SOIL ANALYSIS IN POTATO CROP PRODUCTION

POPESCU C.V.

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ABSTRACT

By considering its high yielding potential and its nutritional value, potato (Solanum tuberosum L.), is an important crop in the agricultural production. The potato potential yield cannot be reached in the production systems as the biotic and abiotic factors interfere with the potato crop by negatively affecting the plant growth and the tuber development. The study aimed to emphasize the importance of the soil analysis for the potato crop. Soil samples were collected in 2020 from farm fields located in Brașov and Covasna departments, where farmers are traditionally involved in the potato production. Considering the registered results, the soil's content in available nitrogen, phosphorous and potassium, it is essential to perform soil analysis to successfully implement integrated soil – plant nutrient management action plans aiming better quantitative and qualitative tuber yields.

INTRODUCTION

Potato *(Solanum tuberosum L.*) is an important crop in the agricultural production. Potatoes are a good source of energy, minerals, proteins, fats and vitamins.

The potato potential yield cannot be reached in production systems as biotic and abiotic factors interfere with the potato crop negatively affecting the plant growth and tuber development. Important biotic stress factors in potato production include pathogens like Phytophthora sp., Alternaria sp., Helminthosporium sp., Rhizoctonia, Fusarium and Verticillium.

Plant parasitic nematodes can affect potato yield and production – Globodera sp. are the main important nematode species affecting potato. The abiotic stresses that reduce yield include high radiation, heat and cold stress - the most important abiotic factor affecting yield and quality is represented by the drought stress (Koch M. et al, 2020).

For an optimum production, potato crop requires well-drained, light, deep, loose soil, high in organic matter.

Potatoes are grown on a range of soils varying from sands to clay loams, all with different water holding capacities.

An ideal potato soil is to be well structured, with good drainage to allow proper root aeration, tuber development with minimal root disease infestation.

Potatoes produce a fibrous root system. These roots are at best no more than 60 cm long and so, potatoes are shallow rooted compared to cereals being often unable to exploit nutrients and soil moisture at depth within a soil profile.

While root growth occurs when soil temperatures are between 10 to 35˚C, most active root development is at soil temperatures between 15 and 20˚C. Leaf (haulm) growth occurs at temperatures of between 7 to 30˚C, but optimal growth is at around 20 to 25˚C. Optimum temperatures for the stolon growth are similar.

The potato tuber is an enlarged portion of the stolon. The initiation of this tuber is triggered by short day lengths (photoperiods), and involves growth hormones.

The colder the soil temperature, the more rapid the initiation of tubers and the greater the number of tubers formed. The optimum soil temperature for tuber initiation is 15 to 20˚C. Under these conditions, the potato plant will have short stolons and shoots. Longer day lengths delay tuber initiation and favor the growth of the stolon and shoot.

Unlike most vegetables, potatoes perform best in acid soil with pH 4.8 - 5.5 - in practice, potatoes are grown in soil pH's from 4.5 to 8.5 and this has a significant impact on the availability of some of the nutrients. At lower pH values potatoes can suffer from aluminum and other heavy metal ion toxicity, as well as restricted P or Mo availability. Liming can ameliorate the low pH soil values - lime should be applied at least 6 months before the potatoes are to be planted.

At pH values above 7.5, nutrient availability, in particular of phosphorus and the micronutrients, can be reduced, even though high total amounts of these elements may be present in the soil. Potatoes are more prone to common scab when grown in high pH soils.

Optimum potato growth and profitable production depend on many management factors, one of which is ensuring a balanced supply of nutrients. There are 14 soil-derived elements or nutrients considered to be essential for growth of plants. When the supply of nutrients from the soil is not adequate to meet the demands for growth, fertilizer application becomes necessary. As mentioned, potatoes have a shallow root system and a relatively high demand for many nutrients. Therefore, a comprehensive nutrient management program is essential for maintaining a healthy potato crop, optimizing tuber yield and quality, and minimizing undesirable impacts on the environment (Rosen C.J., 2020).

Among all the elements, nitrogen (N), phosphorous (P) and potassium (K) are the most commonly used for the potato production. Most literature is available for these nutrients with respect to potato production, especially in terms of fertilization strategies and recommendations.

For optimal growth of the potato, a balanced fertilization is required. The right fertilizer has to be applied at the right time, according to the growth stages of the potato plant.

The yield of agricultural crops is the result of a combination of the genetic potential of the genotype, the management of the crop and the environmental conditions (soil, drought, heat) from the local cultivation area (Bonea, 2016; Bonea, 2020).

The yield's level and quality are to be maintained or improved by respecting the correct technological steps.

This can be realized by a qualitative genotypes' selection and, most important, by a comprehensive set of biochemical analysis on the soil before the crop establishment and during the vegetation period.

Most soil testing programs make recommendations for pH, organic matter, P, K, Ca, Mg, Zn, and B. Soil nitrate tests are generally most accurate when used in dry climates on finer-textured soils and when taken to a depth of 30 cm. Other nutrients such as S, Mn, Fe, and Cu can be determined if a problem is suspected. While the actual soil test results should be fairly similar from one lab to the next, extractants may differ and interpretations may vary widely. For most accurate fertilizer recommendations, soil test interpretations should be based on local or regional research (Rosen C.J., 2020).

Optimal soil test levels for potato differ due to varying subsoil fertility, nutrient buffering capacities, soil yield potentials, and different management assumptions. Soil testing is the most convenient and economical method of evaluating the fertility levels of a soil and accurately assessing nutrient requirements.

Fertile soil is developed and maintained through the addition of nutrients lost through harvest. Nutrient uptake by plants is inherently inefficient and the nutrients remaining in the soil after uptake can cause negative air and water resource impacts. Poor fertilizer efficiency is a waste of natural resources and potentially reduces yields, crop quality, and grower profits. Enhancing fertilizer efficiency in potato is particularly important because relatively high rates of fertilizer and water are necessary to compensate for an inefficient rooting system and extreme sensitivity to deficiencies. (Hopkins B.G. et al., 2008).

The study was initiated to fill-in the information deficit by evaluating the available soil nutrients, before a potato crop establishment.

MATERIAL AND METHOD

The studied fields are situated in Brașov and Covasna departments. There were manually collected 10 soil samples from areas designated for the establishment of the potato crop (different farmer fields), according to the standardized soil sampling methodologies. Soil analysis was performed using the laboratory current methodologies - nitrogen by Kjeldahl distillation / CNS analyzer, organic matter by Dumas, phosphorous by Olsen method and 1 M ammonium nitrate /solution spectrophotometry/ICP for most of the other elements.

As for the nitrogen, the samples have been analyzed for available nitrate (NO_3) and ammonia (NH_3) nitrogen which are quoted in parts per million (ppm). These figures have been used to calculate the level of soil mineral nitrogen in kg/ha in the profile submitted. Previous cropping, manure applications, rainfall and soil type must be taken into account when assessing future nitrogen applications.

RESULTS AND DISCUSSIONS

The potato crop has to get an adequate supply of all the essential nutrients.

There were analyzed the main soil available macro and micronutrients - results are presented in table 1 (availability guidelines values are varying according to the soil reaction/pH values). It can be observed from the table that:

- pH values are between 5,4 – 7,7. Lowering the high pH values should be of high importance to farmers although is not an easy task to accomplish;
- available nitrogen content is variable due to the fact that some of the farmers are applying various rates of mineral nitrogen fertilizers according to their fertilizing management plans. Nitrogen is often applied at rates greater than potatoes can immediately absorb/utilize - the nitrogen fertilizers efficiency in most of the cases is low and losses are important. The soil mineral nitrogen figures should not be used in isolation as there are a number of factors which will affect the accuracy of assessing the soil nitrogen supply.
- for the studied soil samples, the available phosphorous results are lower than or close to the potato guidelines, due to its retrogradation with the soil cations - phosphorus that is applied from the conventional fertilizers will be limited once it reaches the soil - the possibility of being more or less absorbed by the plant is depending on the soil's reaction and its compounds - up to 75% becomes insoluble / readily unavailable.

It is compulsory to adapt phosphorous nutrition schemes by using technological fertilizers based on a new generation of polymers for phosphorous retrogradation protection technologies and by using beneficial PGPR's (phosphate solubilizing bacteria);

- available potassium content is medium to high - farmers are using short crop rotation schemes and apply high quantities of potassium to the potato crop. Potatoes take up significant quantities of K and this nutrient play important roles in tuber yield and quality;
- generally speaking, for all the samples, magnesium and calcium most probably will not present deficiencies but excess magnesium may negatively impact the potassium availability;
- high copper values can determine possible interference with the availability of manganese. Leaf analysis will be required further during the vegetation period to determine their level – as in the case of other nutrients, leaf analysis is

one of the most important tools to determine crop's deficiencies and prevent them;
- sulfur soil level is low for most of the samples. Sulfur recommendations are based on avoiding deficiency, since S may have additional effects – sulphur fertilizers may increase yield and reduce tuber defects. Elementar sulfur and/or sulphates as potassium sulphate may be applied at seedbed preparation and/or in the vegetation period;
- boron is slightly low – an appropriate quality boron fertilizer can be used in the nutritional schemes considering its requirements and avoiding high doses;
- zinc application should be considered after foliar analysis like in the case of other deficient micronutrients;
- sodium level is not an issue for the moment for the studied samples;
- cation exchange capacity levels are showing good nutrient holding capacities and the organic matter content is low for most of the samples - the use of organic fertilizers/manure is further required.

CONCLUSIONS

The optimal pH value for increased soil nutrient availability is 6,5. Many soils used for potato production have become increasingly more acid over time due to use of ammonium containing fertilizers and leaching of cations from the rootzone.

Acid conditions are generally favored for potatoes in order to minimize the incidence of common scab (Streptomyces scabies), which is most widespread when soil pH is above 5.5. Use of liming amendments is often avoided to minimize scab. Controlling scab in this manner, however, can result in a soil pH that will cause nutrient imbalances. Once soil pH drops below 4.9, nutrient deficiencies and toxicities become more common. In particular, Mn and Al toxicity and P, K, Ca, and Mg deficiencies may occur in these low pH soils (Rosen C.J., 2020).

Manure is a source of macronutrients and micronutrients and can be used to help meet the nutrient needs of potato. Manure testing is recommended prior to application to any cropland - manure should be thoroughly mixed with the soil.

Factors to consider when deciding on the rate of N to apply include: variety, yield potential or goal, growing season, soil organic matter content, and previous crop. If manure is used, then an estimate of N availability from the manure should be incorporated into the overall N applied. In general, early maturing varieties and those grown for early markets require less N than late maturing varieties.

Too high a rate of N will delay tuber initiation and maturity leading to excessive vine growth at the expense of tuber growth. Delayed maturity can result in tubers with lower specific gravity. High N will induce vigorous foliage, which can lead to an increase in vine rot diseases. On the other hand, lack of N can increase the early blight infestations. In general, split applications of N are recommended for potatoes from both a production and an environmental standpoint. A portion of the N should be applied preplant or planting and the remainder at emergence and hilling.

Nitrogen uptake by the potato plant is highest during the tuber bulking stage. Split applications will generally improve N use efficiency by reducing leaching losses due to excessive rainfall and providing available N when it is needed for tuber growth.

Applications of N after hilling should be based on petiole nitrate analysis. Quality nitrogen fertilizers based on urease and nitrification inhibitors are required in order to prevent nitrogen losses by leaching and denitrification and environment pollution;

Phosphorus is very immobile in most soils. Weak acid soils are causing interferences on the phosphorous availability - good quality fertilizers protected from retrogradation are required.

Several new fertilizer materials have been designed to enhance fertilizer efficiency. The modes of action of these materials include: slow or controlled release to meet plant need in a more timely fashion, the addition of high charge-density materials that isolate nutrients from interfering elements and compounds; complexation or chelation of the nutrient to enhance solubility; and (iv) modification of the micro-site pH to enhance nutrient solubility (Hopkins B.G. et al., 2008).

As an example, the NUTRI-TOP NPK product range developed by CiCh Năvodari is including AMESAL, a polymer with a high cationic exchange capacity (its specific molecular structure enhances phosphorous availability and absorption by doubling fertilizer efficiency when coated onto phosphate fertilizers - due to its phosphorus enhancement technology, the phosphorus no longer gets retrograded into the soils, regardless of the soil's reaction).

Potassium has high influence on potato yield and quality. When soil tests are in the medium range or below, sufficient potassium should be added to meet the needs of potato crop.

Elemental sulfur can be used as a sulfur source. Elemental sulfur is not an immediately available form and must be oxidized by soil bacteria to sulfate before it is can be used by the plant. The oxidation of sulfate forms sulfuric acid and will have an acidifying effect on the soil. This process is relatively slow, especially when sulfur is top-dressed.

In the case of micronutrients, pesticide sprays may contain enough Cu and Zn to meet plant demands. Boron may be limiting in sandy soils; however, potatoes have a low demand for B and responses to applied B are not common. In addition, excessive B applications can be toxic. If B is needed, soil application is recommended because B applied to the foliage is not readily transported to the tuber. Potato responses to Mo are not well documented. Leaf/tissue analysis will be required further during the vegetation period to determine the nutrients' level – leaf analysis is one of the most important tools to determine crop's deficiencies and prevent them.

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Table 1

Soil available nutrient content analysis

Analysis / Sample no.	Guidelines	1	2	3	4	5	6	7	8	9	10
pH	*6,5*	5,5	6,1	6,7	7,7	5,8	5,4	5,6	7,2	6,1	6,4
Nitrogen (Kg/ha) Ammonium N (ppm) Nitrate N (ppm)	-	145 1,6 46,7	39 1,4 11,6	31 2,4 7,8	35 1,1 10,5	46 1,5 13,7	37 1,2 11,0	23 0,7 6,9	5 0,8 0,8	14 0,8 3,9	41 0,7 12,9
P (ppm)	*16-30*	25	20	44	14	24	21	20	32	30	12
K (ppm)	*51-121*	305	283	610	307	161	202	231	256	247	156
Mg (ppm)	*51 - 100*	322	244	195	165	204	179	180	100	184	237
Ca (ppm)	*1600-2000*	3040	3787	4312	4889	2374	1726	1887	2550	2646	3028
S (ppm)	*10*	10	4	12	8	2	2	3	8	2	5
Mn (ppm)	*10-20-105-110*	89	66	76	182	98	87	76	124	79	87
Cu (ppm)	*2,1*	12,4	11,4	15,1	17,2	10,6	5,6	6,5	6,6	6,3	8,1
B (ppm)	*1,6-2,1*	1,21	1,34	1,51	1,78	1,23	0,96	1,1	1,25	1,15	1,22
Zn (ppm)	*4,1*	2,1	2,2	7,0	4,1	2,0	1,5	1,3	1,7	1,8	2,2
Mo (ppm)	*0.30 - 0.60*	0,24	0,32	0,25	0,21	0,38	0,46	0,44	0,52	0,34	0,32
Fe (ppm)	*200*	473	494	435	415	387	372	372	174	277	317
Na (ppm)	*90*	36	29	33	36	28	17	21	19	31	33
C.E.C. (meq/100g)	*15*	25,9	26,5	30,2	26,7	18,8	16,6	16,3	15,0	19	21,2
E.C. (μS/cm)	*2610*	2070	1990	2030	2070	1990	1950	1980	1990	2400	2300
Mat. org. DUMAS (%)	*3,00*	3,4	3,5	3,7	3,1	2,1	1,8	2,1	1,8	1,95	2,0

(green)	*Normal*	(red)	*Very low*	(yellow)	*Low / Slightly low*	(orange)	*High / Very high*