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Bibliographic Review

Dynamics of nutrients in the soil in areas intended for the production of forage maize (*Zea mays* L.)

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Abstract

Maize, when grown for fodder production requires special care with respect to the management of the soil. With the total harvest of aerial part, large quantities of nutrients are removed, and it can cause an imbalance of nutrients and rapid impoverishment of the soil and, as a consequence, the drop in productivity and low quality of silage in subsequent crops. The objective of this study was to elucidate the dynamics of extraction and export of nutrients from the soil by cultivation of maize for silage production. The absorption of nutrients by the culture is strongly influenced by factors such as climate, genotype, cropping systems and the level of productivity. In addition to increase on the quantities of nutrients in soil fertility of the maize for feed, it is essential to practice crop rotation and do not use the same area for consecutive years for the production of silage, due to the non-maintenance of coverage and susceptibility of the land to the occurrence of erosion. The cultivation of maize when grown for silage exports of the area of cultivation mean values of 21 kg N, 76 kg of K, 20 kg of Ca and 3.5 kg of Mg to more per hectare than when grown for the production of grain. The cultivation of maize for the production of forage promotes greater export of nutrients from the soil, when compared with the grain harvest.

Key Words: uptake and accumulation of nutrients, extraction and export of nutrients, production of dry matter, corn silage

Introduction

The greater professionalization of the animal husbandry observed currently in the Brazilian production systems, either beef or dairy cattle, has instigated the maintenance of the food intake of animals along the year through techniques of forage. It is known that the cattle breeders who base the animal feed in pasture have risks due to the climate and pasture seasonality (NEUMANN, 2011).

When maize is cultivated with aims at producing silage, we must perform the management of fertilization of later conduction of the area only as grains, since besides grains, the vegetative part is cut and removed from field before that the crop completes its cycle, making that the most part of the nutrients that were extracted from soil during the life cycle of the crop are exported of the area of cultivation, and may cause unbalance of nutrients and quick impoverishment of the soil, having as consequence the drop of productivity and low quality of silage in later cultivation (COELHO, 2006).

Almost two decades ago, NUSSIO (1993) reported that only a small fraction of the producers used the practice of ensilage of maize in a satisfactory way, and most of the cultivations were in an almost extractivist way, with use of fertilizers and correctives in amounts bellow the recommended, or even still with only the natural fertility of soil. He still emphasized the need of establishing a philosophy of cultivation which focuses on the high productivity based on the reposition of nutrients to the soil, being necessary to establish concepts relative to the fertilization of these plants for the ensilage different from those developed for the grain production, in which there is the recycling of nutrients in the system.

In the current context, a few changes happened in the mentality and attitude of the producers and techniques involved in the activity. The nutritional management of the livestock have been evaluating, however a little importance has been given to the sustainability and maintenance of the soil fertility. Although the commission of chemistry and soil fertility (CQFS RS/SC, 2004) recommends specific

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fertilization for maize and sorghum destined to the production of silage, in which the amounts of fertilizer are superior in relation to the grain harvest, a few producers adopt these recommendations.

However, the attitude of only elevating the levels of fertilizer during planting is questionable when one intends to maintain the sustainability of the system, because the charge added to nutrients available to the crops may generate as reflex the induction of higher productive response to them, and with this the exceeding of nutrients provided would be extracted and exported from soil in the same way.

The objective of this work is to make clear aspects of the dynamics of extraction and exportation of soil nutrients by the maize crop to the production of silage.

Characterization and Discussions

The problem with the production of silage with high quality

According to VELHO et al. (2007), maize when cultivated for green forage and/or silage of the aerial part has potential to provide from 50 to 100% more of energy per hectare than any other forage. Besides that, the harvest of one area of maize for silage enables the obtaining of 40 to 50% more of total energy than when it is compared to a cultivation which aims at the grain harvest (FRANÇA and COELHO, 2001). It is a very efficient crop in the conversion of photosynthetic energy to the production of biomass.

For a better comprehension of this attainment of energy, it is important to consider the concepts of the primordial law of conservation of matter proposed by Lavoisier, which says: "In Nature, nothing is created, nothing is destroyed, everything is transformed". Obviously the generation of this extra energy did not appear in a spontaneous way, it comes from photo-assimilated compounds composed mainly by elements which come from the atmosphere (C, H and O), however there are also in its composition nutrients which come from soil (N, P, K, S, Ca and Mg) (RITCHIE et al., 2003).

As it is explained by VASCONCELLOS et al. (2002), maize for being a C_4 plant is very efficient in the use of radiation, absorption of H_2O and assimilation of CO_2 and approximately 90% of the dry matter (DM) of the plant comes from the fixing of atmospheric elements by the process of photosynthesis, and the rest of the phytomass composed by nutrients extracted from soil. Even though the soil nutrients represent approximately 10% of the dry matter produced, they are essential for the crop development, each one with its function and percentage of participation in the phytomass (RITCHIE et al., 2003).

Even though the maize crop aiming at the harvest only of grains demands high amount of soil nutrients, still, it will receive back part of the nutrients by the decomposition of the straw resultant of the harvest. However, it does not happen when the objective is to harvest maize for forage, and, due to that, problems with soil fertility will manifest earlier in the production of silage than in the production of grains, mainly if it is obtained for several consecutive years and without the proper soil management and appropriated fertilization (MARTIN et al., 2011).

In this context, it is necessary that one aims to perform the restitution of the elements extracted by the crops so that the soil fertility is maintained. This concept does not represent news, since it began with the law of the restitution instituted by VOISIN (1973), in which: "The nutrients exported by the crops or lost by erosion, volatilization, leaching and fixation must be replaced in the soil, aiming at the maintenance of the balance and productive potential of the soil".

SILVA et al. (2010), monitored the soil fertility for six consecutive years of an area destined to the successive cultivation of winter forage (black oat and ryegrass) and summer forage (maize and sorghum) for the confection of silage, and found low levels of electric conductivity in the layer from 0 to 80 cm of depth of soil in the end of the six years of study, even with the supply of 100% of the mineral fertilization recommended for each crop. Since the electric conductivity is an evaluation method which may be related to the content of ions in the soil solution, the achievement of inferior values suggests the occurrence of low contents of compounds of soluble mineral elements in solution. The authors concluded that the low electric conductivity along the profile is referent to the depletion of nutrients of the soil due to the removal of the entire plant, since the factor which influenced the most was the low content of K available, which is an indicative of the high exportation of this nutrient by the forage.

The determination of the nutritional needs of plants occurs by the quantification of the nutrients which they extract during their cycle. Therefore, the total extraction is dependent on the yield of phytomass obtained by the crop and of the concentration of nutrients in the grains and in the straw. And still, due to the fact that crops with higher yield extract and export larger amount of nutrients and, therefore, they need different doses of fertilizers, in the official recommendations of fertilization for the maize crop in Brazil, the doses of the nutrients are segmented according to the expected yield (FRANÇA and COELHO, 2001).

According to COELHO (2006), data of experiments conducted with moderated to high doses of fertilizers available for the development of the maize crop for grains and/or silage demonstrated that the extraction of nutrients by the cultivated plants was higher in the level of high fertilization since it increases linearly the response of the crop in producing phytomass, and, with this, improves the extraction of N, P, K, Ca and Mg.

These concepts enable to deduce earlier that the maintenance of the areas of forage conducted only by increase in the recommendation of fertilizers for the crops is incorrect in this way of thinking. This can be said because the higher the charge of nutrients that is provided to a certain culture, the higher will be its production and consequent extraction and exportation of nutrients of the soil. Besides that, the successive cultivation of forage interferes negatively in the production of straw for the soil cover and, as a consequence, in the accumulation of organic matter, fact commonly observed in the areas which surround the installations of animal food and/or storage silos for the production of silage.

The soil capacity to supply nutrients ranges with the soil type and with the history in the area, therefore, in order to establish a program of fertilization which ensure high productivity, profitability and environmental preservation, it is necessary to make periodically the evaluation of the soil fertility, trough the chemical and physical analysis. Since a large amount of nutrients is exported in the maize harvest for the silage, mainly N and K, the monitoring of the area, through chemical analysis, should be done annually, because the content of K in soil is reduced drastically with a few years of cultivation, especially in sandy soils. Thus, either in the production of grains or in the silage, it will be necessary to make available to the plant the total amount of nutrients that it extracts, and that should be also provided by soil, and not only through fertilization. (FRANÇA and COELHO, 2001).

In order to do so, it is necessary that different manages are practiced for the strengthening and maintenance of the fertility of the plot destined to the production of forages. COELHO (2006) emphasizes that among several technologies which could be used it is noteworthy the awareness by the producers of the need to improve the soil quality, aiming at a sustained production. This improvement in the soil quality is directly related to the appropriate management, which includes among other practices the base concepts of agricultural production, as the crop rotation, no-tillage system, management of fertility through liming, gypsum and fertilization balanced with macro and micronutrients, using chemical and/or organic fertilizers (manure, compounds, green fertilization, etc).

MARTIN et al. (2011) still add that besides increasing the amount of nutrients in the base fertilization of maize for forage, it is essential to make crop rotation and not to use the same area for consequent years for the production of silage, due to the non maintenance of cover and susceptibility of the land to the occurrence of erosion. However, it is important to remember that a great part of the cattle breeders do not make available agricultural areas to implant a rotary system of production of forage, resulting in successive cultivation of crops for the production of forage in same plot. Another factor that cannot be forgotten is that the further the harvest in from the silo of storage and of the installation of food, the higher will be the system cost of production caused by the enlargement of the costs with the transportation of the volume food, which may in some cases make the production unviable.

In these cases in which there is no malleability in the use of the soil, which becomes a constant source of nutrients for the animal food, there must obligatorily be techniques to maintain the sustainability of the system.

Dynamics of the absorption and accumulation of nutrients from maize culture

According to FRANÇA and COELHO (2001), the nutritional need of one culture are determined by the amount of nutrients that the plants are capable to extract from soil, so the recommendations of fertilization for maize are performed according to curves of response of yield under doses of providence of nutrients. However, the total amount and the nutrient absorption rate are influenced by factors as climate, genotype and cultivation system. In general, nutrients are absorbed during all the cycle and the differences verified in the velocity of absorption are due to the genotype cycle and stage in which it is found, and in the leaf and stem translocation for the reproductive organs.

The availability of nutrients in soil is one of the main causes of the variation in the concentration of nutrients and capacity of absorption by plants, followed by climate changes during the period of culture development and technological level. Also, the variations found in the nutritional stage of plants may be associated to the great genetic diversity present in the genotypes traded currently (FERREIRA, 2009).

FERREIRA (2009), in two years of evaluation, verified that the concentration of nutrients of maize cultivar range according to the technological level, observing that simple hybrids, in the first crop, and simple and triple hybrids, in the second crop, had lower concentration of N. The increase in the technological level of the genotypes caused the reduction in the concentration of N, P and K in leaves and stem. In relation to the cultivation year, it was evidenced that the concentration of nutrients, mainly N, P and K, increased in the second crop in which the availability of water was favorable to the absorption of ions, and consequently there was a higher exportation of nutrients for the grains comparing to the first crop, in which there was a period of draught.

The absorptions of N, P, K, Ca and Mg increased linearly with the increase of the productivity of the maize crop. In a general way, in the entire plant (grains and straws), N is the nutrient absorbed in higher quantity, followed in decreasing order by K, P, Ca, Mg (VASCONCELLOS et al., 1983; FRANÇA and COELHO, 2001; PAULETTI, 2004; VON PINHO et al., 2009) and by S (VON PINHO et al., 2009).

In another way, FERREIRA (2009) in experiment evaluating different genotypes for two consecutive crops, found concentration of macronutrients extracted in the following order: N > K > Mg > Ca > P for most of the hybrids evaluated in the first year of evaluation; ; K > N > Ca = Mg > P for all the improved and regional varieties, also in the second year of evaluation. The author emphasizes that the morphophysiological changes of maize modern hybrids are responsible for the alterations in the dynamics of absorption of N and low extraction of P in the first year of cultivation may be related to the low availability of water occurred, and the water is one predominant factor for the contact of this nutrient with roots.

In relation to the accumulation of micronutrients in the maize culture, FRANÇA and COELHO (2001) infer that the extraction follows the decreasing order: Fe > Zn = Mn > B > Cu > Mo. PAULETTI (2004), when determining means obtained by several authors found values expressed in grams per megagram of DM produced of 233.3; 44.4; 37.8; 18.9; 12.2; 1.0 for Fe, Zn, Mn, B, Cu and Mo, respectively. COELHO (2006) reports that for a production of de 9 Mg ha^{-1} of grains it is extracted 2100 g of Fe, 400 g of Zn, 340 g of Mn, 170 g of B, 110 g of Cu and 9 g of Mo.

According to VON PINHO (2009), the growth of the maize plant is linear function of time, and the accumulation of DM follows a lightly sigmoid curve, being linear in most part of the vegetative period and becoming decreasing in the final period, when it begins a light reduction in plant weight, possibly due to the drop of senescent leaves and leaching of K from leaves and stems. Still, in general, the absorption and accumulation of most part of the nutrients extracted from soil follow quantitatively the same dynamics of plant development, therefore, the knowledge of quantities and periods with highest nutrient absorption are fundamental to promote the supply of nutrients in appropriated quantities and moments, aiming to increase the efficiency and use of the crop inputs and yield.

In Table 1 it is presented the mean values obtained from several works for the production of grains, total DM production in the stage of maturation, accumulation of the macronutrients in kg ha^{-1}, and next, the concentration of macronutrients in DM for the works which enabled the calculation, the amount of nutrients extracted per megagram of accumulated DM and in the end it is opposed the results of PAULETTI (2004) obtained from several works.

According to data presented in Table 1, it is possible to observe that there is a great difference in the extraction of macronutrients among the cultivars tested by the authors in several regions, however, in general the amount of nutrients extracted are higher with the increase of grain yield and DM. The results obtained from seven works, in the total of twenty cultivars, present mean yield of 7.59 and 17.87 Mg ha^{-1} of grains and accumulated DM respectively, the extraction of nutrients in kg ha^{-1} followed the decreasing order of 184.18 (N); 163.88 (K); 34.10 (Ca); 33.66 (P); 30.57 (Mg); and 26.96 (S). The mean concentration of nutrients in the DM, for the works which have the production data of DM, were 1.08% for N; 0.87% of K; 0.19% of P; 0.18% for Ca and Mg; and 0,11% of S. It can also be observed that the general values of nutrient extraction per megagram of DM produced were inferior to those found by PAULETTI (2004).

RITCHIE et al. (2003) describe that in relation to the total N absorbed by plants, in the phase of physiological maturity, approximately 65% are found in grains, 20% in leaves, 6% in stem, 3% in corncob, stalk and hair, 3% in the leaf sheaths and 3% in straws and lower ear insertion.

Concerning P, approximately 75% is concentrated in grains, 10% in leaves, 7% in stem, 3% in corncob, stalk and hair, 3% in the leaf sheaths and 2% in straws and lower ear insertion. K, different from the other elements, had the highest concentration in the vegetative structure of the plant, in which approximately 35% are concentrated in grains, 5% in leaves, 30% in stem, 10% in corncob, stalk and hair, 10% in the leaf sheaths and 10% in straws and lower ear insertion in plant.

DUARTE et al. (2003) studied the concentration of nutrients in stem, leaves and ears of five maize cultivars, and concluded that with the ear development there was reduction of the proportion of nutrients accumulated in leaves and stems, expressed as percentage of the total accumulated in the plant, with emphasis to N, P, S and Zn. In the same study, Ca was the nutrient accumulated in lower proportion in ears, either in the flowering as in the physiological maturity of grains. The stem was the main compartment of accumulation of K, Mg, Fe and Mn in the stage of maturity. Leaves and stems act as the main drains of N during the stage of vegetative development, later, during the reproductive stage there is considerable remobilization of photoassimilated compounds and nutrients of the vegetative organs accumulated before the flowering to promote the grain development.

According to COELHO (2006), during the period of cultivation, maize presents periods in which there is an intense absorption of soil nutrients, the first one occurs in the stage of vegetative development (12 to 18 leaves), when the potential number of grains is being defined, and the second in the reproductive stage or formation of ear, when the productive potential is reached.

Table 1. Means of grain yield and total dry matter (DM), accumulation of macronutrients in the aerial part of cultivars, concentration of elements in the DM and accumulation of elements per megagram of DM produced, obtained by the compilation of different publications.

Works	Grains	DM	N	P	K	Ca	Mg	S
	Mg ha^{-1}		kg ha^{-1}					
Von Pinho et al. (2009)[1]	14.05	31.25	364.00	84.00	314.00	60.50	42.00	27.00
Duarte et al. (2003)[2]	7.70	16.20	204.00	25.00	162.00	24.00	41.00	11.00
Bull (1993)[3]	9.10	-	190.00	39.00	196.00	40.00	44.00	21.00
Hiroce et al. (1989)[4]	4.90	13.50	135.73	22.54	86.24	20.58	22.54	12.74
Vasconcellos et al. (1983)[5]	5.10	12.10	103.00	19.50	43.50	21.50	13.50	-
Furlani et al. (1977)[6]	6.80	-	111.52	14.58	127.16	37.40	14.96	57.80
Andrade et al. (1975)[7]	6.20	16.30	181.04	31.00	218.24	34.72	35.96	32.24
Means	7.69	17.87	184.18	33.66	163.88	34.10	30.57	26.96
			Concentration (% in DM)					
Work means[1; 2; 4; 5; 7]	7.59	17.87	1.08	0.19	0.87	0.18	0.18	0.11
			Accumulation of nutrients (kg Mg^{-1} of DM)					
			10.78	1.88	8.68	1.77	1.77	1.12
Pauletti (2004)[8]			20.3	4.3	16.9	3.1	3.0	-

SOURCE: Changed from VON PINHO et al. (2009)

[1]Mean from two cultivars GNZ2004 and P 30F33, one with high capacity of accumulation of DM and other with potential for grain production, in Lavras - MG

[2]Mean from five cultivars, Palmital – SP.

[4]Mean from four commercial hybrids and six populations, Campinas – SP.

[5]Respective mean from cultivars BR126 and BR105,with and without irrigation, Sete Lagoas – MG.

[6]Means of cultivars HS1227 and HS7777, Campinas – SP.

[7]Mean of five cultivars, Piracicaba – SP.

[8]Mean from different authors found by Pauletti (2004), expressed in kg Mg^{-1} of accumulated DM in plants in the stage of maturation.

These authors still emphasize that for the elements N and P, maize presents periods with maximum absorption during the stages of vegetative and reproductive development or ear formation, in the stages of vegetative and reproductive development or ear formation, in the stages of emission of the tassel and beginning of the formation of the ear it is observed lower rates of absorption. K presents a different dynamics of absorption of N and P, and the maximum absorption occurs in the stage of vegetative development, with high rate of accumulation in the first 30 to 40 days of development, in which the rate of absorption is higher than the rate of N and P, suggesting a higher necessity of N in the initial stage as an element of "start-up".

Complementing, RICHIE et al. (2003) demonstrated that the absorption of K is completed soon after the flowering, however, the absorption of the other essential nutrients as N and P continues until close to the maturity, following the dynamics of accumulation of DM. Since a good part of N, P and some other nutrients is translocated from the vegetative parts of the plant from the grains, unless the appropriated quantities of nutrients are available for plants in this period.

In other studies, VON PINHO et al. (2009) observed in two maize cultivars the linear behavior in the accumulation of N along the crop cycle. They verified that for each day after emergence (DAE) the accumulation of N in the DM increased in average 2.89 kg ha^{-1}, the hybrids presented low accumulation of N in the initial stages, with a significant increase occurring 44 DAE (8 folded leaves) and an increasing and linear accumulation until the final stages of development. Concerning the accumulation of P during the cycle, for each DAE there was accumulation of 0.67 kg ha^{-1}, there was a significant increase in the total of P accumulated in the final stages, mainly from the 125 DAE (chalky grains). However, the accumulation of K had quadratic behavior along the cycle, the accumulation in plants had a first peak of absorption (282 kg ha^{-1}) due to the 55 DAE (12 leaves completely folded), when it was verified an intense vegetative growth, and a second period of absorption (313 kg ha^{-1}) in the physiological maturity (140 DAE), which generated the maximum accumulation of this nutrient in the maize plant. The results found for the accumulation of K are opposed to most of the works performed, since they found an absorption peak in the end of the cycle.

Still in the same work, the authors evidenced that the accumulation of Ca by plants had a quadratic behavior during the cycle, with a first peak of absorption in the occasion of flowering (60 DAE) and a second peak of absorption in the maturity. The accumulation of Mg in the cultivars presented linear behavior, the total amount of Mg accumulated in the initial stages were low, and there was a small increase 44 DAE (8 unfolded leaves) until the end of flowering (70 DAE), from 85 DAE (milky grains), there was significant increase in the accumulation of Mg, which increased in a linear way until the end of the cycle. The accumulation of S presented linear behavior; the accumulation of S increased little until the 71 DAE, considering that, at 85 DAE there was a significant increase in the total accumulated, the maximum accumulation of S occurred 125 DAE (chalky grains).

The great variation of results found is due to conditions of the cultivation environment, genotypes and soil fertility. According to FERREIRA (2009) these changes in the concentrations may be related to the interference of one nutrient in the absorption of another element or in the excessive availability of the element in soil.

These nutrient concentrations are an important tool for the monitoring of maize crops and, when used together with the plan of application of nutrients, may enlarge the levels of accuracy of the soil and plant fertilization. Besides that, in a plan of sustainable agriculture, the balance of income and output of nutrients in the system is important to define the economy of production and the levels of soil fertility (HECKMAN et al., 2003).

Exportation of nutrients trough the production of forage maize

In maize, nutrients have different rates of translocation between tissues (stems, leaves and grains), concerning the nutrient exportation, when the aim is at producing grains (total of nutrients extracted by the plant/total of nutrients in grains), the P is almost all translocated to grains (77 to 86%), followed by N (70 to 77%), S (60%), Mg (47 to 69%), K (26 to 43%) and Ca (3 to 7%). Based on these rated of nutrient exportation by grains, it is seen that even though the component grain has great concentration of most of the elements removed from soil, still the incorporation of the cultural waste of maize returns to soil great part of them, mainly K and Ca, contained in the straw (COELHO, 2006).

RITCHIE et al. (2003) say that, in average, for each megagram of grain produced the maize plant extracts from soil 24.9 kg of N; 5.9 kg of P; 26.7 kg of K; 6.6 kg of Ca; 7.9 kg of Mg; 2.5 kg of S; 66.6 g of Zn; 21 g of B; and 21.2 g of Cu. Considering one megagram of produced grains, from the total extracted from the soil by the maize plant, it is exported to grains 15.6 kg of N; 4.8 kg of P; 5.1 kg of K; 0.4 kg of Ca; 2.2 kg of Mg; 1.2 kg of S; 24.4 g of Zn; 3.8 g of B; and 2.1 g of Cu. The authors concluded that a great part of the N and P absorbed by the plant is removed in the grains which are harvested, but most part of the K absorbed is returned to soil by leaves, stems and other plant wastes, unless the other parts of the plant are removed to make silage or other forms of food.

PAULETTI (2004) determined the average of the extraction and the exportation trough grains of macro and micronutrients in maize plants in the stage of maturation with the results found by several authors, the values obtained for the extraction and exportation, respectively, expressed in kg Mg^{-1} for macro and g Mg^{-1} for micro, were: N: 20.3 and 15.8; P: 4.3 and 3.8; K: 16.9 and 4.8; Ca: 3.1 and 0.5; Mg: 3.0 and 1.5; S: (inexistent extraction) and 1.1; Fe: 233.3 and 11.6; Cu: 12.2 and 1.2; Zn: 44.4 and 27.6; B: 18.9 and 3.2; Mn: 37.8 and 6.1; Mo: 1.0 and 0.6.

KARLEN et al. (1987), in the USA, obtained average production of 12 Mg ha^{-1} of grains and 24 Mg ha^{-1} of DM in the aerial part and extraction of 239, 44 and 232 kg ha^{-1} of N, P and K respectively, and obtained relation of 2.0 Mg of dry matter of aerial part per 1 Mg of grains. In Brazil, the extraction of N per produced grain unit and the grain yield in the aerial mass are lower; also the higher accumulation of DM is not necessarily related to the production of grains (VASCONCELLOS et al., 1983).

VON PINHO et al. (2009) evaluated two maize cultivars, GNZ2004 with forage potential presented productivity of 13.5 Mg ha^{-1} of grains and 32,9 Mg ha^{-1} of DM, and cultivar P 30F33 with grass potential had productivity of 14.7 Mg ha^{-1} and 29.7 Mg ha^{-1} of DM. The total accumulation of macronutrients by cultivars, respectively, followed the following decreasing order of values (expressed in kg ha^{-1}): N: 401 and 327; K: 312 and 316; P: 92 and 76; Ca: 61 and 60; Mg: 47 and 37; and S: 30 and 24.

The authors observed that the cultivar GNZ2004 exports higher amount of nutrients by megagram of nutrient produced, despite the lower grain yield obtained. For DM yield, the behavior of the cultivars was the inverse, with P30F33 exporting a higher amount of nutrients per megagram of DM produced. With this, it was concluded that the cultivar with forage characteristics, despite having lower concentration of nutrients in the DM, extracted higher amount of soil nutrients due to the compensation for the higher production of phytomass.

There are also other species as sorghum and sugarcane which are widely exploited with forage aims, and follow the same problem raised concerning the maintenance and sustainability of the production. FRANCO (2011), evaluating two sorghum cultivars obtained the production of 18.3 Mg ha^{-1} of DM for BRS 610 (forage) and 15.5 Mg ha^{-1} of DM for DKB 599 (grass), observed accumulation of 288.97 and 318.99 kg ha^{-1} of N; 48.73 and 61.78 kg ha^{-1} of P; 331.19 and 251.26 kg ha^{-1} of K; 104.30 and 83.27 kg ha^{-1} of Ca; 34.16 and 34.74 kg ha^{-1} of Mg; 19.82 and 21.78 kg ha^{-1} of S, respectively for cultivars BRS 610 and DKB 599.

When we compare the accumulation of sorghum nutrients in the work of FRANCO (2011) with the accumulation in maize obtained by VON PINHO et al. (2009), sorghum presented lower production of DM and nutrient extraction (N, P, K, Mg and S) per hectare, however the extraction of all the nutrients proportional to the phytomass produced were higher for the sorghum culture, which in the average of the cultivars sorghum presented extraction of 6.6; 7.1; 0.7; 3.6; 0.7; 0.4 kg Mg^{-1} more than the maize culture for N, K, P, Ca, Mg and S, respectively. Therefore, maize presented higher production of phytomass and extraction of nutrients per hectare, however, sorghum extracted from soil higher amount of nutrients per megagram of DM produced.

OLIVEIRA et al. (2010a), evaluating 11 cultivars of sugarcane obtained mean yield of 195 kg ha^{-1} of stem, the extraction of nutrients in the aerial part of cane plant presented, on average, values of 179, 25, 325, 226 and 87 kg ha^{-1} of N, P, K, Ca and Mg, respectively, which provided the following order of extraction: K > Ca > N > Mg > P. The mean exportation of N, P, K, Ca and Mg by the stem of the irrigated varieties was 92; 15; 188; 187; and 66 kg ha^{-1}, corresponding, respectively, to 51, 60, 58, 83 and 76 % of all the nutrients extracted in the aerial part of the cane-plant. For the production of one megagram of stem per hectare, it was demanded four varieties, during the cane-plant cycle, mean values of 0.91; 0.13; 1.71; 1.18; and 0.44 kg of N, P, K, Ca and Mg, respectively.

The difference between the quantity of total extraction of nutrients and the exportation by the grain harvest, in the physiological maturity, helps us to have an idea of the proportion of nutrients that are exported when the phytomass is removed from the area for the production of silage. However, it is emphasized that the values cannot be compared when the crop is destined to ensilage, since the content of nutrient previously related represent the grain and phytomass in stage of complete physiological maturation. It is important to remember that, according to NEUMANN et al. (2011), the point recommended for the plant harvest for ensilage is found in the grain stage milky to chalky, and the phytomass between 30 and 35% of DM. Thus, the relation of nutrient exportation in changes, since the plant has not completed its plain development yet, and as it was earlier exposed it would be extracting nutrients from soil.

However, works performed by the same authors (NEUMANN et al., 2011), comparing harvest point in maize ensilage, with 30 and 40% of DM, demonstrate that silages with higher stage of maturation (chalky to hard, 40% of DM) presented better animal and economical performance, in which maize reaches the maximum realization concerning grain filling. Still, the modernization of the implements of forage cutting and the appearance of self-propelled machines may instigate the trend to delay the cutting point of forages as maize, since the current machines when well conducted may improve the pattern of cutting of forage and still maintain an effective processing of dryer grains.

In Table 2 it is presented values of exportation of macronutrients of different levels of yield, either for the production of grains or for the production of silage, as well as the concentration of nutrients contained in the matter and the relation of nutrients extracted by megagram of the produced mass.

The example demonstrated by COELHO (2006) helps to clarify the relation of extraction of nutrients from crops destined to the production of silage or grain harvest, and due to the great variation between the levels of exportation, the presentation of values in concentration of nutrients in the phytomass (% in the DM of the phytomass) and extraction for each gram of DM produced contribute for a better comprehension of the results. However, the respective values of exportation per production levels for grains or silage may not be related, since they come from different plantations, i.e., the plantation which produced 11.6 Mg of silage DM is not the same which produced 5.8 Mg of grains, deduced due to the levels of P and K informed.

This is another important question that should be better established, since in order to obtain the exact relation between the difference of exportation by the silage and exportation by the grain harvest it should be analyzed the content of nutrients from the produced matter (grains or phytomass) of the same harvest and in its exact points of harvest.

According to Table 2, the nutrient with higher impact when we compared the type of exportation is K, for the production of grains there is an extraction between 95 to 157 kg ha^{-1} of K. However, when silage is produced, the observed exportation was up to 259 kg ha^{-1} of K, fact which may lead to the early soil wear concerning this nutrient (COELHO, 2006). Concerning this problems, JAREMTCHUK et al. (2006) evaluated the exportation of K in 5 cultivars of maize harvested in two cutting heights for the

Table 2. Mean extraction of nutrients, concentration in the matter and extraction per megagram of mass produced by the maize crop destined to the production of grains and silage in different levels of yield.

Type of exportation	Production (kg ha^{-1})	Nutrients extracted[1] (kg ha^{-1})					Concentration (% in the matter)					Extraction per megagram of produced matter (kg Mg^{-1})				
		N	P	K	Ca	Mg	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Grains	5.800	100	19	95	17	17	1.72	0.33	1.64	0.29	0.29	17.24	3.28	16.38	2.93	2.93
	7.870	167	33	113	27	25	2.12	0.42	1.44	0.34	0.32	21.22	4.19	14.36	3.43	3.18
	9.170	187	34	143	30	28	2.04	0.37	1.56	0.33	0.31	20.39	3.71	15.59	3.27	3.05
	10.150	217	42	157	32	33	2.14	0.41	1.55	0.32	0.33	21.38	4.14	15.47	3.15	3.25
Silage (DM)	11.600	115	15	69	35	26	0.99	0.13	0.59	0.30	0.22	9.91	1.29	5.95	3.02	2.24
	15.310	181	21	213	41	28	1.18	0.14	1.39	0.27	0.18	11.82	1.37	13.91	2.68	1.83
	17.130	230	23	271	52	31	1.34	0.13	1.58	0.30	0.18	13.43	1.34	15.82	3.04	1.81
	18.650	231	26	259	58	32	1.24	0.14	1.39	0.31	0.17	12.39	1.39	13.89	3.11	1.72

SOURCE: Modifyied from COELHO and FRANÇA (1995) quoted by COELHO (2006).

[1] *To convert P in P_2O_5; K in K_2O; Ca in CaO and Mg in MgO, multiply by 2.29; 1.20; 1.39 and 1.66; respectively.*

production of silage, 20 and 40 cm from soil, and verified that the extraction of K ranged between 52.95 and 74.05 and between 47.53 and 59.06 kg ha^{-1} for the heights of 20 and 40 cm respectively. The elevation in the cutting height reduced in average 19.15% the extraction of K, which should return to the soil.

OLIVEIRA et al. (2010b), aiming to evaluate the production and extraction of nutrients from different forages, implanted an experiment with the maize, sudan sorghum, forage sorghum and sunflower and obtained production of 21.0, 19.6, 23.1, 15.9 Mg ha^{-1} of DM respectively. The values of exportation for the maize crop were 199.3 kg ha^{-1} of N; 28.9 kg ha^{-1} of Ca; 33.1 kg ha^{-1} of P; 208.1 kg ha^{-1} of K; 26.5 kg ha^{-1} of Mg; and 11.2 kg ha^{-1} of Na. Comparatively, the sunflower crop extracted the highest amount of Ca (136.9 kg ha^{-1}), K (380.5 kg ha^{-1}) and Mg (54.5 kg ha^{-1}), while sudan sorghum presented the highest extraction of P (46.1 kg ha^{-1}), the extraction of N did not differ among crops, presenting average of 206,2 kg ha^{-1}. The authors concluded that the maize and forage sorghum presented highest yield of DM per area, and the extraction of minerals is higher in the sunflower crop.

General considerations

The cultivation of maize for the production of forage causes higher exportation of soil nutrients when compared to the harvest of only grains; moreover, the levels of exportation are highly dependent on variables as climate, genotype, characteristics of cultivation, and production levels obtained.

In a general way, the harvest for forage extracts from soil potassium and nitrogen in higher amounts, followed by calcium, magnesium and phosphorus respectively, however, when it is harvested only grains there are higher exportation of nutrients in the decreasing order of nitrogen, potassium, phosphorus, calcium and magnesium. However, despite the high potential of production of phytomass and consequent nutrient extraction, maize is not necessarily the forage species which promoted higher nutrient depletion of soil per unit of phytomass produced.

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