Soil Nutrient Status in Selected Potato Growing Districts of West Shoa Zone as Determined Through Different Methods

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Abstract

A study was conducted in West Shoa Zone of Oromiya regional state to investigate the soil nutrient status of potato fields in major potato growing districts. Soil samples, from a depth of 0-30 cm were collected from six districts namely Jeldu, Tikur Inchini, Jibat, Cheliya, Ejere and Wolmera districts during the *Belg* (March-June) cropping season pf 2012 to analyse for nutrient contents. Soil pH was determined using both water and 0.01 M calcium chloride solutions. The ratio between the soil and the water/calcium chloride solution was mainatained at 1: 2.5. The organic matter (OM) content of the soil was determined using both Walkley and Black and CNS methods. Available phosphorus content was determined using both CAL and Olsen methods. Potassium content of the soil was determined both by extracting the potassium with Calcium Acetate Lactate (CAL) solution as well as by 1 M ammonium acetate solution. Total nitrogen and sulphur content was determined by using CNS autoanalyzer. Results showed that the pH in most soils of the surveyed districts ranged from moderately acidic to strongly acidic. 51.2% and 36.6% of the sampled field sites in all the districts had OM content rated as *very high* and *high*, respectively. 58.5% of the sampled field sites had a CAL-K value in the *very high* class and above. 56% of the sampled field sites had an ammonium acetate extractable K content in a class ranging from *moderately high* to *very high.* 41.5% and 56% of the sampled field sites in all the districts had total nitrogen content in *high* and *medium* classes, respectively with only 2.5% in the *low* class. Likewise, 17%, 9.8% and 68.3% of the surveyed fields showed *very high*, *high* and *medium* class total sulphur content, respectively. In conclusion, the status of all other soil nutrients of the surveyed area was in a good condition except for phosphorus where nearly 70% of the soil phosphorus status was rated as *low, very low* and *extremely low* according to Olsen P test.

Key words: Available phosphorus, available potassium, total nitrogen, total sulphur, organic matter content, soil pH

Introduction

In Ethiopia, potato growers pay less attention to soil fertility management (Gildemacher *et al.*, 2009) and this has been one of the major factors constraining potato productivity on farmers field in the country creating a huge gap between actual yield and potential yield (Elmar, 2013). In the central highlands of Ethiopia, where farmers grow potato twice a year, a conspicuous decline in the soil fertility status is being observed since the concept of maintenance fertilization is absent among farmers and crop residues are usually removed from the field further worsening the situation. Attempts have been made in the past as well as currently to improve Ethiopian soils productivity through encouraging the use of mineral fertilizers. However, following the government withdrawal from fertilizer subsidy, the application of fertilizer, especially by resource poor farmers has tremendously declined due to escalated fertilizer price thus further posing a negative impact on soil fertility and hence on crop yield.

An important aspect of soil fertility management, which is often overlooked, is to decide the appropriate fertilizer type and rate to use, based on soil test results. The availability of limited number of soil testing laboratories in the country and their limited capacity could be the reason to until very recently remain with blanket fertilizer recommendations for all crops. However, it is significant to note that fertilizer response is directly related to the nature of soil, emphasizing that soil varying in fertility status results in different crop response to applied fertilizers (Bashour and Sayegh, 2007). Fertilizer recommendation should also consider textural classes of soil as nutrients can easily be lost through leaching in sand dominated soils than clay dominated ones (MAFF, 2000). It was with this assumption that most European countries and Americans follow soil nutrient index based fertilizer application (MAFF, 2000) for soils of different textural classes. A sound soil fertility management programme should provide crops with an adequate amount and in balanced proportion of all essential nutrients to attain optimum crop yields and crop quality and this call for determination of soil nutrient contents and their textural classes before running into recommendations.

Although, the application of mineral fertilizers has been reported to tremendously increase potato growth and yield (Berga et al., 1994), the type and quantity of fertilizer to be applied for economically acceptable yield cannot be known unless the initial soil fertility regime of a specific area is determined through soil testing. Moreover, the national blanket recommendation for the crop which is currently being used throughout the country is not based on local soil conditions and undermines the concept of economics of fertilizer application. This study is, therefore, undertaken to partly address some of these gaps at least in some field sites of selected districts of West Shoa Zone. The objective of the study was, therefore, to evaluate the nutrient status of soils in the major potato growing areas of Western Shoa Zone to lay a baseline information for soil nutrient index based suitable fertilizer recommendations for higher and sustainable crop yield in the sub-region.

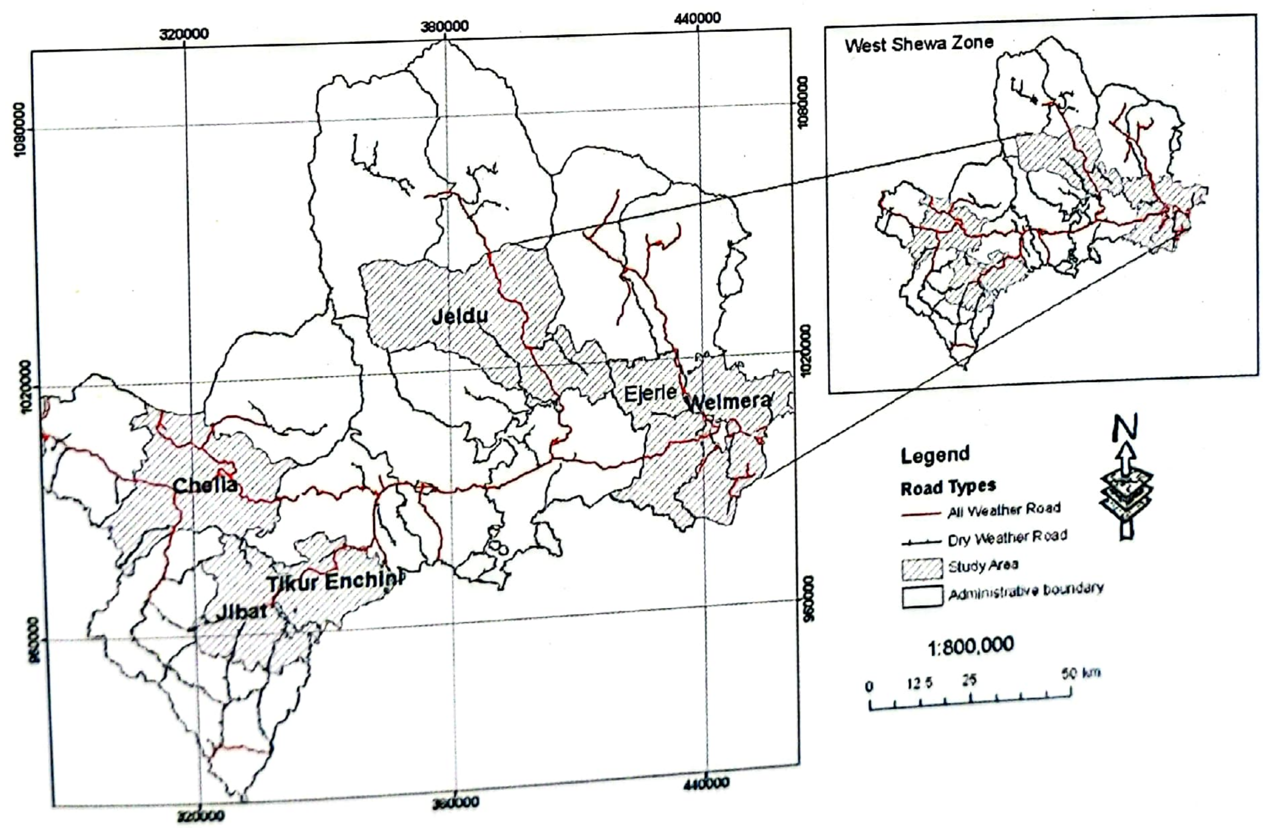
Materials and Methods

Description of the study area

The study was conducted during the *Belg* cropping season (March-June) of 2012. The study districts were all located in the highland parts of West Shoa Zone (Figure 1). In terms of climatic condition, the study area is characterized as given in Table 1.

Table 1: Important meteorological and other data of the study area

District	Annual Average Total Rain fall (mm)	Annual Average temperature (^{o}C)	Altitude Range (masl)
Jeldu	812-699	17-25	1900-3206
Tikur-Inchini	1000-1800	6-24	2200-3023
Jibat	800-1500	18-24	1600-3200
Cheliya	900-1400	10-25	1500-3051
Ejere	900-1200	22-28	2060-3185
Welmera	760-1062	7-24	2400



Source: West Shoa Zone Agriculture Office

Figure 1: Map of the study districts

Soil sample collection

Both soil and plant samples were collected from five major potato growing districts of West Shoa Zone, Ethiopia namely Jeldu, Tikur Inchini, Shenen, Cheliya and Wolmera districts during the *Belg* (March-June) cropping season of 2012. From each district 10 to 11 field sites which were at a distance of 3-5 km from each other were sampled except for Tikur-Inchini and Shenen where 10 samples were collected for both districts. The soil samples (0-30 cm depth) were taken into polyethylene bags in a zig-zag manner from 10-15 spots per field site using auger and later on made into one composite sample. The soil samples were immediately air dried and sieved through a 2 mm sieve.

Determination of soil parameters

a. Determination of soil pH

Soil pH was determined using both water and 0.01 M calcium chloride solutions according to Peter et. al. (2011). The ratio between the soil and the water/calcium chloride solution was mainatained at 1: 2.5. With both methods 20 g of soil was mixed with 50 mL of the respective solution.The content was stirred for few minutes and the solution was allowed to stand for about 2 hrs. After clear suspension was obtained the portable pH meter was calibrated using a standard pH buffer solutions (7 and 4). The calibrated pH meter electode was then immersed into the suspension and the reading was recorded.

b. Determination of soil organic matter content

The organic matter (OM) content of the soil was determined using Walkley and Black method (Walkely and Black, 1934) and CNS method. With the Walkley and Black method the amount of Ferrous sulphate solution used for back titrating the excess dichromate was recorded and used for carbon estimation. With CNS method 20 mg soil sample was put in an Aluminium foil, wrapped up and heated to a temperature of 1200^{o}C using Tungsten (III) oxide as a reaction catalyzer in the presence of oxygen supply. The amount of carbon in the sample was determined using CNS autoanalyser (Elemetar Vario III). The organic matter content was calculated from the carbon content value obtained by multilying with a factor 1.724 with the assumprion that organic matter contains 58% C.

Determination of soil nutrient content

Available phosphorus content in the soil was determined using both CAL method (Schüller,1969) in which Calcium Acetate and Lactate (composed of calcium lactate pentahydrate, calcium acetate hydrate and acetic acid) solution was used as an extractant and the Olsen method (Olsen et al., 1954) in which sodium bicarbonate (0.5 M $NaHCO_3$ at a pH=8.5) was used as an extracting solution. P concentration in the extract was measured using spectrophotometer (µQuant MQX200) at 405 and 882 nm for CAL and Olsen methods, respectively following addition of appropriate color reagents. Likewise, the potassium content of the soil was determined both by extracting the potassium with Calcium Acetate Lactate (CAL) solution as well as by 1 M ammonium acetate solution according to Warncke and Brown (2007). Both the potassium extracted using CAL solution and 1 M ammonium acetate solution was measured using flame photometer (Eppendorf Elex 6361, Flammenphotometer). The total nitrogen and sulphur content was determined by using CNS autoanalyzer (Elementar Vairo EL III) in which 20 mg soil sample was put in an Aluminium foil, wrapped up and heated up to a temperature of 1200^{O}C using Tungsten (III) oxide as a reaction catalyzer in the presence of oxygen supply as described above for carbon.

Results

Soil pH

The summarized results of the soil pH measurement for all the districts are presented in Figure 2. The soil pH determined using 1:2.5 soil: $CaCl_2$ suspension was generally lower as compared to the ones determined using 1:2.5 soil: water suspension (data not shown). According to Soil Survey Division Staff (1993) soil reaction classification, the soil pH results in water suspension showed that 22% of the soils surveyed were characterized as very strongly acidic, 34% as strongly acidic, 27% as moderately acidic and the rest 17% of the soil as being slightly acidic. On the other hand, according to the same classification, the soil pH results in 0.01 M calcium chloride suspension showed that 12% of the soils were extremely acidic, 41.5% were very strongly acidic, 27% were strongly acidic whereas 19.5% were moderately acidic for the whole survey area (Figure 2).

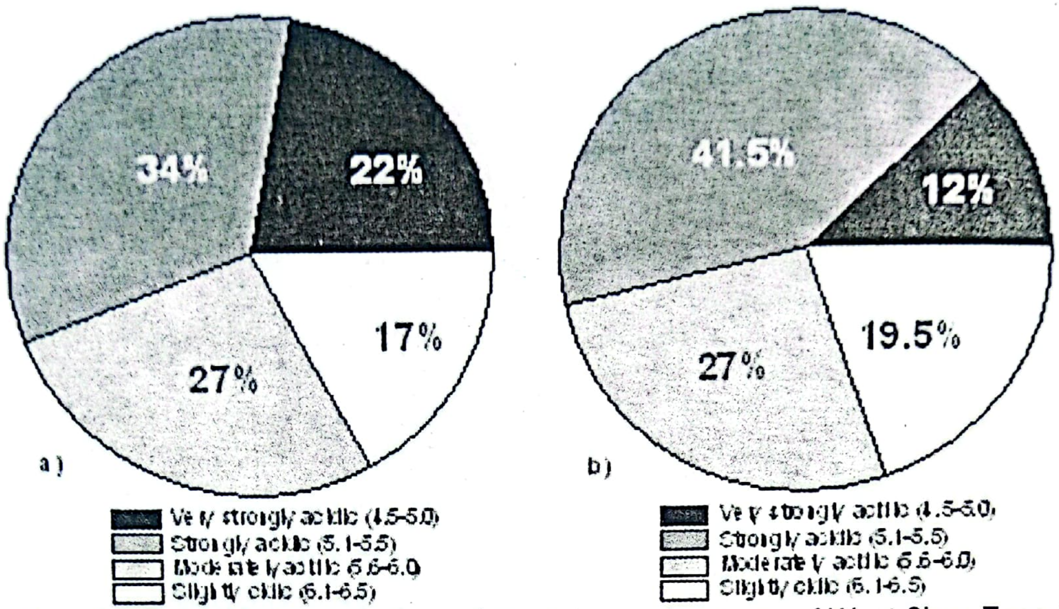


Figure 2: Reaction of soils in pH classes in the major potato growing areas of West Shoa Zone (n=41). (*(a) in water suspension and (b) in 0.01 M calcium chloride*)

Soil organic matter content

The summarized results of soil organic matter (OM) content percentage of the surveyed districts is presented in figure 3. Determination of soil organic matter using both methods resulted in similar results. As a result only the OM content determined through CNS was presented in figure 3. Results indicated that 51.2% and 36.6% of the surveyed sites has a soil organic matter content falling in the category of very high and high, respectively.

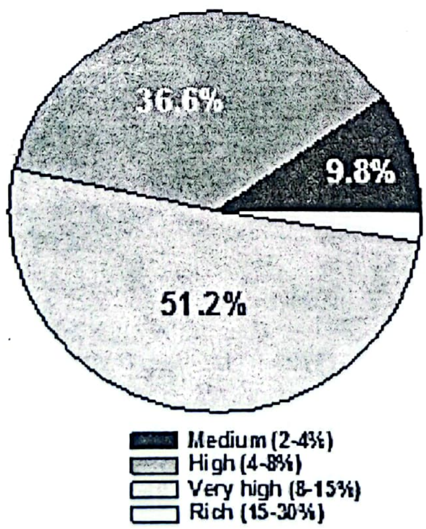


Figure 3: Classification of soils of surveyed area in terms of organic matter content

Soil available phosphorus

Available phosphorus content of soils determined through both Calcium Acetate and Lactate (CAL) method and Olsen method are presented in figure 4.

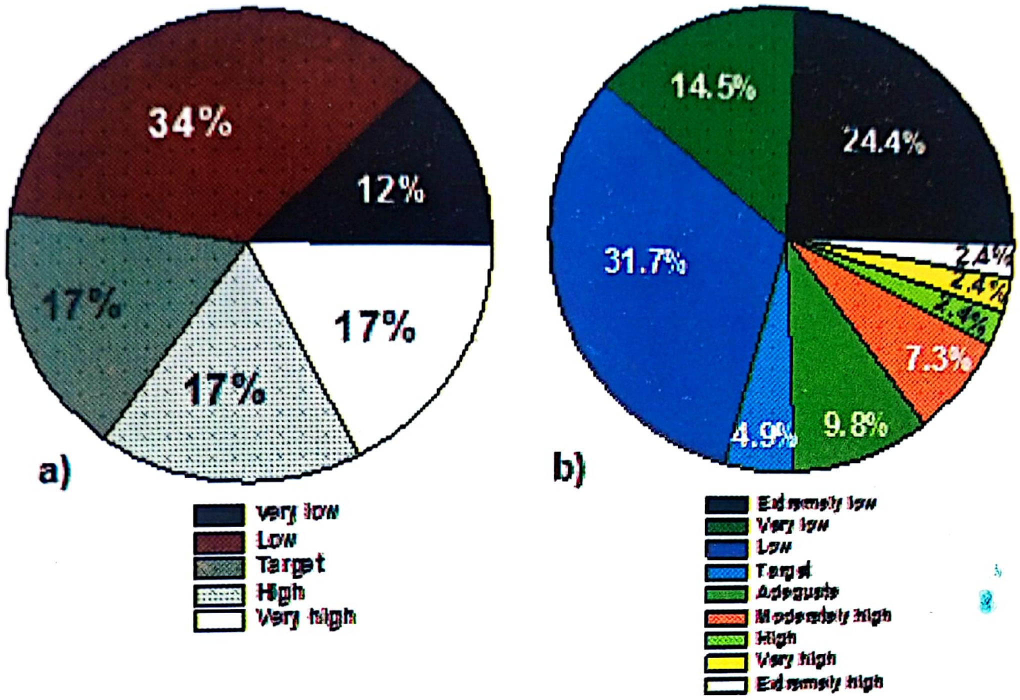


Figure 4: Classification of soils of surveyed area in terms of CAL-P index (a) and Olsen P index (b)

According to CAL-P soil class indexing, 46% of the field sites surveyed had *low/very low* CAL-P value whereas 54% had CAL-P value ranging from *target* to *very high* classes. On the other hand, according to DEFRA (2010) of Olsen P indexing, 70% of the field sites surveyed had Olsen P value from *low* to *extremely low* range whereas 30% of the field sites had Olsen P value from *target* to an *extremely high* range (Figure 4).

Soil potassium contents

Data on potassium content in the soil extracted with CAL and ammonium acetate solutions are presented in Figure 5.

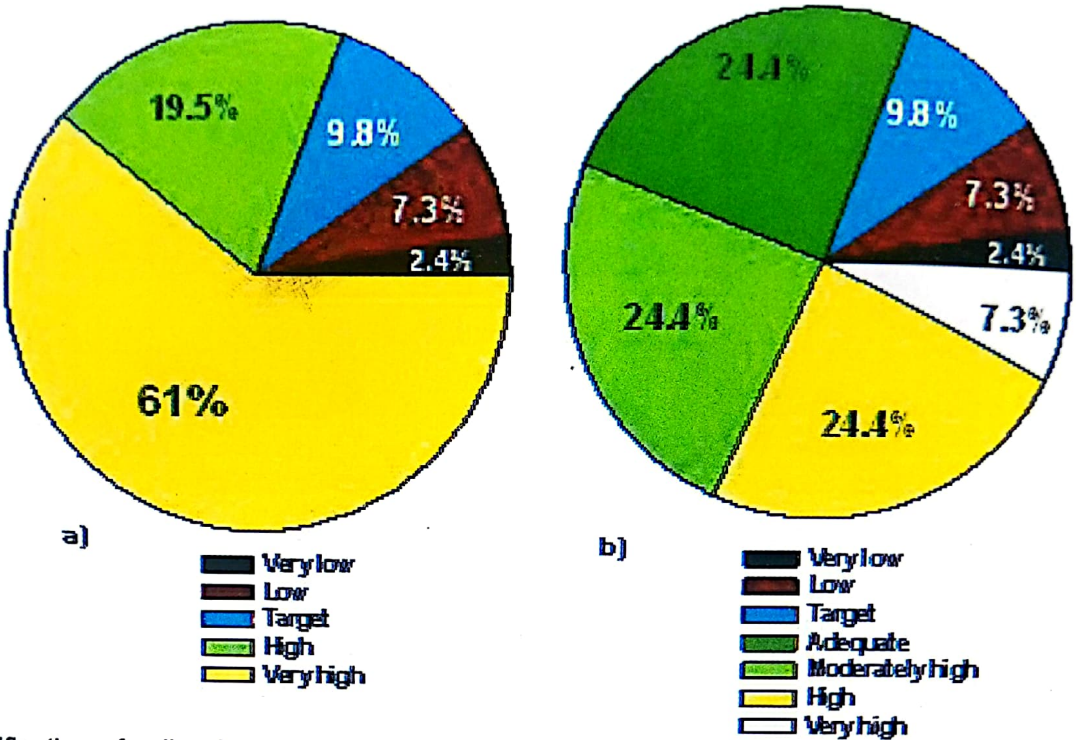


Figure 5: Classification of soils of surveyed area in terms of CAL-K index (a) and ammonium acetate extractable-K index (b)

58.5% of the sampled fields had a CAL-K value in the *very high* class or above indicating that more than half of the sampled field sites were very rich in potassium content. According to DEFRA (2010) ammonium acetate extractable soil potassium indexing, 9.8% of the sampled field sites had *very low* to *low* ammonium acetate extractable K content. Another 9.8% of the sampled field sites had ammonium acetate extractable K content of a *target* class whereas 56% of the sampled field sites had an ammonium acetate extractable K content in a class ranging from *moderately high* to *very high* (Figure 5).

Nitrogen and Sulphur contents in soil

41.5% and 56% of the sampled field sites in all the districts had total nitrogen content in *high* and *medium* classes, respectively with only 2.5% in the *low* class total nitrogen content (Figure 3). Most of the sampled field sites in all the districts (68.3%) had *medium* class total sulphur status and 17.1% *very high* class total sulphur status (Figure 6).

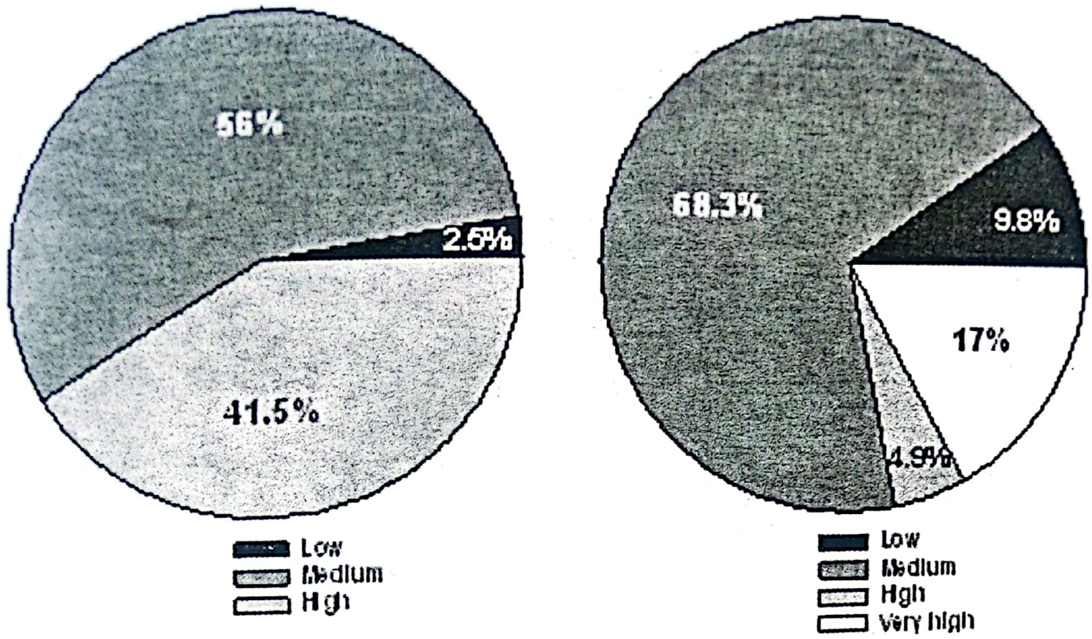


Figure 6: Classification of soils of surveyed area in terms of total nitrogen (left) and sulphur (right) content

Discussion

The soil pH of all the surveyed districts was in the acidic range. In such lower soil pH availability of nutrients such as phosphorus can negatively be influenced unless the soils are reclaimed through lime application. Lower soil pH reduces availability of phosphorus for plant uptake since phosphorus precipitate as Al or Fe phosphates. Such lower pH can also result in toxicity of micronutrients such as manganese. Organic matter content of the sampled field sites area was generally high almost for all the districts. Such high OM content in the surveyed potato fields might be due to the fact that potatoes were grown very close to the residential houses making such fields more accessible to farmers to apply manures and composts to their fields enhancing the OM content. The highly significant positive relationship ($r= 9.05$, $P<0.001$) observed between OM contents determined through CNS and Walkley and Black methods indicate that both methods (Figure 7) can reliably be used for organic matter determination.

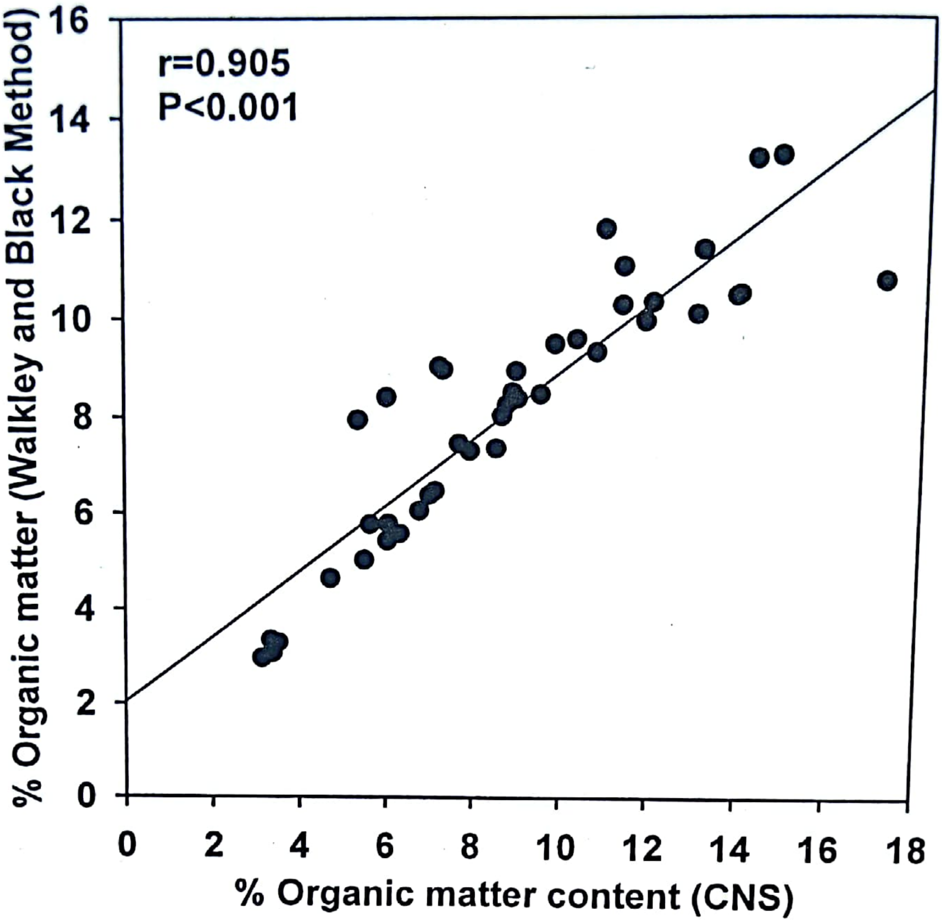


Figure 7: Relationship between OM content determined through CNS and Walkley and Black methods

The CAL-P values were generally higher compared to Olsen P values although the factor of difference varied with field sites and districts probably due to variation in soil characteristics such as soil pH (Figure 1) and soil texture (data not shown) as suggested by Mallarino (1995) and Wolf and Baker (1985). However, despite difference in the actual amount of P extracted, the CAL-P and Olsen P values significantly correlated (Figure 8). In agreement with the present observation, Wolf and Baker (1985) also observed that Olsen method was able to extract only half of the P that was extracted by Bray-1 and accounted the difference between the two methods to difference in soil texture. The fact that most of the sampled field site showed a *very low* and *low* P class demonstrates that most of the soils in the major potato growing districts of West Shoa Zone were poor in available phosphorus, which might be related to the acidic nature of the soil since in such soils phosphorus can be fixed in the form of Al and Fe-phosphates or strongly adsorbed to oxides or hydroxides of these elements. The potassium extracted using 0.01 M ammonium acetate solution was higher than the ones extracted using CAL solution, on average by a factor of 1.7. The potassium content determined through both extraction methods however, showed highly significant positive correlation (Figure 8). Most of the field sites surveyed had potassium content above the *target level* despite the absence of potassium fertilizer application in all the districts. This indicates that the parent material from which the soil was formed was rich in potassium. Some soils even had *very high* potassium content.

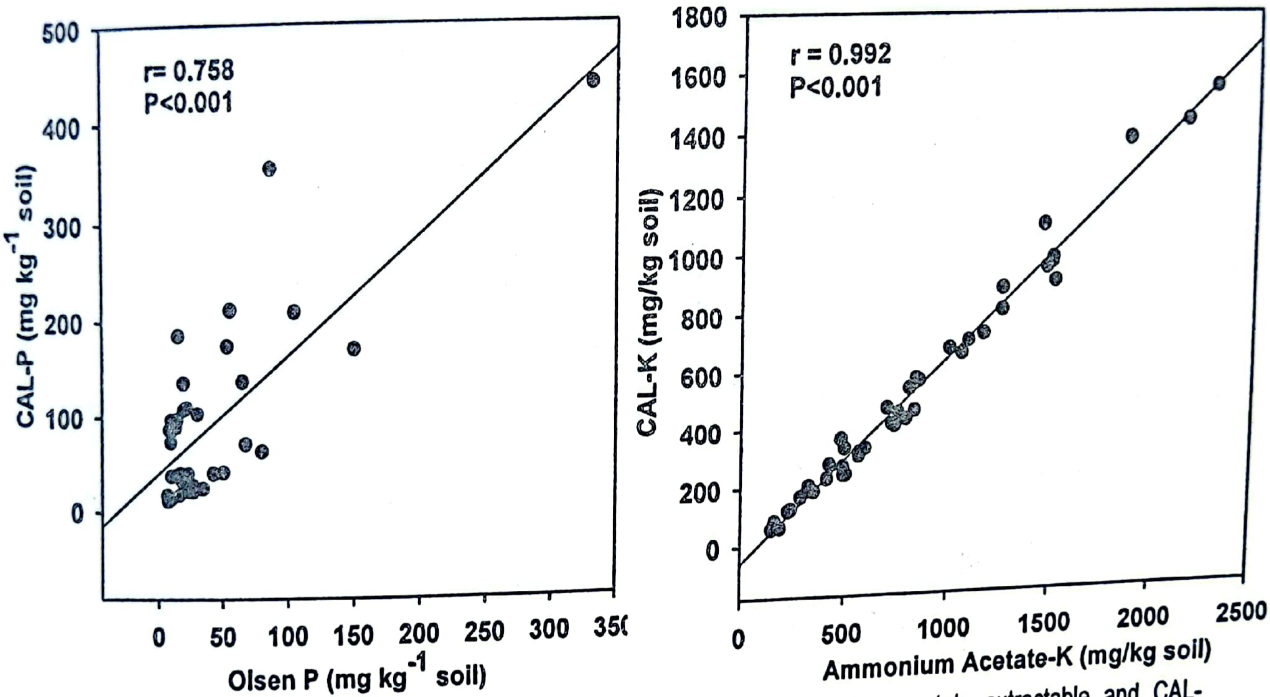


Figure 8: Relationship between CAL-P and Olsen-P (left) and ammonium acetate extractable and CAL-extractable soil potassium content (right)

The total nitrogen status of most of the soils (97.5%) of the study area belonged from *medium* to *high* class (figure 5). In principle the organic fraction of soil total nitrogen can further enhance plant available nitrogen content of the soil through mineralization to sustain higher crop yield. In this study, a highly significant positive relationship was found between soil total nitrogen content and soil organic matter content (figure 8). To the contrary, the total sulphur content of the soil was not related to organic matter content (figure 8) and this may indicate that most of the total sulphur probably composes of the inorganic fractions. Therefore, the relatively higher soil total sulphur status in many of the sampled field sites could be not be attributed to the higher OM content of the soil since the two parameters did not show any relationship.

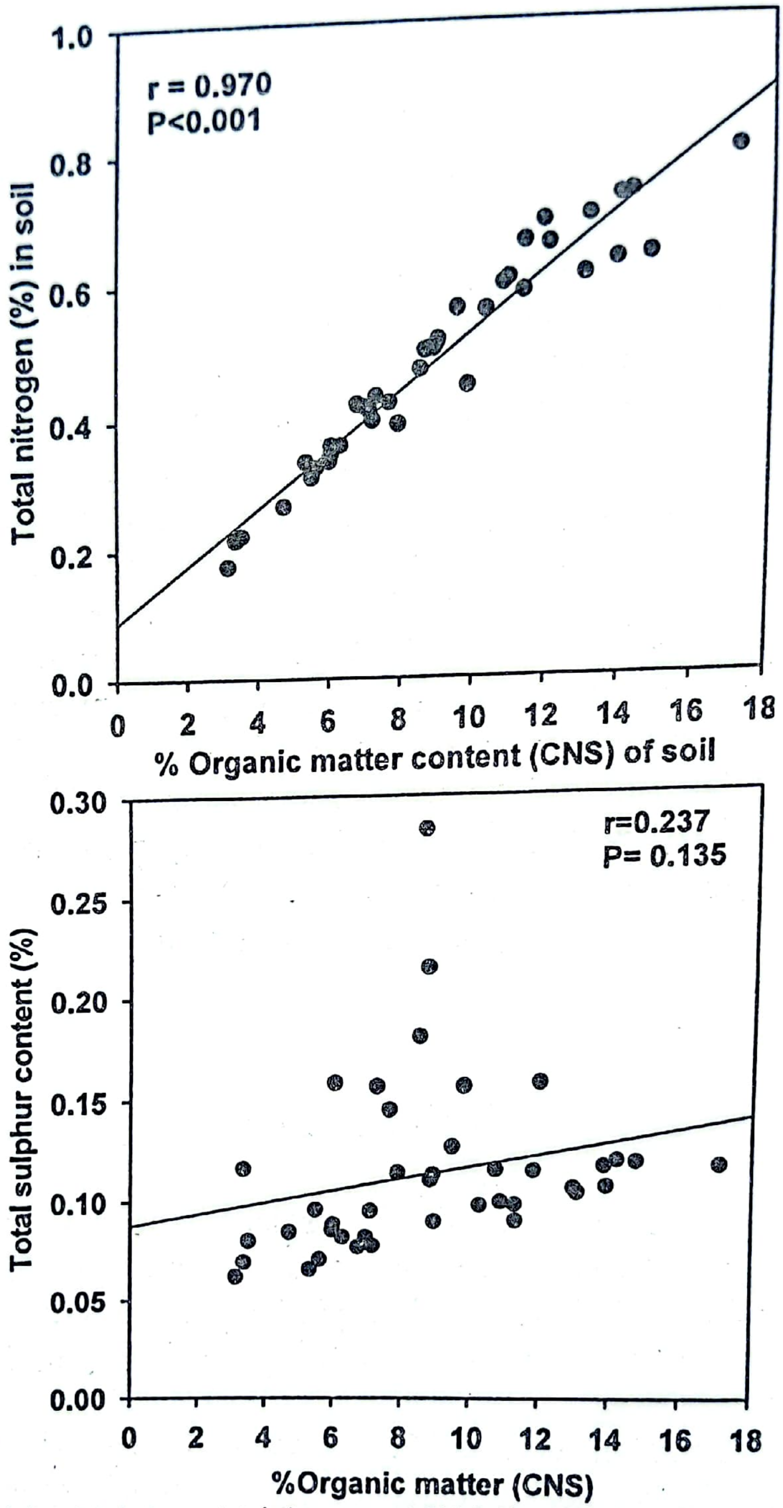


Figure 9: Relationship between total nitrogen and OM (left) and total sulphur and OM (right)

Conclusion and Recommendations

The soil pH of all the surveyed area was in the acidic range with most of the soils (80.5%) falling either in the strongly acidic, very strongly acidic or extremely acidic range. The results of the soil analysis revealed that the status of all other soil nutrients of the surveyed area was in a good condition except for phosphorus where nearly 70% of the soil phosphorus status was rated as *low, very low* and *extremely low* according to Olsen P test. Only

9.5% of the surveyed soil was rated as having *low* or *very low* potassium status whereas the rest 80.5% of the surveyed soils were rated as having potassium status of *target* value and above. 97.5% and 91.2% of the surveyed soil had a total nitrogen and total sulphur status ranging from *medium* to *high/very high* classes, respectively, indicating sufficiency of these nutrients in the soil. Total nitrogen in the soil showed highly significant positive relationship with organic matter content while total sulphur didn't. Since most of the surveyed area had a low soil pH, which can result in deficiency of phosphorus and toxicity of manganese and aluminium, multi-location field experiment should be conducted in low pH spot areas to investigate liming effect on plant growth and P availability. Since few pocket areas in the current investigation showed lower potassium content, crop response to potassium fertilizer application in these particular areas should be assessed through conducting multi-location field experiments. Since the organic matter content of the surveyed area was high for most field sites surveyed, this need to be proved if it also applies to other crop fields through assessing soil OM content of the soils at various radius from the residential areas of different farm holdings. Since the current result showed the availability of quite huge amount of both total nitrogen and readily available N forms in the soils, field trials on estimation of net N mineralization shall be executed.

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