NUTRITIONAL DEMAND OF SOYBEAN AND MAIZE BASED ON NUTRIENT UPTAKE AND EXPORT RANGES

Bruno Marcos Nunes Cosmo[1]

[1]*Professor at Centro Técnico-Educational Superior do Oeste Paranaense (UNIMEO-CTESOP), Ph.D. in Agronomy (Agriculture), São Paulo State University (UNESP). (brunomcosmo@gmail.com)*

Abstract: The study estimated the nutritional demand of soybean and maize crops by determining nutrient uptake and export ranges. A literature review of publications from 2010 onwards was conducted, standardizing data to grams or kilograms of nutrient per tonne of grain. Ranges were established for macro and micronutrients for both crops, highlighting that knowledge of nutritional demand supports fertilizer management and high yields.

Keywords: Agribusiness; Nutrient Extraction; Nutrient Export; Productivity.

INTRODUCTION

Over the last few decades, the global population has experienced rising growth rates, consequently increasing the demand for food and products such as clothing, fuel, and the like (Gazzoni, 2017). This scenario places pressure on sectors like agribusiness to meet such demands by seeking ways to increase production efficiently while complying with legal and environmental requirements and overcoming limitations such as adverse weather conditions and finite land availability (Sampaio, Sampaio, & Bertrand, 2012; Hirakuri & Lazzarotto, 2014; Saath & Fachinello, 2018).

These demands have driven the development of various agricultural segments, including genetic improvement (Vargas et al., 2018), seed technology (Silva et al., 2014), plant nutrition (Bitencourt et al., 2015), phytosanitary management (Rangel, 2019), harvesting and post-harvest technology (Santos et al., 2018), the adoption of irrigation (Almeida et al., 2018) and precision agriculture (Bernardi et al., 2014), soil management (Tiecher, 2016), and related areas. However, it is worth noting that understanding and managing nutritional requirements are fundamental to maintaining and increasing productivity (Lima, 2019).

Nevertheless, these factors are not always managed adequately; although many producers fertilize their crops, this management is not always based on technical-scientific recommendations (Lacerda et al., 2015). In this context, the question arises: What fertilization parameters can be used consistently and practically across different production scenarios for soybean and maize?

One alternative is the use of manuals such as "Bulletin 100" in São Paulo (Raij et al., 1997) though even these regional manuals cover vast areas, and some were developed over 10 or 20 years ago. Another option for managing fertilization is based on nutrient extraction and export rates; according to Oliveira et al. (2010), these rates refer to the amount of a specific nutrient required for crop development (extraction) and the amount removed from the system (export) per unit of production.

In this context, the general objective of this study was to estimate the nutritional demand of soybean and maize crops, with the specific objectives of determining the nutrient extraction and export ranges for these crops.

Studies in this area are justified by the importance of understanding crop nutrition. Although some production systems allow for the exclusion of soil (such as hydroponics), nutritional knowledge becomes even more essential in such cases (Louro & Reis, 2020). It is also worth noting that fertilizers account for a significant portion of production costs; for soybean and maize, they can represent one-third of variable costs (Cosmo & Galeriani, 2020). Brazil is also a major consumer of imported fertilizers ranking fourth globally (Cella & Rossi, 2010) demonstrating that up-to-date knowledge regarding the nutritional demands of key crops can significantly impact both production efficiency and costs.

Therefore, to achieve the objective of estimating the nutritional demand of soybean and maize crops, a literature review was conducted using domestic articles containing information on the nutritional requirements of these crops. Data from these articles were standardized to express the required amount of each nutrient in grams or kilograms per tonne of grain produced. Whenever possible, the yield levels associated with these demands were also reported, aiming to establish not only the range of requirements for each element but also the conditions under which those demands were observed.

THEORETICAL FRAMEWORK

As mentioned in the introduction, the global population is growing rapidly, driving a need for food and other products largely supplied by the agricultural sector (Gazzoni, 2017). Alongside population growth, the demand for these products is rising in terms of both quantity and quality. Consequently, increasing productivity (production per unit area) has become a key strategy for meeting these demands sustainably (Saath & Fachinello, 2018).

In this context, knowledge regarding soil fertility and plant nutrition offers several benefits, including improved fertilizer management and efficiency; it also enables higher yields with lower input usage, provided the nutrients are supplied appropriately (Tiecher, 2016; Reetz, 2017).

Soil fertility can be defined as the soil's capacity to satisfactorily supply the elements necessary for plant development while ensuring that limiting elements are either absent or present only at tolerable levels; this concept focuses particularly on soil chemistry (Nicolodi et al., 2008; Batista et al., 2018). Understanding soil fertility allows for integrated system management aimed at raising fertility levels and maintaining them over longer periods (Pimenta et al., 2010; Tiecher, 2016).

Due to natural formation processes, soils in the country are generally considered acidic and of low natural fertility, containing high levels of aluminum and iron oxides that reduce phosphorus availability for crops (Ronquin, 2010). This underscores the importance of nutritional management. Crop nutritional demand can be assessed through nutrient extraction and export that is, the quantities of each nutrient required for crop development and those removed from the system after harvest, respectively (Oliveira et al., 2010). In general, the amount of nutrients to be applied to a crop can be determined by assessing crop requirements, subtracting the amount of the element already available in the soil, and adjusting the result based on the nutrient use efficiency factor and the nutrient content of a specific fertilizer (Vitti et al., 2005; Silva et al., 2017). However, the process begins with the quantity required by the crop, which can be defined by its nutrient extraction or export levels.

Determining crop requirements can be based on comparing them with soil nutrient levels obtained through soil analysis or by using procedures involving plant tissue analysis (Mendes, 2007). Another relevant aspect is defining the doses for Maximum Agronomic Efficiency (DMEA) and Maximum Economic Efficiency (DMEE); although the goal is often to increase productivity, the associated costs are not always economically viable. Some authors, such as Simões Neto et al. (2012), demonstrate that the DMEE can be generally established as 90% of the DMEA.

Therefore, even with the availability of manuals for interpreting results and recommending fertilization, many aspects related to management and agricultural productivity come into play. Various soil fertility factors can affect nutrient availability and uptake; furthermore, achieving the highest productivity does not always translate into the highest profit for the producer. Given this, defining fertilization management strategies such as understanding nutrient extraction and export provides valuable supporting information for crop management.

Soybean cultivation

Soybean (*Glycine max* L.) is one of the world's major agricultural commodities, considered the most widely produced and consumed oilseed globally (Fiametti, 2015). Brazil ranks as the second-largest producer of the crop, behind the United States, with a production of nearly 120 million tonnes in the 2018/2019 season and an average yield exceeding 3,300 kg ha^{-1} during that same season (Companhia Nacional de Abastecimento – Conab, 2020a). The crop serves as a protein source for human and animal nutrition, in addition to having various industrial applications and uses in biofuel production (Hirakuri; Lazzarotto, 2014).

The crop originates from trailing plants native to the East (East Asia) (Gazola et al., 2012); although its cultivation began millennia ago, its exploitation in Brazil only started in 1882 initially as a forage crop and later for grain production (Lopes, 2013; Fiametti, 2015). The crop's evolution was so significant that, by the 1970s, it had already become the leading crop in Brazilian agribusiness (Freitas, 2011; Dall'agnol, 2016; Dias, 2017).

Soybean is a dicotyledon belonging to the Fabaceae family (Oliveira et al., 2019a). It is classified as an annual C3 plant; morphologically, it is an erect, herbaceous plant ranging from 0.3 to 2.0 m in height. It features a hispid, sparsely branched stem and three types of leaves (cotyledonary, unifoliolate, and trifoliolate); the flowers are complete varying in color between white, violet, and yellow and are self-fertilizing. The fruit is a pod containing up to five seeds. The root system is taprooted and capable of forming associations with nitrogen-fixing bacteria. Growth habits can be determinate, semi-determinate, or indeterminate (Ormond, 2013; Dias, 2017; Tejo; Fernandes; Buratto, 2019).

Regarding crop development, Rocha et al. (2012) note that cultivation typically occurs at latitudes above 30° in temperate climates; however, in Brazil, it is cultivated at latitudes below 20°, demonstrating its adaptability to tropical regions. The crop develops across a wide range of altitudes, with no specific limits defined for this factor (Oliveira et al., 2019a). Photoperiod is one of the key climatic factors influencing soybean development, as it triggers the transition from the vegetative to the reproductive phase. Soybeans are considered short-day plants, flowering when the dark period (night) exceeds a specific light period (day); however, the critical photoperiod duration varies (Trentin et al., 2013; Dias, 2017).

Temperature is another important climatic factor; generally, soybeans develop well between 20°C and 30°C, with an optimum temperature near 30°C, though this varies depending on the growth cycle, cultivar, region, intended use, and other factors. Cultivation is not recommended in regions with temperatures below 10°C or above 40°C, due to growth retardation (<10°C) or growth disturbances (>40°C). Temperature also affects flowering which is induced by temperatures above 13°C meaning the interaction between temperature and photoperiod can accelerate or delay flowering (Farias, Nepomuceno, & Neumaier, 2007; Cavero, 2016; Duarte, 2016).

Regarding the crop's water requirements, rainfall totaling 450 to 800 mm during the growth cycle is sufficient to achieve satisfactory yields, with peak demand occurring during flowering and grain filling, requiring 7 to 8 mm/day during this phase. The distribution of water requirements can be assessed using the crop coefficient (Kc), which ranges from 0.4 to 1.2 (Carvalho et al., 2013; Simeão, 2015). Therefore, although soybeans are cultivated across nearly the entire national territory and much of the globe, a proper understanding of the aforementioned information complemented by other data regarding crop management, for instance ensures continuous evolution and progress, whether in adapting the crop to new environments, genetic improvement, or management techniques.

Maize cultivation

Maize (*Zea mays* L.) is one of the world's major agricultural commodities, also influenced by the domestic market (Cosmo et al., 2017). Brazil ranks as the third-largest producer of the cereal globally (Nascimento; Figueiredo; Miranda, 2018), with a production exceeding 100 million tonnes in the 2018/2019 season and a national average yield of over 5,500 kg ha^{-1} during the same season (Conab, 2020b). Key applications include human consumption, animal feed, and industrial uses (Galvão et al., 2014; Silveira; Silva; Rego, 2017).

Maize originated in southern Mexico and northern Guatemala through the evolution of teosinte (Barros; Calado, 2014; Darós, 2015) and has been cultivated for over 7,000 years (Silva, 2013; Dantas Junior; Chaves; Fernandes, 2016). It is considered the most widely produced and consumed cereal in the world (Giovanelli, 2019).

Maize is a monocotyledon belonging to the Poaceae family (Barros; Calado, 2014). Classified as a C4 plant (Cruz et al., 2011), it is an erect plant that can exceed 2.0 m in height, characterized by a segmented stem, long and narrow leaves, complete flowers, a caryopsis-type fruit, and a fasciculated root system (Turco, 2011; Giroti, 2017).

Regarding its developmental requirements, the crop is notably well-adapted to tropical, subtropical, and temperate climates, growing at altitudes ranging from sea level to over 3,600 m, which allows for a wide variety of production environments (Barros; Calado, 2014). Like soybeans, maize is classified as a short-day plant, with a critical photoperiod of approximately 12 hours; flowering is induced when days have fewer than 12 hours of light. However, some authors also classify the crop as photoneutral that is, insensitive to photoperiod (Wordell Filho; Elias, 2012).

Another important aspect of maize cultivation is the need to accumulate a specific amount of thermal units, or growing degree-days, to complete its growth cycle (Giroti, 2017). In Brazil, this accumulation is generally measured up to the flowering stage, classifying varieties as "super-early" (sum below 825 degrees), "early" (830 to 900 degrees), and "normal" (above 900 degrees) (Zucareli et al., 2010).

Thermal accumulation, like plant development, is affected by temperature; ranges of 25–30°C during the day and 16–19°C at night are considered optimal, while 10°C is the base temperature for thermal accumulation calculations (Zucareli et al., 2010; Paula, 2017). It is also worth noting that a temperature difference (amplitude) of approximately 10°C between day and night is required for proper development (Cruz et al., 2011).

Regarding water requirements, Barros and Calado (2014) cite 150 mm per cycle as the lower limit for development without irrigation. Meanwhile, Carvalho et al. (2013) cite a range of 500 to 800 mm per cycle as adequate, noting that in Brazil, this range can vary between 380 and 550 mm, with peak demand occurring at flowering requiring up to 7 mm per day. Maize crop coefficient (Kc) values range from 0.5 to 1.4 (Souza et al., 2015; Comunello et al., 2018).

Therefore, it is worth highlighting once again that, despite the significant advances and expansion of maize cultivation, knowledge regarding the crop's morphology and environmental requirements enables the advancement and refinement of production systems encompassing genetic improvement, management evolution, and nutrition, among other aspects.

MATERIALS AND METHODS

To achieve the objective of estimating nutritional demand by determining nutrient uptake and export ranges for soybean and maize crops, a study with a fundamental purpose was adopted, aiming to accumulate knowledge for use in applied contexts (Fontelles et al., 2009).

Regarding its approach, the research is classified as quantitative seeking to identify the ranges of nutrients taken up and exported by soybean and maize crops and qualitative seeking to describe the importance of this information, as well as the data already gathered in the theoretical framework (Fernandes et al., 2018). The research objectives are exploratory, as they aim to familiarize the researcher with the subject matter and provide a basis for structuring the results (Fontelles et al., 2009). The purpose of research is classified as descriptive (Silva et al., 2016).

Regarding methodology, a bibliographic research approach was adopted; this relies on gathering information from data already discussed and analyzed in previously published studies. Bibliographic research seeks to solve a problem or answer a question through the analysis, comparison, and/or discussion of findings from various studies, thereby providing a broad and reliable data source (Pizzani et al., 2012; Pradanov & Freitas, 2013; Praça, 2015).

To conduct the research, studies of various types were used; however, preference was given to scientific articles, dissertations, theses, books, and similar materials preferably published after 2010 to ensure the information was up-to-date. Materials were sourced from search platforms for journals and other online resources, such as Google Scholar and SciELO. To focus the search for material, descriptors were used terms and/or "keywords" that, according to Galvão (2010), guide the search and accelerate data collection. Examples of such descriptors include "soybean nutritional demand," "maize nutritional demand," "nutrient uptake and export in soybean," "nutrient uptake and export in maize," and similar terms. Once obtained, the material was filtered and selected based on the research approach.

To determine uptake and export ranges, only studies conducted in Brazil were selected preferably those covering the 2010 growing season or later from which values for the uptake and export of one or more nutrients could be obtained, alongside information on yield and the growing season (where available). To standardize the results, the levels of elements required in larger quantities (macronutrients) were expressed in kg t^{-1}, while those required in smaller quantities (micronutrients) were expressed in g t^{-1}. The qualitative analysis relied on concepts established in the literature.

It should also be noted that if yield figures and/or nutrient levels fell significantly above or below the average values found in the majority of the studies, the result was partially or entirely discarded (although it is acknowledged that there is naturally wide variation in this type of assessment). Finally, the results section was structured by crop, as detailed in the following sections.

RESULTS AND DISCUSSION

As previously described, the results are categorized into qualitative and quantitative information; however, to facilitate understanding, the quantitative results by crop will be presented first, followed by the qualitative results, thereby contextualizing the importance of the information and its application.

The essential mineral nutrients absorbed by plants fall into two categories: while all are essential, some are required in larger quantities (macronutrients) and others in smaller quantities (micronutrients). Macronutrients include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), whereas micronutrients include boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) (Mendes, 2007).

Nutrient Extraction and Export in Soybean Crops

Soybean is the leading oilseed crop produced worldwide (Fiametti, 2015), with average national yields recorded from 2010 onwards ranging from 2,600 to 3,500 kg ha^{-1} (Conab, 2020a). However, actual field yields can be much higher, given that the national average accounts for a vast area. Yamada (1982) previously estimated the theoretical maximum grain yield to be in the range of 11,000 kg ha^{-1}, while Alambert (2010) cites studies reporting field yields of 6,000 to 7,000 kg ha^{-1}.

Crop productivity is known to fluctuate under different scenarios, and while there is significant potential for increasing yields, the availability of nutrients is essential for proper plant development (Gitti; Roscoe; Rizzato, 2018). Accordingly, Tables 1 and 2 the compiled ranges for nutrient extraction and export in soybeans, compiled from various studies.

Table 1. Extraction of macro and micronutrients in soybeans.

Table 2. Export of macro and micronutrients in soybeans.

An analysis of Tables 1 and 2 reveals a wide range of values for all elements; although most results stem from recent years with relatively similar productivity levels, factors such as the specific environment, cultivar, management practices, and other production aspects can influence the crop's nutritional requirements. Nitrogen (N), for instance despite being required in the largest quantities is typically supplied through biological nitrogen fixation, indicating that its management differs from that of other nutrients (Steiner et al., 2018).

Therefore, understanding nutrient uptake and export ranges in soybeans enables producers to plan fertilization strategies such as supplying only the amounts taken up or exported when soil nutrient levels are high or to determine the DMEE (Dose for Maximum Economic Efficiency), as described by Simões Neto et al. (2012). This highlights the importance of such knowledge, which should be integrated with other management practices.

Nutrient Extraction and Export in Maize Crops

Maize is the most widely produced and consumed cereal in the world (Giovanelli, 2019), with average national yields ranging from 4.2 to 5.7 t ha^{-1} since 2010 (Conab, 2020b). However, as with soybeans, higher yields can be achieved in the field; according to Coelho, Cruz, and Pereira Filho (2004) and Assis et al. (2006), theoretical maximum grain yields can range from 19 to 31 t ha^{-1}.

Meanwhile, Kappes, Arf, and Andrade (2013) obtained yields of 6.8 to 8.3 t ha^{-1} using different soil management practices. Once again, significant yield variation is observed, which is also influenced by crop nutrition; in this regard, Tables 3 and 4 the compiled ranges for nutrient uptake and export in maize.

Table 3. Extraction of macro and micronutrient in maize.

Table 4. Export of macro and micronutrients in maize.

Based on Tables 3 and 4, it is evident that the variation in maize productivity is greater than that of soybeans; while the variation from the lowest to the highest recorded soybean yield is 50% (3.0 to 4.5 t ha^{-1}), for maize, this variation rises to nearly 180% (6.4 to 18 t ha^{-1}). Consequently, significant variations in the amounts of nutrients extracted and exported are also to be expected.

The study by Simões Neto et al. (2012) is again highlighted, as it underscores the importance of understanding the DMEE (Dose for Maximum Economic Efficiency), given that the DMEA (Dose for Maximum Agronomic Efficiency) does not always correspond to the point of maximum profitability. However, these concepts vary depending on the environment and the hybrids cultivated (with more significant variation in maize than in soybeans). Referring back to the studies by Coelho, Cruz, and Pereira Filho (2004) and Assis et al. (2006), it is noteworthy that the highest yield found in this survey remains below 60% of the crop's theoretical maximum grain yield, which is 31 t ha^{-1}.

It is worth noting that when making fertilizer recommendations such as those based on the manuals by Raij et al. (1997) for São Paulo and/or Pauletti and Motta (2017) for Paraná knowledge of the crop's nutrient requirements, combined with soil analysis, enables not only management aimed at achieving high productivity but also the anticipation and/or mitigation of nutrient deficiencies and/or physiological disorders in the crop.

Table 1. Extraction of macro and micronutrients in soybeans.

Element	1	2	3	4	5		6		7*	8	9**		Range	
	Mean	Mean	Mean	Mean	Min.	Max.	Min.	Max.	Mean	Mean	Min.	Max.	Min.	Max.
Nutrient extraction ranges for soybeans (kg of element per tonne of grain)														
N	101.5	83.0	82.0	----	53.7	159.6	----	----	66.1	99.2	76.0	83.0	53.7	159.6
P	10.2	15.4	7.3	----	33.0	77.1	----	----	6.1	8.9	5.7	15.4	5.7	77.1
K	42.3	38.0	34.0	----	10.8	31.0	----	----	30.1	35.9	24.5	40.0	10.8	42.3
Ca	20.5	12.2	16.0	----	8.1	29.0	----	----	9.5	12.4	12.2	20.0	8.1	29.0
Mg	9.5	6.7	10.0	----	5.2	16.2	----	----	6.3	8.6	4.4	9.1	4.4	16.2
S	9.4	15.4	4.5	----	1.3	5.8	----	----	13.4	8.2	3.1	15.4	1.3	15.4
Soybean Nutrient Extraction Ranges (g of element per tonne of grain)														
B	60.5	77.0	----	75.0	52.8	101.1	75.0	91.0	67.0	----	77.0	77.0	52.8	101.1
Cl	----	515.0	----	----	----	----	----	----	448.1	----	----	----	448.1	515.0
Cu	52.3	26.0	----	20.0	9.4	48.8	13.0	22.0	17.4	----	26.0	26.0	9.4	52.3
Fe	259.9	460.0	----	200.0	82.0	610.6	368.0	900.0	277.0	----	460.0	460.0	82.0	900.0
Mn	100.3	130.0	----	180.0	20.9	96.0	200.0	321.0	20.0	----	130.0	130.0	20.0	321.0
Mo	----	7.0	----	----	----	----	----	----	6.1	----	6.0	7.0	6.0	7.0
Zn	99.9	61.0	----	75.0	32.1	92.4	70.0	89.0	47.4	----	61.0	61.0	32.1	99.8
Crop Season	2001/02	----	2010/11-2011/12	2010/11-2011/12	2013/14		2013/14		----	----	----	----	----	----
Prod. (kg ha^{-1})	4,000.0	----	3,000.0-3,300.0	3,000.0-3,300.0	3,400.0-4,500.0		3,000.0-4,000.0		----	4,500.0	----	----	3,000.0	4,500.0

Note: * Fertilization and liming manual for the state of Paraná (results from a compilation of studies); ** Compilation of 7 studies conducted prior to the year 2000.
Source: 1) Kurihara et al. (2013); 2) Embrapa Soja (2013); 3) Oliveira Junior et al. (2014a); 4) Oliveira Junior et al. (2014b); 5) Teixeira et al. (2015); 6) Quarezemin et al. (2015); 7) Pauletti and Motta (2017); 8) Moreira and Moraes (2018); 9) Mosaic Team (2019a).

Table 2. Export of macro and micronutrients in soybeans.

Element	1	2	3	4	5		6		7*	8	9**		Range	
	Mean	Mean	Mean	Mean	Min.	Max.	Min.	Max.	Mean	Mean	Min.	Max.	Min.	Max.
Nutrient export ranges in soybean (kg of element per tonne of grain)														
N	61.4	51.0	65.0	----	47.2	64.7	----	----	47.1	60.9	51.0	64.4	47.1	65.0
P	5.9	10.0	5.8	----	13.0	18.2	----	----	4.5	5.7	4.7	10.0	4.5	18.2
K	13.8	20.0	20.0	----	8.5	11.0	----	----	14.2	18.4	16.5	24.0	8.5	24.0
Ca	2.5	3.0	3.2	----	1.3	2.9	----	----	2.3	3.0	1.9	3.2	1.3	3.2
Mg	2.7	2.0	2.8	----	1.8	2.9	----	----	1.8	2.5	2.0	3.2	1.8	3.2
S	6.5	5.4	3.0	----	1.1	2.0	----	----	4.7	2.8	2.0	5.4	1.1	6.5
Nutrient export ranges in soybeans (g of element per tonne of grain)														
B	25.8	20.0	----	30.0	21.1	28.1	24.0	30.0	17.4	----	2.0	24.0	2.0	3.0
Cl	----	237.0	----	----	----	----	----	----	206.2	----	----	----	206.2	237.0
Cu	27.0	10.0	----	15.0	7.0	15.5	8.0	9.0	8.9	----	10.0	15.0	7.0	27.0
Fe	77.6	70.0	----	65.0	45.2	103.1	48.0	61.0	76.1	----	70.0	218.0	45.2	218.0
Mn	31.6	30.0	----	50.0	12.6	25.4	32.0	67.0	7.0	----	28.0	43.0	7.0	67.0
Mo	----	5.0	----	----	----	----	----	----	4.4	----	5.0	5.0	4.4	5.0
Zn	63.3	40.0	----	55.0	26.1	38.2	34.0	39.0	29.6	----	30.0	43.0	26.1	63.3
Crop Season	2001/02	----	2010/11-2011/12	2010/11-2011/12	2013/14		2013/14		----	----	----	----	----	----
Prod. (kg ha^{-1})	4,000.0	----	3,000.0-3,300.0	3,000.0-3,300.0	3,400.0-4,500.0		3,000.0-4,000.0		----	4,500.0	----	----	3,000.0	4,500.0

Note: * Fertilization and liming manual for the state of Paraná (results from a compilation of studies); ** Compilation of 7 studies conducted prior to the year 2000.
Source: 1) Kurihara et al. (2013); 2) Embrapa Soja (2013); 3) Oliveira Junior et al. (2014a); 4) Oliveira Junior et al. (2014b); 5) Teixeira et al. (2015); 6) Quarezemin et al. (2015); 7) Pauletti and Motta (2017); 8) Moreira and Moraes (2018); 9) Mosaic Team (2019a).

Table 3. Extraction of macro and micronutrient in maize.

Element	1		2		3		4*	5		6		7		8		9***		Range	
Nutrient Extraction Ranges for Maize (kg of element per tonne of grain)																			
	Min	Max.	Min	Max.	Min	Max.	Mean	Min	Max.	Min	Max.	Min	Max.	Min	Max.	Min	Max.	Min	Max.
N	19.4	21.9	22.8	29.9	----	----	21.5	49.7	50.1	20.2	23.0	19.1	26.2	11.9	14.4	20.3	27.7	11.9	50.1
P	4.0	4.6	4.9	6.8	----	----	3.9	7.7	8.6	1.8	2.0	----	----	2.8	5.4	3.6	4.7	1.8	8.6
K	18.3	20.4	10.2	19.6	----	----	17.1	40.0	46.7	11.8	15.4	17.5	34.7	12.1	18.0	16.3	25.4	10.2	46.7
Ca	2.9	4.1	4.0	5.4	----	----	2.4	9.3	11.0	2.1	2.4	7.1	9.2	2.9	3.9	3.1	5.5	2.1	11.0
Mg	2.5	2.8	2.7	3.7	----	----	2.8	6.2	7.7	2.0	2.9	3.5	5.4	2.8	3.6	3.0	6.4	2.0	7.7
S	1.1	1.3	1.6	2.1	----	----	2.6	4.5	4.6	1.5	1.5	----	----	0.6	0.6	2.3	2.7	0.6	4.6
Nutrient Extraction Ranges in Maize (g of element per tonne of grain)																			
B	8.6	9.9	----	----	----	----	19.3	50.2	63.7	----	----	----	----	----	----	17.0	23.0	8.6	63.7
Cl**	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	8.9 A	
Cu	8.5	10.3	----	----	5.7	9.3	6.8	65.9	77.5	5.2	5.4	----	----	----	----	7.0	21.0	5.2	77.5
Fe	253.6	485.2	----	----	175.0	255.6	161.0	263.9	407.3	171.8	172.5	----	----	----	----	208.0	288.0	161.0	485.5
Mn	30.3	56.4	----	----	46.5	68.8	37.4	283.2	284.9	27.0	27.9	----	----	----	----	37.0	79.0	27.0	284.9
Mo	----	----	----	----	----	----	1.0	----	----	----	----	----	----	----	----	1.0	1.0	0.9 B	1.0
Zn	36.6	43.6	----	----	36.9	43.0	37.5	72.4	116.1	26.8	27.5	----	----	----	----	43.0	56.0	26.8	116.1
Crop Season	2010/11		2014/15		2014/15		----	2014/15		2014		2013/14 e 2014/15		2014/15		----		----	----
Prod. (kg ha^{-1})	10,723.0-13,717.0		8,794.0-13,993.0		8,794.0-13,993.0		----	6,443.0-6,832.0		6,949.0-8,736.0		7,948.0-10,437.0		13,000.0-18,000.0		----		6,443.0	18,000.0

Note: * Fertilization and liming manual for the state of Paraná (results from a compilation of studies); ** Information regarding the extraction and export of this element is scarce (Borges, 2006); *** Compilation of 7 studies conducted prior to the year 2000.
Source: 1) Faria (2014); 2) Silva (2016); 3) Gutiérrez (2016); 4) Pauletti and Motta (2017); 5) Rosa (2017); 6) Simão et al. (2017); 7) Lange et al. (2019); 8) Oliveira et al. (2019b); 9) Mosaic Team (2019b); A) Arf (2016?); B) Vitti et al. (2014).

Table 4. Export of macro and micronutrients in maize.

Element	1		2		3		4*	5		6		7		8		9***		Range	
Nutrient Export Ranges in Maize (kg of element per tonne of grain)																			
	Min	Max.	Min	Max.	Min	Max.	Mean	Min	Max.	Min	Max.	Min	Max.	Min	Max.	Min	Max.	Min	Max.
N	12.9	14.0	12.2	16.1	----	----	14.4	15.0	17.4	12.9	15.3	12.0	16.4	8.2	11.3	12.8	16.3	8.2	17.4
P	3.5	4.0	3.7	4.9	----	----	3.4	2.8	3.3	1.4	1.5	----	----	2.7	5.1	3.0	4.0	1.4	5.1
K	6.4	7.1	3.1	4.3	----	----	5.4	6.1	7.3	2.4	3.1	1.0	5.3	4.7	6.2	3.9	5.1	1.0	7.3
Ca	1.1	1.9	<0.1	<0.1	----	----	0.3	0.5	0.6	0.1	0.1	0.6	1.2	0.5	1.9	<0.1	0.6	<0.1	1.9
Mg	1.0	1.2	0.7	0.7	----	----	1.1	1.7	1.8	0.6	0.8	0.7	1.5	1.2	1.9	1.0	1.7	0.6	1.9
S	0.6	0.7	0.8	0.8	----	----	1.1	1.4	1.6	0.9	1.0	----	----	0.3	0.3	1.0	1.3	0.3	1.6
Nutrient Export Ranges in Maize (g of element per tonne of grain)																			
B	4.1	4.5	----	----	----	----	3.3	8.2	8.3	----	----	----	----	----	----	3.0	4.4	3.0	8.3
Cl**	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.5 A	
Cu	4.2	4.8	----	----	1.6	1.9	1.1	17.3	21.8	1.6	2.4	----	----	----	----	1.0	2.2	1.0	21.8
Fe	28.3	32.4	----	----	9.8	11.3	21.0	26.9	28.8	8.7	14.8	----	----	----	----	11.1	12.1	8.7	32.4
Mn	7.2	10.4	----	----	3.8	4.7	7.4	25.6	29.0	3.7	4.0	----	----	----	----	5.6	6.6	3.7	29.0
Mo	----	----	----	----	----	----	0.6	----	----	----	----	----	----	----	----	0.6	0.7	0.5 B	0.7
Zn	26.1	29.5	----	----	16.5	16.5	24.8	23.8	35.3	14.2	17.3	----	----	----	----	18.9	29.0	14.2	35.3
Crop Season	2010/11		2014/15		2014/15		----	2014/15		2014		2013/14 e 2014/15		2014/15		----		----	----
Prod. (kg ha^{-1})	10,723.0-13,717.0		8,794.0-13,993.0		8,794.0-13,993.0		----	6,443.0-6,832.0		6,949.0-8,736.0		7,948.0-10,437.0		13,000.0-18,000.0		----		6,443.0	18,000.0

Note: * Fertilization and liming manual for the state of Paraná (results from a compilation of studies); ** Information regarding the extraction and export of this element is scarce (Borges, 2006); *** Compilation of 7 studies conducted prior to the year 2000.
Source: 1) Faria (2014); 2) Silva (2016); 3) Gutiérrez (2016); 4) Pauletti and Motta (2017); 5) Rosa (2017); 6) Simão et al. (2017); 7) Lange et al. (2019); 8) Oliveira et al. (2019b); 9) Mosaic Team (2019b); A) Arf (2016?); B) Vitti et al. (2014).

CONCLUSION

Regarding the objectives of estimating the nutritional demand of soybean and maize crops by determining nutrient uptake and export ranges, it is worth noting that the observed grain yields varied from 3.0 to 4.5 t ha^{-1} for soybeans and from 6.4 to 18.0 t ha^{-1} for maize. Significant variation was also observed between nutrient uptake and export at these yield levels. Nevertheless, despite this variation, such data serve as valuable tools whether supplementary or primary for determining the fertilization strategy to be adopted for the crop.

Thus, the study's objectives were achieved. It is important to highlight that, even with the availability of fertilization manuals and other tools, understanding crop nutritional demand both for development (uptake) and regarding the nutrients removed from the system at harvest (export) is increasingly relevant for crop management and the pursuit of high productivity.

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