation comes from N and P, particularly the latter. However, when there are excesses of P in the water, the cyanophycean group of algae (Cyanophyceae) thrive more than the rest of the aquatic population, since they have the ability to take up atmospheric N, while the rest of the microorganisms are affected by the lack of N (Suttle and Harrison, 2009).

P in the water normally decants and is found in the deeper parts of the water column, where there is usually little oxygen which makes it impossible for cyanophyceae to grow. However, in the summer months, the water undergoes internal currents due to temperatures that bring P to the surface and alkalinise the water, making eutrophication of the water possible (Mortimer, 1969; Welch et al, 1975; Kagalou et al, 2008; Suikkanen et al, 2013).

As this increased growth of microorganisms occurs, the amount of oxygen and nutrients in the water decreases. In addition, sunlight does not enter the water as it is blocked by the microorganisms on the surface, resulting in the mortality of microorganisms, algae and fish in the system, leading to a decrease in biological diversity and habitat degradation in general. In addition, ammonium and various toxins are released during algal blooms, making the water unsafe for drinking and causing disease in both humans and animals (Vollenweider, 1965; Mazzeo et al, 2002; Johnson et al, 2007).

This phenomenon has grown in recent decades, with an estimated 54% of lakes in Asia, 53% in Europe, 28% in Africa, 48% in North America and 41% in South America being eutrophicated (Bartram et al, 1999).

In Uruguay there is no information on how many eutrophicated water sources exist, but there are situations of eutrophication of important water sources such as the Santa Lucia, Río Negro, Cuareim and Uruguay rivers (Kruk et al, 2013).

It is also estimated that 1.1% of CO_2 emissions in Uruguay are related to manure applied to soils and 1.5% to the management of these wastes. Mineral fertilisers are responsible for 2% of these emissions (FAO, 2017).

Likewise, the repeated use of chicken litter or nitrogen fertilisers in large doses can lead to the contamination of surface and deep waters by excess nitrates, which when ingested with water are transformed into nitrites and produce oxyhaemoglobinaemia in children (known as Blue Baby disease in children). In turn, surface water can be contaminated with hormones and antibiotics, which can have a serious environmental impact (Cabrera et al, 1993; Nguyen, 2010).

On the other hand, excessive applications of poultry litter can lead to soil contamination of heavy metals such as zinc (Zn), copper (Cu), cadmium (Cd), nickel (Ni) and lead (Pb) which, when eroded from the soil, can also contaminate surface water sources (Uchimiya et al, 2010), or be absorbed by plants, constituting a risk to the food chain.

Also, applying untreated or uncomposted poultry litter adds pathogens to the soil, where the bacterial load can exceed 1010 CFU g^{-1}, although this varies depending on the age of the chickens, litter material and litter management (Terzich et al, 2000; Macklin et al, 2005).

2.4 MAIZE

The area planted to maize (*Zea mays* L.) has grown significantly in the last 20 years and its production has almost doubled worldwide, with the United States being the largest producer and the Americas accounting for more than half of the world's grain production (FAO, 2017).

Most of the world's maize production is used for human consumption (47% in 2001), and animal consumption (42% in 2001) leaving the rest for other types of production, such as bioethanol production (Paliwal et al, 2001).

Quantifying the evolution of maize production in Uruguay is complex given the large number of uses it is put to (fodder, grain, horticulture) and the inconsistency of the different national databases (Pazos, 2008). However, the largest maize production in Uruguay is carried out by large producers, who have increased the area planted and production (DIEA, 2010; DIEA, 2016; FAO, 2017). In addition, it is known that agricultural/industrial use is predominant over human consumption (FAO, 2017; Mercado Modelo, 2017) and that the use of maize for silage has increased in recent years (Medina et al, 2001).

The maize plant is adapted to warm climates, needing good soil moisture and minimum temperatures between 9ºC and 10ºC, with the optimum temperature for growth being between 21.1ºC and 26.7ºC in the month of January (for the southern hemisphere) where its cycle is 140 days on average (Berger, 1962). The crop adapts to various soil conditions, the optimum being well-drained, aerated, deep soils with a pH between 6 and 7 (Berger, 1962; Shaw cited by Fassio et al., 1998).

Maize has a high demand for macronutrients, although nutrient uptake from the soil is usually very low in the early vegetative stages. In the case of N and P it reaches its maximum at grain filling, while K practically reaches its maximum shortly after the corn stalks emerge (Berger, 1962; Hanway, 1966; Tisdale and Nelson, 1977; Echeverría and García, 2014).

2.5 GROWTH CURVES

There are several ways of determining growth and nutrient uptake curves in plants, although all are based on Blackman's studies published by Evans and Kvet et al cited by Medina (1977). Growth analyses allow us to understand how plants produce organic matter and, therefore, what final crop yields will be like (Medina, 1977). At the same time, it allows the determination of critical moments that will generate management factors such as moments of refertilisation or irrigation (Soplín et al, 1993).

The growth of aerial biomass is fundamentally determined by the capacity of plants to develop their leaf area, which gives them a greater capacity to take advantage of solar energy (Yosida cited by Soplín et al., 1993). This is not constant, but presents curves affected by environmental factors (Medina, 1977), although they always tend to have a sigmoidal shape, the generalised growth curve for crops (Tisdale and Nelson, 1977; Rabuffetti, 1981; Barrera and Melgarejo, 2010). On the other hand, the duration in time of growth will be established fundamentally by temperature, which determines the slopes of the different parts of the curve (Baethgen, 1994). To estimate the length of the cycle in maize, degree days are used, taking 12.8ºC as a starting point and requiring 15 units of heat to determine one day of the cycle (Aldrich and Leng, 1974).

To determine these growth curves, periodic sampling must be carried out on a population, which must be uniform, as sampling is destructive. In this, parameters such as weight, leaf area or nutrient concentration are determined; the greater the number of samples taken, the more accurate the calculated curve will be (Medina, 1977).

One of the ways of observing plant growth is to record how the parameters to be observed accumulate over time (Evans, 1972; Barrera and Melgarejo, 2010).

On the other hand, the relative growth rate of these parameters can also be analysed by calculating the increase of these parameters in the time intervals between samplings (Medina, 1977; Barrera and Melgarejo, 2010).

2.6 RESPONCE CURVES

Response curves relate nutrient supply to the plant response it generates.

There are three main models that attempt to explain this phenomenon, the law of minimum, Mitscherilch's law and the law of diminishing returns (or polynomial equations).

The "law of minimum", formulated by Liebig, states that "if one nutrient is absent or deficient, while all the others are present, the soil will be deficient for all crops requiring that nutrient" (Liebig cited by Rabuffetti, 1983).

On the other hand, the exponential equations or Mitscherlich's law states that "the increase in yield obtained per unit increase in the supply of a nutrient decreases as the current yield approaches the maximum yield obtainable when that nutrient is not limiting" (Mitscherlich cited by Rabuffetti, 1983), where the formula is as follows:

$$y = A[1 - 10^{-c(x+b)}]$$

y = yield.

A = maximum harvest obtained.

C = proportionality constant, where for N the C = 0.0049 ha kg^{-1} and for manure the C = 0.018 is accepted. ha kg^{-1} (Pimentel Gomes, 1978).

x = amount of nutrient applied.

b = amount of nutrient present in the soil.

The disadvantage of this method is that it cannot analyse the interaction of more than one nutrient at a time (Rabuffetti, 1983).

In the group of quadratic polynomial equations, we cite those of Niklas and Miller, who determine that for each nutrient there is a quantity "h" associated with the maximum yield of a given crop. The increase in plant response to the addition of this nutrient per unit decreases as this "h" value is approached. Once past this value, yields will start to decrease.

This is expressed mathematically in a quadratic equation of the type:

$$y = b_0 + b_1x - b_2x^2$$

In this way, a parabolic response curve is obtained that allows predicting the amount of nutrients associated with a maximum yield value.

One of the advantages of this equation is that it allows the study of the plant response when more than one nutrient is added at the same time (x_1 and x_2), in this case the formula would be:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_1^2 + b_4x_2^2 + b_5x_1x_2$$

Where:

y is the crop yield.

x_1 and x_2 are the amounts of nutrient to be added.

b_1 and b_2 are the regression coefficients of the linear effects.

b_3 and b_4 are the regression coefficients of the quadratic effects.

b_5 is the regression coefficient of interactions.

When calculating this curve, the linear coefficients in the equation are positive, while the quadratic coefficients are negative, the interaction coefficients can be positive or negative depending on whether the interaction between them is positive or negative (Rabuffetti, 1983).

3 GENERAL OBJETIVE

To quantify the effect of different combinations of poultry litter and urea on growth, nutrient accumulation and yield of silage maize, as well as P accumulation in the soil.

4 SPECIFIC OBJETIVES

- Determine and analyse the growth and nutrient uptake curve of maize according to N sources and doses to determine critical moments of nutrient need.
- Determine and analyse the maize response curve according to N sources and doses.
- Compare different sources of nitrogen fertilisation and their combinations in terms of the plant growth generated and the residual nitrogen they leave in the soil.

5 MATERIALS AND METHODS

5.1 LOCATION OF THE EXPERIMENT

The trial was carried out in the experimental field of the Faculty of Agricultural Sciences of the Universidad de la Empresa, located on Route 62 km 55 in the department of Canelones, Uruguay (34°26'37.40"S; 56°18'57.35"W). The average annual temperature in the area is 17°C, and the average maximum and minimum temperatures are 23°C and 12°C respectively. The average annual precipitation is 1200 mm of maritime rainfall with transition to continental rainfall. The average relative humidity is 74% and the average annual potential evapotranspiration is 1000 mm (Castaño et al, 2010).

The experiment was carried out on a Argiudoll (U.S.D.A., 1999) or a Brunosol on the Uruguayan classification (M.G.A.P., 1976), in three distinct phases. The previous history of the soil is of intensive agricultural use without manure addition in the last 10 years. The chemical and physical properties of the soil are presented in Tables 1 and 2, and a more detailed description in Annex 1.

Before setting up the trials, vertical tillage with chisel, vibro cultivator and tine harrow was carried out in order to prepare the soil; and the soil P level was brought to 30 µg g^{-1} with triple superphosphate so that it was not limiting.

Table 1 - Chemical properties of the soil used in the field experiment.

Blocks	O.M.	pH H_2O	pH KCl	NO_3	P	Ca	Mg	K	Na
	%			µg g^{-1}		cmol kg^{-1} soil			
A	3.4	6.7	5.8	15	12	18.3	5.4	0.57	0.90
B	2.8	6.2	5.1	25	8	13.6	5.2	0.45	1.19
C	2.6	6.4	5.3	14	9	14.8	6.0	0.47	1.95

Table 2 - Physical properties of the A horizon of the soil used in the field experiment.

Soil	Depth (cm)	Sand	Silt	Clay	Apparent Density (gr cc^{-1})	H_2O available (mm 10 cm^{-1})
		- - - - - - - -	(%)	- - - - - -		
Brunosol	0-25	35	42	23	1.28	16.1

5.2 NITROGEN SOURCES

The chicken litter used was rice husk with two broiler rearing processes of 60 days each. The chemical characterisation of the litter was carried out in the laboratory of INIA Las Brujas with results shown in table 3. 46-0-0 commercial urea was used.

Table 3 - Chemical composition of poultry litter (dry basis).

MS %	C %	N %	P %	K %	C:N
82.4	38.2	1.48	1.24	2.14	25.8

As chicken litter is highly variable in composition, it was sampled by mixing the litter prior to each single sample taking and maximising the amount of litter as indicated by Dou et al (1997).

5.3 THE CORN

The hybrid Dekalb cultivar DK692RR2 BT, with an intermediate cycle and high yield potential, was used. Sowing was carried out with a Semeato SHM 11 precision drill with an inter-row spacing of 67 cm. After emergence it was thinned at a density of 70,000 plants ha^{-1}.

It was sown on 6 December 2014 and harvested on 12 March 2015 (103 days of cycle).

Harvest was carried out when the milk line was at mid-grain, with an overall average dry matter of 32% in whole plant and 51% in grain.

Crop growth was affected by a severe water deficit in February, which affected growth at times. The rainfall regime of the cycle recorded at the experimental site is presented in Annex 2, as well as the average daily temperatures recorded by the INIA Las Brujas Experimental Station (located 25 kilometres away in a straight line in a south-south-westerly direction).

5.4 TREATMENTS AND EXPERIMENTAL DESIGN

The experimental variables were: three doses of poultry litter based on its N supply (0, 180 and 360 kg N ha^{-1}) and three doses of urea (0, 90 and 180 kg N ha^{-1}), combined in a factorial design. To achieve the poultry litter doses, the equivalent of 14.65 and 29.5 ton ha^{-1} on a fresh basis were added to the plots. The treatments were applied in 4 x 8 m (32 m^2) plots, establishing three blocks associated with soil differences; the treatments (Table 4) were randomly distributed within each block.

Doses of mineral N (N_{min}) from urea were determined according to crop requirements. The doses of organic N (N_{org}) from poultry litter double those of N_{min} as it is estimated that in the cycle half of the N is mineralised and available to the plants (Rabuffetti, 2010).

The materials were applied 15 days before sowing. The application of chicken litter was broadcast with the full dose, while N_{min}, pure and in mixture with N_{org}, was applied in two moments:

a) a basal dose at sowing of 30 kg N ha^{-1}.

b) the dose was completed at the sixth leaf emergence, phenological stage V6 on the Ritchie and Hanway (1982) scale. The treatments applied before sowing were integrated into the soil with an eccentric disking.

Table 4 - N doses provided by urea and poultry litter in the 9 treatments.

Treatment	Urea	Chicken litter
	Kg N ha^{-1}	
1	0	0
2	0	180
3	0	360
4	90	0
5	90	180
6	90	360
7	180	0
8	180	180
9	180	360

5.5 MESUREMENTS AND DATA ANALYSIS

Sampling was carried out at the flag leaf phenological stage, at the beginning of flowering (VT) to determine N, P and K concentrations (Sumner cited by Echeverría and García, 2014).

To determine yield, 5 linear metres of the two central rows of the plots were harvested. Harvesting was done at the pasty grain stage (R4), when dry matter (DM) is estimated to be in the order of 30 - 35% (Pigurina and Pérez Gomar, 1994). The total weight of the harvested crop was recorded and sub-sampled for DM, N, P and K analysis.

In treatments 1, 3, 7 and 9, a "growth analysis" was carried out by periodic sampling (every 15 days) of the whole plant. In each sampling, dry matter and N, P and K concentrations were determined. In addition, the length and width of all leaves of two representative plants in the plot were measured to obtain data on total leaf area and leaf area index (LAI) according to Montgomery (cited by Fakorede and Mock, 1980).

In plants and litters samples, N was determined by Kjeldahl, P by colorimetry, K by atomic absorption spectrophotometer and C by calcination (Schlinchting et al., 1995). In soil, organic matter was determined by the Walkley-Black method, nitrates by salicylic acid transnitrification (Bremner and Mulvaney, 1982), P was determined by the Bray 1 method and exchangeable bases by extraction in 1N ammonium acetate at pH 7.

The data obtained were tested for normality and homogeneity of variance (Shapiro-Wilk and Bartlett).

Analyses of variance (ANOVA) were performed to evaluate main effects and interactions, and a Fisher's test with a 95% confidence interval was performed on the harvest. Linear and non-linear regressions were also performed, and the goodness of fit was measured using the pseudo R2 (SR2) method. Analyses of covariance (ANCOVA) between dry matter yield and N, P and K extracted by the crop, and the organic carbon, thickness and penetrability of the soil A horizon of all the plots were also carried out with the harvest data, to rule out other factors that could have affected the results obtained.

Non-linear regressions were performed for growth curves and nutrient accumulation curves, and multiple linear regressions were performed for the IAF. For each sampling, an ANOVA and a test of means were carried out to determine when the differences between treatments occurred.

In the study of the harvest data, analysis of variances, tests of means and multiple linear regressions were performed to obtain the response curves to nutrient addition. Similar studies were carried out for the post-harvest soil nutrient analysis as above.

The data for yield, N, P and K absorbed and P in soil were correlated using Spearman's method, and the Pairwise two-sided method was used to obtain the significance of the values.

The N, P and K data from the leaf analysis showed to be non-normal and non-homogeneous, so Friedman analyses were performed.

Statistical analyses of the data obtained were carried out with the R statistical software (Version 1.0.143).

6 RESULTS AND DISCUSSION

The growth analysis data as well as the harvest data are presented in Annexes 3 and 4.

An uneven distribution of yields was observed in the trial, with the highest yields occurring at the western end of the trial, as shown in the figure in Annex 5. Therefore, it was decided to perform covariance analyses with the following soil parameters: A horizon thickness, penetration resistance and organic matter content, in an attempt to determine any effects of these on the results obtained. The analyses did not determine any effects of the parameters on the treatments (all information is available in Annex 6).

6.1 GROWTH ANALYSIS

Due to insurmountable drawbacks with the first three samplings, it was not possible to properly adjust the N, P and K accumulation curves. This was in addition to the period of water deficit during the crop cycle, which most likely affected the uptake of the three nutrients (Hu and Schmidhalter, 2005; He and Dijkstra, 2014).

It should be noted that in all cases maize was harvested with the aim of producing whole plant silage, so it was harvested earlier than is traditional for a dry grain crop, so it was also shorter in nutrient uptake period, according to most studies on growth and nutrient extraction.

Despite the drawbacks, it was possible to determine and analyse the nutrient uptake curves, obtaining results similar to those of Sayre (1948).

The physiological stages observed in the crop were similar to those described by Amado et al (2017) with similar cycle length and temperature conditions.

6.1.1 Dry matter accumulation

The average values of the samples taken to obtain the DM accumulation curves are shown in Table 5.

Table 5 - DM accumulation according to the physiological state of the crop.

Physiological state	V3	V6	V9	VT	R1	R3	R4
Time (das)	24	44	53	67	82	97	103
Treatment				kg ha^{-1}			
T1	298 a	1169 b	2497 b	4958 b	5504 b	7515 b	7632 c
T3	437 a	1933 a	3907 a	9279 a	11264 a	13665 a	13814 b
T7	503 a	2458 a	4790 a	9573 a	13124 a	16201 a	17434 a
T9	382 a	2102 a	4724 a	10048 a	13524 a	16172 a	17136 a

T1 – Witness T3 – 360 kg N_{org} ha^{-1} T7 – 180 kg N_{min} ha^{-1} T9 – 360 kg N_{org} ha^{-1} + 180 kg N_{min} ha^{-1}
das – days after sowing.

Figure 1 shows the DM accumulation curves with the characteristic sigmoidal shape (Hanway, 1966; Rabuffetti, 1981; Hunt, 1990; Vanderlip cited by Echeverría and García, 2014).

All treatments showed rapid vegetative growth, differing from the control 44 days after sowing with a significance greater than 95% confidence and from day 53 with a significance greater than 99%. At harvest, the treatment with the highest addition of N_{org} (T3) was significantly different from the control and the treatments with N_{min}.

It is at the V6 stage that the treatments with nitrogen fertilisation begin to differentiate from the control, which indicates a critical moment in the management of nitrogen fertilisation; a result that agrees with those of Echeverría and García (2014), Sangoi et al (2007) and Walsh (2006), among others.

Annex 7 shows the analysis of variance and mean tests carried out, and Annex 8 shows the individual DM accumulation curves with their regression tables and mathematical formula.

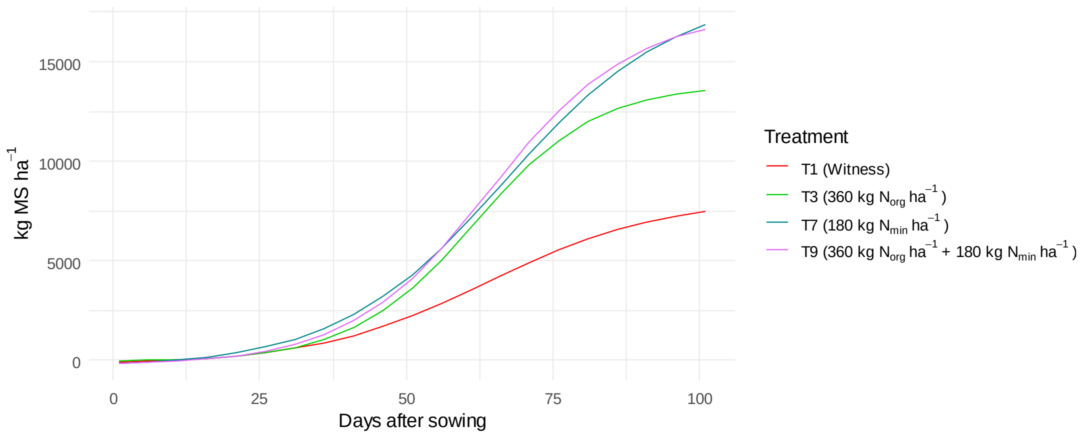


Figure 1 - DM accumulation according to treatments.

6.1.2 N uptake

The average values of the samples taken to obtain the N uptake curves are shown in Table 6.

Table 6 - N uptake according to the physiological state of the crop.

Physiological state	V9	VT	R1	R3	R4
Time (das)	53	67	82	97	103
Treatment			kg ha^{-1}		
T1 (Witness)	31 b	37 c	43 c	56 c	66 b
T3 (360 kg N_{org} ha^{-1})	50 b	71 b	86 b	86 bc	87 b
T7 (180 kg N_{min} ha^{-1})	100 a	115 a	123 a	154 a	182 a
T9 (360 kg N_{org} ha^{-1} + 180 kg N_{min} ha^{-1})	90 a	112 a	126 a	141 ab	158 a

das - days after sowing

In the case of extracted N, the N_{min} treatments differed from the Norg-only treatment and the control from the beginning, the latter two not being different from each other. On day 67, the N_{org} treatments differed transiently from the control and the N_{min} treatments, but at harvest this treatment was equal to the control, and the N_{min} treatments are equal to each other, but different from each other (Table 6, Figure 2). These results are in agreement with the studies of Nyamangara et al (2003) with urea and cattle manure, where N availability and plant uptake efficiency were affected by a period of drought, altering Norg mineralisation.

The analysis of variance and mean tests are given in Annex 7, and the individual N accumulation curves with their regression tables and mathematical formula in Annex 8.

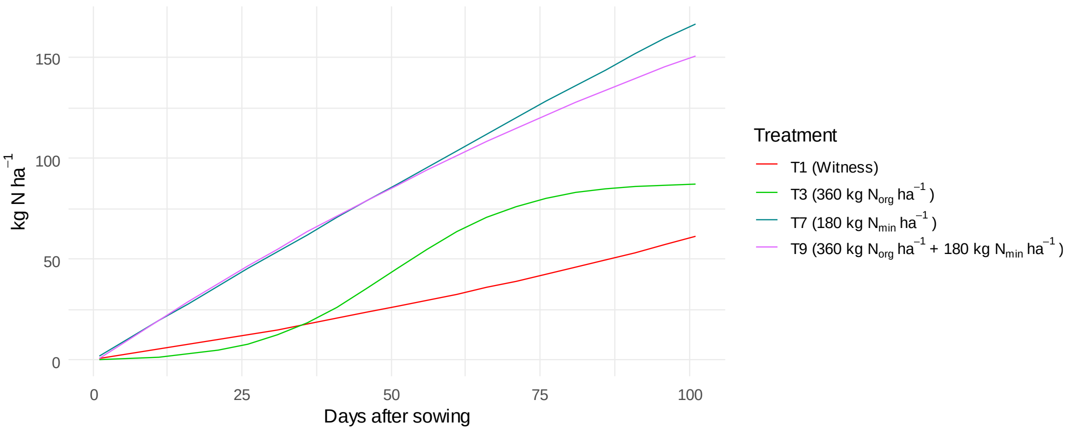


Figure 2 - N accumulation according to treatments..

6.1.3 P uptake

The average values of the samples taken to obtain the P uptake curves are shown in Table 7.

Table 7 - P uptake according to the physiological state of the crop.

Physiological state	V9	VT	R1	R3	R4
Time (das)	53	67	82	97	103
Treatment			kg ha^{-1}		
T1 (Witness)	6 c	9 b	9 b	11 b	13 b
T3 (360 kg N_{org} ha^{-1})	11 bc	17 a	17 a	19 ab	24 a
T7 (180 kg N_{min} ha^{-1})	14 ab	16 a	16 ab	21 a	25 a
T9 (360 kg N_{org} ha^{-1} + 180 kg N_{min} ha^{-1})	17 a	20 a	21 a	25 a	28 a

das - days after sowing

Regarding P uptake, all treatments differed from the control with some fluctuations during growth. P uptake (Figure 3) showed an almost linear behaviour which is consistent with the studies of Vanderlip (cited by Echeverría and García, 2014). The P uptake rate of the fertilised treatments was double that of the control, with no major differences between them. This agrees with the studies of Ciampitti et al (1987), which showed a lower P uptake in the absence of other mineral nutrients, explained by a lower root development.

The analysis of variance and mean tests are given in Annex 7 and the individual P accumulation curves with their regression tables and mathematical formula in Annex 8.

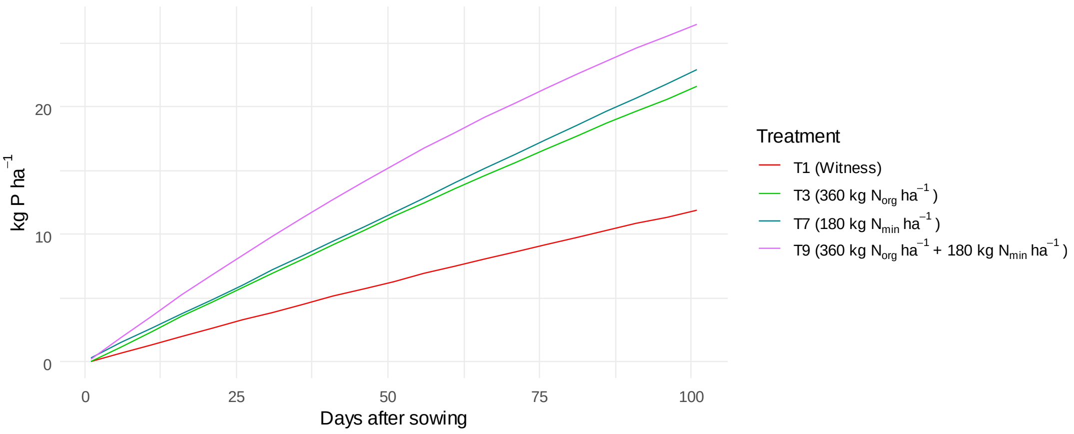


Figure 3 - P accumulation according to treatments.

6.1.4 K uptake

The average values of the samples taken to obtain the K absorption curves are shown in Table 8.

Table 8 - K uptake according to the physiological state of the crop.

Physiological state	V9	VT	R1	R3	R4
Time (das)	53	67	82	97	103
Treatment			$kg\ ha^{-1}$		
T1 (Witness)	54 c	66 c	76 c	74 c	72 c
T3 (360 kg N_{org} ha^{-1})	101 b	114 b	116 b	119 b	120 b
T7 (180 kg N_{min} ha^{-1})	147 a	203 a	209 a	222 a	238 a
T9 (360 kg N_{org} ha^{-1} + 180 kg N_{min} ha^{-1})	153 a	189 a	192 a	203 a	214 a

das - days after sowing

For K, sigmoidal curves were obtained (Figure 4); at the time of emergence of the maize stalks (phonological stage R1), absorption decreases and the curve becomes horizontal. This is in agreement with Hanway (1966), Hunt (1990) and Roy et al, cited by Echeverría and García (2014). The curve for T3 (360 kg N_{org} ha^{-1}) is not presented because it could not be modelled due to a lack of points. In any case, a comparison of means was made with the available data.

For K, the differences between treatments remained constant throughout the growth period, with the dose containing only N_{org} and the treatments with N_{min} being different from the control. In addition, it was observed that from the second sampling there were significant differences between blocks A and B with block C, probably due to the higher Na content in the soil (Table 1), this is explained by Izzo et al and Wu et al (cited by Parida and Das, 2005).

Analyses of variance and tests of means are given in Annex 7, and the individual accumulation curves for DM, N, P, K and IAF with their regression tables and mathematical formula in Annex 8.

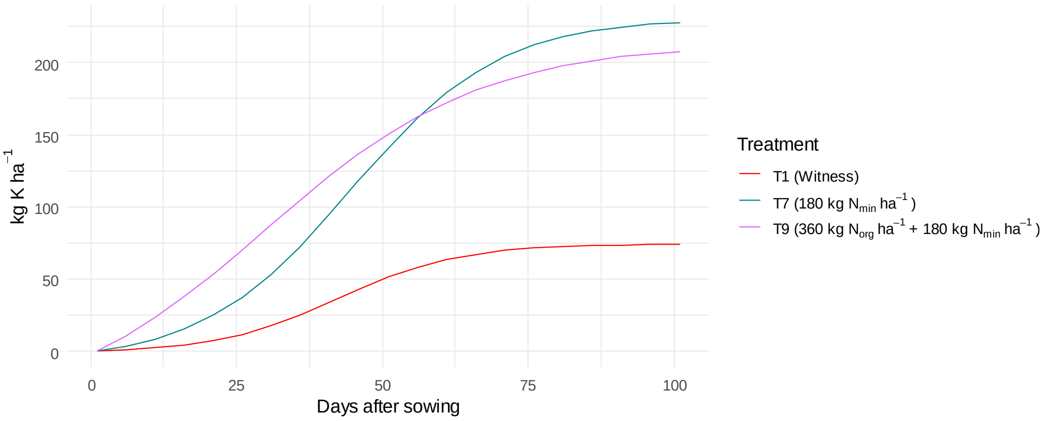


Figure 4 - K accumulation according to treatments..

6.1.5 Leaf Area Index (LAI)

The average values of the samples taken to obtain the LAI curves are shown in Table 9.

Table 9 - Leaf area index according to the physiological state of the crop.

Physiological state	V6	V9	VT	R1	R3
Time (das)	44	53	67	82	97
Treatment	$m^2_{hoja}\ m^{-2}_{suelo}$				
T1 (Witness)	0,81 c	1,81 c	1,79 b	1,52 c	1,55 b
T3 (360 kg N_{org} ha^{-1})	1,78 b	2,13 bc	3,24 a	2,44 b	2,57 a
T7 (180 kg N_{min} ha^{-1})	1,75 b	2,67 b	4,12 a	3,40 a	3,37 a
T9 (360 kg N_{org} ha^{-1} + 180 kg N_{min} ha^{-1})	2,37 a	3,54 a	3,66 a	3,47 a	3,34 a

das - days after sowing

In the case of the LAI, exponential curves (Hunt, 1990) could be fitted, all with significant t-values and with a high R2 (all greater than 0.94).

In Figure 5 and Table 9, it can be seen how the treatments with added N differ from the control, the exception being the addition of Norg with the control on day 53. In the treatments fertilised with N, regardless of the source, it can be seen that although there were significant differences in the early stages of the crop, they disappear towards the end of the cycle. In the model it is observed that the LAI starts to decline only at T9.

It should be noted that the development of the LAI presents similar characteristics to DM accumulation (Figure 1), due to the relationship between both parameters (Yosida cited by Soplín et al, 1993). The values obtained are similar to those found by Wilhelm and Schlemmer (2000).

The analysis of variance and mean tests are presented in Annex 7, and in Annex 8 the individual curves of the LAI increase with their regression tables and the mathematical formula.

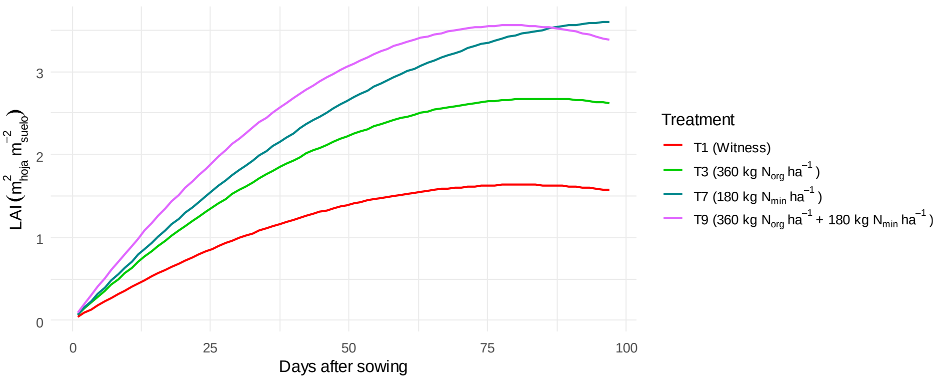


Figure 5 - Increase in the LAI according to treatments.

6.2 HARVEST

Prior to harvest, at the beginning of flowering, foliar sampling was carried out to determine the nutritional status of the crop. The information is presented in Annex 9 and its statistical analysis in Annex 10.

The average N concentration was lower than that described by Jones and Eck (cited by Cornforth and Steele, 1981), Uhat and Echeverría (cited by Echeverría and García, 2014) and Correndo and García (2017); this is probably due to the lack of mineralisation due to the severe water deficit period that affected the crop (He and Dijkstra, 2014). On the other hand, P and K values are within those described by Correndo and García (2017), while P values are in deficiency and K in sufficiency according to Voss and Gascho (cited by Rabuffetti, 2014).

The fact that N values were presented as insufficient while the same did not occur with P and K is explained by the independence of this nutrient in this analysis, as shown by Ramírez (1980).

The analysis of means shows that the treatments containing N_{min} had the highest N, P and K values while those containing N_{org} had the lowest values. On the other hand, the mixtures with the highest doses obtained high values, while the mixtures with the intermediate doses obtained medium values for these nutrients. This result could show a low mineralisation of the organic material which resulted in a lower N uptake by the crop.

The statistical differences found between the different treatments in N, P and K in the foliar sampling do not closely match those found in the absorption of these nutrients at harvest. According to Rabuffetti (2014), these differences are due to the fact that different plant organs of the crop were chemically analysed, one being a foliar sample and the other a whole plant sample.

6.2.1 Dry matter

The average yield of the trial was 14893 kg DM ha^{-1}, with a maximum of 19430 kg DM ha^{-1} (T8) and a minimum of 7632 kg DM ha^{-1} (T1). When analysing the results obtained, it can be seen that there were significant differences at 0.1% in the treatments with N_{min}, at 5% with N_{org} and at 1% in the interaction. This can be seen in the ANOVA table (Table 1) in Annex 11. The comparison of the means of the treatments is shown in Table 10.

Table 10 - Fisher's test of DM performance.

Treatament	N_{min}	N_{org} kg ha^{-1}	Mean	Groups
T08	180	180	19430	a
T07	180	0	17430	ab
T09	180	360	17140	abc
T04	90	0	16060	abc
T05	90	180	15690	bc
T06	90	360	15650	bc
T03	0	360	13810	cd
T02	0	180	11190	de
T01	0	0	7632	e

Least significant difference: 3618

Table 11 - Fisher's block test of harvested DM.

Block	Mean kg ha^{-1}	Groups
A	16838	a
B	14765	b
C	13075	c

Least significant difference: 1245

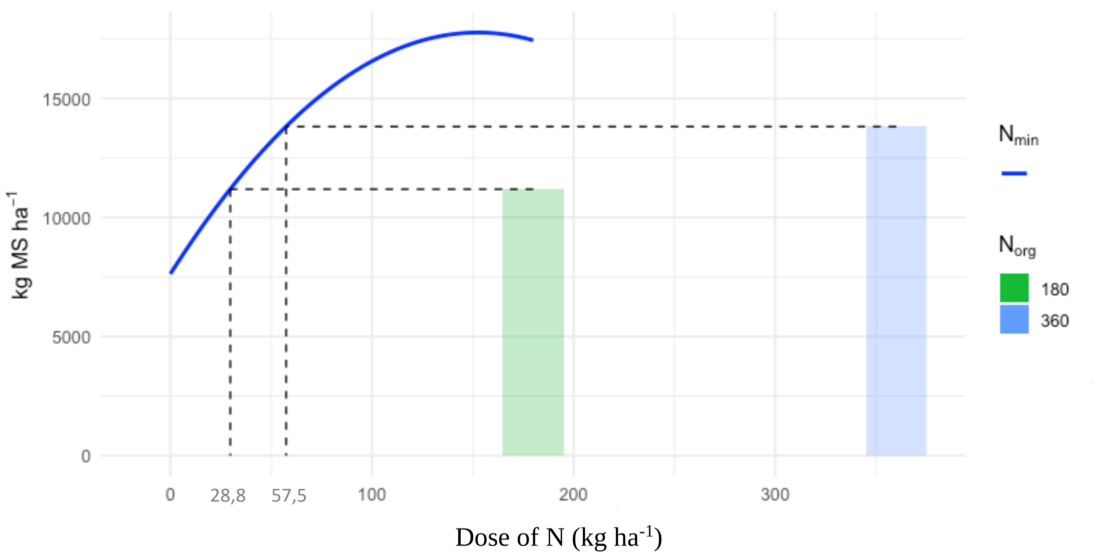
N_{min} has the greatest influence on DM production, however, when these treatments are compared statistically, it is observed that all treatments with N_{min} do not differ from each other, except T8 (180 kg N ha^{-1} from both sources) which yielded the most (Table 10).

The plant response for the treatments with N_{min} and without N_{org} had the following equation (regression data can be found in Table 2 of Annex 11 and Figure 1):

$$y(kg\ DM\ ha^{-1}) = -0.44N_{min}^2 + 132.83N_{min} + 7632.29$$

$$R^2 = 0.78$$

Figure 6 shows the graphical representation of the above formula together with the means of the different treatments containing only Norg.



The rest of the significant differences are due to the addition of N_{org}. It is observed that the maximum dose of N_{org} produces a statistically equal effect as adding 90 kg N_{min} ha^{-1} mixed with any dose of N_{org}. If the addition of N_{org} without N_{min} is analysed, it can be seen that the two doses are not significantly different from each other. Furthermore, the lower dose of N_{org} does not differ from the control.

If the equation in Figure 6 is equated with the two doses of N_{org} alone, the equivalence to the use of N_{min} is obtained, i.e. the addition of 360 kg N_{org} ha^{-1} has the same yield potential as adding 57.5 kg N_{min} ha^{-1}, and adding 180 kg N_{org} ha^{-1} would be equivalent to applying 28.8 kg N_{min} ha^{-1}. This does not agree with the studies of

Rabuffetti et al (2010) with irrigated maize, where the plant response generated by N_{org} was approximately 50% of the response generated by N_{min}. In the present study the plant response was 16%. This is probably due to the lack of mineralisation of organic materials during the water deficiency period as explained by Eghball et al (2002).

Fitting the response curve of the two added N sources (N_{min} and N_{org}) gives the equation presented below (the regression table can be found in Annex 11 Table 3) and is represented graphically in Figure 7:

$$y(kg\ DM\ ha^{-1}) = -0{,}17N_{min}^2 - 0{,}1N_{org}^2 + 87{,}87N_{min} + 23{,}09N_{org} - 0{,}1N_{min}N_{org} + 8074{,}63$$

$R^2 = 0{,}73$

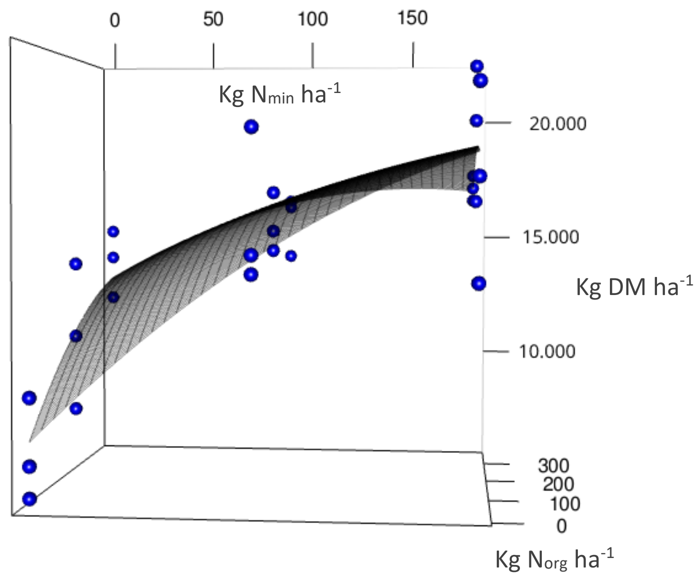


Figure 7 - Performance according to the aggregate of N_{min} and N_{org}.

It can be seen that the point with the highest N addition from the two sources enters the zone of yield decrease. The curve shows the depressive effect of the joint addition of the two N sources at their maximum doses (Rabuffetti, 1983).

It can also be observed that in the polynomial response equation, N_{min} has a higher regression coefficient of linear effects than N_{org}, which coincides with what was indicated above, that the higher plant response is more related to the addition of N_{min} than to N_{org}.

This phenomenon can be partly explained by the fact that during crop development there was a period of low rainfall, which decreased soil moisture and therefore the rate of N_{org} mineralisation as explained by Eghball et al (2002).

These results are similar to those obtained by Khaliq et al (2004), who achieved the highest maize grain yields in combinations of poultry litter and urea, although this combination was not different from the same dose of N provided by urea alone.

The differences observed in this work with the N_{org}-only treatments are in agreement with the results obtained by Farhad et al (2009).

6.2.2 N extraction

The average crop extraction was 112 kg N ha^{-1}, with a maximum of 181.5 kg N ha^{-1} (T7) and a minimum of 60.7 kg N ha^{-1} (T1). There were significant differences at 0.1% only in the N_{min} treatments, which can be seen in the ANOVA table in Annex 11 (Table 4). The comparison of the means of the treatments is shown in Table 12.

Table 12 - Fisher's test of N extracted at harvest.

Treatament	N_{min}	N_{org} kg ha^{-1}	Mean	Groups
T07	180	0	181.5	a
T08	180	180	165.8	a
T09	180	360	158.5	a
T05	90	180	110.3	b
T06	90	360	89.7	bc
T04	90	0	87.1	bc
T03	0	360	86.6	bc
T02	0	180	67.1	c
T01	0	0	60.7	c

Least significant difference: 31.65

Table 13 - Fisher's block test for N extracted at harvest.

Block	Mean kg ha^{-1}	Groups
A	125.28	a
B	111.21	ab
C	99.24	b

Least significant difference: 18.27

In the N uptake of the crop, it is observed that N_{org} does not generate differences, even when the interaction with N_{min} is taken into account (Annex 11, Table 4).

When comparing the averages of the treatments, it is observed that the treatments with a higher dose of N_{min}, regardless of whether or not they are accompanied by N_{org}, do not differ from each other and do differ from the rest. The same happens with the low dose of N_{min}, they do not differ from each other, nor do they differ from those treatments that present the maximum dose of N_{org} only. It is also observed that all the treatments with only N_{org} and the treatments with the lowest dose of N_{min}, except for T05 (90 kg N_{min} ha^{-1} + 180 kg N_{org} ha^{-1}), are not statistically different from the control.

The N extraction values are similar to those described by Roy and Wright (cited by Echeverría and García, 2014). Furthermore, the experimental results obtained are similar to those of Alizadeh et al (2012) in their trials with urea and cattle manure in maize and to those of Hirzel et al (2007) using chicken litter compared to urea in maize silage production.

In the correlation study in Annex 12, the correlation between N uptake and final yield is 84% with a significance level of 0.1%. This coincides with the studies of Moll (1982) with his trials on maize fertilised with different doses of urea.

6.2.3 P extraction

The average crop extraction was 23 kg P ha^{-1}, with a maximum of 29.3 kg P ha^{-1} (T8) and a minimum of 12.8 kg P ha^{-1} (T1). When analysing the results obtained, it can be seen that there were significant differences of 0.1% with N_{min} and 1% with N_{org}, which can be seen in the ANOVA table (Table 5) in Annex 11. The comparison of the means of the treatments is shown in Table 14.

Table 14 - Fisher's test of P extracted at harvest.

Tratament	N_{min}	N_{org} kg ha^{-1}	Mean	Groups
T08	180	180	29.3	a
T09	180	360	28.5	a
T07	180	0	25.4	ab
T06	90	360	25.0	ab
T05	90	180	24.7	ab
T03	0	360	23.8	ab
T04	90	0	21.9	b
T02	0	180	20.0	b
T01	0	0	12.8	c

Minimal significant difference: 6.2

Table 15 - Fisher's block test for P extracted at harvest.

Block	Mean kg ha^{-1}	Groups
A	27.3	a
B	23.4	b
C	19.7	c

Minimal significant difference: 3.6

Significant differences are generated by the addition of N_{min} and N_{org}, not by their interaction. All treatments differ from the control and the lowest dose of N_{min} and the lowest dose of N_{org} are different from high doses of N_{min} combined with any dose of N_{org}. This coincides with the results of the P accumulation analysis, where the rate of crop uptake was much higher in any treatment compared to the control without differing much from each other (Table 7). This is probably due to the fact that the addition of N resulted in greater root development which allowed greater P extraction (Ciampitti et al, 1987). This is confirmed by the correlation analysis shown in Annex 12, where the correlation between the variables is 66% with a significance of 0.1%.

The P extraction values are similar to those described by Roy and Wright (cited by Echeverría and García, 2014) and the differences obtained are similar to those of Eghball and Power (1999).

It should be remembered that a basal dose of P was applied to the soils with the aim of not limiting crop growth, which is why there were no major differences, since the P applied through the chicken litter was not largely used by the crop (Mohanty et al, 2006).

6.2.4 K extraction

The average crop extraction was 152 kg K ha^{-1}, with a maximum of 219.5 kg K ha^{-1} (T7) and a minimum of 68.4 kg K ha^{-1} (T1). When analysing the results obtained, it can be seen that there were significant differences at 0.1% with the addition of N_{min}, which can be seen in the ANOVA table in Annex 11 (Table 6). The comparison of the means of the treatments is shown in Table 18.

Table 16 - Fisher's test for K extracted at harvest.

Treatament	N_{min}	N_{org}	Mean	Groups
	kg ha^{-1}			
T07	180	0	219.5	a
T08	180	180	204.7	a
T09	180	360	202.5	a
T04	90	0	175.3	ab
T05	90	180	145.0	bc
T06	90	360	139.8	bcd
T03	0	360	120.1	cde
T02	0	180	89.4	de
T01	0	0	68.4	e

Minimal significant difference: 52.1

Table 17 - Fisher's block test for K extracted at harvest.

Block	Mean kg ha^{-1}	Groups
A	177.89	a
B	160.95	a
C	116.07	b

Minimal significant difference: 30.06

The main differences in K uptake are generated by the N_{min} dose and the block. If the treatments are ordered according to K extraction, it is observed that the highest extractions are with N_{min} doses, and that with N_{min} supply the extraction is ordered inversely to the N_{org} dose; in the treatments without N_{min}, it is ordered in an increasing order according to the N_{org} dose. This may be due to the fact that chicken litter contains Na and Ca (Barbazán et al, 2011; Rabuffetti, 2012), which can interfere with K absorption (Rabuffetti, 2017). Sosa (2008) determined a decrease in yields in wheat fertilised with poultry litter and attributed it to excess Na.

High doses of N_{min} and low doses of only N_{min} did not differ from each other; all low doses of N_{min} did not differ from each other and all doses containing no added N_{min} did not differ from each other. The uptake of N and K were similar because the extraction of these nutrients by the crops is similar (Black, 1975). This is confirmed by the correlation analysis shown in Annex 12, where the correlation between the variables is 81% with a significance of 0.1%.

Table 17 shows that block C showed lower K uptake, which is explained, as in the K accumulation curves, by the higher Na content of the block (Table 1); this probably affected the K uptake by the plant as described by Wu et al (cited by Parida and Das, 2005) and by Izzo et al (1991).

All plant K values are in agreement with those described by Rabuffetti (2017) and Ciampitti (cited by Echeverría and García, 2014).

K extraction in crops whose objective is to harvest for whole-plant silage, when repeated in the same place, can lead to K deficiencies in a few years. The speed with which this occurs depends on the management of fertilisation with this nutrient and the soil's reserves of this nutrient (Hernández, 1996).

6.3 SOILS

Tables 18 and 19 present the post-harvest soil chemistry data in µg g^{-1}, details of which can be found in Annex 13.

Table 18 - Summary of NO_3 in soil.

N_{org}/N_{min}	0	90	180
0	31	31	29
180	22	36	35
360	25	27	33

Table 19 - Summary of P in soil.

N_{org}/N_{min}	0	90	180
0	29	32	35
180	58	57	56
360	117	90	85

6.3.1 Nitrates

Nitrates remaining in the soil after harvest show no differences between treatments (Annex 14, Table 1); this is in agreement with the work done by Taverna and Charlón (1999) with maize and dairy manure.

Other authors have found significant differences in nitrates in the soil after crop harvesting. Kazmi and Ali (2010) found differences between treatments with urea and the combination of different doses of urea mixed with chicken manure. Sharpley et al (1992) found differences between chicken litter application treatments and controls, while Tyson and Cabrera (1993) described how nitrate increases days before the application of different sources of N_{org}. Rabuffetti et al (2010), in trials with chicken manure and urea in maize, found that these differences begin to appear as treatments are repeated over the years. These results, together with the problems of mineralisation of organic material due to water deficit, may explain why no significant differences between treatments were found in this study.

6.3.2 Available phosphorus

For the remaining soil P, the factors that generated differences are N_{org} and the interaction between N_{org} and N_{min} with a significance of 0.1%, this can be seen in the ANOVA table in Annex 11 (Table 2).

Table 20 - Fisher's test for post-harvest P in soil.

Treatament	N_{min} kg ha^{-1}	N_{org}	Mean $\mu g\ g^{-1}$	Groups
T03	0	360	117.3	a
T06	90	360	90.7	b
T09	180	360	85.0	b
T02	0	180	58.3	c
T05	90	180	57.7	c
T08	180	180	56.0	c
T07	180	0	35.0	d
T04	90	0	32.3	d
T01	0	0	29.7	d

Least significant difference: 15.8

It is a known phenomenon that the addition of poultry litter (N_{org}) generates excess P in the soil. A negative interaction was found between the addition of urea and poultry litter on the remaining P in the soil, on which no bibliographic information has been found.

When comparing the averages of the treatments, the differences are determined by the dose of poultry litter. However, it is worth noting the difference between the treatments with the maximum dose of poultry litter when it is combined or not with urea. This indicates that, with high doses of this organic material, the combination with N_{min} (urea) can reduce the available P content in the soil.

The P balance of the experiment is presented in table 21.

Table 21 - P balance in the trial.

Treatments	N_{min}	N_{org}	P in pre-sowing soil	Total P applied in the treatments	Crop extraction	P in soil post-harvest
				kg ha^{-1}		
T1	0	0	34	0	13	33
T2	0	180	34	150	20	65
T3	0	360	34	300	24	131
T4	90	0	34	0	22	36
T5	90	180	34	150	25	65
T6	90	360	34	300	25	101
T7	180	0	34	0	25	39
T8	180	180	34	150	29	63
T9	180	360	34	300	29	95

It should be noted that the P in the soil and the extracted P is plant-available P while the P applied by the treatments is total P.

The increase of P in the soil with the addition of poultry litter (without urea) was modelled and it was found that it behaves exponentially. That is, as the dose of poultry litter increases, the increase in P in the soil becomes greater and greater. A possible explanation for this behaviour is that when very high doses of P are used, the retrogradation mechanisms lose efficiency, so that a greater proportion of the P becomes available to the plants.

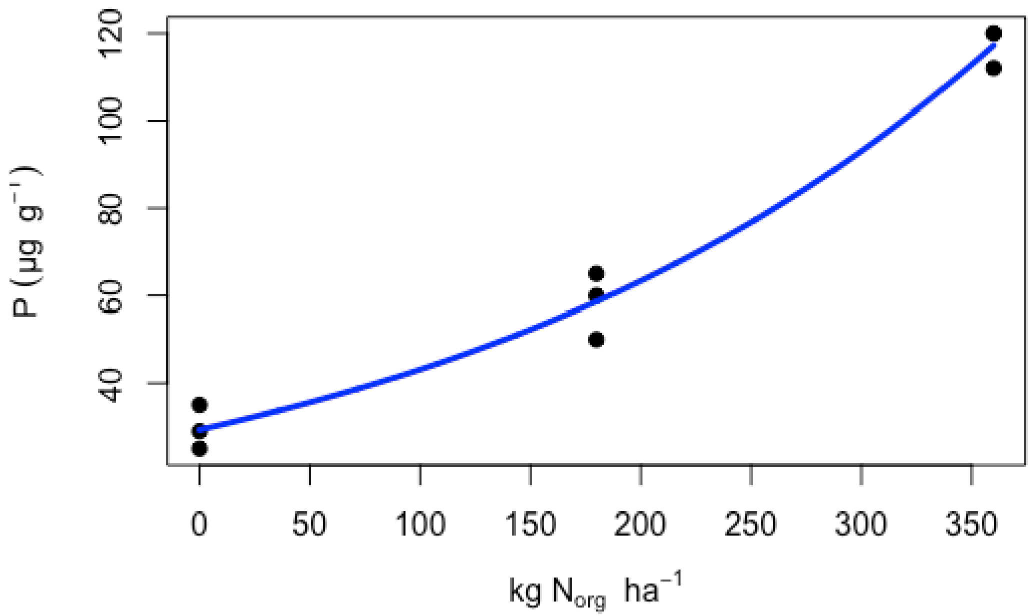


Figure 8 - P available in the soil with the addition of poultry litter (N_{org}).

$$P(\mu g\ g^{-1}) = 29{,}34\ e^{0{,}004 N_{org}}$$

$SR^2 = 0{,}98$

As no bibliographic information could be found, this model was used as the best fit. The table of these regression analyses can be found in Annex 14, Tables 3 to 6.

Applying the same procedure with the incorporation of the N_{min} treatments, it was possible to establish that the addition of N_{min} reduces the amount of P remaining in the soil after harvest (figures 9 and 10). As can be seen in Table 21, the treatments with higher doses of N_{org} and N_{min} extracted more P from the soil, results that coincide with those of Cremona and Vezzoso (1990) in their trials on maize fertilised with N and P.

The correlation analysis between the P absorbed by the crop and the P remaining in the soil determined a 44% correlation with a significance of 5%, which supports the hypothesis that this higher extraction could explain the lower amount of P in the soil at the same dose of N_{org}.

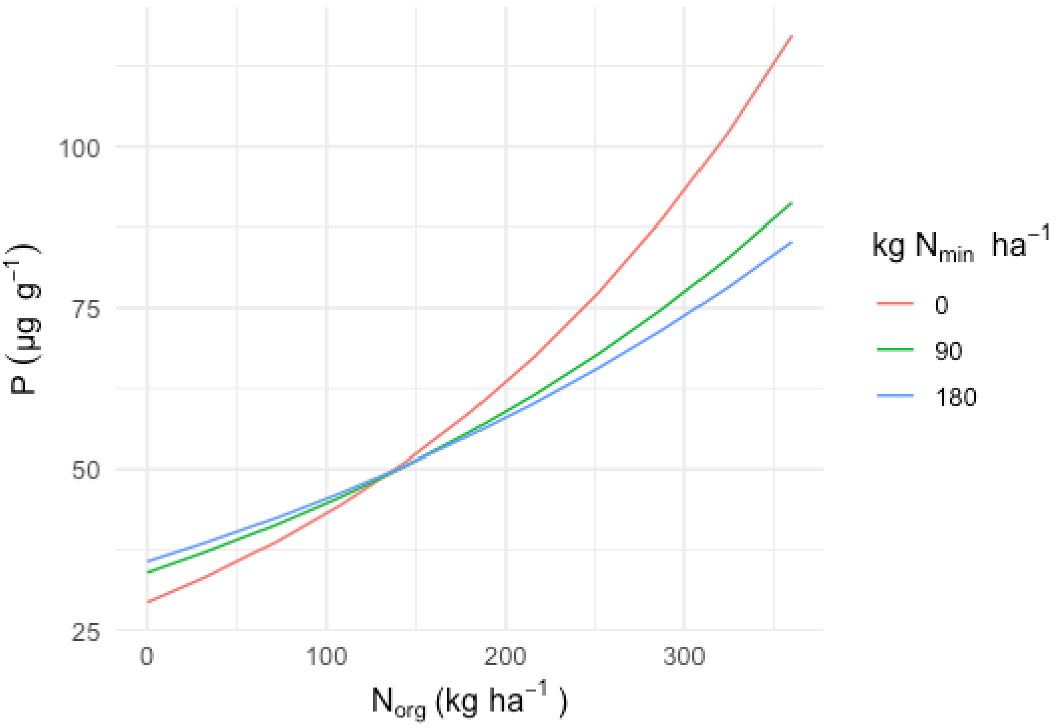


Figure 9 - P in soil with the addition of poultry litter (N_{org}) and urea (N_{min}).

Attempting to quantify this phenomenon and assuming that this relationship is a plane in space, a linear regression was performed between both sources and the level of P in the soil obtaining the equation:

$$P(\mu g\ g^{-1}) = -0{,}05N_{min} + 0{,}18N_{org} + 34{,}6$$

$R^2 = 0{,}85$

The R2 value allows to establish that for the conditions of the study, the addition of 1 kg N_{min} reduces by about 0.05 µg g^{-1} the remaining P in the soil from the poultry litter. The regression analysis is available in Table 7 of Annex 14.

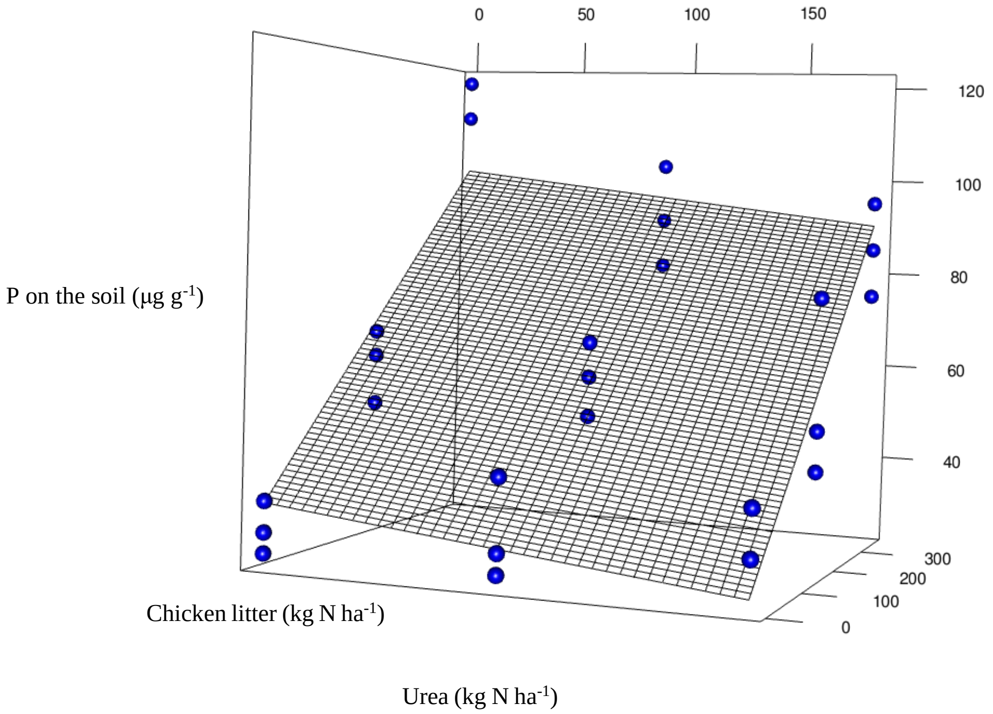


Figure 10 - P in post-harvest soil according to the addition of N_{org} and N_{min}.

The same regression was performed adjusting the total aggregate P instead of Norg and obtained:

$$P(\mu g\ g^{-1}) = -0{,}05N_{min} + 0{,}22P_{total} + 34{,}6$$

$$R^2 = 0{,}85$$

For each kilogram of total P added with chicken litter, the assimilable P remaining in the soil after harvest is 0.22 µg g^{-1}. The tables of this regression can be found in Annex 15.

7 CONCLUTION

According to the results obtained and for the experimental conditions it is concluded:

- During the growth cycle, close to the V6 stage, nitrogen fertilisation treatments begin to differentiate from the control in DM production. This implies that this is a critical moment in the management of N fertilisation.
- No critical points for P and K fertilisation could be determined, but it was observed that the uptake of these nutrients is related to N uptake and DM production.
- Norg mineralisation was 32% lower than the literature because of the lack of soil moisture, which affected plant response and resulted in lower yields when the N source was exclusively organic.
- A positive interaction between N_{min} and N_{org} was observed in the DM production of the crop, which becomes negative at the maximum dose of both sources. However, this interaction does not manifest itself in N and K extraction, where the N_{min} dose is the one that generates differences. In the case of P uptake, it was possible to determine that the differences occur as a consequence of the application of N_{min} and N_{org}, without verifying the existence of an interaction between the two.
- The results of this experiment show that the P content of the soil made available by the addition of poultry litter increases exponentially. When modelling the data obtained in a plane, it can be seen that for each kg Norg ha^{-1} added, the P content in the soil increased by 0.24 µg g^{-1}. At the same time, there is a negative interaction with the addition of N_{min}, which causes a decrease in the remaining N_{min} in the soil. This decrease in P could be explained by the greater extraction of this nutrient by the crop when N_{min} was added. No literature has been found on this behaviour. It would be necessary to repeat this experiment in order to verify the tendency found.

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9 ANNEXES

Annex 1. Soil description of the experimental site

Horizon Depth (cm)	Morphological characteristics
0 - 12 A	Brown to dark greyish brown (10YR 3.5/2), mottled yellowish brown (10YR 5/6), small, few, irregular edges; silt loam (p) with fine sand, common; subangular, medium, moderate to weak blocks; consistency when wet friable, and when wet slightly plastic and slightly sticky; abundant fine roots; clear transition.
12 - 23 AB	Very dark grey (10YR 3/1), yellowish red mottled (5YR 5/6); silty clay to silty clay loam (p); medium to coarse, strong subangular blocks; consistency when wet firm, when wet slightly plastic, sticky; roots common to abundant; gradual transition to clear.
23 - 46 Bt_1	Black (10YR 2.5/1); silty clay; angular, coarse, firm blocks; wet consistency very firm, wet consistency very plastic and very sticky; common, thin and discontinuous clay films; few, fine and medium Fe and Mn concretions; common, fine roots present; gradual transition.
46 – 67 Bt_2	Dark grey to very dark grey (10YR 3.5/1); silty clay; angular, coarse, firm blocks; wet consistency very firm, wet consistency very plastic and very sticky; clay films, common, continuous; fine roots common; calcium carbonate concretions; gradual transition.
67 – 80 BC	Brown (10YR 5/3); silty clay; angular blocks breaking into subangular, medium and coarse, firm; consistency when wet firm and when wet slightly plastic and slightly sticky; strong reaction to HCl; clear transition.
80 - + C	Pale brown (10YR 6/3), black betas; silty clay; calcium carbonate concretions, abundant, strong reaction to HCl. (Libertad Formation)

Geographic location: 34° 26´ 37,9” S , 56° 18´ 54,9” O

Uruguayan classification: Brunosol Eutrico Típico, FL.

USDA classification: Fine, mixed, superactive, thermic, Typic (Vertic) Argiudoll.

Horizon Depth (cm)	Morphological characteristics
0 -12 A	Very dark greyish brown (10YR 3/2); silty clay loam; subangular, medium, moderate to heavy blocks; consistency when wet friable, and when wet slightly plastic and slightly sticky; abundant fine roots; gradual transition.
12 - 26 BA	Very dark brown (10YR 2/2); silty clay loam (p); medium to coarse, strong subangular blocks; consistency when wet firm, when wet slightly plastic, sticky; roots common to abundant; clear transition.
26 - 50 Bt_1	Black (10YR 2/1); silty clay; angular, coarse, firm blocks; wet consistency very firm, wet consistency plastic and sticky; common, thin, discontinuous clay films; common to abundant fine roots present; gradual transition.
50 – 70 Bt_2	Dark greyish brown (10YR 3.5/1); clayey; angular, coarse, firm blocks; consistency when wet very firm, when wet very plastic and very sticky; clay films, common, continuous; fine roots common; rock fragments, few small; gradual transition.
70 - 80 BC	Brown (10YR 4.5/2); silty clay; angular blocks breaking into subangular, medium and coarse, firm; consistency when wet firm, when wet plastic and sticky; calcium carbonate concretions, common; black betas; strong reaction to HCl; clear to abrupt transition.
80 - + C	Pale brown (10YR 6/3), black betas; calcium carbonate concretions, abundant, strong reaction to HCl. (Libertad Formation)

Geographic location: 34° 26´ 38,1” S, 56° 18´ 56,2” O

Uruguayan classification: Brunosol Eutrico Típico, FL.

USDA classification: Fine, mixed, active, thermic, Typic (Vertic) Argiudoll.

Horizon Depth (cm)	Morphological characteristics
0 - 18 A	Dark greyish brown (10YR 4/2), reddish mottling (5YR 5/6), small to medium, common; silt loam (p); subangular, medium, moderate blocks; consistency when wet very friable, and when wet slightly plastic and slightly sticky; fine roots common; clear transition.
18 - 50 Bt_1	Black (10YR 3/1); silty clay; angular, coarse, firm blocks; wet consistency very firm, wet consistency very plastic and very sticky; common, thin, discontinuous clay films; few, fine and medium Fe and Mn concretions; common, fine roots present; gradual transition.
50 - 60 Bt_2	Dark grey to very dark grey (10YR 3.5/1); silty clay; angular, coarse, firm blocks; wet consistency very firm, wet consistency very plastic and very sticky; clay films, common, continuous; fine roots common; calcium carbonate concretions; gradual transition.
60 - 70 Bt_3	Brown (10YR 5/3); silty clay; angular blocks breaking into subangular, medium and coarse, firm; consistency when wet firm and when wet slightly plastic and slightly sticky; strong reaction to HCl; clear transition.
70 - + C	Pale brown (10YR 6/3), black betas; silty clay; calcium carbonate concretions, abundant, strong reaction to HCl. (Libertad Formation).

Geographic location: 34° 26´ 36,7” S, 56° 18´ 55,3” O

Uruguayan classification: Brunosol Subeutrico Lúvico, FL.

USDA classification: Fine, mixed, active, thermic, natric, Argiudoll

Annex 2. Rainfall recorded during the experiment at the experimental station of the Facultad de Ciencias Agrarias, Canelones, Uruguay.

Table 1 - Rainfall recorded during the experiment (mm).

Month/day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total
December		1					3			9										3	19	2								11		48
January						11			17				24			15			3								5	32	4			111
February																				10					1							11
March			30	13																					22							65
April				5						2	2						28															37

Table 2 - Average temperature (°C) recorded at INIA L.B. during the experiment.

Month/day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mean
December	17.5	17.5	19.4	22.6	23.5	25.2	21.4	20.8	24.1	19.4	17.7	20	20.5	18.1	20.1	21.7	22.2	23.4	26.4	21.8	17.6	16.2	17.5	20.2	24.2	22.6	23.3	24.1	25.5	26.4	22.4	20
January	20	18.8	20.8	19.4	23.7	22	23	24.9	24.7	24.8	25.7	26.3	21.3	22.8	22.2	24.4	21	21.2	20.9	20	19.2	21.3	22.7	23.5	24.9	25.9	25.7	20.2	18.5	17.8	20.7	21,2
February	22.9	23.8	23.4	25.7	25.1	23.9	23.3	23.8	25.1	23.1	22.2	23.6	19.3	19.9	22.2	23.2	23.7	23.2	19.3	19.8	21.3	23.4	24.7	25.7	23.4	23.7	20.2	18.7				22,8
March	22.7	23.8	22	22.1	22.2	21.5	22.7	22.9	24.1	25	22.9	22.9	23.5	22.9	22.1	21.5	23.4	22.5	23.1	23.6	17.8	16.6	15.9	16	16.3	16.5	16.8	16.3	20.4	20.6	18.5	21
April	17.5	20.5	20.9	20.6	19	15.5	15.9	18.1	19.7	21.4	19	17.2	20.8	20.6	20.2	20.4	17.2	16.6	17.3	17.1	15.4	15.2	15.9	16.5	18	18.2	18.6	18.4	15.3	15.6		18,7

Annex 3. Data for growth analysis

Table 1 - DM data (kg) used for growth analysis.

	30/12/14			13/01/15			22/01/15		
Treat./Block	A	B	C	A	B	C	A	B	C
1	408	201	285	1707	1033	767	2987	2827	1676
3	596	433	282	2691	1958	1152	5209	3614	2897
7	891	277	342	3457	2293	1623	6132	4273	3964
9	509	336	301	2290	2365	1652	4972	4859	4342

	05/02/15			20/02/15			06/03/15		
Treat./Block	A	B	C	A	B	C	A	B	C
1	5347	6837	2690	6082	7156	3273	9505	7178	5861
3	10068	9197	8573	14235	9302	10255	14831	13992	12171
7	9695	10959	8066	15896	13610	9866	20178	14966	13460
9	10833	9791	9521	15699	11494	13379	16600	15177	16738

	12/03/15		
Treat./Block	A	B	C
1	9654	7201	6041
3	15170	14021	12251
7	20855	17578	13868
9	17132	16606	17668

Table 2 - Concentration of N, P and K in the plant at the different sampling points.

		22/01/15			05/02/15			20/02/15			06/03/15		
Treat.	Block	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
1	A	1	0.26	2.06	0.64	0.18	1.27	0.78	0.14	1.4	0.73	0.15	0.9
1	B	1.65	0.27	2.1	0.85	0.17	1.14	0.84	0.18	1.24	0.84	0.17	1.19
1	C	0.95	0.22	2.53	0.66	0.2	1.97	0.63	0.2	1.62	0.65	0.11	0.87
3	A	1.34	0.32	2.05	0.8	0.22	1.24	0.7	0.17	0.9	0.64	0.16	0.85
3	B	1.13	0.29	2.88	0.6	0.17	1.33	0.85	0.15	1.35	0.61	0.2	0.96
3	C	1.3	0.26	3.19	0.89	0.21	1.09	0.76	0.17	0.9	0.64	0.15	0.78
7	A	1.99	0.3	3.25	1.28	0.19	2.48	0.8	0.13	1.58	1.03	0.14	1.32
7	B	2.08	0.3	3.37	1.15	0.15	2.1	1.08	0.11	1.68	0.99	0.11	1.58
7	C	2.27	0.24	2.28	1.16	0.15	1.44	0.97	0.13	1.1	0.8	0.12	0.97
9	A	1.91	0.33	3.28	1.05	0.18	1.82	0.73	0.16	1.3	0.83	0.15	1.29
9	B	1.99	0.41	3.23	1.14	0.2	2.03	0.96	0.16	1.72	0.78	0.14	1.35
9	C	1.82	0.32	3.23	1.15	0.21	1.79	1.15	0.16	1.29	0.99	0.17	1.13

Table 3 - Plant N accumulation (kg ha^{-1}) at different sampling times.

	22/01/15			05/02/15			20/02/15		
Treat./Block	A	B	C	A	B	C	A	B	C
1	30	47	16	34	58	18	47	60	21
3	70	41	38	80	55	76	99	79	78
7	122	89	90	124	126	94	127	147	96
9	95	96	79	114	111	110	115	111	154

	06/03/15			12/03/15		
Treat./Block	A	B	C	A	B	C
1	69	60	38	75,3	63,4	59,6
3	95	85	77	91,4	84,5	83,9
7	207	149	107	219,0	174,0	151,6
9	138	119	166	164,6	132,5	178,4

Table 4 - Plant P accumulation (kg ha^{-1}) at different sampling times.

	22/01/15			05/02/15			20/02/15		
Treat./Block	A	B	C	A	B	C	A	B	C
1	8	8	4	10	12	6	9	13	6
3	17	8	8	22	12	18	24	10	17
7	18	13	10	19	17	12	21	16	13
9	17	20	14	20	20	20	25	18	21

	06/03/15			12/03/15		
Treat./Block	A	B	C	A	B	C
1	14	12	6	16	12	11
3	24	14	18	30	25	17
7	29	17	16	33	23	20
9	25	21	29	27	28	30

Table 5 - Plant K accumulation (kg ha^{-1}) at different sampling times.

	22/01/15			05/02/15			20/02/15		
Treat./Block	A	B	C	A	B	C	A	B	C
1	62	59	42	68	78	53	85	89	53
3	107	104	92	125	123	94	128	126	93
7	199	144	99	241	230	137	251	229	147
9	163	157	140	197	199	171	205	198	173

	06/03/15			12/03/15		
Treat./Block	A	B	C	A	B	C
1	85	86	51	91,2	68,9	57,1
3	127	135	95	121,4	140,2	98,6
7	267	236	162	267,9	273,4	172,8
9	214	205	189	227,6	217,5	197,4

Annex 4. Harvest data

Table 1 - DM harvest data (kg ha^{-1}).

	A	B	C	Mean	N_{min}	N_{org}
T1	9655	7201	6041	7632	0	0
T2	14083	11196	8281	11186	0	180
T3	15171	14021	12251	13814	0	360
T4	16060	14794	14114	14990	90	0
T5	16951	15437	14673	15687	90	180
T6	16540	16273	14144	15653	90	360
T7	20856	17578	13869	17434	180	0
T8	21880	19775	16632	19429	180	180
T9	17133	16606	17669	17136	180	360
Mean	16481	14765	13075	14773		

Table 2 - Harvest data of absorbed N (kg ha^{-1}).

	A	B	C	Mean	N_{min}	N_{org}
T1	75.3	63.4	59.6	66	0	0
T2	80.3	71.1	49.9	67	0	180
T3	91.4	84.5	83.9	87	0	360
T4	96.2	91.5	73.5	87	90	0
T5	110.4	103.1	117.4	110	90	180
T6	115.8	98.0	55.2	90	90	360
T7	219.0	174.0	151.6	182	180	0
T8	174.6	190.0	132.7	166	180	180
T9	164.6	132.5	178.4	158	180	360
Mean	125	112	100	112		

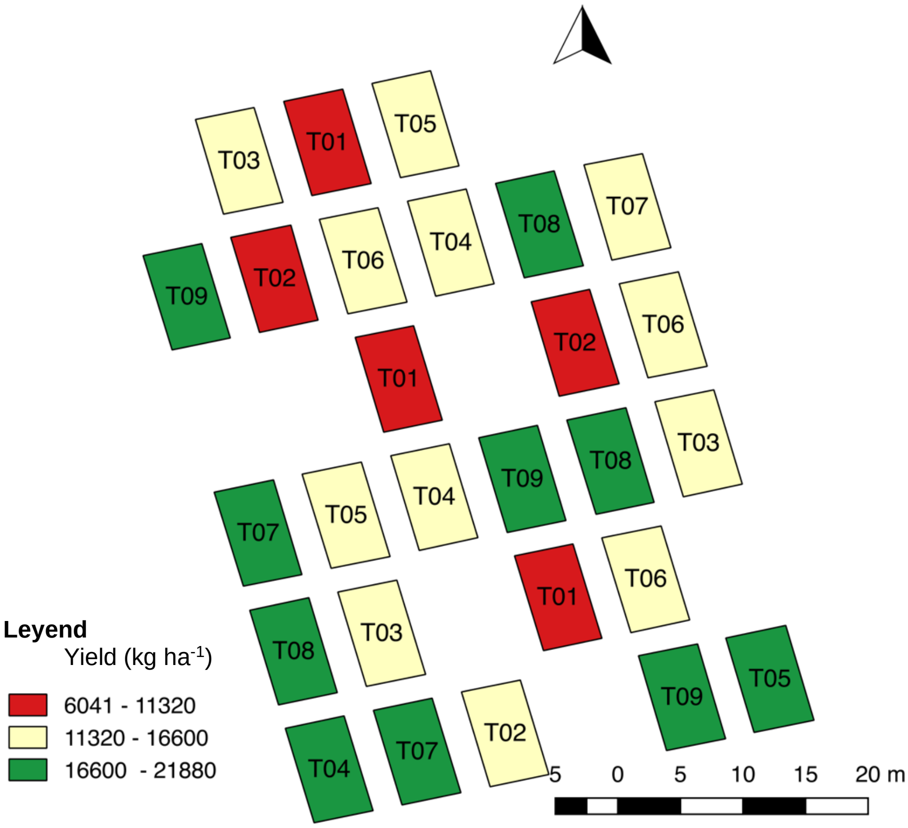
Table 3 - Harvest data of absorbed P (kg ha^{-1}).

	A	B	C	Mean	N_{min}	N_{org}
T1	15.6	11.7	11.1	13	0	0
T2	22.4	23.7	14.0	20	0	180
T3	29.8	25.1	16.6	24	0	360
T4	29.3	19.5	16.7	22	90	0
T5	26.4	25.4	22.3	25	90	180
T6	26.4	22.9	25.7	25	90	360
T7	32.8	23.1	20.2	25	180	0
T8	36.1	30.8	21.0	29	180	180
T9	27.3	28.5	29.7	28	180	360
Mean	27	23	19	23		

Table 4 - Harvest data of absorbed K (kg ha^{-1}).

	A	B	C	Mean	N_{min}	N_{org}
T1	91.2	68.9	57.1	72	0	0
T2	114.5	93.7	60.0	89	0	180
T3	121.4	140.2	98.6	120	0	360
T4	241.1	173.0	111.7	175	90	0
T5	160.1	166.9	108.1	145	90	180
T6	142.7	139.1	137.6	140	90	360
T7	267.9	273.4	172.8	238	180	0
T8	234.4	210.8	169.0	205	180	180
T9	227.6	217.5	197.4	214	180	360
Mean	177	164	123	155		

Annex 5. Yield map



Annex 6. Analysis of covariance

Table 1 - Data obtained to perform the ANCOVA.

Plot	Treatment	Block	Organic C (%)	Thickness of A horizon (cm)	Penetrability
1	T5	A	1.6	18	180
2	T9	A	2.3	19	187.5
4	T2	A	2.2	18	155
5	T7	A	2.4	18	150
6	T4	A	2.3	16	185
8	T6	A	1.9	17	180
9	T1	A	2.1	18	172.5
11	T3	A	2.2	17	150
12	T8	A	2.4	16	157.5
13	T3	B	1.7	17	162.5
14	T8	B	1.8	17	162.5
15	T9	B	1.8	18	170
16	T4	B	3.1	17	167.5
17	T5	B	1.7	17	152.5
18	T7	B	1.9	16	150
19	T6	B	1.6	17	152.5
20	T2	B	1.5	17	175
22	T1	B	1.6	18	157.5
25	T7	C	1.4	16	160
26	T8	C	2.6	17	192.5
27	T4	C	2.6	16	190
28	T6	C	1.6	18	155
29	T2	C	1.7	16	170
30	T9	C	1.5	18	175
33	T5	C	1.6	16	155
34	T1	C	1.8	17	177.5
35	T3	C	1.6	16	155

Table 2 - ANCOVA organic C and yield of kg DM ha^{-1}.

	Df	SS	MS	F	
Treatment	8	306769687	38346211	9.23	**
Org. C (%)	1	8155182	8155182	1.96	
Interaction	8	43236992	5404624	1.30	
Error	9	37373791	4152643		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 3 - ANCOVA thickness of the A horizon and yield in kg DM ha^{-1}.

	Df	SS	MS	F	
Treatment	8	306769687	38346211	11.704	***
Thickness A	1	15478945	15478945	4.724	.
Interaction	8	43798864	5474858	1.671	
Error	9	29488156	3276462		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 4 - ANCOVA penetrability and yields in kg DM ha^{-1}.

	Df	SS	MS	F	
Treatment	8	306769687	38346211	7.846	***
Penetrability	1	4883001	4883001	0.999	
Interaction	8	39897469	4987184	1.020	
Error	9	43985495	4887277		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 5 - ANCOVA organic C and N_{abs} in kg ha^{-1}.

	Df	SS	MS	F	
Treatment	8	50186	6273	14.603	***
Org. C (%)	1	924	924	2.151	
Interaction	8	5604	700	1.630	
Error	9	3866	430		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 6 - ANCOVA thickness of the A horizon and N_{abs} in kg ha^{-1}.

	Df	SS	MS	F	
Treatment	8	48917	6115	15.006	***
Thickness A	1	575	575	1.411	
Interaction	8	4166	521	1.278	
Error	9	3667	407		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 7 - ANCOVA penetrability and N_{abs} in kg ha^{-1}.

	Df	SS	MS	F	
Treatment	8	48917	6115	13.109	***
Penetrability	1	253	253	0.542	
Interaction	8	3957	495	1.060	
Error	9	4198	466		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 8 - ANCOVA organic C and P_{abs} in kg ha^{-1}.

	Df	SS	MS	F
Treatment	8	586.5	73.32	2.616
Org. C (%)	1	12.3	12.33	0.440
Interaction	8	203.4	25.42	0.907
Error	9	252.3	28.03	

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 9 - ANCOVA horizon A thickness and P_{abs} in kg ha^{-1}.

	Df	SS	MS	F	
Treatment	8	586.5	73.32	2.616	*
Thickness A	1	67.3	67.34	3.414	
Interaction	8	223.1	27.88	1.413	
Error	9	177.6	19.73		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 10 - ANCOVA penetrability and P_{abs} in kg ha^{-1}.

	Df	SS	MS	F
Treatment	8	586.5	73.32	2.189
Penetrability	1	29.9	29.86	0.892
Interaction	8	136.7	17.09	0.510
Error	9	301.4	33.49	

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 11 - ANCOVA % organic C and K_{abs} in kg ha^{-1}.

	Df	SS	MS	F	
Treatment	8	67731	8466	4.383	*
Org. C (%)	1	3261	3261	1.688	
Interaction	8	12203	1525	0.790	
Error	9	17386	1932		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 12 - ANCOVA horizon A thickness and K_{abs} in kg ha^{-1}.

	Df	SS	MS	F	
Treatment	8	67731	8466	3.355	*
Thickness A	1	5356	5356	2.122	
Interaction	8	4782	598	0.237	
Error	9	22712	2524		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 13 - ANCOVA penetrability and K_{abs} in kg ha^{-1}.

	Df	SS	MS	F	
Treatment	8	67731	8466	6.040	**
Penetrability	1	1574	1574	1.123	
Interaction	8	18661	2333	1.664	
Error	9	12615	1402		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Annex 7. Analysis of variance of growth curves.

Table 1 - ANOVA de MS para curva de crecimiento día 24.

	Df	SS	MS	F	
Treatment	3	68014	22671	1.465	
Block	2	230471	115236	7.445	*
Error	6	92875	15479		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

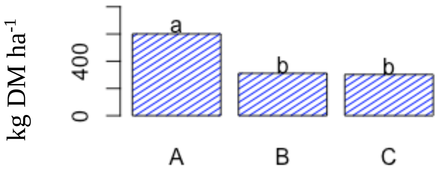


Figure 1 - Fisher's Block DM test day 24.

Least significant difference: 215.27

Table 2 - ANOVA of DM for growth curve day 44.

	Df	SS	MS	F	
Treatment	3	2659331	886444	8.578	*
Block	2	3064120	1532060	14.826	**
Error	6	620036	103339		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

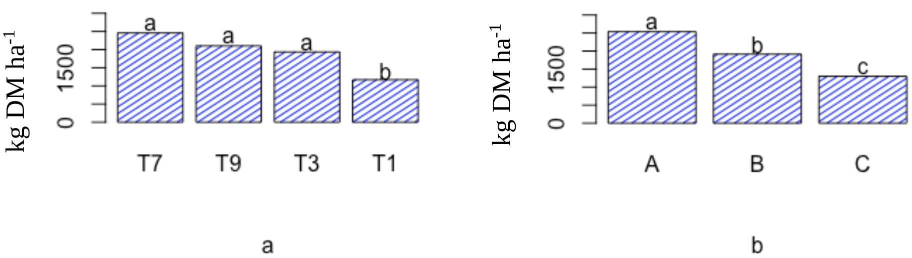


Figure 2 - Fisher's test of DM in Treatments (a) and Blocks (b) day 44.

Least significant difference in treatment: 642.25
Least significant difference in block: 556.21

Table 3 - ANOVA of LAI for growth curve day 44.

	Df	SS	MS	F	
Treatment	3	3.716	1.2388	32.734	***
Block	2	0.571	0.2855	7.545	*
Error	6	0.227	0.0378		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

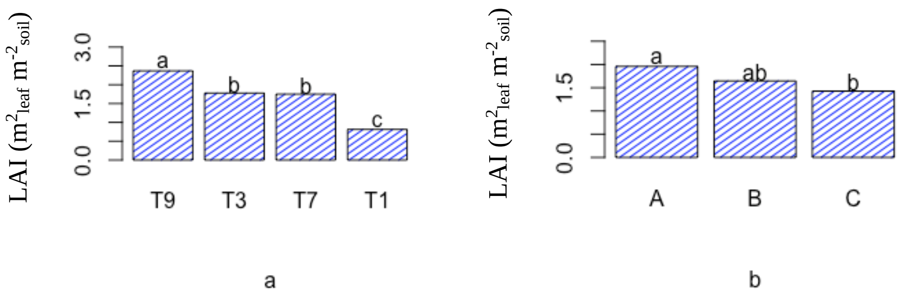


Figure 3 - Fisher's test of LAI in Treatments (a) and Blocks (b) day 44.

Least significant difference in treatment: 0.39
Least significant difference in block: 0.34

Table 4 - ANOVA of DM for growth curve day 53.

	Df	SS	MS	F	
Treatment	3	10245738	3415246	12.789	**
Block	2	5198117	2599059	9.733	*
Error	6	1602257	267043		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

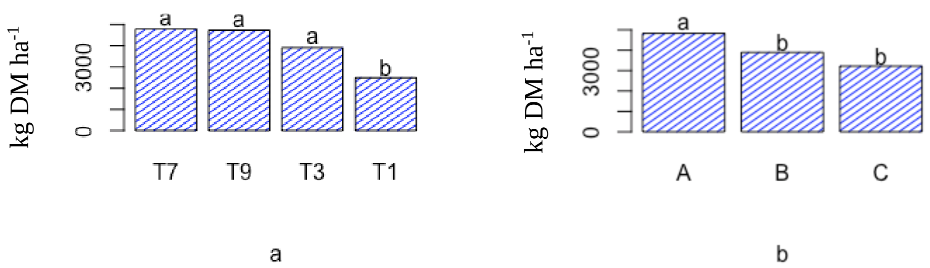


Figure 4 - Fisher's test of DM in Treatments (a) and Blocks (b) day 53.

Least significant difference in treatment: 1032.44
Least significant difference in block: 894.12

Table 5 - ANOVA of N for growth curve day 53.

	Df	SS	MS	F	
Treatment	3	9740	3247	22.250	**
Block	2	1108	554	3.795	.
Error	6	876	146		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

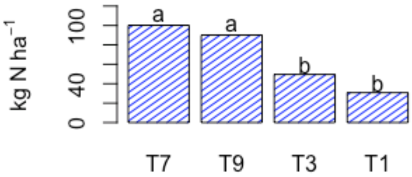


Figure 5 - Fisher's test of N in Treatments day 53.

Least significant difference: 24.13

Table 6 - ANOVA of P for growth curve day 53.

	Df	SS	MS	F	
Treatment	3	171.22	57.07	8.044	*
Block	2	76.20	38.10	5.370	*
Error	6	42.57	7.10		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

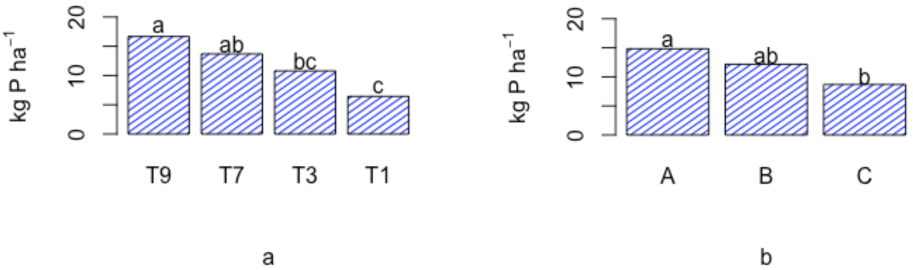


Figure 6 - Fisher's test for P in Treatments (a) and Blocks (b) day 53.

Least significant difference in treatment: 5.32
Least significant difference in block: 4.61

Table 7 - ANOVA of K for growth curve day 53.

	Df	SS	MS	F	
Treatment	3	19157	6386	14.96	**
Block	2	3100	1550	3.63	.
Error	6	2562	427		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

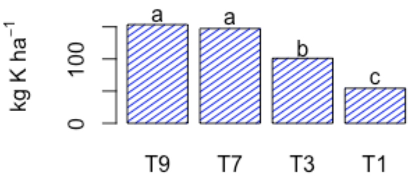


Figure 7 - Fisher's test of K in Treatments day 53.

Least significant difference: 41.28

Table 8 - ANOVA of LAI for growth curve day 53.

	Df	SS	MS	F	
Treatment	3	5.195	1.7316	20.661	**
Block	2	1.158	0.5789	6.908	*
Error	6	0.503	0.0838		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

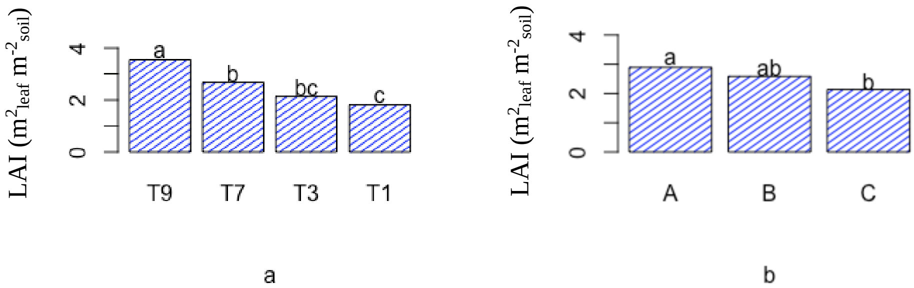


Figure 8 - Fisher's test of LAI in Treatments (a) and Blocks (b) day 53.

Least significant difference in treatment: 0.58
Least significant difference in block: 0.50

Table 9 - ANOVA of DM for growth curve day 67.

	Df	SS	MS	F	
Treatment	3	50092604	16697535	17.816	**
Block	2	9497191	4748595	5.067	.
Error	6	5623207	937201		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

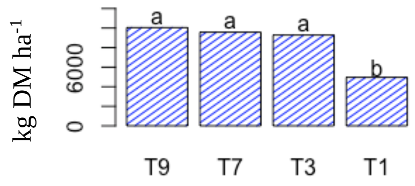


Figure 9 - Fisher's test of DM in Treatments day 67.

Least significant difference: 1934.15

Table 10 - ANOVA of N for growth curve day 67.

	Df	SS	MS	F	
Treatment	3	12357	4119	18.32	**
Block	2	490	245	1.09	
Error	6	1349	225		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

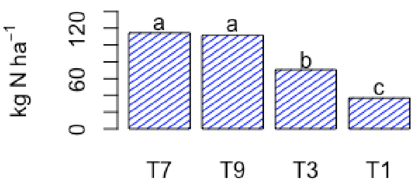


Figure 10 - Fisher's test of N on Treatments day 67.

Least significant difference: 29.96

Table 11 - ANOVA of P for growth curve day 67.

	Df	SS	MS	F	
Treatment	3	190.33	63.44	5.768	*
Block	2	29.17	14.58	1.326	
Error	6	66.00	11.00		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

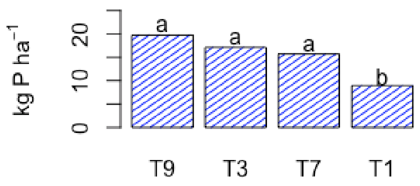


Figure 11 - Fisher's test for P in Treatments day 67.

Least significant difference: 6.63

Table 12 - ANOVA of K for growth curve day 67.

	Df	SS	MS	F	
Treatment	3	37125	12375	26.863	***
Block	2	5143	2571	5.582	*
Error	6	2764	461		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

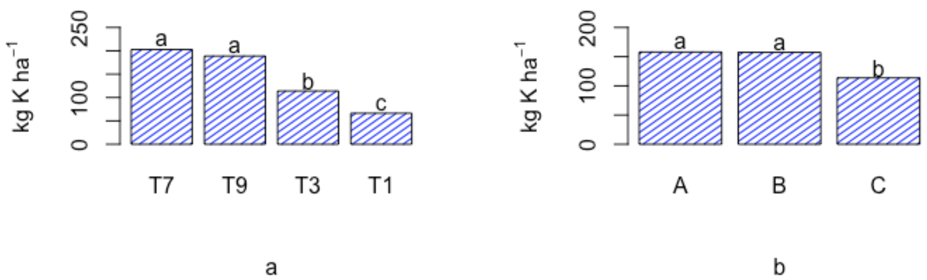


Figure 12 - Fisher's test of K in Treatments (a) and Blocks (b) day 67.

Least significant difference in treatment: 42.88
Least significant difference in block: 37.14

Table 13 - ANOVA of LAI for growth curve day 67.

	Df	SS	MS	F	
Treatment	3	9.088	3.0294	11.880	**
Block	2	0.549	0.274	1.077	
Error	6	1.530	0.2550		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

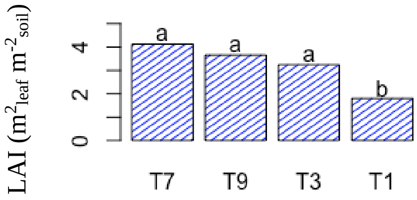


Figure 13 - Fisher's test of LAI on Treatments day 67.

Least significant difference: 1.01

Table 14 - ANOVA of DM for growth curve day 82.

	Df	SS	MS	F	
Treatment	3	123227900	41075967	12.833	**
Block	2	29937195	14968598	4.676	.
Error	6	19205013	3200836		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

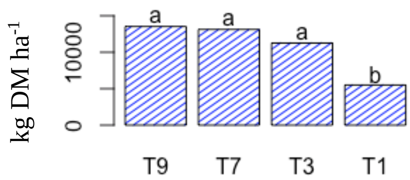


Figure 14 - Fisher's test of DM in Treatments day 82.

Least significant difference: 3574.41

Table 15 - ANOVA of N for growth curve day 82.

	Df	SS	MS	F	
Treatment	3	13829	4610	8.566	*
Block	2	330	165	0.307	
Error	6	3229	538		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

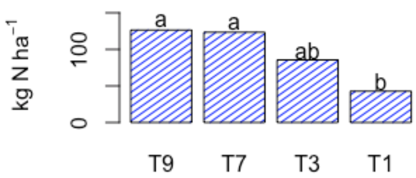


Figure 15 - Fisher's test of N on Treatments day 82.

Least significant difference: 46.35

Table 16 - ANOVA of P for growth curve day 82.

	Df	SS	MS	F	
Treatment	3	225.87	75.29	4.928	*
Block	2	74.81	37.40	2.448	
Error	6	91.67	15.28		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

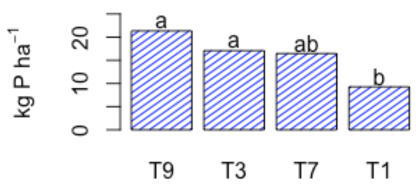


Figure 16 - Fisher's test of P on Treatments day 82.

Least significant difference: 7.81

Table 17 - ANOVA of K for growth curve day 82.

	Df	SS	MS	F	
Treatment	3	35812	11937	34.236	***
Block	2	6124	3062	8.782	*
Error	6	2092	349		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

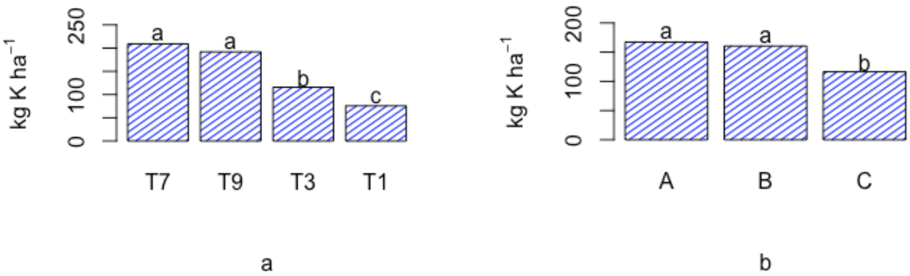


Figure 17 - Fisher's test of K in Treatments (a) and Blocks (b) day 82.

Least significant difference in treatment: 37.31
Least significant difference in block: 32.31

Table 18 - ANOVA of LAI for growth curve day 82.

	GL	SC	CM	F	
Treatment	3	7.639	2.5462	14.265	**
Block	2	1.317	0.6583	3.688	.
Error	6	1.071	0.1785		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

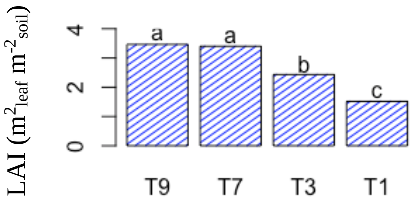


Figure 18 - Fisher's test of LAI on Treatments day 82.

Least significant difference: 0.84

Table 19 - ANOVA of DM for growth curve day 97.

	Df	SS	MS	F	
Treatment	3	150708700	50236233	21.188	**
Block	2	22630162	11315081	4.772	.
Error	6	14226143	2371024		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

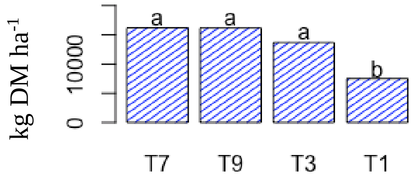


Figure 19 - Fisher's test of DM on Treatments day 97.

Least significant difference: 3076.39

Table 20 - ANOVA of N for growth curve day 97.

	Df	SS	MS	F	
Treatment	3	19300	6433	8.034	*
Block	2	2022	1011	1.263	
Error	6	4805	801		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

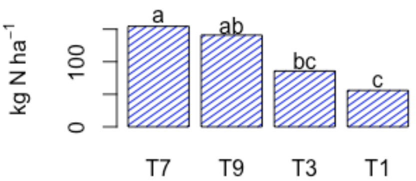


Figure 20 - Fisher's test of N on Treatments day 97.

Least significant difference: 56.54

Table 21 - ANOVA of P for growth curve day 97.

	Df	SS	MS	F	
Treatment	3	306.1	102.02	5.775	*
Block	2	105.5	52.77	2.987	
Error	6	106.0	17.66		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

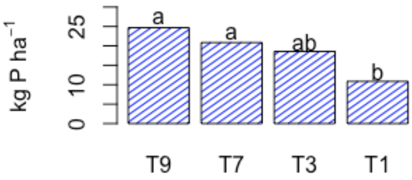


Figure 21 - Fisher's test of P on Treatments day 97.

Least significant difference: 8.40

Table 22 - ANOVA of K for growth curve day 97.

	Df	SS	MS	F	
Treatment	3	43920	14640	38.02	***
Block	2	5552	2776	7.21	*
Error	6	2310	385		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

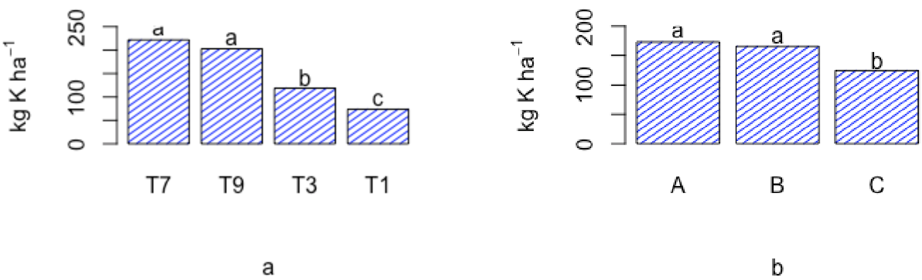


Figure 22 - Fisher's test of K in Treatments (a) and Blocks (b) day 97.

Least significant difference in treatment: 39.20
Least significant difference in block: 33.95

Table 23 - ANOVA of LAI for growth curve day 97.

	Df	SS	MS	F	
Treatment	3	6.634	2.2113	13.734	**
Block	2	1.365	0.6823	4.238	.
Error	6	0.966	0.1610		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

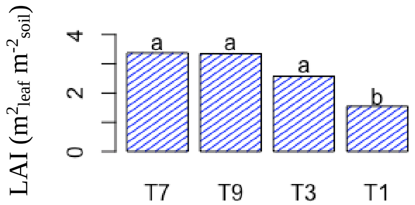


Figura 23 - Fisher's test of IAF on Treatments day 97.

Least significant difference: 0.80

Table 24 - ANOVA of DM for growth curve day 103.

	Df	SS	MS	F	
Treatment	3	186630517	62210172	25.009	***
Block	2	21211302	10605651	4.264	.
Error	6	14924900	2487483		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

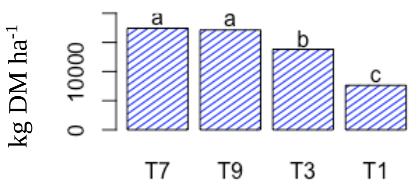


Figure 24 - Fisher's test of DM on Treatments day 103.

Least significant difference: 3151.03

Table 25 - ANOVA of N for growth curve day 103.

	Df	SS	MS	F	
Treatment	3	27748	9249	23.69	**
Block	2	1288	644	1.65	
Error	6	2342	390		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

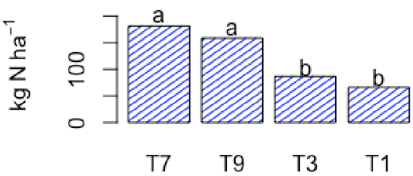


Figure 25 - Fisher's test of N on Treatments day 103.

Least significant difference: 39.47

Table 26 - ANOVA of P for growth curve day 103.

	Df	SS	MS	F	
Treatment	3	421.4	140.45	9.158	*
Block	2	100.0	50.01	3.261	
Error	6	92.0	15.34		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

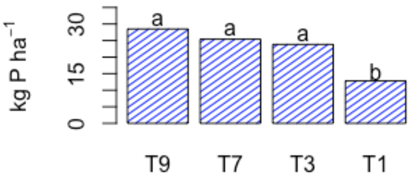


Figure 26 - Fisher's test of P on Treatments day 103.

Least significant difference: 7.82

Table 27 - ANOVA of K for growth curve day 103.

	Df	SS	MS	F	
Treatment	3	54871	18290	36.119	***
Block	2	5304	2652	5.237	*
Error	6	3038	506		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

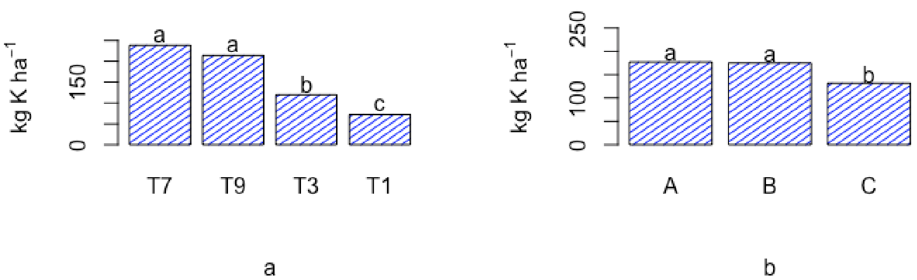


Figure 27 - Fisher's test of K in Treatments (a) and in Blocks (b) day 103.

Least significant difference in treatment: 44.96
Least significant difference in block: 38.93

Annex 8. Response curves

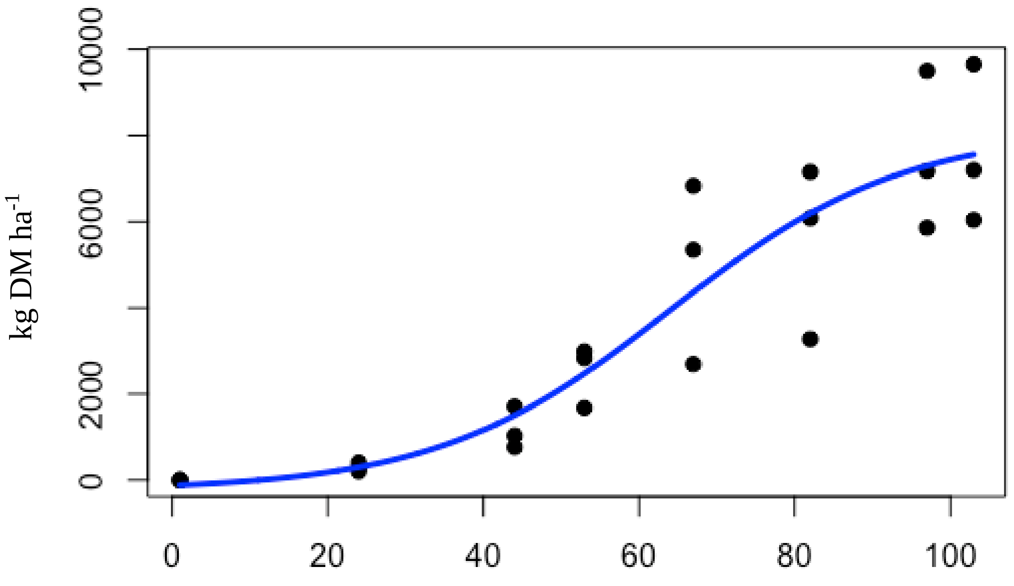


Figure 1 - DM accumulation (kg ha^{-1}) of T1.

Formula: DM = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 1 - Non-linear model of T1 DM accumulation.

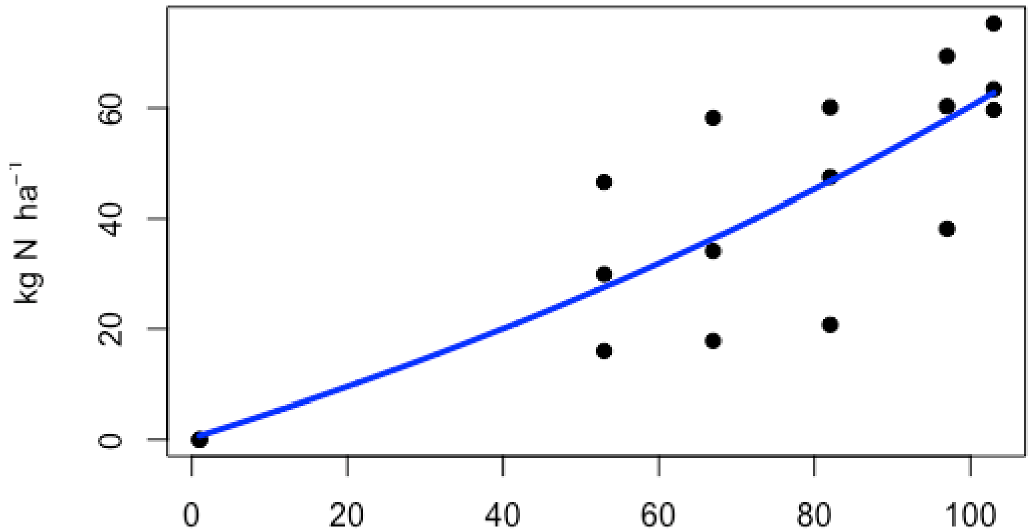
	Estimated	Est. error	t value	
a	-241.65	827.81	-0.292	
b	8133.05	1346.78	6.039	***
c	0.06	0.03	2.154	*
d	64.00	6.95	9.206	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$y(kg\ DM\ ha^{-1}) = -241.65 + \frac{8374.7}{1 - e^{-0,06(Day-64.00)}}$$

$SR^2 = 0.85$



Days after sowing

Figure 2 - N accumulation (kg ha^{-1}) of T1.

Formula: N_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 2 - Non-linear model of T1 N accumulation.

	Estimated	Est. error	t value
a	-64.62	1822	-0.035
b	1198	282900	0.004
c	0.007	0.259	0.027
d	412.6	44610	0.009

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$N_{abs}(kg\ ha^{-1}) = -64.62 + \frac{1262.62}{1 - e^{-0.007(Day-421.6)}}$$

$SR^2 = 0.73$

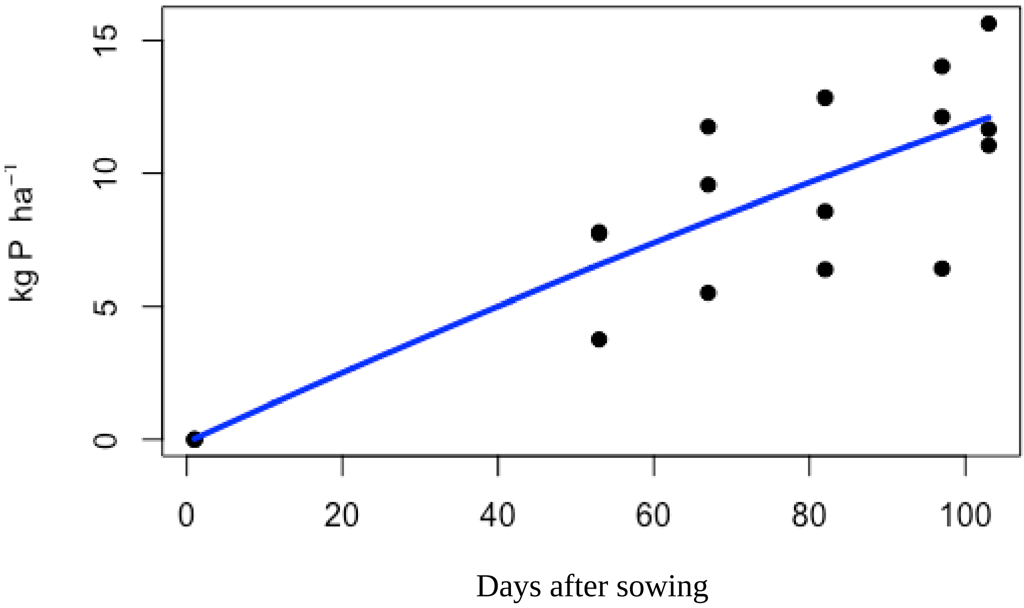


Figure 3 - P accumulation (kg ha^{-1}) of T1.

Formula: P_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 3 - Non-linear model of T1 P accumulation.

	Estimated	Est. error	t value
a	-67.9254	8552.4843	-0.008
b	35.3971	1264.0991	0.028
c	0.0057	0.3674	0.016
d	-113.545	23198.6912	-0.005

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(kg\ ha^{-1}) = -67.92 + \frac{103.32}{1 - e^{-0.006(Day - 113.54)}}$$

$SR^2 = 0.74$

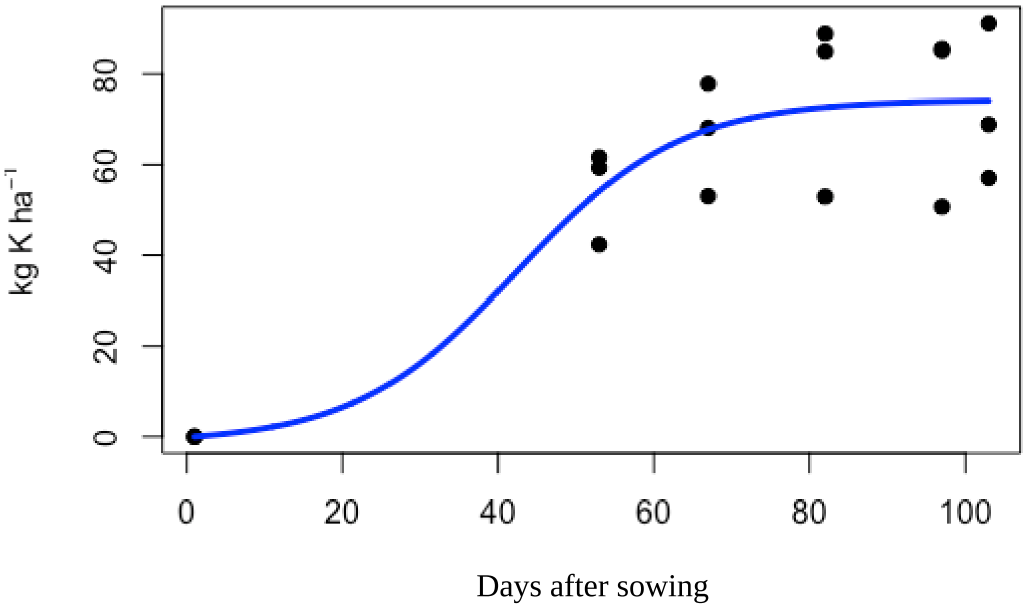


Figure 4 - K accumulation (kg ha^{-1}) of T1.

Formula: K_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 4 - Non-linear model of T1 K accumulation.

	Estimated	Est. error	t value	
a	-1.38324	12.74465	-0.109	
b	74.30368	6.51273	11.409	***
c	0.09597	0.12541	0.765	
d	42.42706	16.54526	2.564	*

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$K_{abs}(kg\ ha^{-1}) = -1.38 + \frac{75.69}{1 - e^{-0.10(Day-42.43)}}$$

$SR^2 = 0.82$

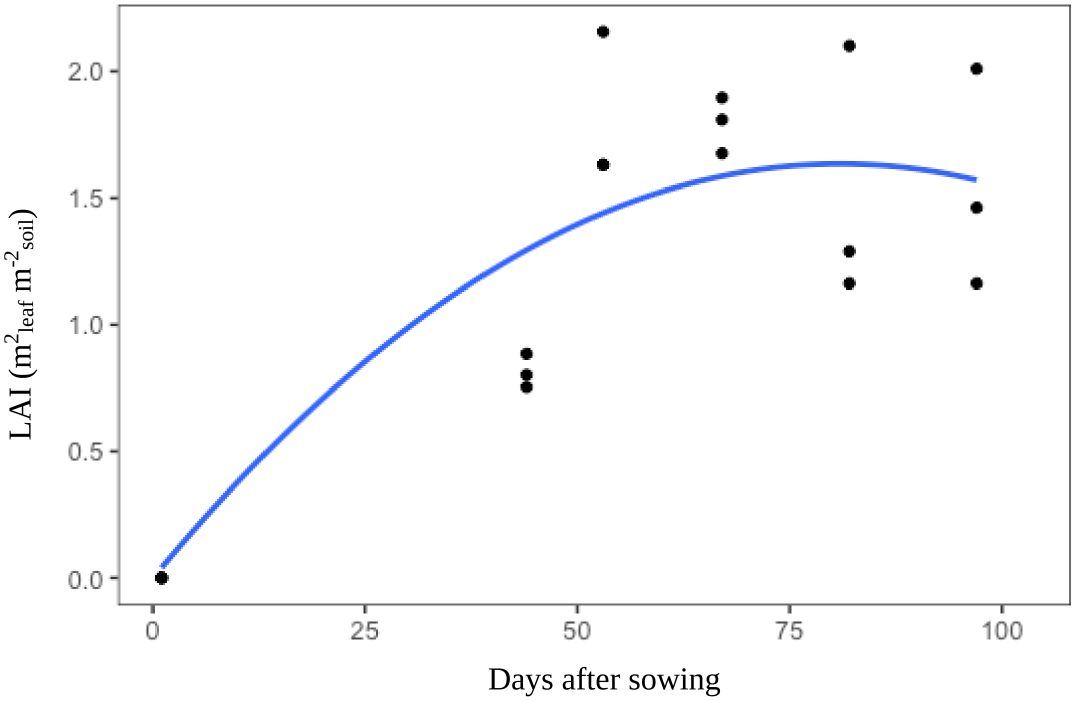


Figure 5 - LAI of T1.

Table 5 - Multiple regression of the T1 LAI.

	Estimated	Est. error	t value	
Day	$4.042x10^{-2}$	$6.344x10^{-03}$	6.37	***
Day^2	$-2.497x10^{-04}$	$7.854x10^{-05}$	-3.18	**

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$LAI\left(m^2_{leaf}\ \ m^{-2}_{soil}\right) = -0.0002\ Day^2 + 0.04\ Day$$

$$R^2 = 0.94$$

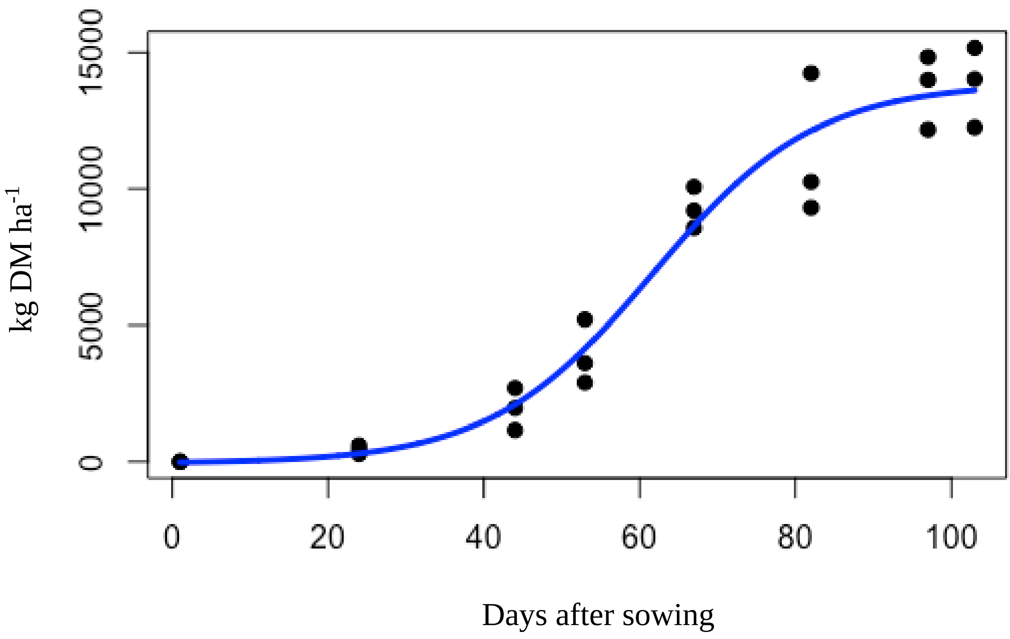


Figure 6 - DM accumulation (kg ha^{-1}) of T3.

Formula: DM = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 6 - Non-linear model of T3 DM accumulation.

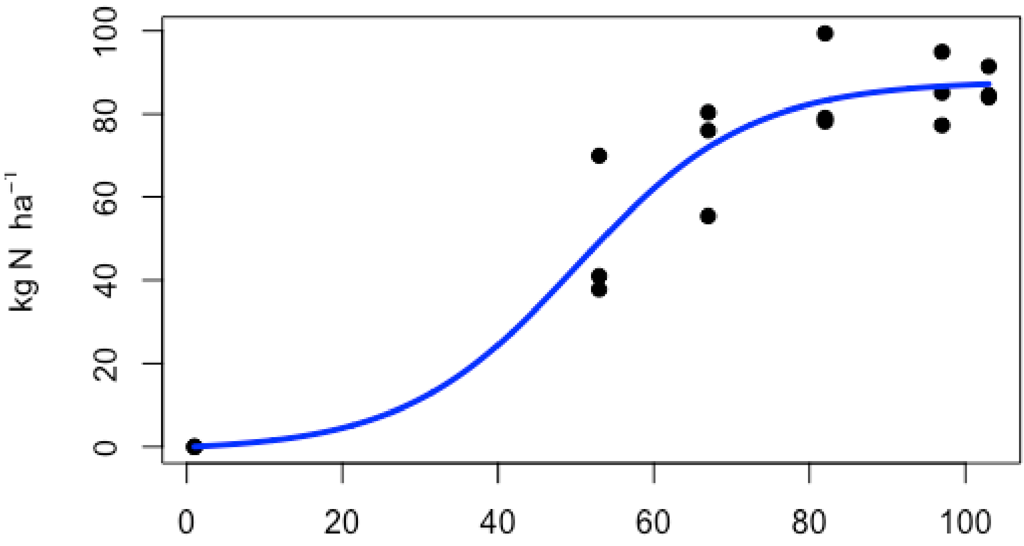
	Estimated	Est. error	t value	
a	-64.28	590.6	-0.109	
b	13870	677.8	20.458	***
c	0.095	0.019	5.018	***
d	61.70	2.289	26.959	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$y(Kg\ DM\ ha^{-1}) = -241.65 + \frac{13934.28}{1 - e^{-0.095(Day-61.70)}}$$

$SR^2 = 0.95$



Days after sowing

Figure 7 - N accumulation (kg ha^{-1}) of T3.

Formula: N_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 7 - Non-linear model of T3 N accumulation.

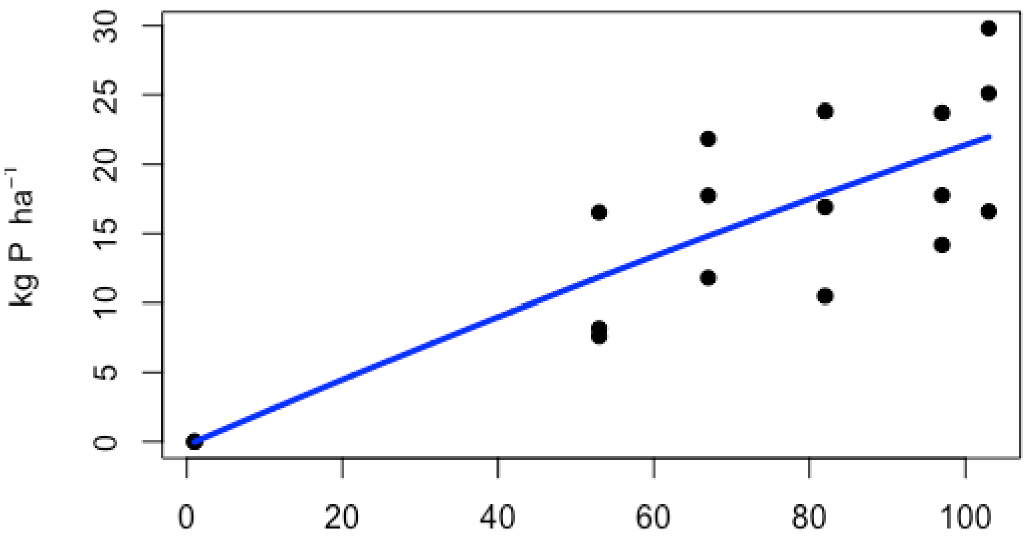
	Estimated	Est. error	t value	
a	-1.00953	6.77319	-0.149	
b	87.87981	5.32279	1.42×10^{-10}	***
c	0.09020	0.04321	0.0556	·
d	50.11136	4.14019	8.38×10^{-09}	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$N_{abs}(kg\ ha^{-1}) = -1.01 + \frac{88.89}{1 - e^{-0.09(Day - 50.11)}}$$

$SR^2 = 0.92$



Days after sowing

Figure 8 - P accumulation (kg ha^{-1}) of T3.

Formula: P_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 8 - Non-linear model of T3 P accumulation.

	Estimated	Est. error	t value
a	-128.0	18190	-0.007
b	67.13	2804	0.024
c	0.054	0.403	0.014
d	-117.5	27210	-0.004

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(kg\ ha^{-1}) = -128.0 + \frac{195.13}{1 - e^{-0.054(Day-117.5)}}$$

$$SR^2 = 0.72$$

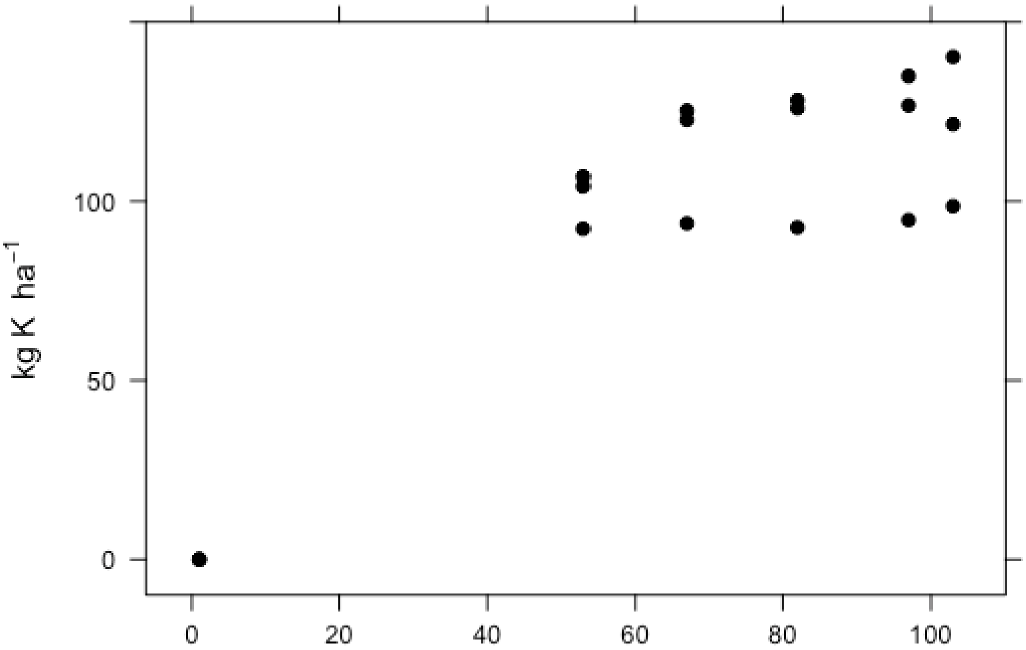


Figure 9 - Point plot of K (kg ha^{-1}) in T3 growth.

The model cannot fit the K-accumulation curve at T3 due to the lack of intermediate points, since the parameters cannot be estimated.

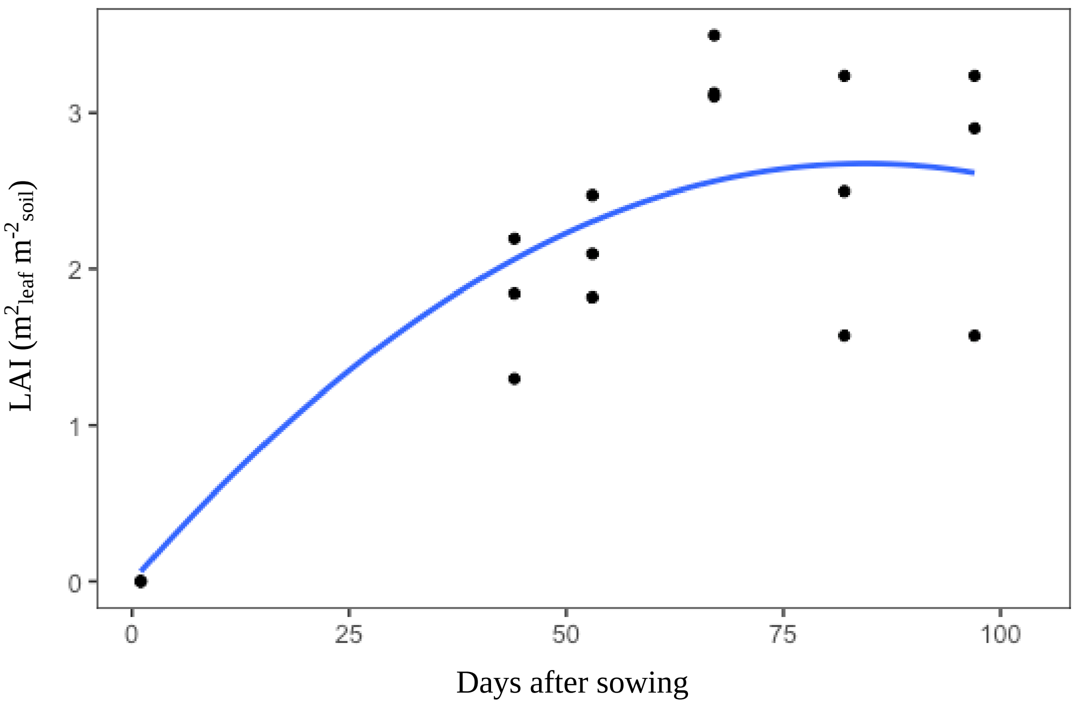


Figure 10 - LAI of T3.

Table 9 - Multiple regression of the T3 LAI.

	Estimated	Est. error	t value	
Day	0.0633805	0.0097017	6.533	***
Day^2	-0.0003755	0.0001201	-3.127	**

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$LAI\left(m_{leaf}^{2}\ \ m_{soil}^{-2}\right) = -0.0004\ Day^{2} + 0.06\ Day$$

$$R^2 = 0.94$$

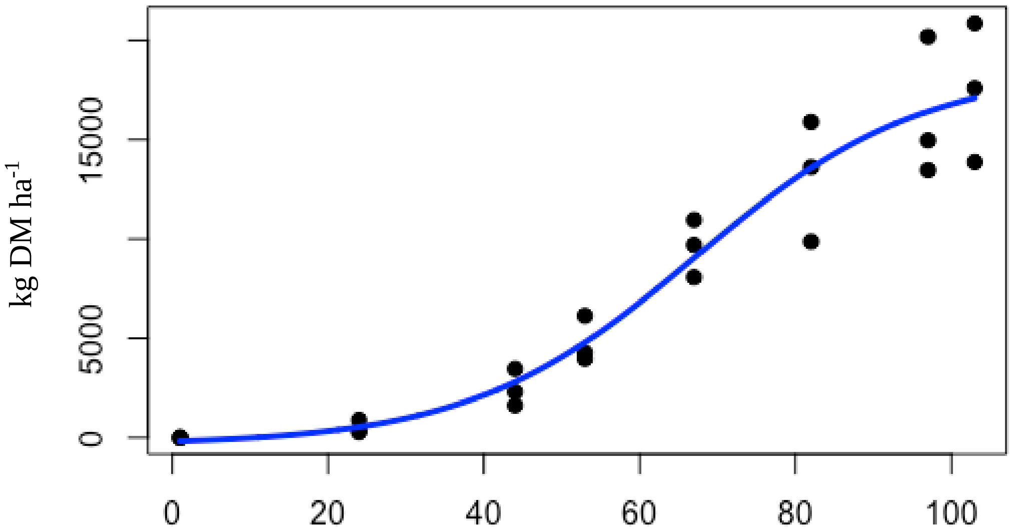


Figure 11 - DM accumulation (kg ha^{-1}) of T7.

Formula: DM = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 10 - Non-linear model of T7 DM accumulation.

	Estimated	Est. error	t value	
a	-365.7	1142	-0.320	
b	18540	2157	8.594	***
c	0.069	0.021	3.270	**
d	67.13	4.759	14.107	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$y(kg\ DM\ ha^{-1}) = -356.7 + \frac{18905.7}{1 - e^{-0.069(Day - 67.13)}}$$

$SR^2 = 0.93$

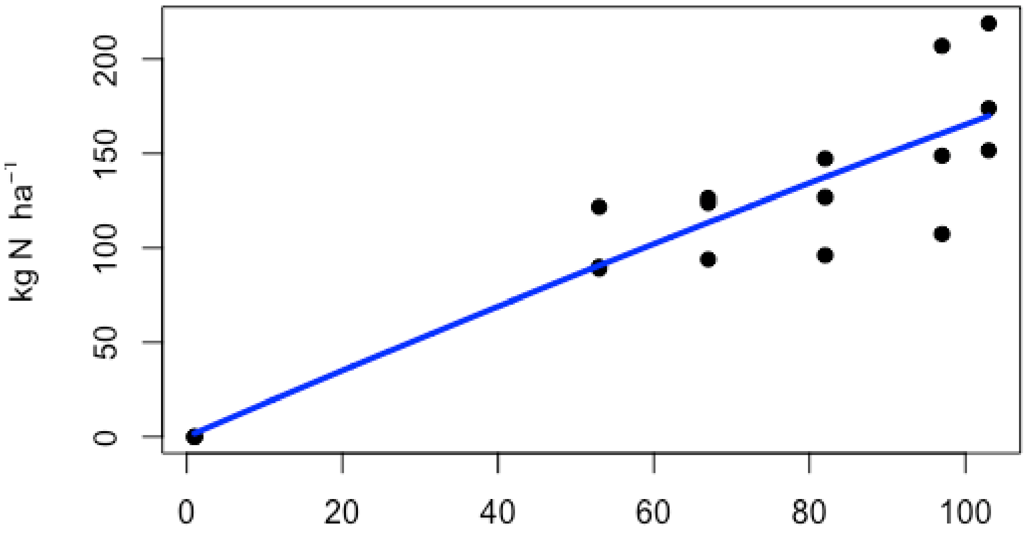


Figure 12 - N accumulation (kg ha^{-1}) of T7.

Formula: N_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 11 - Non-linear model of T7 N accumulation.

	Estimated	Est. error	t value
a	-1204	196400	-0.006
b	693.7	42160	0.016
c	0.004	0.3868	0.010
d	-137.6	38800	-0.004

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$N_{abs}(kg\ ha^{-1}) = -1204 + \frac{1897.7}{1 - e^{-0.004(Day - 137.6)}}$$

$SR^2 = 0.83$

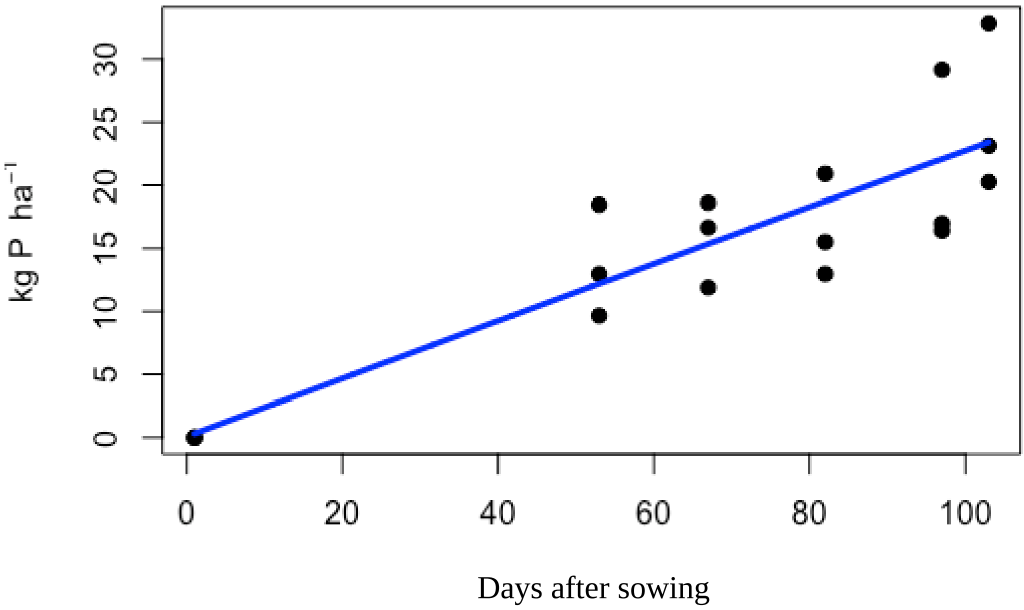


Figure 13 - P accumulation (kg ha-1) of T7.

Formula: $P_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))$

Where:

Table 12 - Non-linear model of T7 P accumulation.

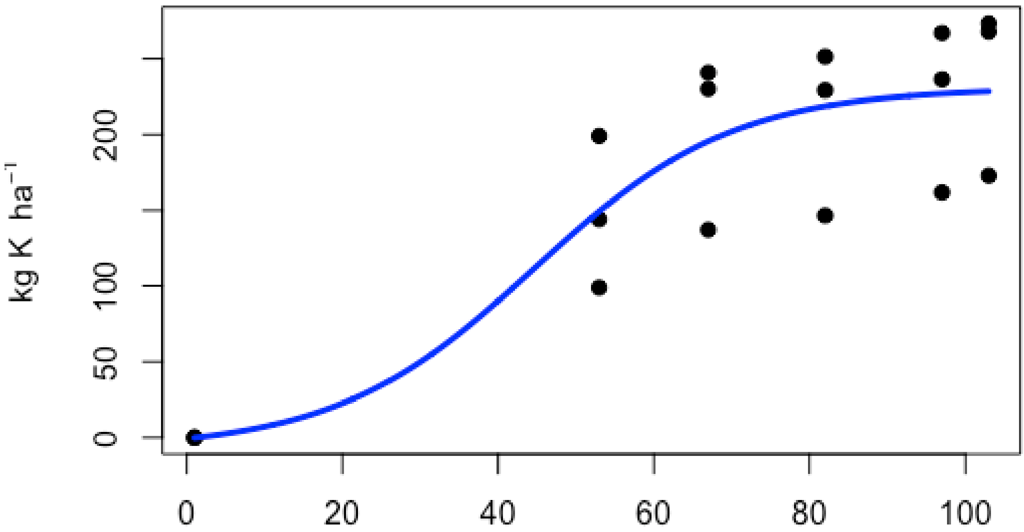
	Estimated	Est. error	t value
a	-165.8	44020	-0.004
b	147.4	25180	0.006
c	0.0029	0.6296	0.005
d	- 40.15	40650	-0.001

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(kg\ ha^{-1}) = -165.8 + \frac{313.2}{1 - e^{-0.003(Day - 40.15)}}$$

$SR^2 = 0.77$



Days after sowing

Figure 14 - K accumulation (kg ha^{-1}) of T7.

Formula: K_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 13 - Non-linear model of T7 K accumulation.

	Estimated	Est. error	t value	
a	-7.66704	48.42069	-0.158	
b	230.8138	27.67791	8.339	***
c	0.07836	0.08939	0.877	
d	44.63197	14.30650	3.120	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$K_{abs}(kg\ ha^{-1}) = -7.67 + \frac{238.48}{1 - e^{-0.078(Day-44.63)}}$$

$SR^2 = 0.79$

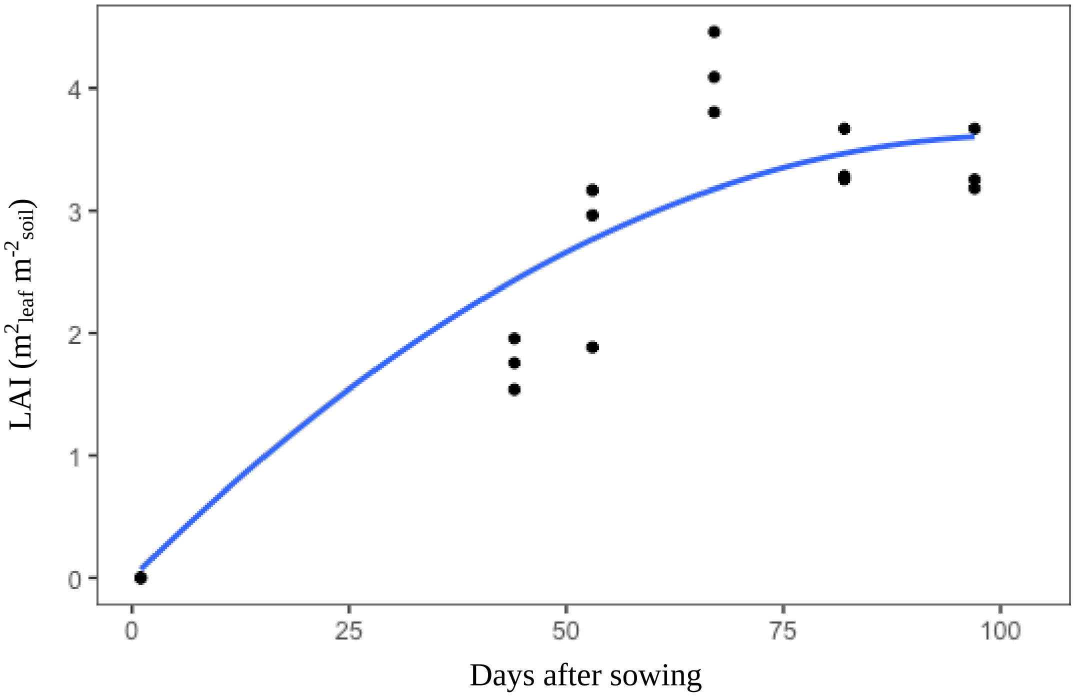


Figure 15 - LAI of T7.

Table 14 - Multiple regression of the T7 LAI.

	Estimated	Est. error	t value	
Day	0.0702966	0.0098900	7.108	***
Day^2	-0.0003417	0.0001224	-2.791	*

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$LAI\left(m_{leaf}^{2}\ \ m_{soil}^{-2}\right) = -0.0003\ Day^{2} + 0.07\ Day$$

$$R^2 = 0.96$$

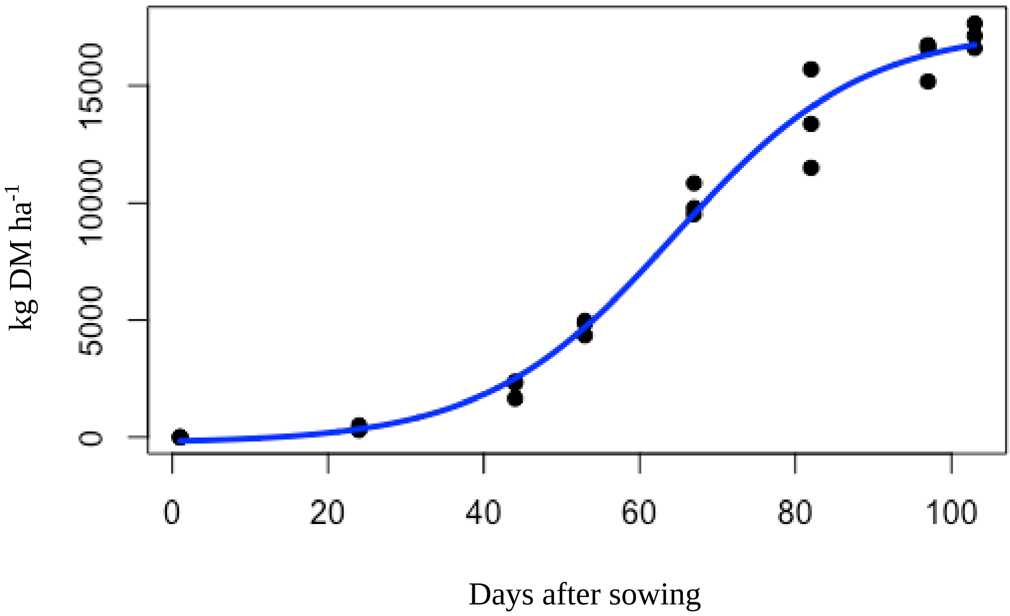


Figure 16 - DM accumulation (kg ha^{-1}) of T9.

Formula: DM = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 15 - Non-linear model of T9 DM accumulation.

	Estimated	Est. error	t value	
a	-256.3	444.0	-0.577	
b	17450	635.2	27.474	***
c	0.083	0.010	8.209	***
d	64.44	1.583	40.700	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$y(kg\ DM\ ha^{-1}) = -256.3 + \frac{17706.3}{1 - e^{-0.083(Day-64.44)}}$$

$SR^2 = 0.98$

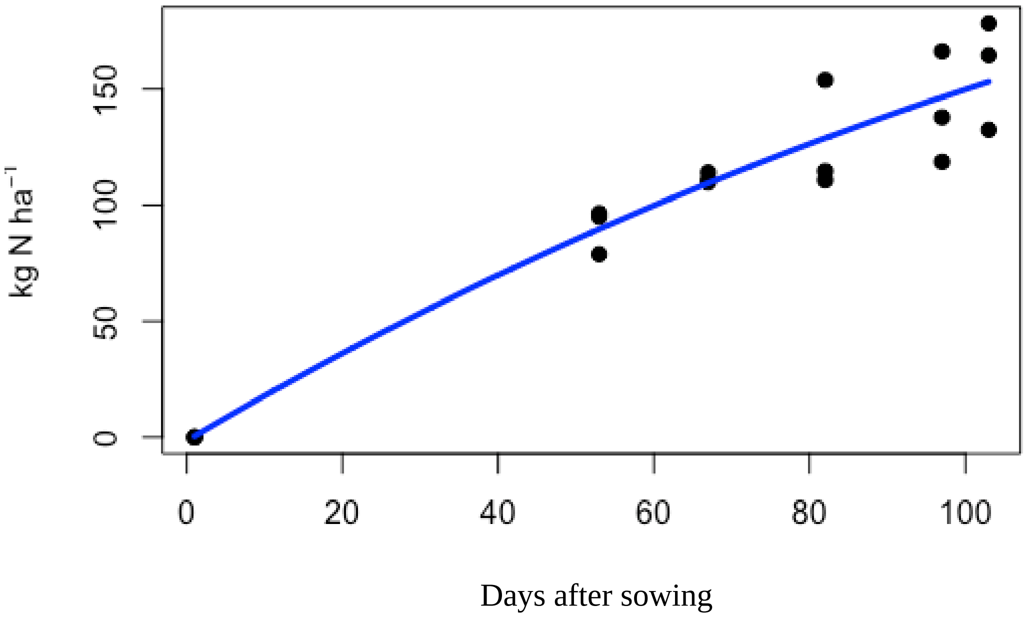


Figure 17 - N accumulation (kg ha^{-1}) of T9.

Formula: $N_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))$

Where:

Table 16 - Non-linear model of T9 N accumulation.

	Estimated	Est. error	t value
a	-1508	121700	-0.012
b	303.6	2160	0.141
c	0.008	0.1432	0.055
d	-204.4	13180	-0.016

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$N_{abs}(kg\ ha^{-1}) = -1508 + \frac{1811.6}{1 - e^{-0.008(Day-204.4)}}$$

$SR^2 = 0.92$

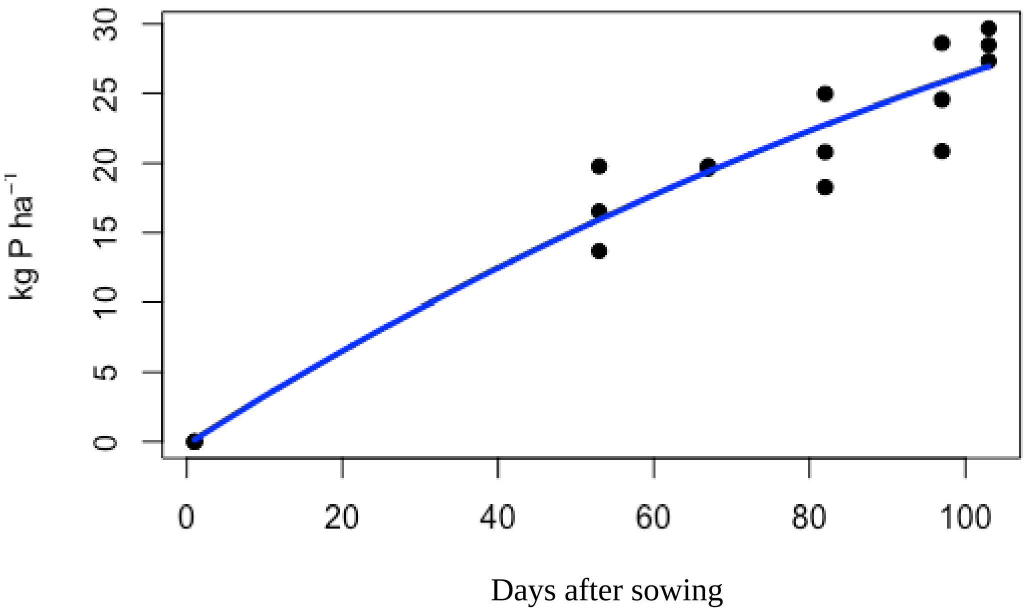


Figure 18 - P accumulation (kg ha^{-1}) of T9.

Formula: $P_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))$

Where:

Table 17 - Non-linear model of T9 P accumulation.

	Estimated	Est. error	t value
a	-494.8	68180	-0.007
b	53.40	363.3	0.147
c	0.0074	0.1367	0.054
d	-301.4	23370	-0.013

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(kg\ ha^{-1}) = -128.0 + \frac{548.2}{1 - e^{-0.008(Day - 301.4)}}$$

$SR^2 = 0.94$

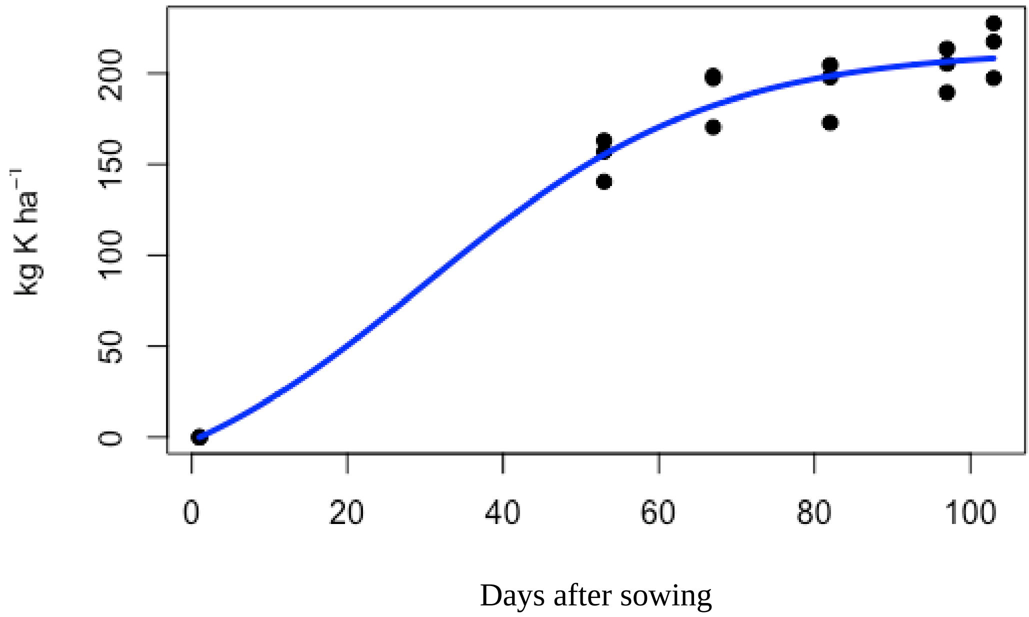


Figure 19 - K accumulation (kg ha^{-1}) of T9.

Formula: K_{abs} = a + ((b - a)/(1 + exp(-c * (Day - d))))

Where:

Table 18 - Non-linear model of T9 K accumulation.

	Estimated	Est. error	t value	
a	-44.4507	103.75841	-0.428	
b	213.2011	13.63596	15.635	***
c	0.05402	0.03595	1.503	
d	30.04165	22.80174	1.318	

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$K_{abs}(kg\ ha^{-1}) = -7.67 + \frac{238.48}{1 - e^{-0.078(Day-44.63)}}$$

$SR^2 = 0.97$

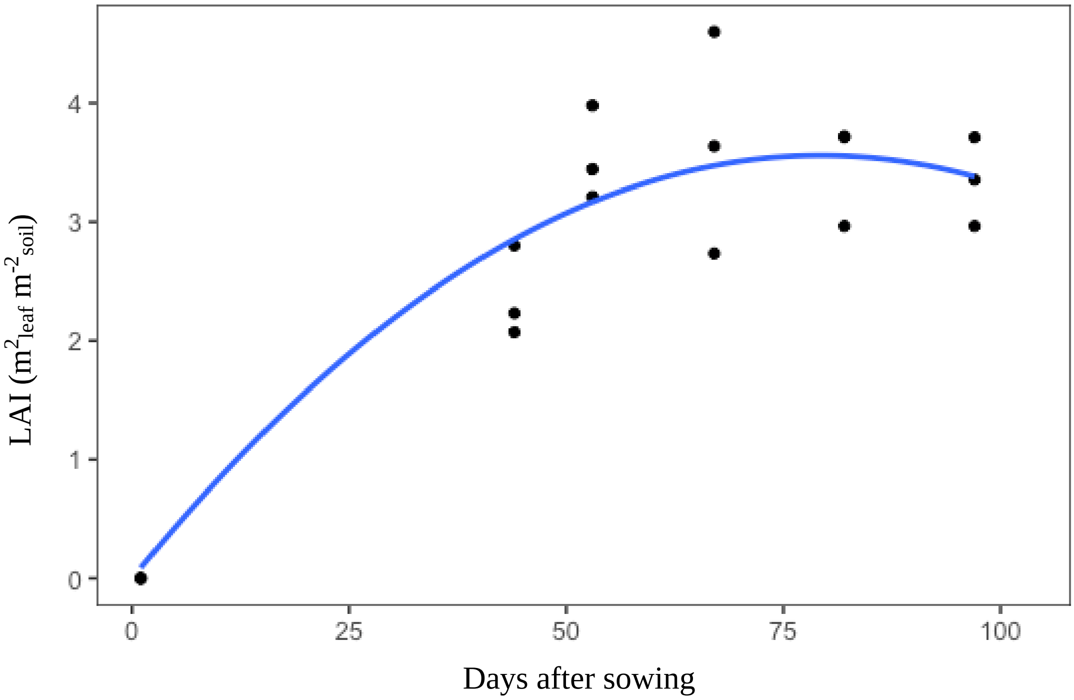


Figure 20 - LAI of T9.

Table 19 - Multiple regression of the T9 LAI.

	Estimated	Est. error	t value	
Day	0.0897442	0.0085163	10.538	***
Day^2	-0.0005659	0.0001054	-5.368	*

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$LAI\left(m^2_{leaf}\ m^{-2}_{soil}\right) = -0.0006Day^2 + 0.09Day$$

$$R^2 = 0.97$$

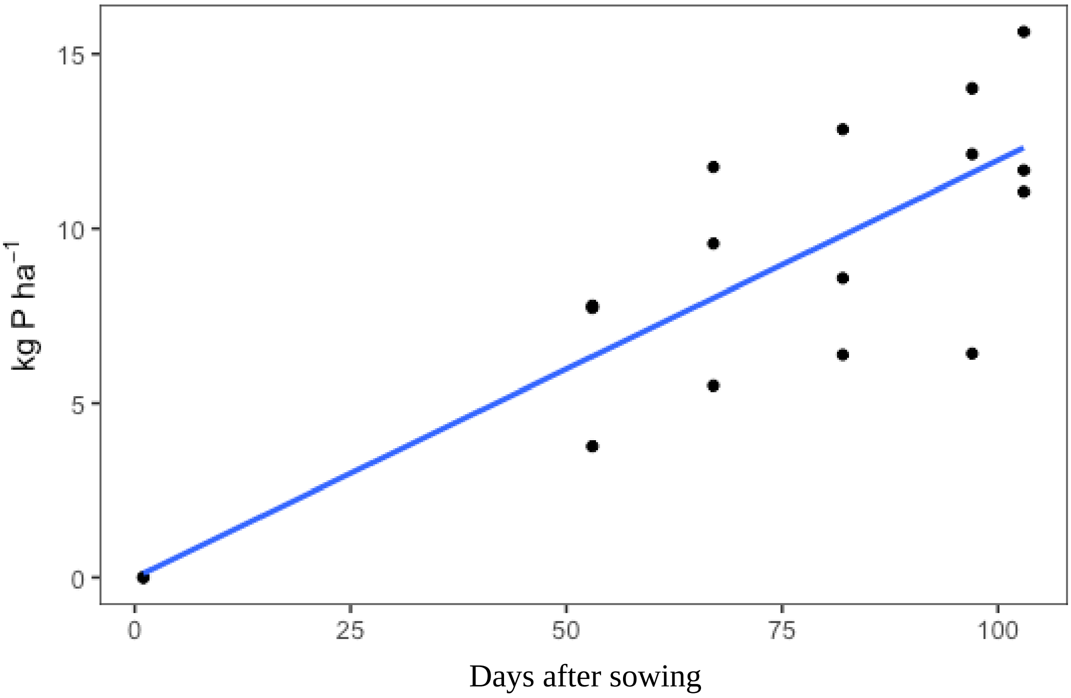


Figure 21 - Linear regression of P absorbed on the T1.

Table 20 - Linear regression of P absorbed on T1.

	Estimated	Est. error	t value	
Day	0.119564	0.007666	15.6	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(\text{kg ha}^{-1}) = 0.12\ Day$$

$$R^2 = 0.93$$

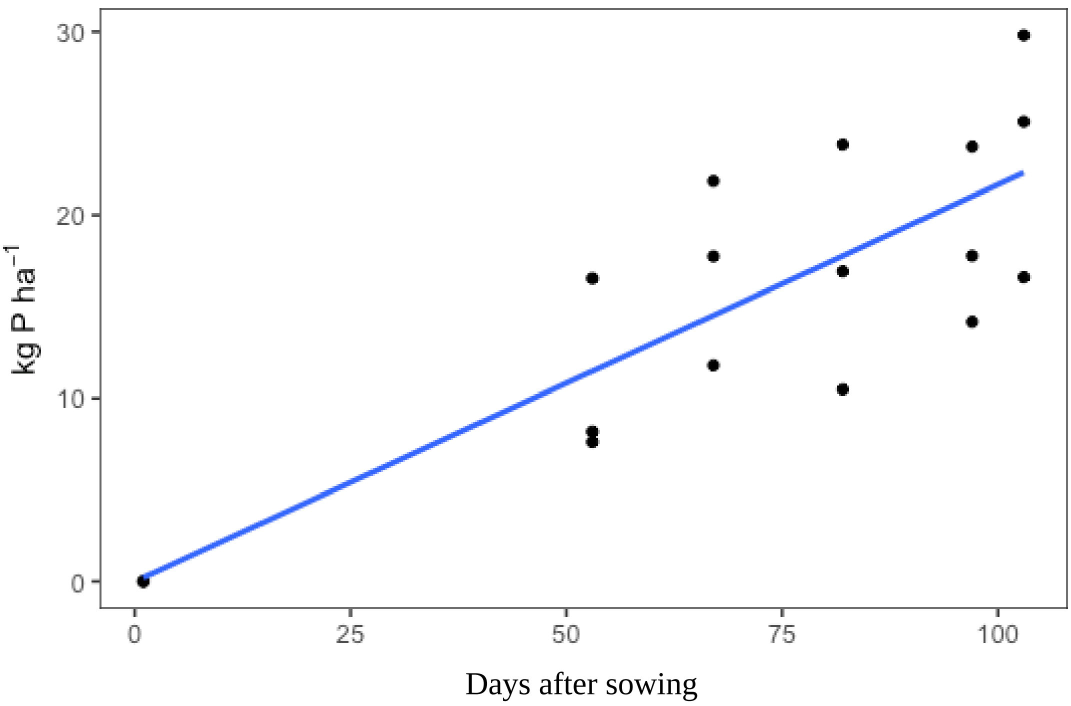


Figure 22 - Linear regression of P absorbed on the T3.

Table 21 - Linear regression of P absorbed on T3.

	Estimated	Est. error	t value	
Day	0.2167	0.0147	14.74	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(kg\ ha^{-1}) = 0.21\ Day$$

R^2=0.93

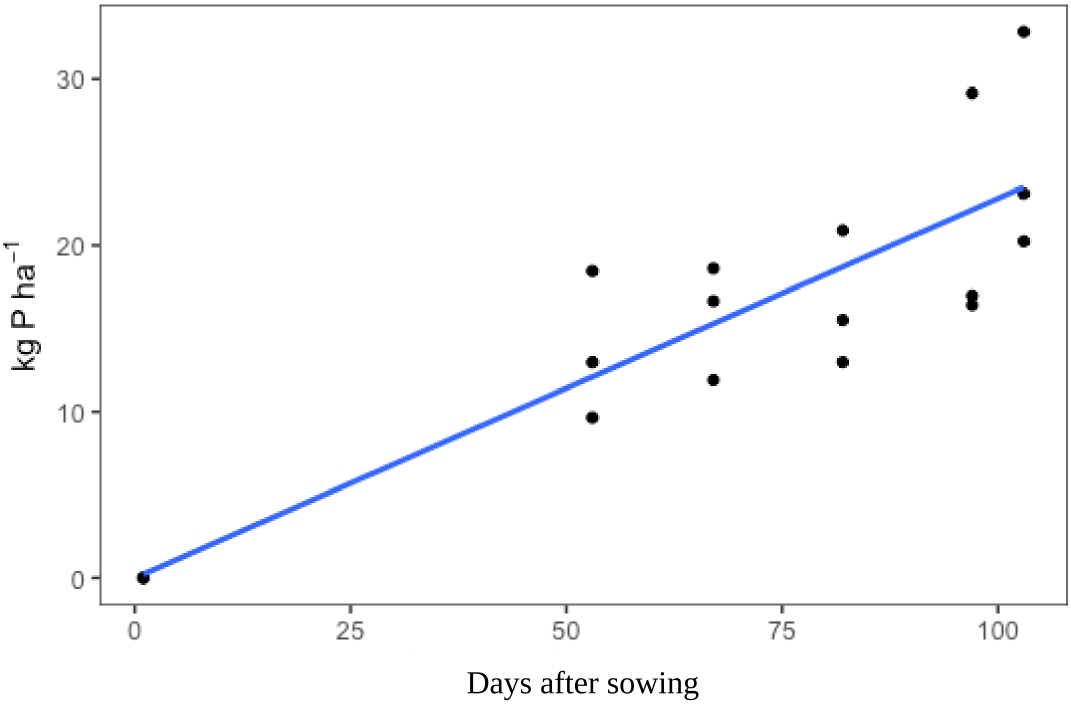


Figura 23 - Linear regression of P absorbed on the T7.

Table 22 - Linear regression of P absorbed on T7.

	Estimated	Est. error	t value	
Day	0.22822	0.01371	16.65	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(kg\ ha^{-1}) = 0.23\ Day$$

R^2=0.94

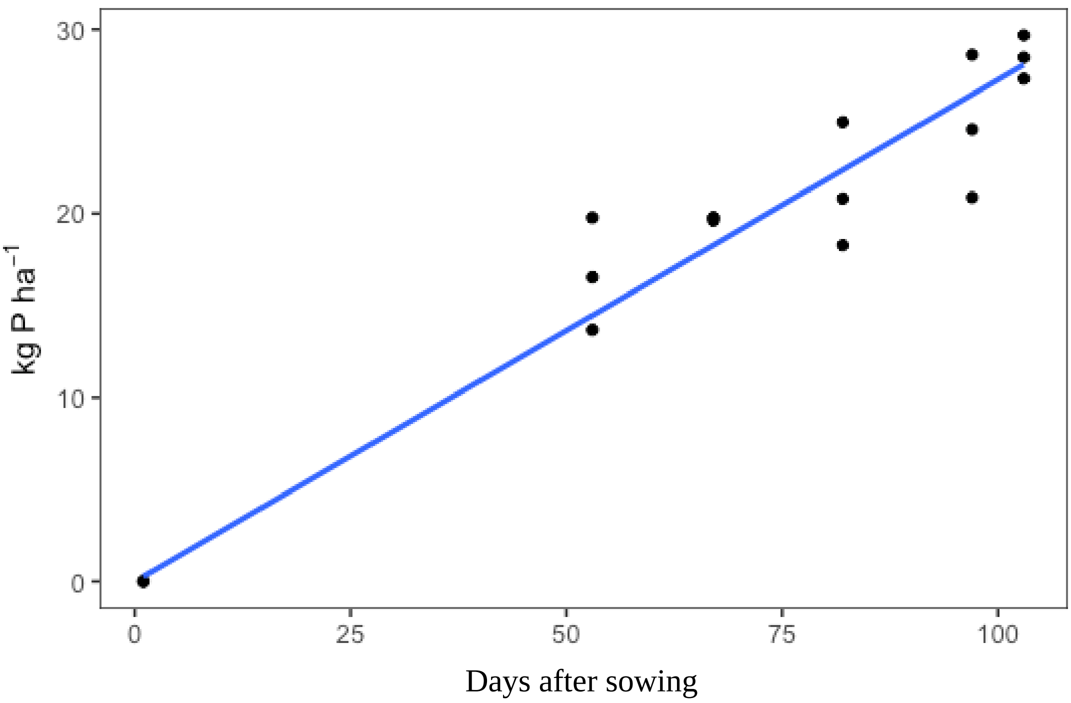


Figure 24 - Linear regression of P absorbed on the T9.

Table 23 - Linear regression of P absorbed on T9.

	Estimated	Est. error	t value	
Day	0.272746	0.007902	34.51	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Therefore:

$$P_{abs}(kg\ ha^{-1}) = 0.27\ Day$$

R^2=0.99

Annex 9. Leaf sample data

Table 1 - Percentage of N in foliar sampling

	A	B	C	Mean	N_{min}	N_{org}
T1	0.74	1.29	1.26	1.10	0	0
T2	1.06	1.42	1.17	1.22	0	180
T3	1.38	1.45	1.19	1.34	0	360
T4	1.08	1.40	1.56	1.35	90	0
T5	1.93	1.44	1.67	1.68	90	180
T6	2.08	1.65	1.54	1.76	90	360
T7	1.10	2.00	2.27	1.79	180	0
T8	1.33	1.60	1.81	1.58	180	180
T9	1.84	1.77	1.70	1.77	180	360
Mean	1.4	1.6	1.6	1.5		

Table 2 - Percentage of P in foliar sampling

	A	B	C	Mean	N_{min}	N_{org}
T1	0.14	0.16	0.16	0.15	0	0
T2	0.18	0.16	0.16	0.17	0	180
T3	0.19	0.17	0.16	0.17	0	360
T4	0.21	0.18	0.15	0.18	90	0
T5	0.20	0.19	0.16	0.18	90	180
T6	0.19	0.20	0.19	0.19	90	360
T7	0.21	0.22	0.19	0.21	180	0
T8	0.23	0.21	0.21	0.21	180	180
T9	0.21	0.21	0.22	0.21	180	360
Mean	0.2	0.2	0.2	0.2		

Table 3 - Percentage of K in foliar sampling

	A	B	C	Mean	N_{min}	N_{org}
T1	2.32	1.97	1.93	2.07	0	0
T2	2.35	1.90	1.94	2.06	0	180
T3	2.37	2.17	2.05	2.19	0	360
T4	2.58	2.40	2.10	2.36	90	0
T5	2.50	2.32	2.08	2.30	90	180
T6	2.28	2.39	2.40	2.36	90	360
T7	2.58	2.45	1.98	2.34	180	0
T8	2.39	2.22	2.32	2.31	180	180
T9	2.29	2.50	2.48	2.42	180	360
Mean	2.4	2.3	2.1	2.3		

Annex 10. Leaf sampling analysis

Nitrogen:

Friedman's analysis gave an F of 3.93 which is significant.

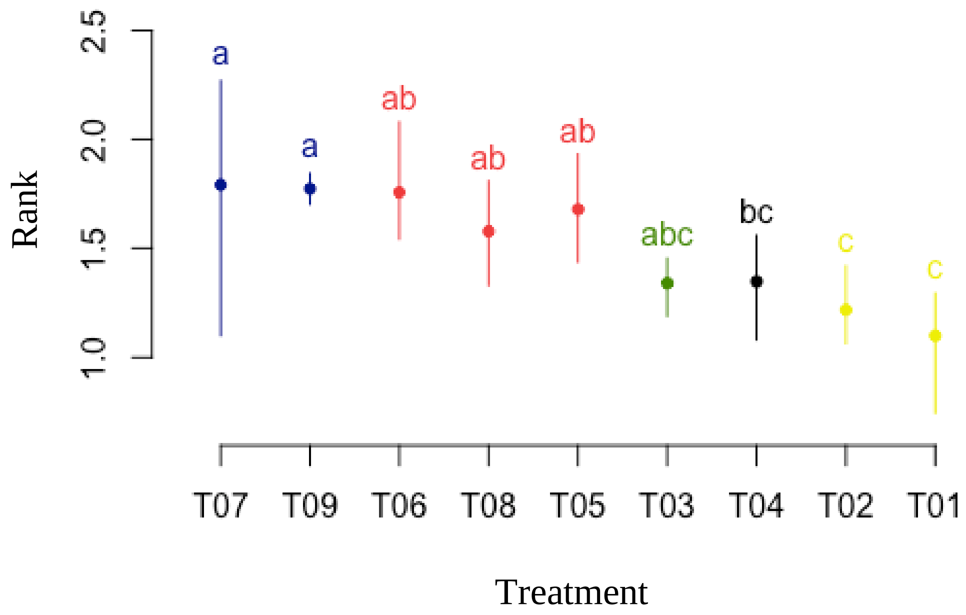


Figure 1 - Fisher's analysis of N in foliar sampling.

Phosphorus:

Friedman's analysis gave an F of 7.45 which is significant.

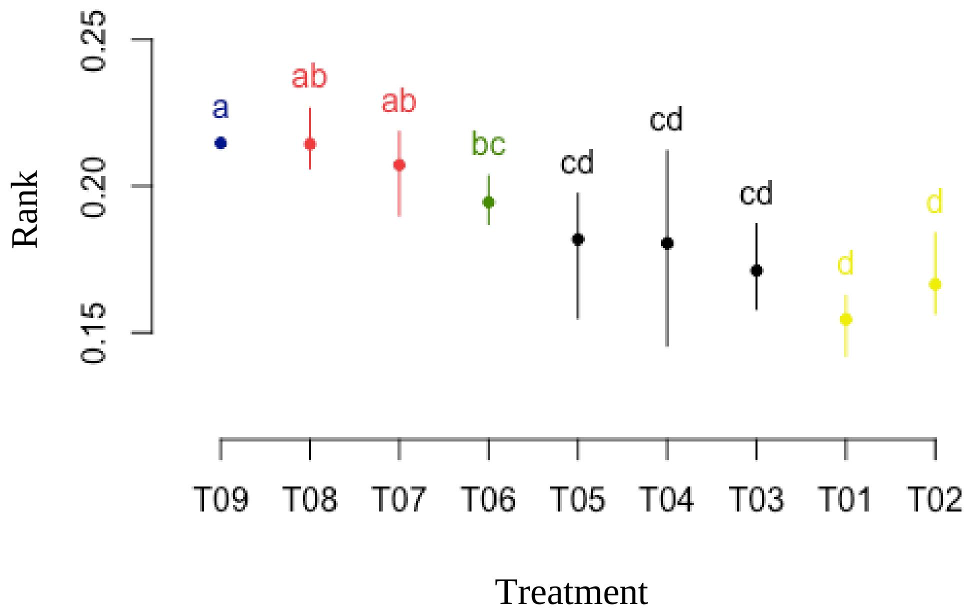


Figure 2 - Fisher's analysis of P in foliar sampling.

Potassium:

Friedman's analysis gave an F of 1.69 which is significant.

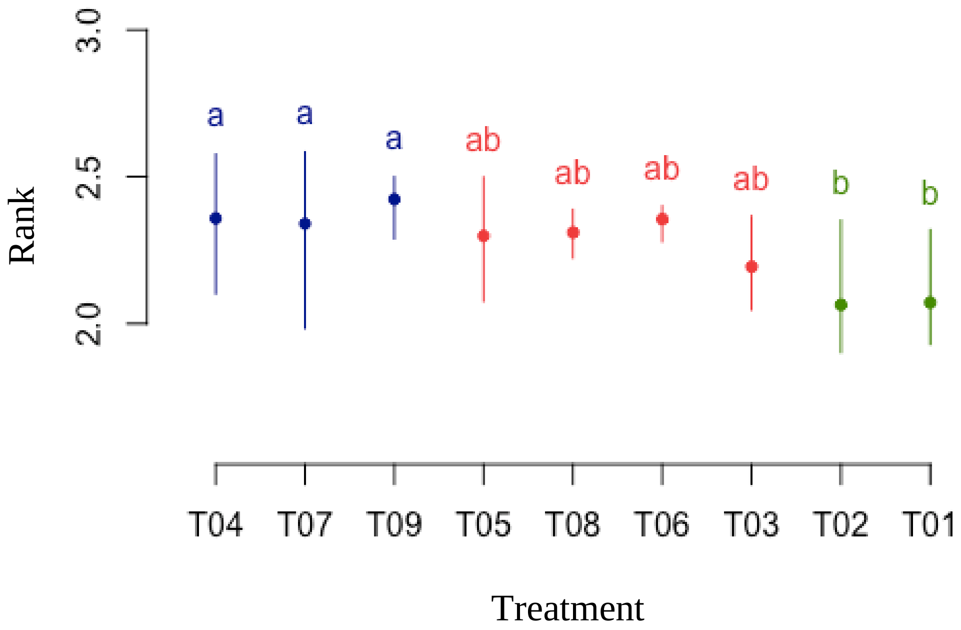


Figure 3 - Fisher's analysis of K in foliar sampling.

Annex 11. Analysis with harvest data.

Table 1 - ANOVA of harvested DM.

	Df	SS	MS	F	
Treatment	8	306769687	38346211	24.713	***
N_{min}	2	239376795	119688398	77.1367	***
N_{org}	2	18955676	9477838	6.1083	*
N_{min} x N_{org}	4	48437216	12109304	7.8042	**
Block	2	63939709	31969855	20.6039	***
Error	16	24826256	1551641		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 2 - Multiple linear regression of DM harvested only in N_{min} treatments.

	Estimated	Standard error	t-value	
Ind. term	7632.2901	1615.1372	4.725	***
N_{min}	132.8362	45.7534	2.903	*
N_{min}^2	-0.4355	0.2442	-1.783	

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

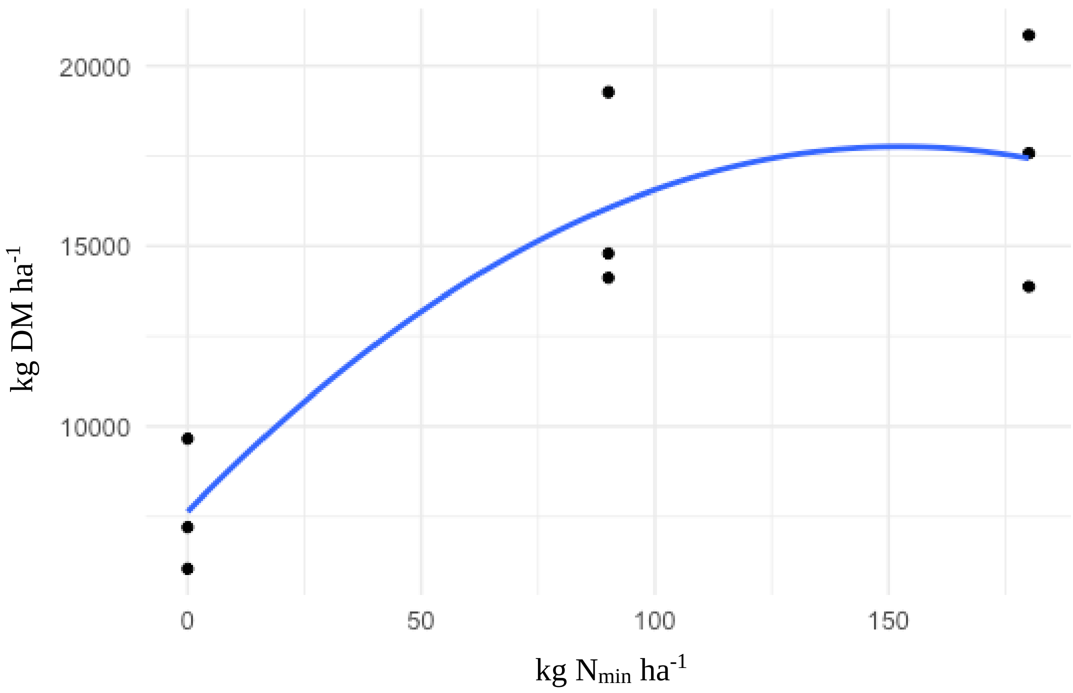


Figure 1 - Multiple linear regression of harvested DM only in treatments with N_{min}.

Table 3 - Multiple linear regression of harvested DM.

	Estimated	Standard error	t-value	
Ind. term	8074.63439	1161.69989	6.951	***
N_{min}	87.86923	22.35692	3.930	***
N_{min}^2	-0.16844	0.11299	-1.491	
N_{org}	23.09067	11.17846	2.066	·
N_{org}^2	-0.09971	0.03995	-2.496	
N_{min} x N_{org}	-0.09771	0.03995	-2.496	*

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 4 - ANOVA of N extracted at harvest.

	Df	SS	MS	F	
Treatment	8	48917	6114.6	18.2863	***
N_{min}	2	46022	23010.8	68.8156	***
N_{org}	2	97	48.3	0.1445	
N_{min} x N_{org}	4	2799	699.7	0.12939	
Block	2	3058	1529.0	4.5725	*
Error	16	5350	334.4		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 5 - ANOVA of P extracted at harvest.

	Df	SS	MS	F	
Treatment	8	586.54	73.317	5.7257	**
N_{min}	2	354.12	177.059	13.8275	***
N_{org}	2	168.35	84.176	6.5737	**
N_{min} x N_{org}	4	64.06	16.016	1.2508	
Block	2	263.09	131.544	10.2730	**
Error	16	204.8	12.805		

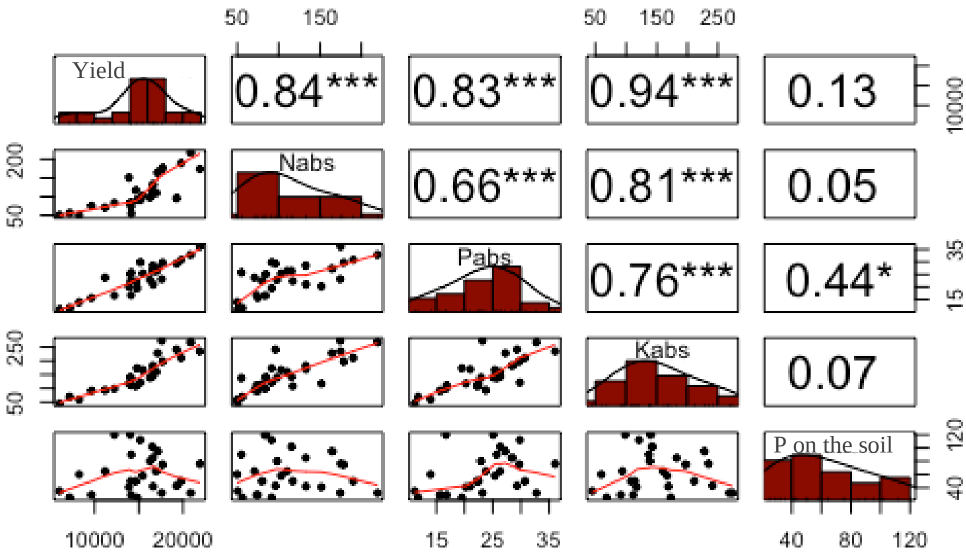
***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 6 - ANOVA of K extracted at harvest.

	Df	SS	MS	F	
Treatment	8	67731	8466.4	9.3551	***
N_{min}	2	60953	30476.6	33.6759	***
N_{org}	2	374	187.1	0.2068	
N_{min} x N_{org}	4	6404	1600.9	1.7689	
Block	2	18370	9185.0	10.1492	**
Error	16	14480	905.0		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Annex 12. Analysis of correlations



***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Annex 13. Post-harvest soil data.

Table 1 - Post harvest N-NO_3 data.

	A	B	C	Mean	N_{min}	N_{org}
T1	30	35	28	31	0	0
T2	25	30	11	22	0	180
T3	26	24	27	26	0	360
T4	35	32	26	31	90	0
T5	42	20	46	36	90	180
T6	32	25	24	27	90	360
T7	36	40	12	29	180	0
T8	52	21	32	35	180	180
T9	54	35	10	33	180	360
Mean	37	29	24	30		

Table 2 - Post harvest P data.

	A	B	C	Mean	N_{min}	N_{org}
T01	29	25	35	30	0	0
T02	50	65	60	58	0	180
T03	112	120	120	117	0	360
T04	43	25	29	32	90	0
T05	65	58	50	58	90	180
T06	102	80	90	91	90	360
T07	32	32	41	35	180	0
T08	76	50	42	56	180	180
T09	95	85	75	85	180	360
Mean	67	60.0	60	62		

Annex 14. Analysis using soil data.

Table 1 - ANOVA N-NO_3 in soil after harvesting.

	Df	SS	MS	F	
Treatment	8	492.7	61.6	0.528	
N_{min}	2	198.2	99.1	0.850	
N_{org}	2	29.6	14.8	0.127	
N_{min} x N_{org}	4	264.9	66.2	0.568	
Block	2	758.2	379.1	3.252	.
Error	16	1865.1	116.6		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 2 - ANOVA P in soil after harvesting.

	Df	SS	MS	F	
Treatment	8	21400.7	2675.08	32.0423	***
N_{min}	2	412.7	206.3	3.0257	.
N_{org}	2	18060.2	9030.1	132.4171	***
N_{min} x N_{org}	4	2203.1	550.8	8.0766	***
Block	2	320.9	160.4	2.3527	
Error	16	1091.1	68.2		

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Table 3 - Non-linear regression of P in soil on the addition of poultry litter.

	Estimated	Standard error	t-value	
a	29.34	2.274	12.90	***
b	$3.848x10^{-3}$	$2.393x10^{-4}$	16.08	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Formula: $y = a.e^{bx}$

$P(\mu g\ g^{-1}) = 29.34.e^{0.004N_{org}}$

$SR^2 = 0.98$

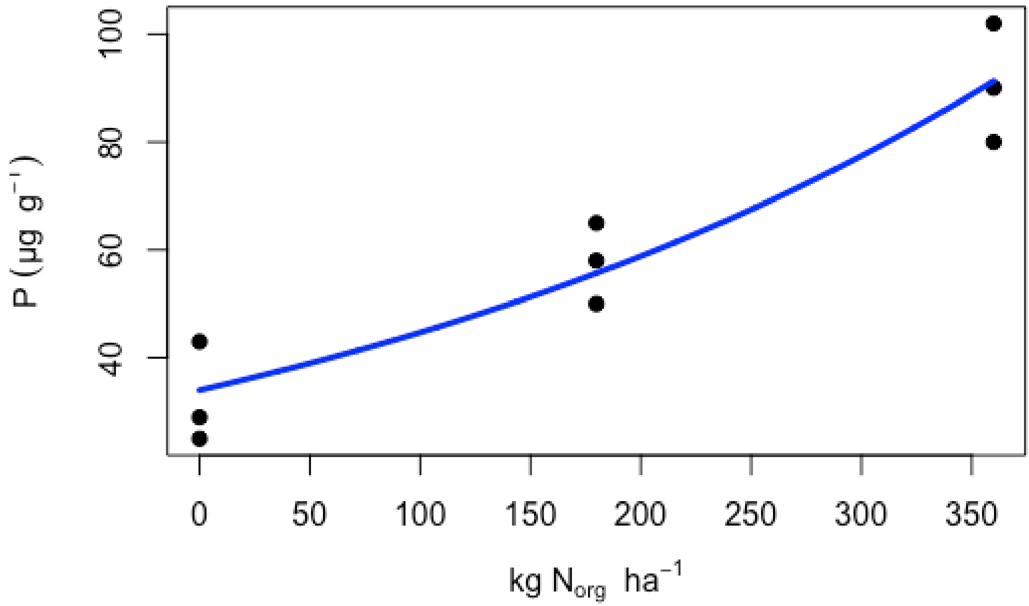


Figure 1 - P in soil with the addition of poultry litter and 90 kg N_{min} ha^{-1}.

Table 4 - Non-linear regression of soil P to the addition of poultry litter and 90 kg N_{min} ha^{-1}.

	Estimated	Standard error	t-value	
a	33.9637	4.0455	8.395	***
b	0.0027	0.0004	7.060	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Formula: $y = a.e^{bx}$

$P(\mu g\ g^{-1}) = 33.96.e^{0.003N_{org}}$

$SR^2 = 0.90$

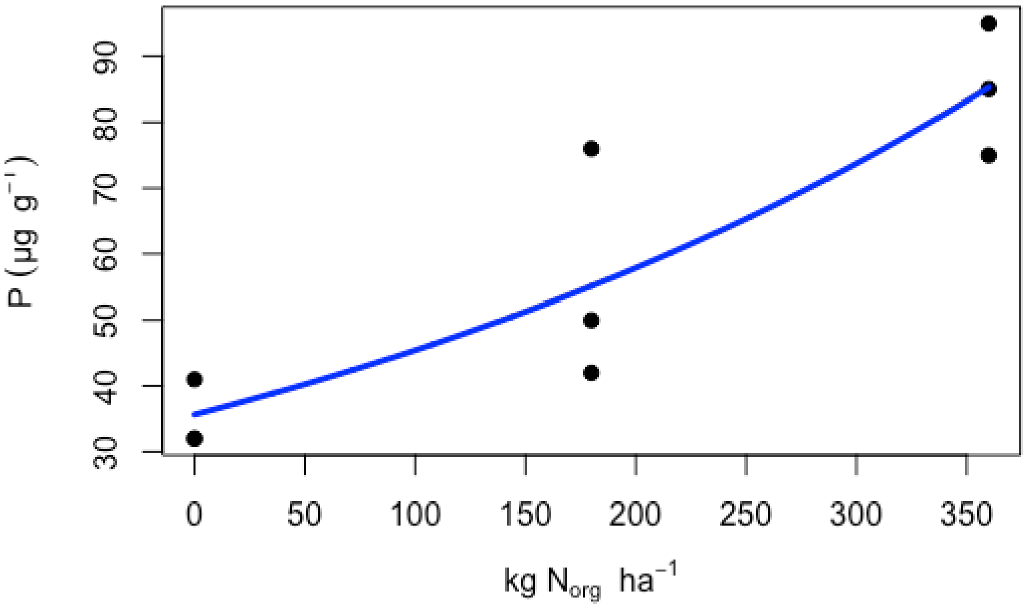


Figure 2 - P on the ground in front of the addition of chicken litter and 180 kg N_{min} ha^{-1}.

Table 5 - Non-linear regression of soil P to the addition of poultry litter and 180 kg N_{min} ha^{-1}.

	Estimated	Standard error	t-value	
a	35.66	5.243	6.802	***
b	0.0024	0.0004	4.938	**

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Formula: $y = a.e^{bx}$

$P(\mu g\ g^{-1}) = 35.66.e^{0.002N_{org}}$

$SR^2 = 0.81$

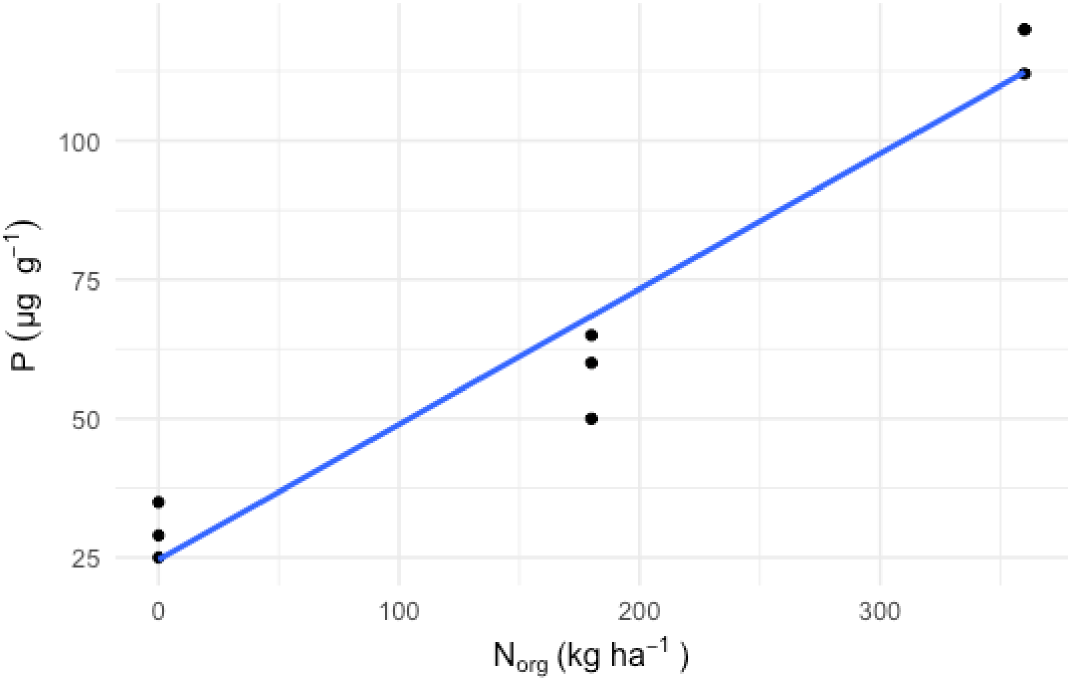


Figure 3 - Linear regression of P in soil on the addition of poultry litter.

Table 6 - Linear regression of P in soil on the addition of poultry litter.

	Estimated	Standard error	t-value	
Ind. term	24.61111	5.15650	4.773	***
N_{min}	0.24352	0.02219	10.974	**

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

Formula: $P(\mu g\ g^{-1}) = 0.24N_{org}+24.61$

$R^2 = 0.94$

Table 7 - Linear regression of P on soil.

	Estimated	Standard error	t-value	
Ind. term	34.66667	4.57614	7.576	***
N_{min}	-0.05432	0.03114	-1.745	.
N_{org}	0.18148	0.01557	11.657	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

$$P(\mu g\ g^{-1}) = -0.05N_{min} + 0.18N_{org} + 34.6$$

$R^2 = 0.85$

Fitting regressions using total P

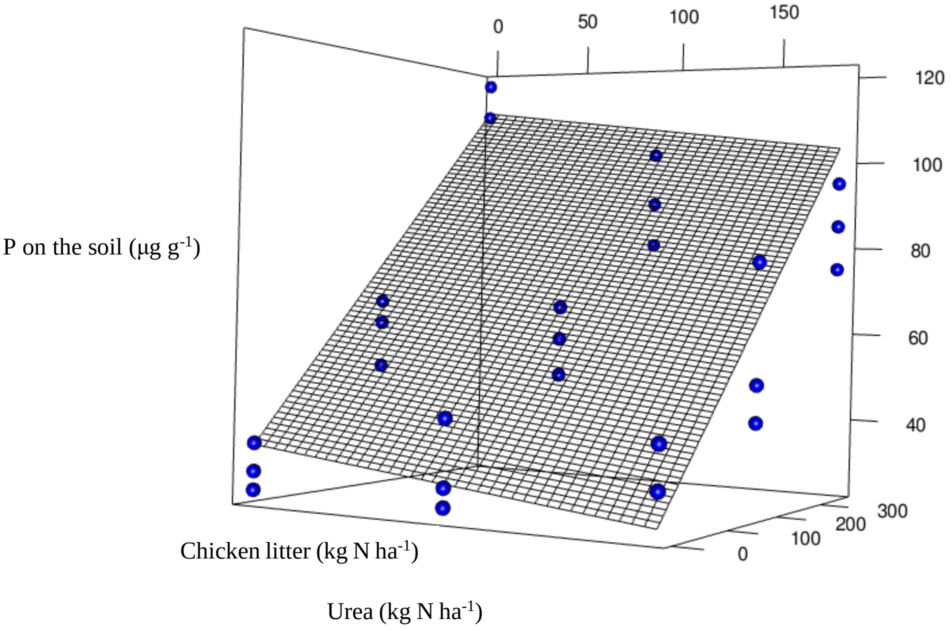


Figure 1 - Linear regression of P on soil.

Table 1 - Linear regression of P on soil.

	Estimated	Standard error	t-value	
Ind. term	34.66667	4.57614	7.576	***
N_{min}	-0.05432	0.03114	-1.745	.
N_{org}	0.21778	0.01868	11.657	***

***Significant at 0.1%, ** significant at 1%, * significant at 5%, · significant at 10%.

$$P(\mu g\ g^{-1}) = -0.05N_{min} + 0.22P_{total} + 34.6$$

$R^2 = 0.85$