

INFLUENCE OF THE PHOSPHORIC FERTILIZATION IN THE FORMATION OF DRY MATTER AND NUTRIENTS EXTRACTION IN A CROP OF GREEN ASPARAGUS (*Asparagus officinalis*, L.)

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ABSTRACT

This work studied the influence of the phosphorus fertilization on the formation of dry matter and nutrients extractions in a crop of green asparagus (var. Plaverd), located in the Protected Geographical Indication of Huétor-Tájar (Andalusia, Spain).

The results show that the influence of the phosphorus applications in the production of dry matter in the asparagus plant, is more pronounced in the second year than in the first year. The root system had the largest formation of dry matter, around 47 %, followed by the ferns around 37.6 %, spears around 14.6 % and the seed berries with values something lower to 0.8%.

The medium levels of annual nutrient extraction expressed in kg.ha⁻¹, for a plantation with density of 15000 plants/ha were of 109.4 (N), 8.16 (P), 101.2 (K), 42.61 (Ca), 9.17 (Mg), 9.20 (Na), 5.68 (Faith), 0.358 (Mn), 0.106 (Cu), 0.139 (Zn) and 0.148 (B).

Key words: Green asparagus, phosphorus fertilization, nutrients extraction

1. INTRODUCTION

The accumulation of the dry matter in the crop of the green asparagus in mediterranean climates is characterized for a maximum in the dry weight of the plant in the period from final of September to the beginning of December. The cladodes contained their maximum dry matter in summer, while the stalks attained maximum dry matter content in the autumn. Regarding the underground part, the rhizome maintains a practically constant dry weight during the whole vegetative cycle, while the roots had their largest dry weight at the end of this vegetative cycle (Espejo, 1994).

The calculation of the extractions is based on the evaluation of the formed vegetable matter and in the mineral analysis during the vegetative cycle. Most of the authors

participation in the assimilation nutritious total of the year (60-90% in plants in full production), should be included in this calculations (Kaufmann and Kaufmann, 1967), however, due to the difficulty of the extraction of the root system, there are few papers that report information on the dry matter and nutrient content of the root system.

According to Kaufmann and Kaufmann (1967), it is an error to establish relationships between the nutritious extractions and the obtained crop, as used in manuals of recommendations of fertilizers, because the climatic conditions during the harvesting of gathering influence strongly on the expression of the potential of crop of the plant.

In spite of the differences, all the works coincident in the fact of always shows a total low extractions compared with other cultivations. In general, the order of extraction of the elements is in the first place the K, continued closely by the N, Ca, P and Mg. It is remarkable the fact indicated by diverse authors about the low extraction of P for the asparagus (Morse, 1916; Brown et al., 1961; Hartmann, 1985), although the extractions of this element increase with the age of the plant, mainly in calcareous soils, due to the acidification of the soil by the root exudates (Espejo et al., 1997).

Regarding the scarce works found in the bibliography on the microelementos extractions, Brown and Carolus (1965) and Espejo and Gonzalez (1992) have found that Fe is the micronutrient extracted in largest quantities with significant differences, followed by the Mn, while Cu, Zn and B which are taken up in small but similar quantities.

The objective of the present work is to study the influence of the phosphoric fertilization in the formation of dry matter and nutrients extraction in a crop of green asparagus along its vegetative cycle during two serial years. This crop is grown on a calcareous soil, where the levels of phosphorus are not high.

2. MATERIAL AND METHODS

The experience is developed in the Protected Geographical Indication of Huétor-Tájar (Andalusia, Spain) during the years 1994 and 1995, using the variety Plaverd (due to its biggest interest for production and representativeness in the study area). The age of the plantation at the beginning of the study was two years, and the soil on which the cultivation is developed is a calcic Luvisol (FAO, 1989).

The experiment involves the study in a randomized triplicates design in parcels of 45 m², with a density of plantation of 15000 plants/ha, where the following variants of phosphoric fertilization are included:

- 0 Kg P/ha:
 - Pre-harvest: 100 kg N/ha and 62.3 Kg K/ha
 - Cover: 300 Kg N/ha
 - Post-harvest: 50 kg.ha⁻¹ de N of slow release
- 11 Kg P/ha:
 - Pre-harvest: 100 kg N/ha, 11 kg/P ha and 62.3 Kg K/ha

- Cover: 300 Kg N/ha
- Post-harvest: 50 kg.ha⁻¹ de N of slow release

The determinations and methods used for determinations of soil and in the vegetable material, are expressed in a previous work of the authors (Espejo et al., 1996). Statistical analysis was done with a computer package Statgraphics 5.0 (Statistical Graphics Corporation, 1991) they were carried out the following statistical treatments: multiple analysis of variance based on the LSD criterion, in order to studying the influence of the phosphoric fertilization in spears, shoots, cladodes, seed berries, rhizomes and roots, as well as to study the influence of the phosphoric fertilization in the production of dry matter and in the extractions of total nutrients of the asparagus plants for the two experimental seasons. An analysis of multiple regression was run in order to find the correlation degree between the production of total dry matter and the different studied nutrients.

3. RESULTS AND DISCUSSION

The soil in which the experience is developed (Table 1) is of clayey nature, basic pH and calcareous character, with medium or low organic matter content, according to the recommendations given by Kaufmann and Kaufmann (1967) and Hartmann (1989). The saturation percentage in exchangeable sodium is lower to 15 % and the conductivity electric measure in the saturation extract indicates absence of negative saline effects in the soil (Francois, 1987). The levels of N are relatively low, which is the reason of using a high dose of N in fertilization (250 kg.ha⁻¹.year), showing a good nutritive potential in K, Ca and Mg. The contents of assimilable P are very low, and so, it is needed a phosphoric fertilization, because although the soil is calcareous, according to the radicular exudates acidified the soil increasing the available-P (Espejo et al., 1997).

Micronutrients, were in sufficient quantities to guarantee the correct nutrition of the plant, except the Zn that is lower due to the calcareous nature of the soil, and the B that is in a level something under, next at the critical level proposed by Knott (1960).

Table 2 shows the analyses of the soil of the different experimental parcels after the harvesting for both experimental years. In the first experimental year a slight fall the pH of the arable layer is observed, coinciding to Espejo et al. (1997). An impoverishment was also observed in organic matter with respect to the O.M. content of the soil before the experiment started, which is logical if we keep in mind that during the harvesting the soil has been lacking vegetable cover that provides organic matter to the soil, taking place mineralization of the existent one.

An increase was not shown in the contents of N in the different parcels, it can be observed in the contents of K. As for the P, a slight increase is observed in parcels fertilized with P. Lastly, regarding the analyzed micronutrients, they are not significant differences among the different studied parcels.

For the second experimental season the analyses of the soil reveal a decrease of the pH, independently of the treatment used fertilizer that drives to identical final values, what corroborates that pointed by Espejo et al. (1997). A descent of the content of organic matter is also observed with regard to the previous season, what confirms that

organic matter of the soils dedicated to the crop of the green asparagus. The values of N, P and K are very similar to observed in the previous season.

The Table 3 shows the medium chemical composition of the spears during the two years, being observed that the dose fertilizer hasn't a significant influence in the mineral composition of the spear, while the sampling date have a marked influence on this mineral composition, especially during the first year, originating an increase of the levels of all the nutrients analyzed except Na, Cu and Zn when advancing in the harvesting date (Amaro Lopez et al., 1995). On the other hand, it is necessary to indicate, according to the previously mentioned bibliography, that the levels are medium to high for K, Fe, Mn and Cu, of medium to lower for Ca, Mg and Zn, lower for N and B and very low for P.

Table 4 presents the compositions mineral content of stalks and cladodes for both years. In general, bigger mineral contents are observed in the cladodes than in the shafts, agreeing with that pointed by Hagg and Belfort (1985). Comparing with the consulted bibliography lower levels of N and P is detected, normal of K, Mg and Na and high for Ca, while for micronutrients they are high for Fe, Mn and Cu, medium for Zn and low for B.

Regarding the influence of the dose fertilizers it continues being not very significant in both seasons, exercising some more significant differences the sampling date in both seasons.

The relationships of nutrients extraction by the seeds was calculated by Depardon and Buron (1947). When comparing the relationships among N: P: K: Ca: Mg using the values of Depardon and Buron (1947) with the relationships obtained from the data of the Table 5, our values are high for N, K and Ca, and of the same order for Mg, and low levels in P motivated by the low contents of the soil. The phosphoric fertilization produces an increase in the contents of N and P although in a significant only in the first year for N and in both for P. Also, a significant descent took place in the potassic levels in the two years. Regarding the micronutrients it is prominent the significant increases found in Zn with the phosphoric dose in the two years.

In the Table 6 the medium chemical composition of the root system appears for both experimental seasons. The results were obtained dividing the root system in the two anatomical organs: rhizome and roots. In general, it is observed bigger contents for all the nutrients in the rhizome than in the roots except for the K that is of the same order in both. Comparing the contents with those described in the bibliography, they are considered normal in both seasons, in rhizomes and roots, in the case of N and Mg being similar to the levels described for Kaufmann and Kaufmann (1967), Hirsch (1985) and Hartmann and Hermann (1989). The P was low in both organs in the two years and the contents of K are considered normal in the rhizome, although they are something lower in the roots if we consider those proposed by Douglas et al. (1989) and Hartmann and Hermann (1989).

The contents of Ca are somewhat lower in the first season in both organs, and high in the second season. Regarding the Na, it is necessary to indicate the high requirements in

Lastly, as for the analyzed micronutrients and comparing the contents obtained with those from Douglas et al. (1989), it can be noted that the levels of Fe and Mn in the roots are high, while they are low in Zn and B.

In general, a good agreement exists among the low levels of the soil in P, Zn and B with those ones in the underground organs, which agree with the good correlations found between soil and underground organs by Hartmann and Hermann (1989). The statistical analysis indicates in a recurrent way in the two years, significant increases in the contents of Ca in the rhizomes, and increases of B in the roots although for this last it is only significant in the second year.

In order to study the influence of the phosphoric fertilization in the production of total dry matter and in the nutrients extractions, as well as to obtain an orientation of the nutrients supply that it is necessary to carry out in the annual fertilization, the necessary calculations for the nutrients extractions of the different experimental parcels.

Table 7 shows the productions of dry matter for hectare made for the different organs of the fern for the two experimental seasons showing the influence of the phosphoric fertilization in this production of dry matter, mainly for the second year. Also, in the Tables 8, 9, 10 and 11 are reflected the extractions of the different studied nutrients, made by the corresponding organs of the plant in two studied experimental seasons, finally the Table 12 reflects the total nutrients extractions of the different sites.

As shown in Table 12, the nutrients which the plant extracts in greater proportions are K and N, followed by Ca, P and Mg, which agrees with the order indicated by different authors (Brown and Carolus, 1965; Kaufmann and Kaufmann, 1967; Lubet et al., 1975; Hartmann et al., 1983; Espejo, 1991 and 1994). As for the Na, although there are few studies about their extractions, Espejo (1991 and 1994) indicates that they are of the same order that the Mg. Regarding the micronutrients, very few bibliographical dates that are about this topic exist. Of these we can mention Brown and Carolus (1965) and Espejo and Gonzalez (1992), although the first ones only study the extractions corresponding to the foliage (spears and ferns). Regarding the order of micronutrients extraction, both groups of authors coincide in the case of the cationics micronutrients, that is the Fe the is extracted in the first place, followed by the Mn, and lastly in same extraction order Cu and Zn. However, this authors, in the case of the B differ in the extraction order, being in the same extraction order that the Mn for Brown and Carolus (1965), and in the case of Espejo and Gonzalez (1992) in the same extraction order that Cu and Zn.

Regarding the level of extractions of each element, consulting the specialized bibliography, we find big oscillations in this extraction levels, justifiable for three questions: (to) to consider or not the participation of the underground system whose importance is showed in the work of Kaufmann and Kaufmann (1967), (b) the old age of the plantation, since the extraction relationship is modified N: P: K with the time (Abadia and Heras, 1969), and (c) the cultivation practices and variety of the asparagus. To this respect, it is necessary to indicate that most of the authors consulted in bibliography don't

expensive and at the same time difficult, since these organs participate in mature plant around 60-90 % in the formation of total dry matter (Kaufmann and Kaufmann, 1967).

Therefore, dry matter content of the underground system (rhizome and roots) was measured. This way, the participation of the dry matter of the underground system in the production of total dry matter, was considered the medium levels about 47 %, continued in importance by the ferns (37.6 %), and next for the spears (14.6 %) and seed berries (0.8 %) (Table 13).

This value of participation of the underground system in the total production of dry matter of the plant, is lower to the one proposed by other authors, since our experimental plantation is younger than the one studied by them. This influence of the production of dry matter at underground level is very marked with the age of the plantation according to that indicated by Kaufmann and Kaufmann (1967) that indicate a participation value around the 60 and 90 % in totally mature plants six seven years old, and in plants youths it hardly arrives to 50 %.

The nutrient and content and the dry matter produced by all the organs of the plant was used to calculate the total uptake of nutrients by the plant (Table 12). If we compare the total levels of extraction with the ones previous described, we find some discrepancies, mainly due to the rigor in the calculations of production of dry matter. In this sense, the extractions found by Kaufmann and Kaufmann (1967) are levels bigger than the ones in the present work, except for the Mg that it is of the same order. On the other hand, if we compare the data with those obtained by Anstett (1969), the levels in the present study are higher for the N, lower for the P and very similar for K. Also, it is compared, with other authors Jacob and Verkull, Knott and Penningfeld and Cold (mentioned by San Agustin, 1988), where in principle it is not known certainly if the participation of the underground system has been included in the calculations of total extractions, we found the same extraction orders for N, K, Ca and Mg that those of the present work, although for P they are clearly inferior in our case.

The comparison of nutrient uptake given by authors that didn't measure the underground system of the plant and the ratios of nutrient uptake by N: P: K: Ca: Mg, considering with P uptake equal to 1 were made. The earlier authors found the following ratios of N: P: K: Ca: and Mg:

- Depardon and Buron (1947): 3.71 :1: 3.80: 2.13: 0.41
 - BROWN and Carolus (1965): 4.39: 1: 5.33: 1.52: 0.36
 - Lubet et al. (1975): 4.47: 1: 4: 1.23: 0.18
 - Hartmann et al. (1983): 3.38: 1: 3.69: 4.92: 0.25
- and in our case the balance presented 5.89: 1: 6.57: 3.23: 0.49.

Of these relationships it is observed generally that the extractions of P in the present work are low in relation to N, K and Ca. On the other hand, the extraction of Mg seems high in our case in relation to these authors.

Everything suggests the low level P in the soil seems to induce some low extractions of this nutrient which is extracted in low proportion by this crop (Brown et al., 1961; Hartmann, 1985).

micronutrients of the air part (spears and ferns), with the suitable ones for Brown and Carolus (1965). It is important to mention first year had the lowest uptake for almost all the micronutrients relative to the second year. This fact is due to the biggest contribution in the extractions of these micronutrients for the first year as shown in the Tables 8 and 9.

Table 13 presents the relative importance of each organ of the plant studied in the extractions of macro and micronutrients of the soil. As you can observe, it is necessary to note the importance of the consideration of the underground system in the calculations of extractions for macro and micronutrients of the soil. So, for N, K and Na it is the radicular system the organ of more importance in the extractions, showing values next to 50 %, and for the case of the P and Mg, this organ is on the second place. Fern uptake of Ca, Mg and Na, occupied first place in the extractions, with the Na, an order of very similar importance that the root system. It is also necessary to indicate that in the case of the P, the spears are the organs that have the biggest participation in the uptake of this nutrient, ending up with about 50 % of the P taken up.

In what concerns to the implication of the different organs in the total extractions of micronutrients, it seems to be in this case that the participation of the underground system in the extractions, in general, is less important for the macronutrients. In this sense, the Fe, Mn and B are the nutrients extracted in greater proportion by the ferns, and Cu and Zn for the spears. This fact doesn't seem to miss in the case of this last one, due to the implications that this micronutrients seems to have in the development of the spear (Amaro Lopez et al., 1995).

On the other hand, they were carried out regression analysis among the total productions of dry matter of the different treatments fertilizers, with the corresponding nutrients extractions. The results appear in the Table 14. The best correlations between the production of dry matter and uptake of nutrients are: N ($R = 0.9729$, $p < 0.0001$), P ($R = 0.9554$, $p < 0.001$) and K ($R = 0.9778$, $p < 0.0001$). As for the micronutrients, although we cannot contrast the results of the present work with others of the bibliography due to the absence of the same ones, it is necessary to indicate it has obtained good correlations for Cu ($R = 0.924$, $p < 0.01$) and B ($R = 0.8833$, $p < 0.01$), and something inferior for Fe ($R = 0.8123$, $p < 0.05$). Everything comes it to confirm, on one hand the biggest importance of the macronutrients N, P and K in the nutrition and dry matter production of the asparagus.

The influence of the phosphoric fertilization on the production of dry matter and the extractions of total nutrients of the plant is shown in (Table 15) The influence of p on Dry matter seems more remarkable in the second year than in the first year, because of the postponed effect of the fertilization on the asparagus plant growth. In this sense, it is necessary to say that the production of matter dry total the second year increased in a significant way ($p < 0.01$) with the phosphorus applications, highlighting the remarkable decrease in the production of dry matter in the plants receiving the zero P applications, which showed a low development of the root mass fundamentally in the second year (Table 7). This result suggest the stimulating effect of the P of the soil, about the growth

which agrees Kaufmann and Kaufmann (1967) and also confirms Adler et al. (1984) finding that P fertilization exerts its effect fundamentally in the growth of all the underground organs.

Regarding to the influence of the phosphoric fertilization on the macronutrients extractions for the green asparagus, Espejo and Gonzalez (1992) described the positive relationship of the phosphoric dose and the extractions of N, P and K. In our case, a bigger extraction of P is appreciated with the increase of the dose, being a dependence in a significant way in the two years ($p < 0.05$), which suggest the improvement of the P in fertilization.

Phosphorus fertilization does not seem to effect the uptake of the micronutrients, no effects on the uptake of Fe or Zn, and doubtful on the Cu. There seems to exist a clear effect of increase of the uptake of B with the P applications, which confirms the possible synergism between the P and B in the assimilation B, which agrees with the results obtained by Warman (1991), who found an increase of the B in the ferns from the plant when increasing the phosphoric dose in the soil.

Nutrient uptake (Table 12), allows us to develop a nutrient application program for annual application to a plantation of green asparagus, in the upward phase of production (3rd to 4th year), being also considered that it is of the variety Plaverd, and that it is in a type of similar soil to the one studied. However, it is necessary to indicate that these orientations mark the minimum values of fertilizer doses occur because almost all volatilization processes (N), of retrogradation to insoluble forms (P, K, Mg, etc.) and lixiviation. According to the previously comment, and adjusting for excesses, the data about the medium of extraction of the Table 12, this work recommends the following minimum recommendations of nutrients per year to maintain the level of fertility of the soil, without considering the possible sources of mentioned losses: 110 kg N/ha, 8.8 kg P/ha, 104 kg K/ha, 60 kg Ca/ha, 10 kg Mg/ha, 10 kg Na/ha, 6 Kg Fe/ha, 0.5 kg Mn/ha, 0.1 Kg Cu/ha, 0.2 kg Zn/ha and 0.2 kg B/ha.

In these recommendations, nevertheless it is necessary to state that the uptake in the ferns at the end of the vegetative cycle are counted, since although, the incorporation of the fern in the soil would recycle some of the nutrients, it is also necessary to state that the incorporation is used most of the cases in a partial way, also, losses like volatilization, especially in the case of the N, shows that the recycling of the nutrients it is not 100 %.

If we compare these recommendations after carrying out the experiment, with the applications made at the beginning of the experiment and using the habitual practices of the study area, it is necessary to indicate that the application of N, can be considered excessive still keeping in mind a low use in this nutrient.

As for the other nutrients applied to the soil, it is necessary to indicate that the dose of P (11 Kg.ha⁻¹), apply with normality in the area can be enough to maintain the nutritious state of the soil, however due to the calcareous characteristics of the same one as well as to the biggest extraction in P for the spears, it is possible that the utilization of this nutrient is low, and that the dose to add should be higher. In this sense, other

Lastly, as for the application of K that was of 62.3 kg.ha⁻¹, it is necessary to say that it is considered quite low in front of the 99.6 kg.ha⁻¹ extracted of this nutrient, and mainly keeping in mind the clayey characteristic of the soil, all that which indicates the necessity to increase the contributed dose of K above 99.6 Kg.ha⁻¹.

4. CONCLUSIONS

From the present study, we can suggest the following conclusions:

- the influence of the phosphoric dose in the production of dry matter of the plant, seems more remarkable in the second season than in the first, due to the released effect of the fertilization in this crop. On the other hand, of all the considered organs, it is in the radicular system where it showed a bigger formation of dry matter, around 47 % , followed by the ferns around 37.6 % , spears around 14.6 % and the seeds berries with values something lower to 0.8 %.

- considering the variety Plaverd, the age of the plantation, as well as the type of studied soil, the medium levels of annual extraction of nutrients expressed in kg.ha⁻¹, for a plantation with density of 15000 plants/ha can be evaluated in:

N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
109.4	8.16	101.2	42.61	9.17	9.20	5.68	0.358	0.106	0.139	0.148

- the analysis of simple variance made on the extraction of nutrients, reveals a positive influence of the increase of the phosphoric dose in the nutrients extraction, accented in the second year. Also, this influence seems to be more marked in the case of P and B, and it is not manifested in the case of the Fe and Zn, not showing you conclusive influences for the other elements.

- considering the levels of nutrients extractions before mentioned, where possible losses have not been evaluated by lixiviation, volatilization and immobilization, it can be considered that under the conditions of the experience, the used dose fertilizers are high in N, medium in P, and low in K.

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Table 1. Soil composition before to the experiment.

	pH (H ₂ O)	% CO ₃ ²⁻	% Sand	% Silt	% Clay	% O. M.	% C	% N	C/N	P available (mg/kg)	Specific conductivity (mS.cm ⁻¹)	Bulk density (g.cm ⁻³)
0-30 cm	7.9	24.3	26	22	52	1.65	0.96	0.06	16	3.70	0.550	1.35
30 cm	7.9	25.5	27	17	56	0.79	0.46	0.05	9	2.80	1.097	1.40

	Fe available (mg/kg)	Mn available (mg/kg)	Cu available (mg/kg)	Zn available (mg/kg)	B available (mg/kg)	Na +(*)	K ⁺ (*)	Ca ⁺⁺ (*)	Mg ⁺⁺ (*)	C.E.C. (*)	% V	P.E.S. (%)
0-30 cm	24.1	62.5	4.5	1.2	0.6	0.1	1.07	24.31	5.14	30.64	100	0.40
30 cm	21.9	72.5	7.2	1.0	0.6	0.5	0.63	25.46	4.91	31.58	100	1.80

(*) : meq/100 g soil P.E.S. : percentage of sodium exchanging

Table 2. Soil composition after the harvesting in the two years.

	0 kg P/ha				11 kg P/ha				22 kg P/ha			
	1 st year		2 nd year		1 st year		2 nd year		1 st year		2 nd year	
	0-30cm	30 cm	0-30cm	30 cm	0-30cm	30cm	0-30 cm	30 cm	0-30 cm	30 cm	0-30cm	30 cm
pH (H ₂ O)	7.6	8.1	7.4	7.7	7.8	8.1	7.4	7.7	7.6	8.0	7.4	7.7
% M.O.	1.57	0.28	0.86	--	1.14	0.53	0.66	--	1.40	0.62	0.88	--
% C	0.56	0.16	0.50	--	0.54	0.31	0.38	--	0.81	0.36	0.51	--
% N	0.05	0.01	0.07	0.03	0.07	0.07	0.07	0.04	0.12	0.07	0.09	0.04
C/N	11	16	7	--	8	5	5	--	7	5	6	--
P available (mg/kg)	5.30	2.44	5.30	2.44	10.13	3.07	10.77	8.93	10.70	9.70	17.70	2.70
Na ⁺ (meq/100 g suelo)	0.66	1.01	0.19	0.90	0.31	0.99	0.10	0.81	0.27	1.01	0.10	0.69
K ⁺ (meq/100 g suelo)	1.77	0.44	1.70	0.59	1.77	0.68	1.56	0.57	1.84	0.49	1.59	0.52
Ca ⁺⁺ (meq/100 g suelo)	28.08	47.51	30.38	32.64	27.19	26.55	26.56	28.04	25.53	26.49	25.86	31.55
Mg ⁺⁺ (meq/100g suelo)	4.58	4.95	4.77	4.61	4.86	5.51	4.00	4.88	4.86	5.22	4.77	4.27
Fe available (mg/kg)	20.1	24.1	--	--	22.8	23.8	--	--	21.3	22.9	--	--
Mn available (mg/kg)	55.4	49.1	--	--	52.9	45.8	--	--	52	42.8	--	--
Cu available (mg/kg)	5.4	5.3	--	--	6.3	6.1	--	--	5.2	5.1	--	--
Zn available (mg/kg)	0.6	0.6	--	--	0.9	0.8	--	--	1.3	1.2	--	--
B available (mg/kg)	0.4	0.4	--	--	0.6	0.5	--	--	0.8	0.3	--	--

Table 3. Average mineral composition of the spears (d. m.) in the two years and results of the multifactor analysis of variance.

	0 kg P/ha		11 kg P/ha		22 kg P/ha		F-ratio fertilizer dose		F-ratio date	
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year
% N	3.61	3.07	3.76	3.14	3.77	3.04	0.800 ^{NS}	0.24 ^{NS}	3.03* (+)	2.79 ^{NS}
% P	0.33	0.43	0.35	0.44	0.36	0.46	1.373 ^{NS}	0.44 ^{NS}	60.12**** (+)	3.37* (+)
% K	2.47	3.42	2.45	4.14	2.41	3.96	0.295 ^{NS}	2.59 ^{NS}	5.14** (+)	2.19 ^{NS}
% Ca	0.16	0.22	0.20	0.23	0.16	0.25	3.238 ^{NS}	1.67 ^{NS}	24.99**** (+)	12.87** (+)
% Mg	0.10	0.13	0.10	0.12	0.10	0.11	1.714 ^{NS}	3.73 ^{NS}	5.54** (+)	1.08 ^{NS}
% Na	0.04	0.08	0.05	0.08	0.05	0.05	0.759 ^{NS}	2.33 ^{NS}	19.51**** (-)	5.49* (-)
Fe (mg/kg)	189	148	177	184	166	151	1.320 ^{NS}	0.34 ^{NS}	20.75**** (+)	22.27**** (+)
Mn (mg/kg)	47.8	27.9	50.8	33.3	46.4	28.9	1.727 ^{NS}	0.33 ^{NS}	20.14**** (+)	2.335 ^{NS}
Cu (mg/kg)	51.8	31.2	49.8	35.4	43.5	34.6	2.828 ^{NS}	0.15 ^{NS}	29.54**** (-)	1.39 ^{NS}
Zn (mg/kg)	70.5	33.2	74.5	34.0	71.5	34.5	1.893 ^{NS}	4.71* (+)	23.94**** (-)	4.134* (-)
B (mg/kg)	20.0	20.0	21.1	18.4	19.9	21.1	1.614 ^{NS}	0.800 ^{NS}	8.77**** (+)	1.92 ^{NS}

(-) The parameter decreases as the factor increases

(+) The parameter increases as the factor increases

^{NS} No significance *p<0.05 **p<0.01 ***p<0.001 ****p<0.0001

Table 4. Average mineral composition of asparagus cladodes and shoots (d. m.) in both years.

FIRST YEAR										
	0 kg P/ha		11 kg P/ha		22 kg P/ha		F-ratio fertilizer dose		F-ratio date	
	Cladodes	Shoots	Cladodes	Shoots	Cladodes	Shoots	Cladodes	Shoots	Cladodes	Shoots
% N	2.81	1.49	2.63	1.48	2.83	1.35	0.424 ^N	0.335 ^{NS}	12.979 ^{**} (+)	4.982 [*] (-)
% P	0.24	0.20	0.24	0.22	0.23	0.21	1.358 ^N	2.042 ^{NS}	102.246 ^{****}	166.187 ^{****} (
% K	1.32	1.37	1.08	1.24	1.19	1.41	0.965 ^N	0.448 ^{NS}	7.886 ^{**} (-)	2.691 ^{NS}
% Ca	0.92	0.46	1.08	0.67	1.18	0.75	0.380 ^N	5.598 [*] (+)	0.749 ^{NS}	13.526 ^{**} (+)
% Mg	0.16	0.08	0.18	0.14	0.17	0.12	0.486 ^N	9.872 ^{**} (+)	2.597 ^{NS}	1.450 ^{NS}
% Na	0.06	0.06	0.05	0.05	0.02	0.02	12.708 [*]	14.021 ^{**} (-)	1.090 ^{NS}	1.191 ^{NS}
Fe (mg/kg)	399	209	383	226	387	164	0.067 ^N	2.373 ^{NS}	6.782 [*] (-)	4.046 [*] (+)
Mn (mg/kg)	118	77.4	132	67.5	115	81.2	2.499 ^N	0.243 ^{NS}	5.577 [*] (-)	6.072 [*] (+)
Cu (mg/kg)	26.4	23.6	33.9	23.6	26.0	20.1	2.828 ^N	0.042 ^{NS}	1.038 ^{NS}	0.652 ^{NS}
Zn (mg/kg)	51.8	36.6	50.4	29.2	49.1	31.2	0.771 ^N	1.293 ^{NS}	21.487 ^{***} (2.564 ^{NS}
B (mg/kg)	74.9	41.4	61.5	42.1	77.2	49.5	11.858 [*]	4.114 ^{NS}	3.646 ^{NS}	1.100 ^{NS}
SECOND YEAR										
	0 kg P/ha		11 kg P/ha		22 kg P/ha		F-ratio fertilizer dose		F-ratio date	
	Cladodes	Shoots	Cladodes	Shoots	Cladodes	Shoots	Cladodes	Shoots	Cladodes	Shoots
% N	2.66	1.36	2.69	1.75	2.69	1.35	0.877 ^N	1.85 ^{NS}	21.84 ^{**} (-) ^c	4.65 ^{NS}
% P	0.18	0.14	0.17	0.12	0.15	0.12	0.517 ^N	0.33 ^{NS}	9.87 ^{**} (-)	14.95 ^{**} (-)
% K	1.67	1.73	1.66	1.73	1.78	1.86	1.378 ^N	1.17 ^{NS}	119.15 ^{****} (81.41 ^{****} (-
% Ca	1.39	0.87	1.40	0.86	1.37	0.86	0.192 ^N	0.002 ^S	22.41 ^{**} (+)	14.50 ^{**} (+)
% Mg	0.27	0.20	0.30	0.23	0.29	0.21	1.929 ^N	1.47 ^{NS}	31.53 ^{***} (+)	2.32 ^{NS}
% Na	0.29	0.28	0.15	0.14	0.14	0.12	7.787 [*]	8.31 [*] (-)	9.12 [*] (+)	5.57 [*] (+)
Fe (mg/kg)	195	75.1	190	69.1	172	66.0	0.634 ^N	0.57 ^{NS}	6.86 [*] (+)	6.29 [*] (-)
Mn (mg/kg)	92.0	28.9	91.4	30.8	87.2	26.4	3.202 ^N	1.04 ^{NS}	106.76 ^{****} (11.37 ^{**} (-)
Cu (mg/kg)	17.0	15.3	16.0	14.3	14.7	14.6	1.056 ^N	0.15 ^{NS}	14.11 ^{**} (-)	16.91 ^{**} (-)
Zn (mg/kg)	19.2	21.6	20.4	18.8	18.6	19.3	0.939 ^N	3.36 ^{NS}	25.27 ^{***} (-)	7.66 [*] (-)
B (mg/kg)	55.1	38.2	52.2	37.1	55.6	45.4	0.671 ^N	2.21 ^{NS}	3.72 ^{NS}	0.57 ^{NS}

(-) The parameter decreases as the factor increases

(+) The parameter increases as the factor increases

^{NS} No significance * p < 0.05 ** p < 0.01 *** p < 0.001 **** p < 0.0001

Table 5. Average mineral composition of asparagus cladodes and shoots (d. m.) in both years.

	0 kg P/ha		11 kg P/ha		22 kg P/ha		F-ratio fertilizer dose	
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year
% N	1.70	1.68	1.74	1.72	1.80	1.72	7.46(+)	0.63 ^{NS}
% P	0.21	0.20	0.28	0.22	0.29	0.19	17.16**(+)	13.76*
% K	1.64	2.01	1.56	1.74	1.56	1.88	27.42**(-)	368.30****(-)
% Ca	0.02	0.11	0.02	0.12	0.02	0.12	1.00 ^{NS}	4.00 ^{NS}
% Mg	0.11	0.20	0.11	0.10	0.10	0.11	2.27 ^{NS}	3.52 ^{NS}
% Na	0.02	0.02	0.02	0.02	0.02	0.02	1.00 ^{NS}	2.84 ^{NS}
Fe (mg/kg)	163.4	33.3	173.6	38.1	99.4	39.0	2.39 ^{NS}	4.51 ^{NS}
Mn (mg/kg)	21.8	12.8	20.5	13.5	19.5	13.5	0.73 ^{NS}	35.61***(+)
Cu (mg/kg)	9.7	10.9	12.3	11.5	11.5	10.4	26.78**(+)	4.33 ^{NS}
Zn (mg/kg)	11.8	11.0	13.0	12.4	16.2	12.8	7.04*(+)	7.66*(+)
B (mg/kg)	10.9	11.1	11.6	10.5	11.2	12.6	3.56 ^S	3.18 ^{NS}

(-) The parameter decreases as the factor increases

(+) The parameter increases as the factor increases

^{NS} No significance * p < 0.05 ** p < 0.01 *** p < 0.001 **** p < 0.0001

Table 6. Average mineral composition of asparagus rhizomes and roots in both years and results of the multifactor analysis of variance.

	0 kg P/ha				11 kg P/ha				22 kg P/ha				F-ratio fertilizer dose			
	Roots		Rhizomes		Roots		Rhizomes		Root		Rhizomes		Roots		Rhizomes	
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year
% N	1.72	1.50	2.01	1.80	1.37	1.43	1.87	1.57	1.26	1.51	1.96	1.95	11** (-)	0.35 ^{NS}	15.7** (-)	21.2** (+)
% P	0.09	0.07	0.14	0.08	0.08	0.07	0.15	0.10	0.07	0.07	0.16	0.07	9* (-)	1.33 ^{NS}	1.03 ^{NS}	4.94 ^{NS}
% K	1.65	1.37	1.17	1.24	1.21	1.30	1.28	1.14	1.10	1.32	1.22	1.28	30.8** (-)	0.35 ^{NS}	3.00 ^{NS}	1.11 ^{NS}
% Ca	0.16	0.32	0.31	0.82	0.14	0.47	0.39	1.07	0.01	0.42	0.34	0.90	3.89 ^{NS}	1.21 ^{NS}	6.33* (+)	7.22* (+)
% Mg	0.12	0.10	0.12	0.14	0.08	0.11	0.13	0.16	0.09	0.10	0.13	0.17	7.92* (-)	1.67 ^{NS}	3.52 ^{NS}	4.06 ^{NS}
% Na	0.11	0.14	0.17	0.21	0.09	0.15	0.17	0.19	0.08	0.14	0.14	0.20	7* (-)	0.17 ^{NS}	0.96 ^{NS}	0.44 ^{NS}
Fe (mg/kg)	470	493	1080	1140	680	937	1537	2071	494	582	1190	1193	1.43 ^{NS}	4.44 ^{NS}	0.61 ^{NS}	8.58* (+)
Mn (mg/kg)	36.6	9.0	55.9	19.7	37.1	10.6	71.3	18.3	31.1	9.1	55.5	19.6	2.1 ^{NS}	4.1 ^{NS}	0.82 ^{NS}	18.6** (+)
Cu (mg/kg)	9.2	24.8	16.7	53.7	8.3	39.1	17.5	79.5	6.1	29.6	15.3	58.6	26.37* * (-)	3.1 ^{NS}	5.86* (-)	1.06 ^{NS}
Zn (mg/kg)	10.5	6.1	22.0	39.6	8.2	6.4	23.5	25.5	8.0	6.1	23.8	35.4	39.7** * (-)	0.18 ^{NS}	15.2** (+)	3.1 ^{NS}
B (mg/kg)	7.9	7.3	12.1	11.3	7.9	6.2	11.8	11.0	8.3	8.5	11.3	11.6	3.7 ^{NS}	9.2* (+)	0.73 ^{NS}	0.06 ^{NS}

(-) The parameter decreases as the factor increases

(+) The parameter increases as the factor increases

^{NS} No significance *p<0.05 **p<0.01 ***p<0.001 ****p<0.0001

Table 7. Formation of dry matter, in kg.ha⁻¹. (Calculations referred to 15000 plants/ha).

	Spears		Ferns		Seed berries		Radicular		Total		Total mean
	1 st year	2 nd year	1 st year	2 nd year	* 1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	
0 kg P/ha	1023	833	2670	2430	80.6	--	2977	1515	6751	4778	5764
11 kg P/ha	980	1111	2550	2640	67.7	--	2798	4965	6396	8716	7556
22 kg P/ha	1029	900	2850	2940	78.5	--	3562	5790	7519	9630	8574
Mean	1011	948	2690	2670	75.6	--	3112	4090	6889	7708	7299

* It has been considered for the calculations, 50% of female plants for all the sites.

The crop of seed berries of 1991 has not been possible to evaluate due to an autumn storm that made that great part of the crop fell to the soil.

Table 8. Nutrients extraction, in kg.ha⁻¹, for spears. (Data referred to 15000 plants/ha).

	0 Kg P/ha		11 Kg P/ha		22 Kg P/ha		Mean		Total mean
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	
N	35.4	25.6	37.4	34.9	38	27.4	36.9	29.3	33.1
P	3.41	3.95	3.36	4.93	3.74	4.18	3.50	4.35	3.93
K	24.98	28.47	23.90	45.98	25.23	34.61	24.71	36.35	30.53
Ca	1.73	1.82	2.04	2.53	1.63	2.14	1.80	2.17	1.98
Mg	1.02	1.08	0.98	1.33	1.03	0.99	1.01	1.13	1.07
Na	0.41	0.67	0.49	0.89	0.51	0.45	0.47	0.67	0.57
Fe	0.19	0.12	0.18	0.20	0.18	0.14	0.18	0.15	0.17
Mn	0.051	0.023	0.05	0.037	0.048	0.026	0.05	0.029	0.039
Cu	0.055	0.043	0.051	0.039	0.044	0.031	0.05	0.038	0.044
Zn	0.068	0.028	0.071	0.038	0.073	0.031	0.071	0.032	0.052
B	0.02	0.017	0.021	0.02	0.021	0.019	0.021	0.019	0.02

Table 9. Nutrients extraction, in kg.ha⁻¹, for the ferns. (Data referred to 15000 plants/ha).

	0 Kg P/ha		11 Kg P/ha		22 Kg P/ha		Mean		Total mean
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	
N	22.2	17.2	23.2	19.0	27.1	15.9	24.17	17.37	20.77
P	0.81	1.23	1.28	1.33	1.72	1.19	1.27	1.25	1.26
K	22.41	19.67	34.69	10.79	29.38	22.08	28.83	17.51	23.17
Ca	20.95	26.27	21.3	35.36	18.11	43.81	20.11	35.15	27.63
Mg	4.00	3.64	4.08	5.02	3.70	5.59	3.93	4.75	4.34
Na	3.20	3.40	3.06	5.81	1.71	6.17	2.66	5.13	3.89
Fe	3.70	1.47	4.21	1.67	3.79	1.98	3.90	1.71	2.81
Mn	0.26	0.10	0.25	0.11	0.24	0.12	0.25	0.11	0.18
Cu	0.024	0.023	0.022	0.024	0.025	0.029	0.024	0.025	0.025
Zn	0.045	0.111	0.032	0.030	0.039	0.032	0.039	0.058	0.049
B	0.088	0.092	0.084	0.096	0.118	0.11	0.097	0.099	0.098

Table 10. Nutrients extraction, in kg.ha⁻¹, for the seed berries. (Data referred to 15000 plants/ha and 50% of female plants).

	0 Kg P/ha	11 Kg P/ha	22 Kg P/ha	Mean
N	1.37	1.18	1.41	1.32
P	0.17	0.19	0.23	0.20
K	1.32	1.05	1.22	1.20
Ca	0.016	0.013	0.016	0.015
Mg	0.089	0.074	0.078	0.080
Na	0.016	0.013	0.016	0.015
Fe	0.0132	0.0117	0.0078	0.0109
Mn	0.0018	0.0014	0.0015	0.0016
Cu	0.0008	0.0008	0.0009	0.0008
Zn	0.0009	0.0009	0.0013	0.0010
B	0.0009	0.0008	0.0009	0.0009

Table 11. Nutrients extraction, in kg.ha⁻¹, for the radicular system. (Data referred to 15000 plants/ha).

	0 Kg P/ha		11 Kg P/ha		22 Kg P/ha		Mean		Total mean
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	
N	52.4	24.4	40.6	71.5	47.9	92.2	46.97	62.7	54.84
P	2.92	1.13	2.58	3.62	2.91	4.09	2.80	2.95	2.88
K	47.1	20.0	34.2	64.0	21.0	76.0	40.31	53.34	46.83
Ca	5.37	7.65	5.02	25.32	5.18	29.36	5.19	20.77	12.98
Mg	3.57	1.74	2.46	5.64	3.38	6.55	3.14	4.64	3.89
Na	3.53	2.52	2.88	7.59	3.10	8.76	3.17	6.29	4.73
Fe	1.66	1.12	2.29	5.06	2.06	4.04	2.00	3.41	2.71
Mn	0.1172	0.054	0.1194	0.2086	0.1213	0.2032	0.1193	0.1553	0.1373
Cu	0.0306	0.0197	0.0273	0.0554	0.0257	0.0642	0.0279	0.0464	0.0372
Zn	0.0362	0.0284	0.0299	0.0387	0.0353	0.0674	0.0338	0.0448	0.0393
B	0.0253	0.0133	0.0239	0.0325	0.0309	0.0526	0.0267	0.0328	0.0298

Table 12. Total nutrients extraction, in kg.ha⁻¹. (Data referred to 15000 plants/ha).

	0 Kg P/ha		11 Kg P/ha		22 Kg P/ha		Mean		Total mean
	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	1 st year	2 nd year	
N	111.4	67.2	102.4	125.4	114.4	135.5	109.4	109.4	109.4
P	7.30	6.31	7.41	9.83	8.6	9.46	7.77	8.54	8.16
K	95.78	68.14	93.79	120.8	95.53	132.7	95.04	107.2	101.8
Ca	28.05	35.78	28.33	63.26	24.92	75.33	27.10	58.13	42.6
Mg	8.68	6.46	7.59	11.99	7.16	13.13	7.81	10.53	9.17
Na	7.16	6.59	6.44	14.29	5.34	15.38	6.31	12.09	9.20
Fe	5.57	2.71	6.69	6.93	6.03	6.15	6.10	5.26	5.68
Mn	0.431	0.180	0.421	0.360	0.409	0.345	0.42	0.295	0.358
Cu	0.110	0.086	0.101	0.118	0.096	0.124	0.102	0.109	0.106
Zn	0.150	0.167	0.134	0.107	0.149	0.130	0.144	0.135	0.139
B	0.134	0.122	0.130	0.148	0.171	0.182	0.145	0.151	0.148

Table 13. Dry matter and percentage of the different organs of the plant in the total extraction of macro and micronutrients.

Nutrient	organ of the plant			
	% element extracted in spears	% element extracted in ferns	% element extracted in seed berries	% element extracted in the radicular system
Dry matter	14.60	37.60	0.80	47.00
N	30.08	18.87	1.20	49.85
P	47.52	15.27	2.40	34.81
K	30.01	22.78	1.17	46.04
Ca	4.65	64.85	0.03	30.47
Mg	11.41	46.27	0.85	41.47
Na	6.20	42.26	0.16	51.38
Fe	2.98	49.29	0.19	47.54
Mn	10.85	50.47	0.45	38.23
Cu	41.13	23.36	0.74	34.77
Zn	36.80	34.68	0.71	27.81
B	13.45	65.90	0.61	20.04

Table 14. Correlation degree and regression equation between the production of total dry matter and the nutrients.

Nutrient	Regression coefficient R	Significance p	Regression equation
N	0.9729	<0.0001	$Y=13.337X+11.815$
P	0.9554	<0.001	$Y=1.641X+6.584$
K	0.9778	<0.0001	$Y=14.207X+19.649$
Ca	0.6005	>0.05	$Y=8.773X-1.445$

Table 15. A nalysis of simple variance of the influence of the phosphoric fertilization in the production of dry matter and in the extractions of total nutrients

FIRST YEAR												
	total dry matter	N	P	K	Ca	Mg	Na	Fe	Mn	Cu	Zn	B
Variance	2.768	1.153	6.521	3.264	5.981	11.25	22.00	3.572	19.43	21.43	2.731	6.548
reason						3	1		3	2		
Significance level	N.S.	N.S.	* (+)	N.S.	* (-)	** (-)	** (-)	N.S.	** (-)	** (-)	N.S.	* (+)
SECOND YEAR												
Variance	18.43	17.93	8.942	16.95	60.93	19.43	17.81	3.243	9.810	16.98	1.543	61.47
reason	2	4		4	2	2	2			7		3
Significance level	** (+)	** (+)	* (+)	** (+)	*** (+)	** (+)	** (+)	N.S.	* (+)	** (+)	N.S.	*** (+)

N.S.= No significance * p< 0.05 ** p<0.01 *** p<0.001 ***** p<0.0001

(+) (-) Increase or decrease of dry matter and nutrients extraction with phosphoric doses.