

Evaluation of Different Extractants for Estimation of P, K, Ca, Mg & Micro-nutrient Cations in Soils of Kashmir Valley

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2022

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Thesis

Submitted to

The Faculty of Agriculture

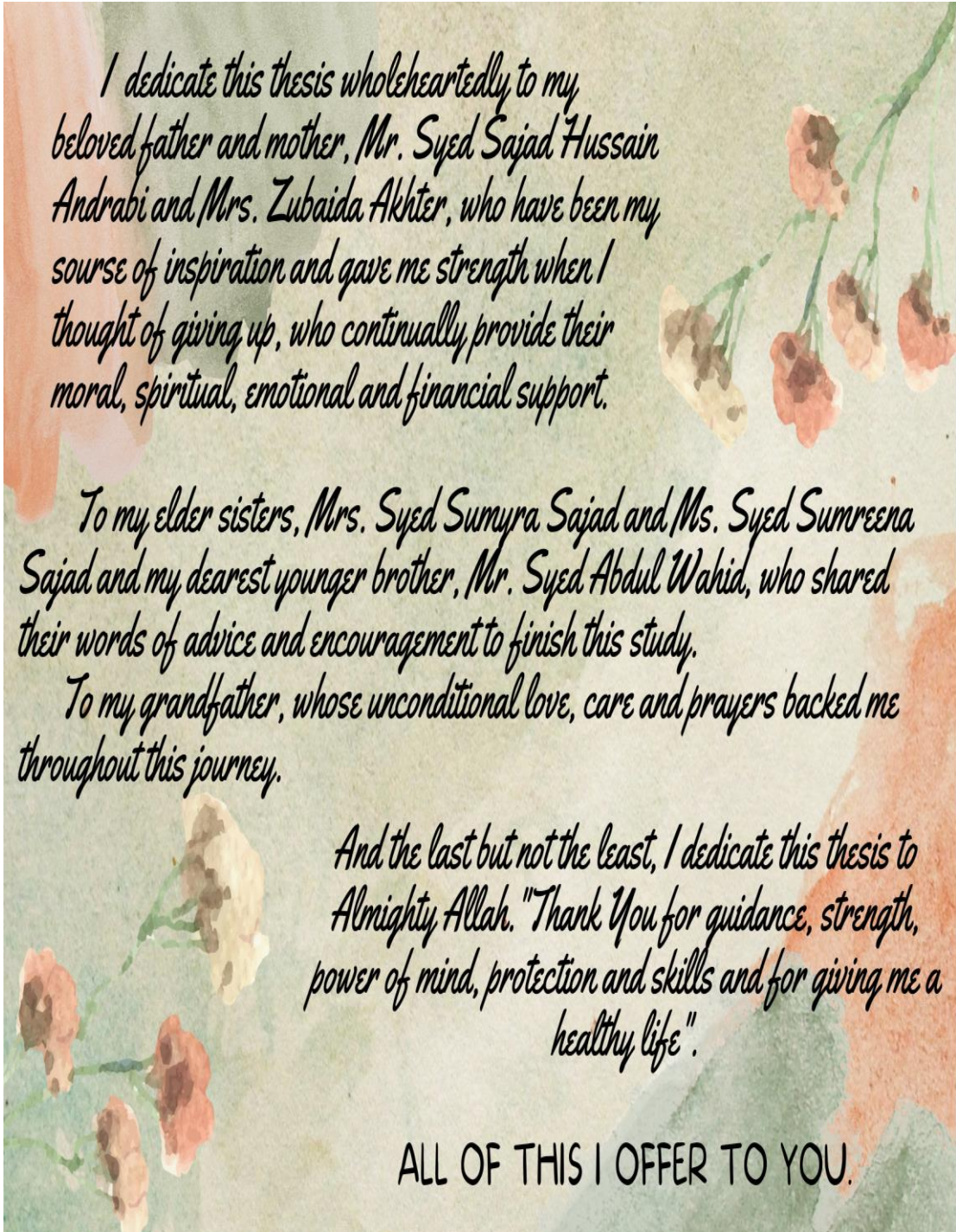
Sher-e-Kashmir

University of Agricultural Sciences & Technology of Kashmir
in partial fulfilment of requirement for the award of the degree of

Master of Science in Agriculture

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2022



I dedicate this thesis wholeheartedly to my beloved father and mother, Mr. Syed Sajad Hussain Andrabi and Mrs. Zubaida Akhter, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, spiritual, emotional and financial support.

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And the last but not the least, I dedicate this thesis to Almighty Allah. "Thank You for guidance, strength, power of mind, protection and skills and for giving me a healthy life".

ALL OF THIS I OFFER TO YOU.

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University of Agricultural Sciences and Technology of Kashmir
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Certificate -I

This is to certify that the thesis entitled, “**Evaluation of Different Extractants for Estimation of P, K, Ca, Mg & Micro-nutrient Cations in Soils of Kashmir Valley**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Soil Science)**, to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Syed Andleeba Jan (Regd. No. MSA-2020-1383)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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We, the members of the Advisory Committee of **Ms. Syed Andleeba Jan (Regd. No. MSA-2020-1383)**, a candidate for the degree of **Master of Science in Agriculture (Soil Science)** have gone through the manuscript of the thesis entitled, **“Evaluation of Different Extractants for Estimation of P, K, Ca, Mg & Micro-nutrient Cations in Soils of Kashmir Valley”** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, “**Evaluation of Different Extractants for Estimation of P, K, Ca, Mg & Micro-nutrient Cations in Soils of Kashmir Valley**” submitted by **Ms. Syed Andleeba Jan (Regd. No. MSA-2020-1383)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Soil Science)** was examined and approved by the Advisory Committee and External Examiner on **03-12-2022**

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Title of the Thesis : **“Evaluation of Different Extractants for
Estimation of P, K, Ca, Mg & Micro-nutrient
Cations in Soils of Kashmir Valley”**

ABSTRACT

The existing chemical methods for determination of available soil nutrients are effective and accurate, however, they involve use of separate analytical methods, extractants and processing which makes them costly, laborious and time consuming. This emphasizes on need of an alternative multi-nutrient extractant solutions for simultaneous determination for more than one nutrient. Therefore, present study was undertaken to compare the suitability of multi-nutrient extractants *viz.*, ammonium bicarbonate-diethylenetriaminepentaacetic acid (AB-DTPA) and acid ammonium acetate-ethylene diamine tetra acetic acid (AAAc-EDTA) with standard methods for determination of P, K, Ca, Mg & micronutrient cations. The soil samples were collected randomly from different parts of valley and categorized on the basis of pH into <6.50, 6.50-7.50, >7.50. In soils having pH < 6.50 Bray extracted more P than other extractants but all extractants were at par with each other. In case of soils with pH 6.50 -7.50 and >7.50, Olsen method extracted more P but it was also same as extracted by AAAc-EDTA. Among K extractants, NH₄OAc extracted more K followed by AB-DTPA and AAAc-EDTA at all pH ranges. In case of Ca and Mg, AAAc-EDTA extracted maximum Ca & Mg followed by Versenate titration & AB-DTPA. For micronutrient cations, AB-DTPA extracted more as compared to CaCl₂-DTPA and AAAc-EDTA for

extraction of Fe and Cu. In case of Zn, AB-DTPA extracted more Zn than other methods at pH<6.50 but at pH 6.50-7.50 and >7.50, CaCl₂-DTPA extracted more Zn followed by AB-DTPA. Correlation studies revealed that a positive and highly significant correlation was observed between AB-DTPA and AAAC-EDTA with standard methods for P, K, Ca, Mg and micronutrient cations except for Zn which had significant correlation with AAAC-EDTA only. Hence at all pH ranges, there is a possibility of using AAAC-EDTA by replacing individual extractants for determination of more than one available nutrient in order to save time, money and energy.

Key words: - Available nutrients, micro-nutrient cations, multi-nutrient extractants.

Signature of Student

Signature of Major Advisor

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Ms. Syed Andleeba Jan

Place: Wadura, Sopore

Dated:

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Chapter-1

INTRODUCTION

Modern world is facing two big challenges. The first is an ever- increasing population and the second is degrading environment. Food consumption is anticipated to increase by 2-5 times in coming decade and at the same time land resources are shrinking. In last century, crop yield was enhanced by increasing land under cultivation and by using inputs like synthetic fertilizers. However, the intensification of agriculture has resulted in deteriorating soil health, increasing nutrient imbalances and declining soil fertility (Selim, 2020). The scenario is clear that feeding millions in the future will require producing more from less which means increase in production has to be achieved by increase in productivity (production per unit area) (Maximilliam *et al.*, 2019). Productivity can be improved only if soils are in optimum state of fertility (Parr *et al.*, 1994). The higher production goals can be achieved through replenishing of nutrients to the soil by proper application of fertilizers based on ascertaining the soil nutrient status. Optimal application of nutrients is important to improve productivity as increasing negative nutrient balance is now considered a big reason limiting crop productivity and quality (Patsios *et al.*, 2021). To ensure proper nutrition of plants, it is important to work out the index of available nutrients in soil and quantify the amount of additional nutrients that must be added to soil for growing a particular crop (El-Ramady *et al.*, 2014). The cost of fertilizers is key determinant of profitability of agriculture especially for small and marginal farmers. The usage of fertilizer in India has been rising steadily since 2002 until 2011. The fertilizer response ratio, however, exhibits a declining trend. The diminishing fertilizer response ratio is a sign that soil fertility is becoming less responsive to fertilizer treatment. (Anonymous, 2019). Thus, it is very important for farmers to have a constant check on their farm soils which is only possible if soils are continuously tested.

Different chemical methods are used for estimation of macro and micro nutrients in soil. Existing chemical methods for extracting different nutrients are quite effective and precise in determining the available content of different nutrients in the soil but they require separate extractants and extraction procedures (Sengupta and Dey, 2019). Therefore, these procedures are time consuming, laborious, cumbersome and expensive because of more use of chemicals, glassware, and energy. Multinutrient extractants provide a good solution to address these problems as multiple nutrients can be extracted simultaneously (Bibiso *et al.*, 2015). However, the suitability and precision of these extractants for determining available nutrients must be confirmed using established analytical methods and their relationship with soil parameters (Sharma *et al.*, 2018). Among nutrients; phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and micronutrient cations form the crucial component of the major soil testing program. Olsen and Bray methods for determination of available phosphorus, ammonium acetate method for determination of available potassium, versenate titration method for available calcium and magnesium, and diethylene triamine penta acetic acid (DTPA) extraction method for available micronutrients are the most commonly used methods for determining different nutrients in soils. Nevertheless, ammonium bicarbonate-diethylenetriaminepentaacetic acid (AB-DTPA) and acid ammonium acetate-ethylene diamine tetra acetic acid (AAAc-EDTA) are the two multinutrient extractants that have been reported to extract all the above nutrients including available P, K, Ca, Mg and micronutrient cations iron (Fe), manganese (Mn), copper (Cu) and zinc (Zn) simultaneously in alkaline and acidic soils, respectively (Sharma *et al.*, 2018, Madurapperuma *et al.*, 1999). The ammonium bicarbonate-diethylenetriaminepentaacetic acid (AB-DTPA) was used for the simultaneous extraction of labile NO₃-N, P, K, Zn, Fe, Mn and Cu from neutral and calcareous soils. Later, it was also used for the extraction of potentially toxic elements such as cadmium (Cd), nickel (Ni), selenium (Se), arsenic (As), boron (B), molybdenum (Mo) and sulfur (S) from soils, minespoils and soils treated with sewage sludge (Soltanpur and Schwab, 1977). This method was further tested for 481 soils with

varying chemical properties and the results correlated well with 0.5 M NaHCO₃ extractable P. It also offers the benefit of being able to extract micronutrients at the same time (Soltanpur and Workman, 1979). Another multi-nutrient extractant, acid ammonium acetate-ethylene diamine tetra acetic acid (AAAc-EDTA) was reported to be capable of simultaneously extracting both available macro and micronutrients (Lakenen and Ervio, 1971). It yielded better correlation for available P, K, Ca, Mg and micronutrient cations compared to that of commonly followed standard methods across the globe (Sharma *et al.*, 2018, Madurapperuma *et al.*, 1999). This approach was deemed unsatisfactory for P testing as it is assumed that the extract is destructive to hydrous Fe and Al oxides. Thus, the amount of P extracted by AAAc-EDTA may overestimate the amount of available P, especially in acid soils (Sareela and Sippolo, 1990). Numerous studies have been done on the suitability of these extractants for assessing the availability of nutrients in various regions of the world, but very little is known about their suitability in India, particularly in the soils of Kashmir. For instance, AB-DTPA test is rarely employed in Indian laboratories, possibly, due to lack of interest in the micronutrient analysis. However, the micronutrient determination is likely to attain more attention in future because of increased micronutrient deficiencies in different crops (Sharma *et al.*, 2018). So, soil testing laboratories are now considering this issue seriously for advisory services. Also, as discussed earlier multinutrient extractants serve as suitable alternative to traditional methods as they are less time consuming and cost effective. Keeping in view the importance of soil testing and need for some less cumbersome methods for determining various macro and micronutrients in soil, current study entitled “Evaluation of Different Extractants for Estimation of P, K, Ca, Mg & Micro-nutrient Cations in Soils of Kashmir Valley” was taken with the following objectives:

1. To compare different soil extractants used for determination of P, K, Ca, Mg and micronutrient cations (Fe, Cu, Mn and Zn)
2. To study the relationship of extracted nutrients with soil properties

Chapter-2

REVIEW OF LITERATURE

For the extraction of soil macro and micro-nutrients, researchers examined several soil test methodologies. The most common extraction methods are; 0.5 M NaHCO₃ (Olsen *et al.*, 1954) and Bray (Bray and Kurtz 1945) for available P, 1 N ammonium acetate for K (Black 1965), Versenate titration for extraction of Ca and Mg (Jackson 1973), DTPA (pH 7.3) extraction method for micro-nutrient cations (Lindsay and Norvell 1978), AB-DTPA and AAAC-EDTA extractant for macro and micro-nutrients including P, K, Ca and Mg (Saltanpour and Schwab 1977, Lakenen and Ervio 1971). The following headings are used to review the relevant literature:

- 2.1 Available phosphorus, potassium, calcium, magnesium and micro-nutrient cations using standard methods.
- 2.2 AB-DTPA extractable phosphorus, potassium, calcium, magnesium and micro-nutrient cations.
- 2.3 AAAC-EDTA extractable phosphorus, potassium, calcium, magnesium and micro-nutrient cations.
- 2.4 Comparison of methods used for phosphorus, potassium, calcium magnesium and micro-nutrient cations.

2.1 Available phosphorus, potassium, calcium, magnesium and micro-nutrient cations using standard methods

Aizpurua *et al.* (2001) compared different extraction methods for determining soil available potassium (K). Soil K was determined by sodium tetra phenyl boron methods and ammonium acetate method before sowing. The soil K determined by these methods was positively correlated with the plant uptake.

Abreu *et al.* (2002) determined zinc in corn and soybean soils using different quantification methods. The methods involved use of diethylene triamine penta acetic acid (DTPA), Mehlich 1 (M-1), Mehlich 3 (M-3) and ammonium bicarbonate

diethylenetriaminepenta acetic acid (AB-DTPA) as extractants. After extraction, Zinc was quantified using inductively coupled plasma-atomic emission spectrometry (ICP-AES). The results showed that DTPA solution was the most efficient extractant for the determination of bio-available Zn when both crops are considered together.

Matula, (2009) conducted an experiment to determine bioavailable potassium, magnesium, phosphorous, manganese, boron by using three multinutrient extractants viz; Mehlich-3, NH₄-acetate and water extraction. No marked difference was found in the correlations between soil tests and the plant in K, Mg and P. But in case of Mn and B M-3 was not found in appropriate agreement with plant, highest universality was found in NH₄-acetate soil test in all studied nutrients.

Gikonyo *et al.* (2010) used conventional soil tests (Mehlich-3 and Bray-1) and a non-conventional test (iron oxide-impregnated paper strip test) to assess impact of triple superphosphate (TSP) and phosphate rocks (PRs) on extractable Phosphorus (P). The levels of P extracted were in the following order: Mehlich-3>Bray-1>strip test. There was a significant correlation between all tests. The strip test removed the same amount of P from both sources, although Bray-1 and Mehlich-3 extracted more P from triple superphosphate than phosphate rocks.

Stagugaitis and Rutkauskiene, (2010) studied magnesium content in soil using following extractants: Egner-Riehm-Domingo method (1 M lactic acid, 3 M acetic acid and 1 M ammonium acetate, at pH was 3.7), calcium chloride (Schachtschabel, 0.0125 M CaCl₂ 1:20), potassium chloride (1 M KCl 1:10), ammonium acetate (1 M NH₄OAc 1:10), M-3 and water-soluble magnesium (1:5). The highest magnesium content in soil was extracted by using A-L followed by other extractants in given order viz calcium chloride>potassium chloride>ammonium acetate>M-3> water extract.

Maghana *et al.* (2012) collected soil samples from three regions having different acidity. Olsen bicarbonate method and acid extract (double acid method) were used for extraction. The methods were correlated with each other. However, double acid method extracted 2.67 times more P than Olsen bicarbonate method.

Ayodele *et al.* (2013) estimate the availability of phosphorus, Potassium and magnesium in 30 surface soil samples using eight methods. The methods used were Bray's P-1 (0.03N NH₄F + 0.025N HCl), Bray's P-1+ 0.01M EDTA, Bray's P-1+ 0.005 M DTPA, AHDF (0.1N NH₄F.HF), AHDF+0.005 M DTPA, Modified Olsen's 0.5 M NaHCO₃ + 0.01 M EDTA, Modified Olsen's 0.5 M NaHCO₃ + 0.005 M DTPA and 1 N NH₄OAc (pH 7.0). Correlation coefficients showed that Bray's P-1 and AHDF (with or without chelates) as well as modified 0.5 M NaHCO₃ can be used to determine available P and exchangeable K in soils but not exchangeable Mg.

Haque *et al.* (2013) evaluated the availability of phosphorus (P) in different soil samples using Olsen, Mehlich-3, and Bray and Kurtz-1 methods. The extractability of P varied greatly, ranging from poor to high. The Olsen method extracted maximum P (2.07-45.36 mg/kg), whereas the Bray and Kurtz approach extracted least (1.02-21.79 mg/kg). The sequence of mean extractable P in soils was Olsen > Mehlich-3 > Bray and Kurtz 1.

Dhamak *et al.* (2014) collected 140 soil samples from different villages having neutral to alkaline reaction. The soil characteristics and micronutrient fertility status of these soils were examined. The soils were having high DTPA-Cu but low DTPA-Fe, DTPA-Mn, and DTPA-Zn. The soils were found to be in low category for available Zn, high for available Cu, and medium for DTPA-Fe and DTPA- Mn, according to the nutrient index value of that particular area.

Joshi *et al.* (2014) collected acidic soil samples from different locations to estimate available zinc and various soil properties. The extractants used were DTPA (pH 7.3), DTPA (pH 5.3), AB-DTPA (pH 7.6), Mehlich 3 (pH 2.0), Modified Olsen

(0.5 M NaHCO₃ + 0.01 M EDTA + 0.1 g superfloc 127 L-1; adjusted to pH 8.6), 0.1 N CaCl₂, 1 M MgCl₂ and ion exchange resins. Chemical fractions and soil extractable concentrations of zinc analyzed by different soil extractants significantly correlated with soil properties. DTPA (pH 5.3) was found to be the most acceptable multi-nutrient soil extractant for determining zinc availability in acidic soils.

Meetei *et al.* (2015) conducted an experiment to evaluate the P availability in different soils. The suitability of the extractants was in the following order: Bray-P1>Mehlich- P1>Bray-P2>Troug P>Olsen P>Morgan P. Also, Bray-P1 showed the highest and positive correlation with P content, P uptake and yield.

Yang *et al.* (2017) evaluated four major soil tests, Mehlich-1, Mehlich-3, 1 N ammonium acetate, 0.01 M sodium nitrate (SN) for extracting potassium, calcium, and magnesium in peanut soils. Results showed that extractants extracted varied amount of K, Ca, and Mg from soils. Strong correlation was found between soil K and Mg determined using M-1 and M-3. The ammonium acetate method had the best relationships to peanut yield, grade and seed calcium concentration.

Zebec *et al.* (2017) compared different extraction methods of soil potassium using ammonium lactate method, ammonium acetate, ammonium acetate ethylene diamine tetra acetic acid, bray and barium chloride. Due to significant statistical correlation between different extraction methods, it was that concluded that any of the above methods can be used to predict the concentration of K in the soil.

Athokpam *et al.* (2018) evaluated six different soil test methods for determining phosphorus application response in 20 soil samples. The suitability of the extractants was found to be in following trend: Bray-P1>Morgan-P>Mehlich-P1>Bray-P2>Olsen-P>Troug P. Also, Bray- P1 extractable P showed highest and positive correlation with dry matter yield, P content and P uptake.

Biswanath *et al.* (2019) evaluated Bray-1, H₃A (Haney-Haney-Hossner-Arnold), Mehlich-3 and Olsen-P in different soil samples for determination of

available P. The results showed that Olsen-P correlated with M-3, whereas, Bray-1 and H₃A didn't correlate with Olsen-P.

Culman *et al.* (2020) studied the relationship between M-3, Bray-1 and ammonium acetate to determine P, K, Ca, and Mg in some soils. It was found that M-3 highly correlated with Bray-1 while as M-3 values were highly related to ammonium acetate method.

Ferrando *et al.* (2020) studied the relationships between ammonium acetate, M-3, and sodium tetra phenyl boron using soils of varying texture and clay minerals. The M-3 and ammonium acetate extractable K concentrations were highly correlated in soils, although ammonium acetate extracted slightly higher amounts of K than M-3.

Rutter *et al.* (2021) compared M-3 and ammonium acetate methods for extraction of calcium and magnesium. Regression analysis revealed linear relationship between M-3-Mg and ammonium acetate-Mg for soil pH and soil organic matter. The relationship between M-3-Ca and ammonium acetate-Ca was found relatively constant for acidic to neutral soils.

2.2 AB-DTPA extractable phosphorus, potassium, calcium, magnesium and micro-nutrient cations

El-rashidi *et al.* (2003) evaluated M-3 and AB-DTPA in acidic and alkaline soils of U.S with conventional methods. They found that AB-DTPA is reliable for alkaline soils and is an appropriate extract for aluminium (Al), cadmium (Cd), Cu, Fe, Mn, nickel (Ni), lead (Pb), and Zn in all soils.

Hundal *et al.* (2006) used AB-DTPA to extract P, K, Ca, Mg, Zn, Cu, Fe, Mn, B, Pb, Ni, Co, Mo, As, Cd and Al from alkaline soils belonging to four different soil orders (Inceptisol, Entisol, Aridisol, and Alfisol). B, Zn, Cu, and Pb concentrations in soils extracted using AB-DTPA extractant solution ranged from 0.56-3.16 mg/Kg soils. More than half of the soil samples were sufficient in available K, according to the AB-DTPA soil test method.

Nazif *et al.* (2006) studied the status of micronutrients and their relationship with various physiochemical properties. Soil samples were analyzed for AB-DTPA extractable Fe, Cu, Zn, and Mn. Fe and Mn gave negative significant correlation with soil pH while as Fe had positive significant correlation with silt. Cu and Zn had positive significant correlation with organic matter. Fe had negative correlation with sand. Other physiochemical properties of soil showed either negative or positive non-significant correlation with micronutrients.

Hossienpur and Shariatmadari (2007) used nine chemical extractants to access the available P in Lucerne-growing soils. With the exception of 0.1 M HCl, the quantity of P extracted by all methods exhibited significant correlation. Collwell extractant was suitable for accessing available P in soils in the first cutting; AB-DTPA, Olsen, Collwell, Bray-1, Bray-2 and Mehlich 2 in the second cutting; and AB-DTPA, Collwell, Bray-1 and Mehlich 3 in third cutting.

Mondal *et al.* (2007) used AB-DTPA extractant to determine macro and micronutrients in different soils. The correlations between the soil physicochemical parameters and available nutrients were predicted using step-wise multiple regression equations. AB-DTPA extractable P had significant and positive regression coefficient with CEC. CEC, EC and organic carbon accounted 44.2 percent variation in AB-DTPA extractable P, according to step-down regression analysis. AB-DTPA extractable K had highly significant positive regression coefficient with CEC and negative with EC. AB-DTPA extractable Zn had significant positive regression coefficient with organic carbon.

Takrattanasaran *et al.* (2010) evaluated the efficiency of M-3 and AB-DTPA for extracting available Zn with DTPA in calcareous soils. They found that M-3 and AB-DTPA can be used for estimation of available Zn in calcareous soils.

Yan-fang *et al.* (2010) determined bioavailability of heavy metals in remediation stimulation experiments of heavy metal contaminated soils. Cu, Zn and Cd were among the polluting elements present. The study found that AB-DTPA

extraction technique was stable and could reliably estimate Cu, Zn, and Cd bioavailability in soil. The AB-DTPA extraction technique can be used in heavy metal polluted soil remediation stimulation tests.

Memon *et al.* (2012) conducted research to access the micronutrient status of soils and associated plant tissues. Cu, Fe, Mn, Zn, and B, as well as selected physico-chemical characteristics of soils were measured in composite soil and plant samples. AB-DTPA Cu, Fe, and Mn contents were adequate in all samples, whereas, in AB-DTPA extractable Zn and hot water-soluble B the values varied in a different way.

Salam *et al.* (2013) studied micronutrient status of various sites in Pakistan, using AB-DTPA extractant for determining Zn, Fe, Cu, and Mn. All of the locations had substantial levels of AB-DTPA extractable Cu and Mn.

Rajput *et al.* (2014) conducted an experiment to analyze the nutrient status of rice tract area. It was observed that the concentration of micronutrients varied with the increase in soil depth. The levels of total N, Olsen P, extractable AB-DTPA (Zn, Mn, Cu, and Fe) were generally low at the depth of 15-30 cm.

2.3 AAAC-EDTA extractable phosphorus, potassium, calcium, magnesium and micronutrient cations

Grigalaviciene *et al.* (2005) studied the accumulation of heavy metals Pb, Cu, and Cd in 81 top soil samples at roadside forest by employing AAAC-EDTA and DTPA methods. The comparison of the results indicated that AAAC-EDTA extraction solution was more efficient and well suited for the determination of Pb, Cu, and Cd.

Malik *et al.* (2013) evaluated relative efficiency of 10 chemical extractants for the extraction of available Cu in 18 different soils. They observed that only DTPA-CaCl₂ (pH 7.3), 1N NH₄OAc (pH 8.0) and AAAC-EDTA (pH 4.6) extracted Cu correlated significantly with Cu uptake by oats. Among soil properties, extractable Cu showed negative relation with pH and CaCO₃ and significant in case

of Cu extracted with DTPA-CaCl₂ (pH 7.3), 0.1 M HCl, 1N NH₄OAc (7.0), 0.02 M EDTA and citric acid (1%).

Njukeng *et al.* (2013) compared CaCl₂ method for the extraction of available Mg to AAAC-EDTA method. The results showed that the choice of extraction procedure may depend on soil properties. However, the AAAC-EDTA extracting solution offers the advantage of extracting many nutrients and saves time and energy.

2.4 Comparison of methods used for phosphorus, potassium, calcium, magnesium and micronutrient cations

AL-Mustafa *et al.* (2001) worked on 42 calcareous soil samples for accessing the ability of five soil extractants AB-DTPA, DTPA, EDTA, 1M NH₄OAc and 1 M NH₄OAc containing 0.02% hydroquinone to predict the response of sorghum to iron fertilizer. The Fe extracted by AB-DTPA, DTPA, and EDTA solutions was consistently associated to sorghum iron absorption. The highest correlation was found in case of AB-DTPA with amorphous Fe, poorly crystalline Fe, pH, organic matter, and clay.

Sharifi and Kalbasi (2001) evaluated K availability and common K extractants for 26 soil samples. NH₄OAc, CaCl₂, NaCl, NaOAc, AB-DTPA, Mehlich 1, Mehlich 3, Morgan-wolf and HNO₃ extractants were used to determine available K from soil samples. The extractants used in this study were divided into three groups based on amount of potassium they extracted from the soils: relatively weak extractants such as CaCl₂, Mehlich 1, Morgan-wolf, relatively strong extractants such as NH₄OAc, NaCl (2 N), and very strong extractants which includes only HNO₃.

Aramrak *et al.* (2007) conducted a study to assess the efficiency of the two multi-nutrient extractants (M-3 and AB-DTPA) with ammonium acetate (NH₄OAc) in predicting available K in some soils. It was found that M-3 and AB-DTPA can be effectively used for determining K availability in some soils.

Khan *et al.* (2007) conducted number of tests to determine plant P and K in soil by comparing P and K extracted through AB-DTPA method with Olsen's method for P and ammonium acetate for K in the soils. They found that AB-DTPA can be used in determining P and K in the soils. Also, amounts of P and K extracted had a positive correlation with soil properties like clay, cation exchange capacity (CEC), organic matter and bicarbonates.

Mondal *et al.* (2007) studied the availability of P in soils using five extractants: Bray-1, Bray-2, Olsen, Mehlich-1 and AB-DTPA for four different land uses. In all the samples Bray-2 method extracted the highest amount of soil P. Under the acidic Tarai agro-climatic zone, Bray reagents were found to be the most effective P extractants.

Suarez *et al.* (2007) used traditional and tested extractants for acid soil such as Bray 2 and ammonium acetate to evaluate multi-element extractants such as AAAC-EDTA, AB-DTPA, and M-3. It was found M-3 and AAAC-EDTA are suitable for assessment of plant available P, K, Ca, Mg, Cu, Zn, and Fe in acid soils.

Hosseinpur and Samarati (2008) conducted an experiment to determine K available to corn in 15 soils using different extractants. Correlation studies showed that NH₄OAc and AB-DTPA cannot be used as available K extractants.

Madurapperuma *et al.* (2008) compared AB-DTPA method with conventional methods to extract available P, K, Na, Ca, Mg, Fe, Mn, Zn, and Cu in lowland rice soils. The result showed that AB-DTPA method is better than conventional methods in evaluating fertility status of low land rice soils. It was also found that this method reduces the time and cost of soil analysis.

Haney *et al.* (2010) developed a new soil extractant (H₃A-1) that can extract ammonical nitrogen (NH₄-N), nitrate nitrogen (NO₃-N) and P from different soils. When compared to the original H₃A-1 as well as standard methods (Olsen, potassium chloride (KCl), water, Mehlich-3, Bray-1, ammonium acetate and

DTPA, correlations revealed improved relationships with NO_3 , NH_4 , PO_4 , P, K, Ca, and Zn.

Morgan *et al.* (2010) evaluated soil extracts for P on sandy soils with high calcium concentrations. Different chemical extractants including Olsen, Bray and AB-DTPA were used. The results showed that Bray and AB-DTPA significantly correlated with water and carbonate extractable P, while as Olsen underestimated water and carbonate extractable soil P.

Sharma *et al.* (2010) conducted a pot experiment on 15 different soils varying widely in their P availability to find the suitable extractants for determination of available P. On the basis of correlation obtained between soil test values and P uptake, they observed Olsen's P and AB-DTPA extractable P were equally good indices of P availability for predicting response to maize.

Hosseinpur and Zarenia, (2012) conducted an experiment by using different extractants to determine K available to Pinto beans in 15 different soils. The correlation studies showed that NH_4OAc , AB-DTPA, BaCl_2 , HCl and boiling HNO_3 cannot be used as available K extractants.

Molina *et al.* (2012) evaluated the suitability of AB-DTPA with conventional methods to quantify the available P, exchangeable cations (K, Ca, Mg, and Na) and micronutrients (Cu, Fe, Mn, and Zn) in alkaline, acidic and volcanic acid soils. They found that AB-DTPA is able to estimate P, K, Mg, Na, Cu, Fe, Mn, and Zn in alkaline and acid soils.

Ali *et al.* (2014) compared DTPA, EDTA, AB-DTPA and six molarities of sodium gluconate as extractants for Cu, Fe, Zn, Mn, Pb, Ni, Cr, and Cd in different soils. Ab-DTPA was found to be the most effective extractant for Cu, Fe, Mn, Pb, Ni and Cr whereas, EDTA was found to be most effective for Cd and Zn.

Bibso *et al.* (2015) evaluated AB-DTPA over DTPA to extract available Fe, Cu, Mn and Zn in different soils. It was found that AB-DTPA is suitable universal extractant for determination of available Fe, Cu, Mn, and Zn in the soils.

Hosseinpur and Motaghain, (2015) performed a greenhouse experiment to evaluate bioavailability of Zn and Pb in beans by using different extractants (DTPA-TEA, AB-DTPA, Mehlich-2, Mehlich-3, 0.01 M CaCl₂, and 0.1 M HCl) in 10 polluted soils. The extraction capacity showed the following trend: Mehlich-3> AB-DTPA>DTPA-TEA>Mehlich-2>CaCl₂>HCl. Results revealed that Zn extracted by DTPA-TEA, AB-DTPA, Mehlich-2, Mehlich-3 showed significant correlation with Zn uptake. Also, significant correlation was found between DTPA-TEA, AB-DTPA, HCl, CaCl₂ with Zn concentration. The concentration of Pb and Pb extracted by DTPA-TEA, AB-DTPA, mhlich-2, Mehlich-3 correlated significantly.

Seth *et al.* (2017) evaluated the efficiency of six complex extractants such as DTPA, M-3, AB-DTPA, modified Morgan, Morgan and diaminocyclohexanetetraacetic acid-glycerol (CDTA) to check their suitability for assessing available Zn status in soils for nutrition of rice. Among the six extractants tested, AB-DTPA and M-3 were the best foe assessing plant available Zn. Also, the extractable soil Zn significantly correlated with soil organic C and clay content.

Anusree *et al.* (2018) compared AB-DTPA with traditional methods for evaluation of P, K, Zn, Cu, Fe and Mn. The estimated values using different extractants showed significant difference for availability of P, Zn, Cu, Fe and Mn but K values were same.

Malathi and Stalin, (2018) evaluated AB-DTPA for simultaneous assessment of P, K, S, Fe, Mn, Zn, and Cu. Fifty soil samples were collected having different pH ranges and were analyzed with AB-DTPA and the standard methods. It was concluded that AB-DTPA can be used as multinutrient extractant for the simultaneous extraction of P, K, S, Fe, Mn, Zn, and Cu in alkaline soils.

Sharma *et al.* (2018) evaluated AB-DTPA and AAAC-EDTA over standard methods for determination of P, K and micronutrient cations. A significant correlation was found between AB-DTPA and DTPA for Cu, Fe, and Zn and AAAC-EDTA correlated highly with Olsen P.

Zang *et al.* (2018) evaluated M-3 and AB-DTPA over conventional methods for extraction of available P, K, Mg, Fe, Cu, Mn, and Zn in various grassland soils. It was found that M-3 and AB-DTPA can be used to measure nutrient availability in grassland soils. Also, AB-DTPA can be recommended to measure availability of nutrients in alkaline soils.

Mekala *et al.* (2019) compared DTPA-CaCl₂ and AB-DTPA for the extraction of Zn, Cu, Fe, and Mn in different soil orders. DTPA-CaCl₂ extracted higher amounts of Zn in all soil orders than AB-DTPA. AB-DTPA extracted higher amounts of Cu in entisols and alfisols than DTPA-CaCl₂. DTPA-CaCl₂ proved to be good extractant for Fe in inceptisols and for Mn in alfisols. It was also found that amount of extracted micronutrient contents highly and significantly correlated with soil properties like electrical conductivity, and organic carbon.

Chapter-3

MATERIALS AND METHODS

This chapter discusses the detailed description of the research methodology adopted for conducting the study entitled “**Evaluation of Different Extractants for Estimation of P, K, Ca, Mg & Micro-nutrient Cations in Soils of Kashmir Valley.**” The methods employed for conducting the study are discussed under following heads:

- 3.1 General description of study area
- 3.2 Collection and preparation of soil samples
- 3.3 Laboratory analysis
- 3.4 Statistical Analysis

3.1 General description of study area

Kashmir is surrounded by Pir Panjal Range on the southwest side and by Himalayan Range on the northeast side. It lies between latitudes 32 and 34 degree north, and longitude 74° and 75° east. Among 10 districts of Kashmir valley district Kulgam, Anantnag, Shopain, Pulwama were selected from southern part of valley and Baramullah and Kupwara were selected from northern part of valley.

3.2 Collection and preparation of soil samples

Forty-five surface soil samples (0-15 cm depth) were randomly collected from different areas of Kashmir based on soil pH (pH <6.5, 6.5-7.5 and >7.5) for the current study and are listed in table 3.1 and as shown in figure 3.1. Each composite sample comprised soil samples from 10-15 spots. The collected samples were air dried and ground using wooden pestle and mortar followed by sieving through a 2 mm sieve. The processed soil samples were stored in polythene bags at room temperature for further analysis. A portion of each sample was stored separately and sieved through 0.5 mm sieve for estimation of organic carbon

3.3 Laboratory Analysis

The processed soil samples were analyzed for different physico-chemical properties viz., texture, pH, electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC), calcium carbonate (CaCO_3 , available P, K, Ca, Mg and micronutrient cations (Fe, Cu, Mn, Zn) according to the procedures listed below:

3.3.1 Soil texture

The particle size analysis was determined by hydrometric method as described by Bouyoucos (1962).

3.3.2 Soil pH (1:2.5)

The pH of soil sample was determined in 1:2.5 soil: water suspension with the help of glass electrode pH meter as described by Jackson (1973).

3.3.3 Electrical conductivity (dS/m)

The electrical conductivity was conducted by Salt bridge conductivity meter as described by Jackson (1973).

3.3.4 Organic carbon (percent)

Organic carbon was determined by rapid titration method given by Walkley and Black (1934).

3.3.5 Cation exchange capacity (Cmol(c)/kg)

CEC was determined by exchanging soil cations using sodium acetate and then replacing sodium with ammonium ions using ammonium acetate solution. It was followed by determination of sodium ions in extractant (Jackson 1973).

3.3.6 Calcium Carbonate

Calcium carbonate was determined by back titration method given by Piper (1966).

3.3.7 Available Phosphorus (kg/ha)

The available phosphorus was estimated by 0.5M NaHCO₃, given by Olsen *et al.* (1954) and Bray method given by Bray and Kurtz (1945).

3.3.8 Available Potassium (kg/ha)

The available potassium was analysed by extraction with 1N neutral ammonium acetate as given by Black (1965).

3.3.9 Exchangeable Calcium (me/100g)

Available calcium was determined by Versenate titration method, given by Jackson (1973).

3.3.10 Exchangeable Magnesium (me/100g)

Exchangeable magnesium was determined by Versenate titration method, given by Jackson (1973).

3.3.11 Available micronutrient analysis (mg/kg)

The micronutrient (iron, copper, manganese and zinc) estimation was done by using the method outlined by Lindsay and Norvell (1978) using Atomic Absorption Spectrophotometer (AAS).

Multi-nutrient extraction methods under assessment for macro and micronutrients are enlisted as under

AB-DTPA method

Preparation of extracting solution and extracting procedure

AB-DTPA extractant was prepared by adding 1.97 g of DTPA to approximately 700 ml of pure water and about 2 ml of 1:1 NH₄OH was added to facilitate dissolution. After the dissolution of DTPA completely, exactly 79.06 g of NH₄HCO₃ was added to it and stirred gently until it dissolved completely. The pH

was adjusted to 7.6 by using either NH_4OH or HCl . The final volume was made upto one litre.

20 ml AB-DTPA was added to 10 g of soil and shaken on reciprocating shaker for 15 minutes at 180 cycles per minute and filtered. Aliquot collected was used for determination of P, K, Ca, Mg & micronutrient cations (Fe, Cu, Mn, Zn).

AAAc-EDTA method

Preparation of extracting solution and extracting procedure

AAAc-EDTA was prepared by adding 7.44 g EDTA to approximately 700 ml of pure water. Then 30 ml of acetic acid was added to dissolve the contents fully with occasional stirring. After dissolution, 38.5 g of ammonium acetate was added and pH was adjusted to 4.65 by using NH_4OH or HCl . The final volume was made upto one litre.

Twenty-five (25) ml AAAc-EDTA was added to 10 g of soil and shaken for 15 minutes and filtered. Aliquot collected was used for determination of P, K, Ca, Mg and micronutrient cations (Fe, Cu, Mn, Zn).

Table 3.1: Soil sampling locations

S.No.	Location	Sample No.	Latitude	Longitude
District Kulgam, Anantnag and Shopain				
1.	Nisarabad	1	33 °40'11"N	75 °01'49"E
2.	Chambgund	2	33 °37'47"N	75 °01'32"E
3.	Adigan	3	33 °38'03"N	74 °55'74"E
4.	Parigam	5	33 °41'58"N	75 °00' 23"E
5.	Ashmuji	6	33 °40' 22"N	75 °04'11"E
6.	Yaripora	8	33 °43' 23"N	75 °01'10"E
7.	Kadoorah	9	33 °39' 32"N	75 °06'149"E
8.	Chanser	10	33 °39' 27"N	75 °01'14"E
9.	Ashmuji	11	33 °40'10"N	75 °04'13"E
10.	Daran	14	33 °36' 53"N	75 °23'09"E
11.	Ratnipora	15	33 °41'12"N	74 °54'07"E
12.	Chawalgam	16	33 °38' 43"N	74 °59'55"E
13.	Shurat	17	33 °39'46"N	75 °02'13"E
14.	Khokharhama	18	33 °38' 08"N	74 °55'01"E
15.	Nisarabad	19	33 °40'16"N	75 °01'51"E
District Pulwama				
16.	Samboora	21	33 °57'58"N	74 °56'32"E
17.	Samboora	22	33 °58'46"N	74 °56'24"E
18.	Samboora	23	33 °57'54"N	74 °56'27"E
19.	Patal	24	33 °58'50"N	74 °55'36"E
20.	Patal	25	33 °458' 46"N	74 °55'44"E
21.	Patal	26	33 °48' 52"N	74 °55'41"E
22.	Patal	27	33 °58' 38"N	74 °55'33"E
23.	Lethpora	28	33 °58' 21"N	74 °57'14"E

24.	Chandhara	30	33 °59'20"N	74 °57'036"E
25.	Chandhara	31	33 °58' 57"N	74 °57'50"E
26.	Chandhara	33	33 °59'22"N	74 °57'41"E
27.	Chandhara	34	33 °59' 10"N	74 °57'31"E
28.	Dusu	35	33 °59'15"N	74 °57'43"E
29.	Dusu	37	33 °59' 14"N	74 °57'50"E
30.	Dusu	40	33 °59' 21"N	74 °58'06"E
District Baramullah and Kupwara				
31.	Diver	41	34 °28' 502"N	74 °26.624"E
32.	Kulangam	42	34 °25' 289"N	74 °18.059"E
33.	Turkpora	43	34 °24' 801"N	74 °12.381"E
34.	Wadipora	44	34 °24' 395"N	74 °14.118"E
35.	Nambla	45	34 °05' 120"N	74 °03.364"E
36.	Dooniwari	46	34 °32' 398"N	74 °21.093"E
37.	Kulangam	47	34 °25' 298"N	74 °18.059"E
38.	Dawaran	48	34 °07' 706"N	74 °05.514"E
39.	Turkpora	49	34 °24' 597"N	74 °12.595"E
40.	Chotipora	50	34 °21' 585"N	74 °15.382"E
41.	Gangbuk	51	34 °31' 462"N	74 °22.981"E
42.	Dorusa	52	34 °28' 101"N	74 °24.321"E
43.	Bandi	53	34 °08' 698"N	74 °03.077"E
44.	Kalsan	54	34 °01' 111"N	74 °03.498"E
45.	Chollen	55	34 °07' 148"N	74 °04.0404"E

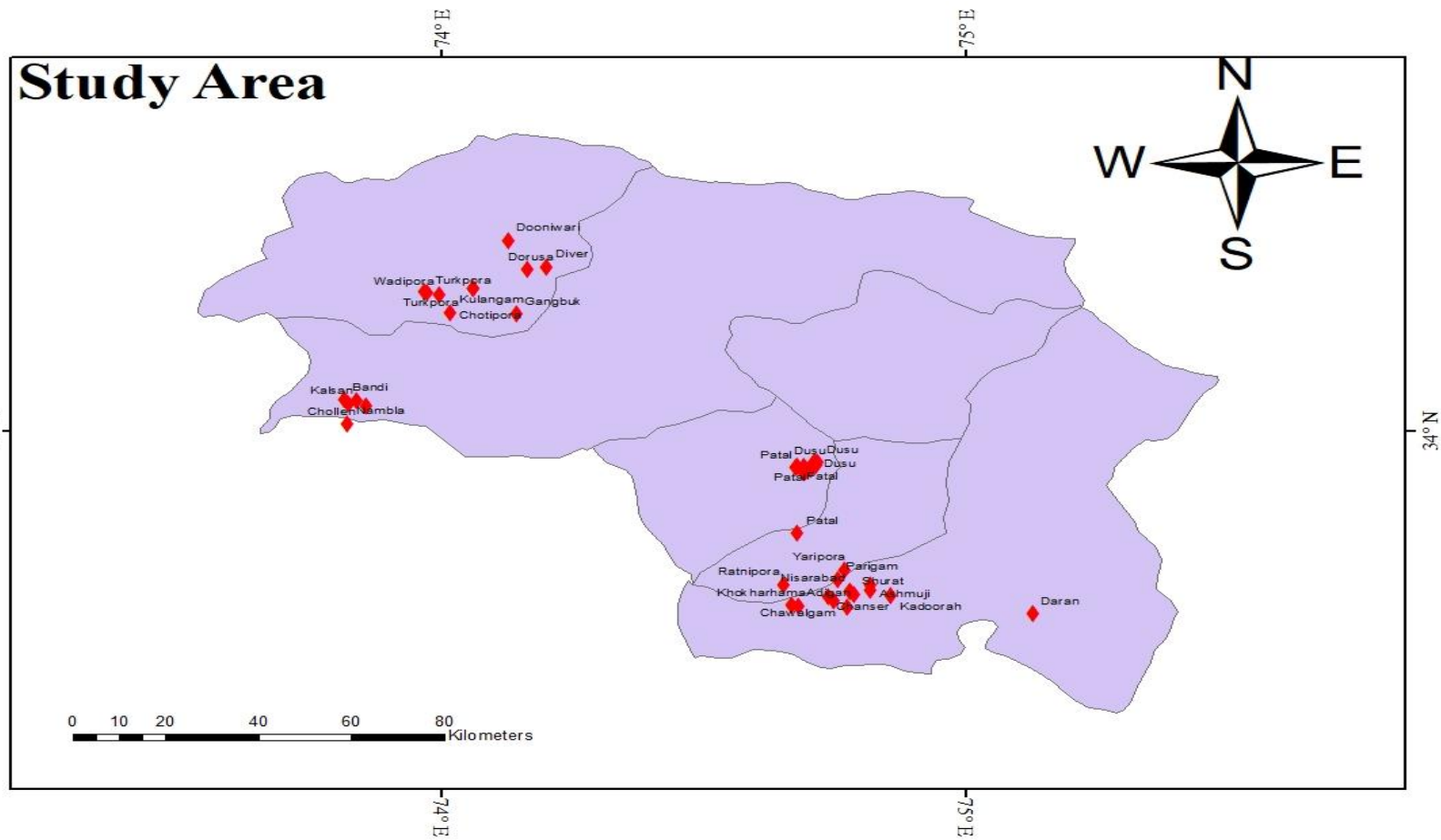


Fig. 3.1: Study Area Map

3.4 Statistical analysis

The standard method of analysis of variance with CRD was used to statistically analyse the experimental data. The software package used for data analysis was R- software. Among statistical operations, the data was subjected to descriptive statistical analysis.



Determination of Soil texture



Estimation of Soil pH



Estimation of organic carbon



Estimation of CEC



Estimation of Calcium carbonate



Phosphorous estimation



Filtration of extract



Addition of stannous chloride



Readings on Spectrophotometer

Available Phosphorous

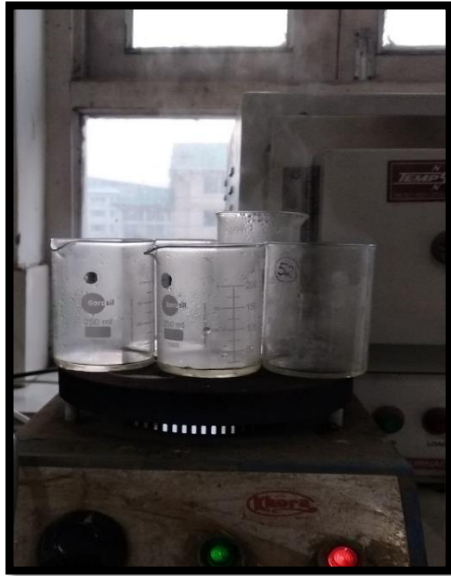


Potassium estimation



Readings from Flame Photometer

Available Potassium



Pre-treatment of soil extract



Titration with 0.01N EDTA



Estimation of Calcium



Estimation of Calcium + Magnesium

Exchangeable Calcium and Magnesium

Plate 1: An overview of lab activities

Chapter-4

EXPERIMENTAL FINDINGS

The results obtained from the present study entitled, “Evaluation of different extractants for estimation of available P, K, Ca, Mg & micronutrient cations in soils of Kashmir Valley” have been presented and discussed in this chapter under the following headings:

4.1 Physico-chemical properties of soils

4.1.1 Mechanical analysis

4.1.2 Soil pH

4.1.3 Electrical conductivity

4.1.4 Organic carbon

4.1.5 Cation exchange capacity

4.1.6 Calcium Carbonate

4.2 Available macro and micro nutrients

4.2.1 Available phosphorus

4.2.2 Available potassium

4.2.3 Exchangeable Calcium

4.2.4 Exchangeable Magnesium

4.2.5 Available iron

4.2.6 Available copper

4.2.7 Available manganese

4.2.8 Available zinc

4.3 Correlation Studies

4.1 Physico-chemical properties of soil samples

4.1.1 Mechanical Analysis

Data showing percentage of different soil separates is presented in table 4.1. The soil texture class of different areas was found to be loam, clay loam, silty clay loam, sandy clay loam and silt loam. The total sand content ranged from 16.30 to 53.80 per cent with a mean value of 28.89, the values of silt content ranged from 22.00 to 56.99 per cent with a mean value of 46.14 and clay content ranged from 11.40 to 33.90 per cent with a mean value of 24.96.

4.1.2 Soil pH

The data related to soil reaction is shown in table 4.2. The data revealed that the soils under investigation had wide range of pH. The pH ranged from 4.90 to 5.90 in the first category with a mean value of 5.62, 6.60 to 7.40 in the second category with a mean value of 7.02 and 7.60 to 7.90 in third category with a mean value of 7.74. The overall pH ranged from 4.90 to 7.90 i.e. highly acidic to alkaline with mean value of 6.79.

4.1.3 Electrical conductivity

The data presented in table 4.2 shows a wide variation in electrical conductivity of soils. The electrical conductivity ranged from 0.04 to 0.23 for pH range of < 6.50 with a mean value of 0.09; 0.11 to 0.43 for pH range of 6.50-7.50 with a mean value of 0.24 and 0.21 to 0.64 for soils having PH > 7.50 with a mean value of 0.41. The overall EC ranged from 0.04 to 0.64 with mean value of 0.25. Also, electrical conductivity of all the samples was found to be under the safe limit (< 0.8 dS/m) for growing different crops.

Table 4.1: Soil mechanical separates (sand, silt and clay) and textural class of soil

S.No.	Location	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	Chambgund	42.30	34.00	23.70	Loam
2	Ratnipora	18.30	47.80	33.90	Silty Clay Loam
3	Chawalgam	22.40	46.60	31.00	Clay Loam
4	Nisarabad	29.10	48.60	22.30	Loam
5	Yaripora	46.00	22.00	32.00	Sandy Clay Loam
6	Kadoorah	43.00	39.00	18.00	Loam
7	Daran	43.30	36.30	20.40	Loam
8	Ashmuji	53.80	22.60	23.60	Sandy Clay Loam
9	Shurat	49.20	28.40	22.40	Loam
10	Nisarabad	29.10	48.60	22.30	Loam
11	Parigam	36.60	38.90	24.50	Loam
12	Chaner	20.30	49.20	30.50	Clay Loam
13	Khokharhama	17.80	51.30	30.40	Silty Clay Loam
14	Adigan	23.80	44.50	31.70	Clay Loam
15	Ashmuji	16.30	51.60	32.10	Silty Clay Loam
16	Chollen	25.65	51.36	22.98	Silt Loam
17	Turkpora	46.41	39.37	14.22	Loam
18	Nambla	32.60	56.00	11.40	Silt Loam
19	Dooniwari	27.64	52.05	20.31	Silt Loam
20	Dawaran	26.67	50.86	22.47	Silt Loam
21	Chotipora	19.34	48.76	31.90	Silty Clay Loam
22	Dorusa	25.96	53.38	20.66	Silt Loam
23	Patal	22.16	50.00	27.84	Clay Loam
24	Diver	17.89	49.10	33.01	Silty Clay Loam

25	Wadipora	26.23	51.92	21.85	Silt Loam
26	Turkpora	39.75	40.64	19.61	Loam
27	Patal	22.16	50.00	27.84	Clay Loam
28	Kulangam	46.37	36.90	16.73	Loam
29	Kulangam	47.87	38.13	14.00	Loam
30	Gangbuk	25.90	51.26	22.84	Silt Loam
31	Samboora	22.16	50.00	27.84	Clay Loam
32	Patal	22.16	50.00	27.84	Clay Loam
33	Chandhara	22.16	50.00	27.84	Clay Loam
34	Dusu	22.16	50.00	27.84	Clay Loam
35	Samboora	22.16	50.00	27.84	Clay Loam
36	Chandhara	22.16	50.00	27.84	Clay Loam
37	Dusu	22.16	50.00	27.84	Clay Loam
38	Dusu	22.16	50.00	27.84	Clay Loam
39	Patal	22.16	50.00	27.84	Clay Loam
40	Chandhara	22.16	50.00	27.84	Clay Loam
41	Bandi	42.94	40.06	17.00	Loam
42	Kalsan	25.14	56.99	17.87	Silt Loam
43	Samboora	22.15	50.00	27.84	Clay Loam
44	Lethpora	22.15	50.00	27.84	Clay Loam
45	Chandhara	22.15	50.00	27.84	Clay Loam
Mean		28.89	46.14	24.96	-
Range		16.30-53.80	22.00-56.99	11.40-33.90	-

Table 4.2: Soil pH (1:2.5) and Electrical Conductivity (dS/m) of soil samples

Category	S.No.	Location	pH	EC
pH<6.50	1.	Chambgund	4.90	0.07
	2	Ratnipora	5.20	0.05
	3	Chawalgam	5.50	0.23
	4	Nisarabad	5.60	0.05
	5	Yaripora	5.60	0.08
	6	Kadoorah	5.60	0.07
	7	Daran	5.60	0.04
	8	Ashmuji	5.70	0.08
	9	Shurat	5.70	0.18
	10	Nisarabad	5.70	0.05
	11	Parigam	5.80	0.12
	12	Chanser	5.80	0.07
	13	Khokharhama	5.80	0.08
	14	Adigan	5.90	0.12
	15	Ashmuji	5.90	0.11
	Mean		5.62	0.09
	Range		4.90-5.90	0.04-0.23
pH 6.50-7.50	16	Chollen	6.60	0.25
	17	Turkpora	6.70	0.16
	18	Nambla	6.70	0.11
	19	Dooniwari	6.80	0.20
	20	Dawaran	6.90	0.14
	21	Chotipora	6.90	0.22
	22	Dorusa	6.90	0.31
	23	Patal	7.10	0.41
	24	Diver	7.10	0.25
	25	Wadipora	7.10	0.16

	26	Turkpora	7.10	0.20
	27	Patal	7.30	0.43
	28	Kulangam	7.30	0.25
	29	Kulangam	7.40	0.29
	30	Gangbuk	7.40	0.21
	Mean		7.02	0.24
	Range		6.60-7.40	0.11-0.43
pH>7.50	31	Samboora	7.60	0.43
	32	Patal	7.60	0.48
	33	Chandhara	7.60	0.52
	34	Dusu	7.60	0.31
	35	Samboora	7.70	0.46
	36	Chandhara	7.70	0.43
	37	Dusu	7.70	0.32
	38	Dusu	7.70	0.47
	39	Patal	7.80	0.64
	40	Chandhara	7.80	0.41
	41	Bandi	7.80	0.30
	42	Kalsan	7.80	0.21
	43	Samboora	7.90	0.44
	44	Lethpora	7.90	0.23
	45	Chandhara	7.90	0.43
	Mean		7.74	0.41
	Range		7.60-7.90	0.21-0.64
Overall	Mean		6.79	0.25
	Range		4.90-7.90	0.04-0.64

4.1.4 Organic Carbon

Data related to organic carbon is shown in table 4.3. Soil organic carbon in soils having pH < 6.50 ranged from 0.62 to 1.89 per cent with a mean value of 1.26 and in soils with pH value of 6.50 to 7.50 soil organic carbon ranged from 0.21 to 1.54 with a mean value of 0.89, while as in soils with pH >7.50, soil organic carbon ranged from 0.12 to 1.92 per cent with a mean value of 0.49. The overall soil organic carbon ranged from 0.12 to 1.92 per cent with mean value of 0.87.

4.1.5 Cation Exchange Capacity

The data presented in table 4.3 depicts that the CEC ranged from 8.90 to 13.80 cmol(c)/kg in soils having pH values less than 6.50 with a mean value of 11.67, CEC for soils having pH values between 6.50 to 7.50 ranged from 7.20 to 16.20 cmol(c)/kg with a mean value of 11.03 and for soils having pH range > 7.50 CEC ranged from 7.10 to 13.60 cmol(c)/kg with a mean value of 8.67. The overall CEC ranged from 7.10 to 16.20 cmol(c)/kg with a mean value of 10.46.

4.1.6 Calcium Carbonate

The data for calcium carbonate is shown in table 4.3. The data shows that the calcium carbonate ranged from 0.10 to 0.90 per cent in soils having pH less than 6.50 with a mean value of 0.49 percent, calcium carbonate for soils having pH between 6.50 to 7.50 ranged from 1.70 to 3.00 per cent with a mean value of 2.21 and for soils having pH greater than 7.50 calcium carbonate ranged from 1.30 to 2.50 per cent with a mean value of 2.06. The overall calcium carbonate ranged from 0.10-3.00 per cent with a mean value of 1.58.

Table 4.3: Soil organic Carbon (%), Cation Exchange Capacity (cmol(c)/kg) and Calcium Carbonate (%) of soil samples

Category	S.No.	Location	OC	CEC	CaCO ₃
pH<6.50	1.	Chambgund	1.65	13.20	0.60
	2	Ratnipora	0.73	10.20	0.50
	3	Chawalgam	1.32	12.60	0.60
	4	Nisarabad	1.19	12.10	0.10
	5	Yaripora	1.80	12.90	0.70
	6	Kadoorah	1.02	11.30	0.20
	7	Daran	0.62	9.20	0.70
	8	Ashmuji	1.89	13.80	0.50
	9	Shurat	1.59	13.20	0.50
	10	Nisarabad	1.02	9.70	0.30
	11	Parigam	1.42	12.60	0.60
	12	Chanser	0.67	8.90	0.90
	13	Khokharhama	1.09	10.30	0.40
	14	Adigan	1.42	12.60	0.40
	15	Ashmuji	1.42	12.40	0.30
	Mean		1.26	11.67	0.49
	Range		0.62-1.89	8.90-13.80	0.10-0.90
pH 6.50-7.50	16	Chollen	0.89	10.70	2.20
	17	Turkpora	0.81	7.60	2.10
	18	Nambla	0.84	9.90	2.20
	19	Dooniwari	1.26	15.50	1.90
	20	Dawaran	1.13	12.10	1.90
	21	Chotipora	1.11	11.50	2.60
	22	Dorusa	1.18	12.50	3.00
	23	Patal	0.56	9.80	2.10
	24	Diver	0.52	9.60	1.70

	25	Wadipora	0.21	7.20	1.90	
	26	Turkpora	1.52	14.6	1.90	
	27	Patal	0.34	9.70	1.90	
	28	Kulangam	1.54	16.2	3.00	
	29	Kulangam	0.29	8.40	2.40	
	30	Gangbuk	0.83	10.20	2.30	
	Mean		0.89	11.03	2.21	
	Range		0.21-1.54	7.20-16.20	1.70-3.00	
pH>7.50	31	Samboora	0.42	8.80	2.20	
	32	Patal	0.12	7.70	2.40	
	33	Chandhara	0.13	7.60	1.70	
	34	Dusu	0.14	7.30	1.50	
	35	Samboora	0.19	7.20	1.80	
	36	Chandhara	0.16	8.90	1.30	
	37	Dusu	0.14	7.80	2.30	
	38	Dusu	0.75	10.30	1.90	
	39	Patal	0.19	7.40	2.30	
	40	Chandhara	0.82	7.10	2.30	
	41	Bandi	1.92	13.60	2.30	
	42	Kalsan	1.66	12.40	2.50	
	43	Samboora	0.16	7.40	2.40	
	44	Lethpora	0.22	8.20	1.90	
	45	Chandhara	0.34	8.40	2.10	
		Mean		0.49	8.67	2.06
		Range		0.12-1.92	7.10-13.60	1.30-2,50
Overall	Mean		0.87	10.46	1.58	
	Range		0.12-1.92	7.10-16.20	0.10-3.00	

4.2 Available Macro and Micro-nutrient Cations

4.2.1 Available Phosphorous

The overall data for available phosphorous is presented in table 4.4. The results reveal that on an average the power of extraction of the different extractants was as follows; Olsen>AAAc-EDTA>Bray>AB-DTPA and the phosphorus extracted ranged from 4.87-32.44, 5.34-36.43, 3.23-39.12 and 3.22-26.63, respectively. For pH range of <6.50, the available phosphorous extracted by Olsen, Bray, AB-DTPA and AAc-EDTA ranged from 6.13 to 32.44, 8.28 to 39.12, 3.22 to 26.63 and 5.34 to 36.43, respectively and for pH range between 6.50 to 7.50 available phosphorous extracted by above four methods ranged from 10.97 to 23.46, 7.63 to 15.41, 5.42 to 12.67 and 9.43 to 19.22. Whereas, for pH range of > 7.50 available phosphorous extracted by above four methods ranged from 4.87 to 19.48, 3.23 to 14.28, 4.44 to 13.13 and 5.67 to 16.45, respectively.

The data comparing different extractants for extracting available phosphorous at different pH ranges is presented in table 4.5 and Fig. 4.1: (a, b, c). The data revealed that, at pH <6.50 the ability of extraction for different methods was as follows; Bray> Olsen> AAc-EDTA>AB-DTPA with mean values of 17.13, 14.79, 14.31 and 10.39, respectively and all the methods were at par with each other. For pH range 6.50 to 7.50 the extracting power of the extractants for available phosphorous was as follows; Olsen> AAc-EDTA> Bray> AB-DTPA with mean values of 15.28, 12.70, 10.16 and 8.31, respectively. For pH range > 7.50 the extracting power of the extractants followed the same trend as in pH range of 6.50 to 7.50 with mean values of 10.71, 8.97, 7.28 and 6.62 for Olsen, AAc-EDTA, Bray and AB-DTPA, respectively and the methods were statistically significant.

Table 4.4: Available phosphorus in soil (kg/ha) as obtained with different extractants

Category	S.No.	Location	Olsen	Bray	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	9.91	11.46	5.12	7.32
	2	Ratnipora	27.96	29.54	19.17	26.23
	3	Chawalgam	6.51	8.28	3.22	5.34
	4	Nisarabad	10.39	12.42	5.82	9.71
	5	Yaripora	28.76	30.22	21.19	26.87
	6	Kadoorah	13.31	15.34	9.35	12.61
	7	Daran	10.13	14.22	8.22	12.55
	8	Ashmuji	12.99	11.72	7.98	10.85
	9	Shurat	32.44	39.12	26.63	36.43
	10	Nisarabad	9.51	12.87	7.18	10.22
	11	Parigam	7.49	9.71	4.11	6.62
	12	Chanser	10.57	12.32	6.93	9.63
	13	Khokharhama	26.52	28.25	19.54	24.36
	14	Adigan	6.13	9.22	4.94	7.44
	15	Ashmuji	9.25	12.22	6.48	8.45
	Mean		14.79	17.13	10.39	14.31
	Range		6.13-32.44	8.28-39.12	3.22-26.63	5.34-36.43
pH 6.50-7.50	16	Chollen	15.87	10.01	9.79	12.45
	17	Turkpora	12.51	9.53	7.47	10.47
	18	Nambla	10.97	11.37	9.78	12.34
	19	Dooniwari	10.98	7.63	5.63	9.67
	20	Dawaran	14.44	12.73	10.45	13.47
	21	Chotipora	22.76	15.41	12.43	19.22
	22	Dorusa	14.97	9.04	7.87	11.34
	23	Patal	16.76	9.51	7.58	12.98
	24	Diver	23.46	15.22	12.67	18.97
	25	Wadipora	14.64	9.42	7.66	12.43
	26	Turkpora	14.12	8.24	6.43	11.56

	27	Patal	13.68	8.15	6.24	10.57
	28	Kulangam	16.66	9.08	7.89	13.49
	29	Kulangam	12.99	7.92	5.42	9.43
	30	Gangbuk	14.34	9.16	7.39	12.15
	Mean		15.28	10.16	8.31	12.70
	Range		10.97-23.46	7.63-15.41	5.42-12.67	9.43-19.22
pH>7.50	31	Samboora	10.89	6.84	5.72	8.34
	32	Patal	11.67	7.32	5.14	9.48
	33	Chandhara	7.67	6.46	4.86	7.21
	34	Dusu	8.18	7.51	4.45	6.32
	35	Samboora	8.87	7.08	7.42	9.64
	36	Chandhara	9.71	8.42	7.32	10.34
	37	Dusu	11.34	5.23	5.07	7.76
	38	Dusu	9.34	4.75	5.77	7.32
	39	Patal	7.86	3.23	4.96	5.67
	40	Chandhara	8.45	3.31	5.86	6.89
	41	Bandi	15.46	12.9	9.54	11.67
	42	Kalsan	13.98	6.8	8.46	10.4
	43	Samboora	19.48	14.28	13.13	16.45
	44	Lethpora	12.87	9.23	7.18	10.78
	45	Chandhara	4.87	5.88	4.44	6.29
	Mean		10.71	7.28	6.62	8.97
Range		4.87-19.48	3.23-14.28	4.44-13.13	5.67-16.45	
Overall	Mean		13.59	11.52	8.44	11.99
	Range		4.87-32.44	3.23-39.12	3.22-26.63	5.34-36.43

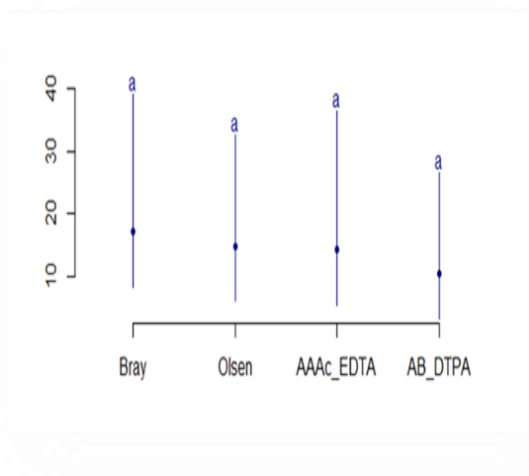


Fig. 4.1: (a)

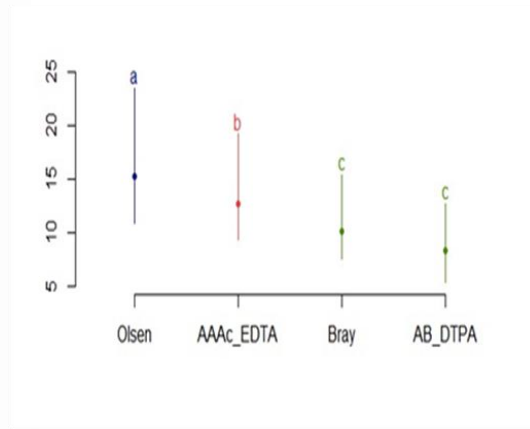


Fig. 4.1: (b)

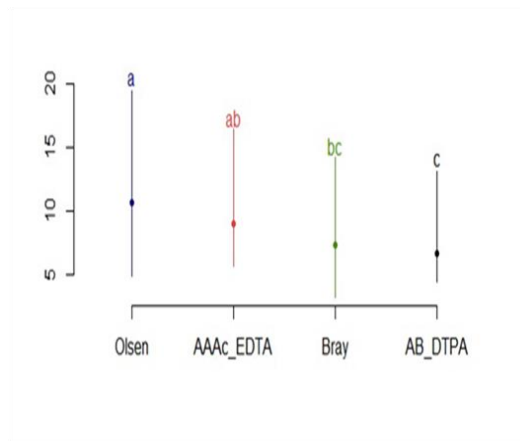


Fig. 4.1: (c)

Fig. 4.1: Comparison among different methods of phosphorous at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50

Table 4.5: Comparison among different extractants for available phosphorous (kg/ha)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
Olsen	14.79 ^a	15.28 ^a	10.71 ^a
Bray	17.13 ^a	10.16 ^c	7.28 ^{bc}
AB-DTPA	10.39 ^a	8.31 ^c	6.62 ^c
AAAc-EDTA	14.31 ^a	12.70 ^b	8.97 ^{ab}

Different letters in columns express significant difference at $\alpha \leq 0.05$

4.2.2 Available Potassium

The overall data for available potassium is presented in table 4.6. The results revealed that on an average the power of extraction of the different extractants was as follows; ammonium acetate > AB-DTPA > AAAC-EDTA and the potassium extracted ranged from 90.54 to 535.36, 65.23 to 481.60 and 50.32 to 374.98 respectively. For pH < 6.50 it was observed that available potassium ranged from 90.54 to 535.36, 65.23 to 481.60 and 50.32 to 374.98 for ammonium acetate, AB-DTPA and AAAC-EDTA. The samples having pH range between 6.50 to 7.50, available potassium ranged from 164.64 to 413.28, 139.67 to 387.40 and 115.25 to 366.23 for the above three methods respectively and for pH > 7.50 available potassium ranged from 208.80 to 380.80, 166.32 to 354.56 and 137.98 to 320.87, respectively.

The data for comparison of different extractants for extracting available potassium at different pH ranges is presented in table 4.7 and Fig. 4.2: (a, b, c). The data revealed that, at all three pH ranges, the extracting power of different extractants was as follows; Ammonium Acetate > AB-DTPA > AAAC-EDTA. At

pH < 6.5 the mean values according to the extracting power of extractants were 245.64, 217.22 and 183.41, respectively and all the methods were at par with each other. For pH range 6.50 to 7.50 the mean values were 302.47, 276.29 and 248.79, respectively and all the methods were at par with each other. For pH range > 7.50 the mean values were 308.40, 274.17 and 240.29, respectively and all the methods were statistically significant.

4.2.3 Exchangeable Calcium

The overall data for exchangeable calcium is presented in table 4.8. The results reveal that on an average the power of extraction of the different extractants was as follows; AAAC-EDTA > versenate titration > AB-DTPA and exchangeable calcium ranged from 1.30 to 5.80, 1.27 to 5.62 and 0.40 to 3.60, respectively. At pH < 6.5 it was observed that exchangeable calcium extracted by versenate titration method, ABDTPA and AAAC-EDTA ranged from 1.60 to 5.62, 0.70 to 3.60 and 1.80 to 5.80, for pH range between 6.50 to 7.50 exchangeable calcium extracted by above three methods ranged from 1.27 to 3.22, 0.40 to 1.40 and 1.30 to 3.40 and for pH > 7.50 exchangeable calcium extracted by above methods ranged from 1.48 to 5.13, 0.60 to 3.30 and 1.60 to 5.20, respectively.

The data comparing different extractants for extracting exchangeable calcium at different pH ranges is presented in table 4.9 and Fig. 4.3: (a, b, c). The data revealed that, at all three pH ranges, the extracting power of different methods was as follows: AAAC-EDTA > Versenate method > AB-DTPA. At pH < 6.5 the mean values according to the power of extraction of extractants were 3.68, 3.57 and 2.09, respectively. For pH range 6.50 to 7.50 the mean values were 2.02, 1.89 and 0.99, respectively and for pH > 7.50 the mean values were 3.63, 3.51 and 1.96, respectively.

Table 4.6: Available potassium in soil (kg/ha) as obtained with different extractants

Category	S.No.	Location	Ammonium acetate	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	135.60	112.65	95.20
	2	Ratnipora	193.23	162.11	145.60
	3	Chawalgam	221.20	199.20	179.20
	4	Nisarabad	90.54	65.23	50.32
	5	Yaripora	334.22	295.67	280.00
	6	Kadoorah	535.36	436.8	374.98
	7	Daran	98.97	80.87	70.40
	8	Ashmuji	478.24	481.60	343.62
	9	Shurat	243.20	225.30	193.20
	10	Nisarabad	90.54	82.81	74.88
	11	Parigam	507.92	459.20	345.41
	12	Chanser	129.89	114.13	102.44
	13	Khokharhama	392.50	345.62	324.80
	14	Adigan	113.68	97.81	89.44
	15	Ashmuji	119.56	99.24	81.61
	Mean		245.64	217.22	183.41
	Range		90.54-535.36	65.23-481.60	50.32-374.98
pH 6.50-7.50	16	Chollen	291.20	248.64	212.54
	17	Turkpora	164.64	139.67	115.25
	18	Nambla	413.28	387.4	342.64
	19	Dooniwari	311.36	281.43	264.56
	20	Dawaran	349.44	318.41	292.13
	21	Chotipora	412.16	384.34	366.23
	22	Dorusa	319.20	297.98	251.14
	23	Patal	179.20	152.16	137.52
	24	Diver	176.96	158.85	131.42
	25	Wadipora	310.24	287.13	265.67
	26	Turkpora	388.64	350.16	320.53

	27	Patal	316.96	289.12	254.2
	28	Kulangam	291.375	277.11	245.76
	29	Kulangam	231.52	218.40	197.10
	30	Gangbuk	380.80	353.52	335.29
	Mean		302.47	276.29	248.79
	Range		164.64-413.28	139.67-387.40	115.25-366.23
pH>7.50	31	Samboora	248.64	223.22	188.32
	32	Patal	369.60	330.68	314.12
	33	Chandhara	320.32	298.12	262.34
	34	Dusu	211.04	166.32	137.98
	35	Samboora	285.60	252.13	229.13
	36	Chandhara	227.84	187.92	143.06
	37	Dusu	208.80	193.36	165.29
	38	Dusu	375.92	329.48	298.34
	39	Patal	359.52	325.15	295.33
	40	Chandhara	380.80	354.56	320.87
	41	Bandi	318.88	267.76	230.26
	42	Kalsan	316.64	282.19	232.10
	43	Samboora	295.68	263.20	215.04
	44	Lethpora	362.88	319.10	284.23
	45	Chandhara	343.84	319.43	287.90
	Mean		308.40	274.17	240.29
	Range		208.80-380.80	166.32-354.56	137.98-320.87
Overall	Mean		285.50	255.89	224.16
	Range		90.54-535.36	65.23-481.60	50.32-374.98

Table 4.7: Comparison among different extractants for available potassium (kg/ha)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
Ammonium acetate	245.64 ^a	302.47 ^a	308.40 ^a
AB-DTPA	217.22 ^a	276.29 ^a	274.17 ^{ab}
AAAc-EDTA	183.41 ^a	248.79 ^a	240.29 ^b

Different letters in columns express significant difference at $\alpha \leq 0.05$

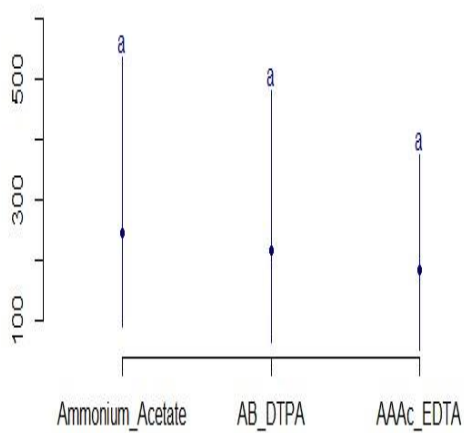


Fig. 4.2: (a)

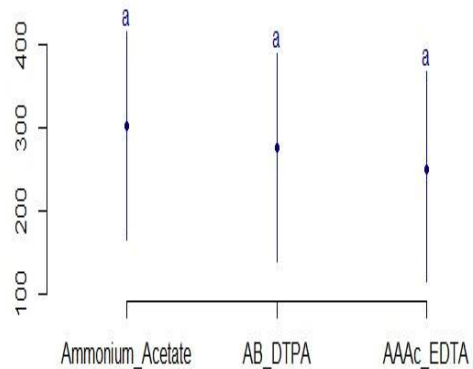


Fig. 4.2: (b)

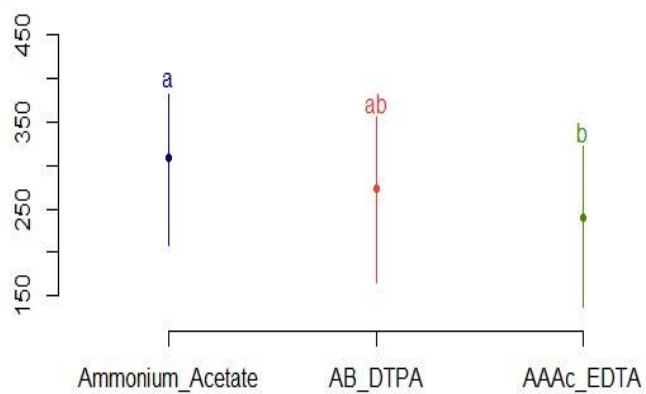


Fig. 4.2: (b)

Fig. 4.2: Comparison among different methods of potassium at a) pH <6.50, b) pH 6.50 to 7.50, c) pH > 7.50

Table 4.8: Exchangeable calcium in soil (me/100 g) as obtained with different extractants

Category	S.No.	Location	Versenate titration method	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	5.07	3.10	5.20
	2	Ratnipora	2.76	1.70	2.90
	3	Chawalgam	4.03	2.50	4.10
	4	Nisarabad	3.49	2.40	3.60
	5	Yaripora	4.18	2.40	4.20
	6	Kadoorah	3.43	2.50	3.50
	7	Daran	2.45	1.10	2.50
	8	Ashmuji	5.62	3.60	5.80
	9	Shurat	4.19	2.90	4.20
	10	Nisarabad	2.60	1.50	2.80
	11	Parigam	3.66	2.60	3.80
	12	Chanser	1.60	0.70	1.30
	13	Khokharhama	3.12	1.90	3.20
	14	Adigan	3.73	1.30	3.90
	15	Ashmuji	3.62	1.20	3.70
	Mean		3.57	2.09	3.68
	Range		1.60-5.62	0.70-3.60	1.80-5.80
pH 6.50-7.50	16	Chollen	1.89	1.20	1.90
	17	Turkpora	1.37	0.40	1.50
	18	Nambla	1.86	0.80	2.10
	19	Dooniwari	2.34	1.40	2.50
	20	Dawaran	1.98	1.30	2.10
	21	Chotipora	1.90	1.10	2.10
	22	Dorusa	2.08	1.10	2.20
	23	Patal	1.78	0.90	1.90
	24	Diver	1.38	0.40	1.50
	25	Wadipora	1.45	1.10	1.60
	26	Turkpora	2.32	1.30	2.50
	27	Patal	1.67	0.90	1.80

	28	Kulangam	3.22	1.30	3.40
	29	Kulangam	1.38	0.40	1.50
	30	Gangbuk	1.87	0.80	1.90
	Mean		1.89	0.99	2.02
	Range		1.27-3.22	0.40-1.40	1.30-3.40
pH>7.50	31	Samboora	4.26	2.40	4.30
	32	Patal	3.08	1.70	3.20
	33	Chandhara	2.92	1.80	3.10
	34	Dusu	2.64	1.70	2.70
	35	Samboora	1.75	0.70	1.90
	36	Chandhara	4.28	2.50	4.40
	37	Dusu	3.74	1.70	3.90
	38	Dusu	4.72	2.60	4.80
	39	Patal	2.74	1.60	2.90
	40	Chandhara	1.48	0.60	1.60
	41	Bandi	5.13	3.30	5.20
	42	Kalsan	4.84	2.70	4.90
	43	Samboora	2.88	1.60	3.10
	44	Lethpora	4.04	2.20	4.10
	45	Chandhara	4.22	2.30	4.30
	Mean		3.51	1.96	3.63
Range		1.48-5.13	0.6-3.30	1.6-5.20	
Overall	Mean		2.99	1.68	3.11
	Range		1.27-5.62	0.40-3.60	1.30-5.80

Table 4.9: Comparison among different extractants for exchangeable calcium (me/100 g)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
Versenate titration method	3.57 ^a	1.89 ^a	3.51 ^a
AB-DTPA	2.09 ^b	0.99 ^b	1.96 ^b
AAAc-EDTA	3.68 ^a	2.02 ^a	3.63 ^a

Different letters in columns express significant difference at $\alpha \leq 0.05$

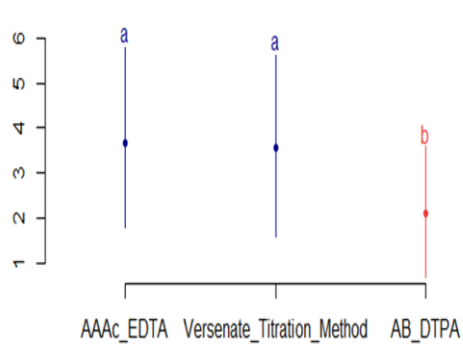


Fig. 4.3: (a)

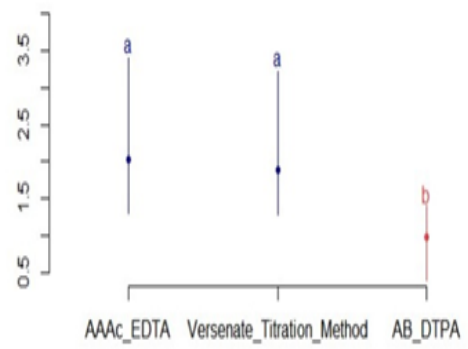


Fig. 4.3: (b)

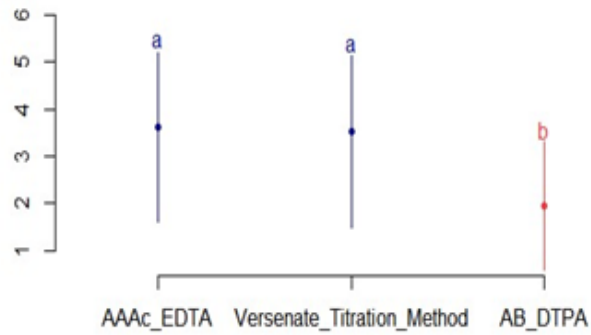


Fig. 4.3: (c)

Fig. 4.3: Comparison among different methods of calcium at (a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50

4.2.4 Exchangeable Magnesium

The overall data for exchangeable magnesium is presented in table 4.10. The results reveal that on an average the power of extraction of the different extractants was as follows: AAAC-EDTA > versenate titration > AB-DTPA and magnesium extracted ranged from 0.70 to 2.90, 0.63 to 2.81 and 0.30 to 1.80, respectively. As for samples having pH < 6.50 it was observed that exchangeable magnesium for versenate titration method, AB-DTPA and AAAC-EDTA ranged from 0.80 to 2.81, 0.40 to 1.70 and 0.90 to 2.90, respectively. For pH range between 6.50 to 7.50 the exchangeable magnesium for above methods ranged from 0.63 to 1.61, 0.30 to 1.20 and 0.70 to 2.10, respectively and for pH > 7.50 exchangeable magnesium for above methods ranged from 0.74 to 2.57, 0.40 to 1.80 and 0.90 to 2.70, respectively.

The data comparing different extractants for extracting exchangeable magnesium at different pH ranges is presented in table 4.11 and Fig. 4.4: (a, b, c). The data revealed that, at all three pH ranges, the extracting power of different methods was as follows: AAAC-EDTA > Versenate method > AB-DTPA. At pH < 6.5 the mean values were 1.91, 1.78 and 0.98, respectively according to the power of extraction of these extractants. For pH range 6.50 to 7.50 the mean values were 1.25, 0.94 and 0.61, respectively according to the above order. For pH > 7.50 the mean values were 1.91, 1.76 and 1.20, respectively with the above order and at pH ranges <6.50 and >7.50 AAAC-EDTA and Versenate method were at par with each other and for pH range 6.50 to 7.50 all the three methods differed significant.

Table 4.10: Exchangeable magnesium in soil (me/100 g) as obtained with different extractants

Category	S.No.	Location	Versenate titration method	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	2.54	1.70	2.70
	2	Ratnipora	1.38	0.90	1.50
	3	Chawalgam	2.01	1.40	2.20
	4	Nisarabad	1.75	0.80	1.90
	5	Yaripora	2.09	1.20	2.10
	6	Kadoorah	1.72	0.70	1.90
	7	Daran	1.22	0.70	1.30
	8	Ashmuji	2.81	1.50	2.90
	9	Shurat	2.09	1.30	2.20
	10	Nisarabad	1.30	0.60	1.50
	11	Parigam	1.86	1.10	2.10
	12	Chanser	0.80	0.40	0.90
	13	Khokharhama	1.56	0.60	1.70
	14	Adigan	1.83	0.90	1.90
	15	Ashmuji	1.81	0.90	1.90
	Mean		1.78	0.98	1.91
	Range		0.80-2.81	0.40-1.70	0.90-2.90
pH 6.50-7.50	16	Chollen	0.94	0.50	1.30
	17	Turkpora	0.63	0.40	0.90
	18	Nambla	0.93	1.20	2.10
	19	Dooniwari	1.17	0.50	1.30
	20	Dawaran	0.99	0.60	1.30
	21	Chotipora	0.95	0.60	2.10
	22	Dorusa	1.04	0.80	1.20
	23	Patal	0.89	0.40	1.20
	24	Diver	0.72	0.40	0.90
	25	Wadipora	0.63	0.30	0.70
	26	Turkpora	1.16	0.90	1.20
	27	Patal	0.83	0.40	0.90

	28	Kulangam	1.61	1.10	1.80
	29	Kulangam	0.68	0.40	0.80
	30	Gangbuk	0.93	0.60	1.10
	Mean		0.94	0.61	1.25
	Range		0.63-1.61	0.30-1.20	0.70-2.10
pH>7.50	31	Samboora	2.13	1.60	2.20
	32	Patal	1.54	1.10	1.80
	33	Chandhara	1.46	0.90	1.60
	34	Dusu	1.32	0.80	1.50
	35	Samboora	0.87	0.40	1.10
	36	Chandhara	2.14	1.50	2.30
	37	Dusu	1.87	1.20	2.10
	38	Dusu	2.36	1.70	2.50
	39	Patal	1.44	0.90	1.60
	40	Chandhara	0.74	0.40	0.90
	41	Bandi	2.57	1.80	2.70
	42	Kalsan	2.42	1.80	2.50
	43	Samboora	1.37	1.10	1.50
	44	Lethpora	2.02	1.50	2.10
	45	Chandhara	2.11	1.30	2.30
Mean		1.76	1.20	1.91	
Range		0.74-2.57	0.40-1.80	0.90-2.70	
Overall	Mean		1.49	0.93	1.69
	Range		0.63-2.81	0.30-1.80	0.70-2.90

Table 4.11: Comparison among different extractants for Exchangeable magnesium (me/100 g)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
Versenate titration method	1.78 ^a	0.94 ^b	1.76 ^a
AB-DTPA	0.98 ^b	0.61 ^c	1.2 ^b
AAAc-EDTA	1.91 ^a	1.25 ^a	1.91 ^a

Different letters in columns express significant difference at $\alpha \leq 0.05$

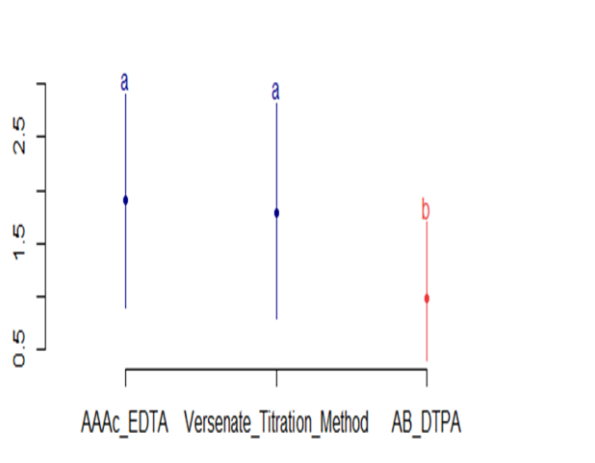


Fig. 4.4: (a)

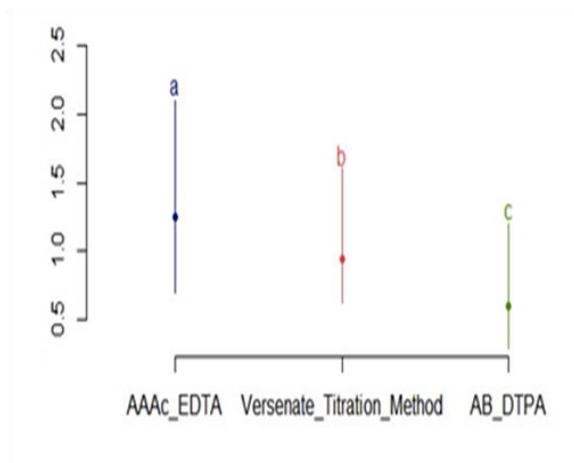


Fig. 4.4: (b)

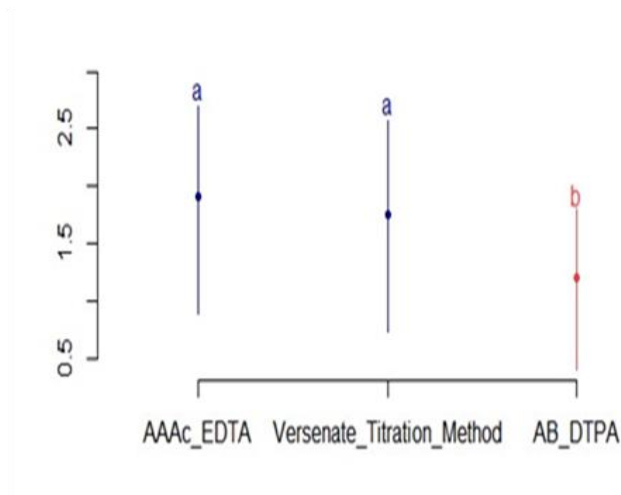


Fig. 4.4: (c)

Fig. 4.4: Comparison of different methods of magnesium at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50

4.2.5 Available Iron (mg/kg)

The overall data for available iron is presented in table 4.12. The results reveal that on an average the power of extraction of the different extractants was as follows: AB-DTPA > CaCl₂-DTPA > AAAC-EDTA and available iron extracted ranged from 12.50 to 34.60, 7.60 to 22.40 and 6.30 to 19.20, respectively. As for samples having pH < 6.50 it was observed that available iron for CaCl₂-DTPA, ABDTPA and AAAC-EDTA ranged from 14.70 to 22.40, 21.60 to 34.60 and 11.80 to 19.20, respectively, for pH range between 6.50 to 7.50 available iron for above methods ranged from 10.30 to 19.20, 14.50 to 26.80 and 7.40 to 18.20, respectively and for samples having pH > 7.50 available iron for above methods ranged from 7.60 to 16.90, 12.50 to 25.80 and 6.30 to 13.60, respectively.

The data comparing different extractants for extracting available iron at different pH ranges is presented in table 4.13 and Fig. 4.5: (a, b, c). The data revealed that, at all three pH ranges, the extracting power of different extractants was as follows: AB-DTPA > CaCl₂-DTPA > AAAC-EDTA. At pH < 6.5 the mean values according to the extracting power of extractants were 27.03, 18.58 and 15.64, respectively. For pH range 6.50 to 7.50 the mean values were 20.51, 15.45 and 11.91, respectively. For pH > 7.50 the mean values were 18.86, 12.96 and 10.39, respectively and at all pH ranges all the methods were statistically significant.

Table 4.12: Available iron in soil (mg/kg) as obtained with different extractants

Category	S.No.	Location	CaCl ₂ -DTPA	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	22.40	21.60	16.30
	2	Ratnipora	21.60	33.40	18.70
	3	Chawalgam	20.40	28.50	18.50
	4	Nisarabad	20.40	34.60	19.20
	5	Yaripora	19.90	26.40	16.30
	6	Kadoorah	19.70	26.80	17.60
	7	Daran	19.40	31.20	15.40
	8	Ashmuji	18.70	29.70	16.20
	9	Shurat	18.40	28.60	14.70
	10	Nisarabad	18.40	28.60	15.80
	11	Parigam	17.30	24.50	12.60
	12	Chanser	16.80	23.20	14.30
	13	Khokharhama	15.20	23.70	13.87
	14	Adigan	15.40	22.60	13.40
	15	Ashmuji	14.70	22.70	11.80
	Mean		18.58	27.07	15.64
	Range		14.70-22.40	21.60-34.60	11.80-19.20
pH 6.50-7.50	16	Chollen	19.20	26.70	14.90
	17	Turkpora	18.90	24.70	15.80
	18	Nambla	18.20	23.60	14.30
	19	Dooniwari	17.60	19.90	12.50
	20	Dawaran	16.60	26.80	18.20
	21	Chotipora	16.40	20.50	12.60
	22	Dorusa	15.70	19.60	11.80
	23	Patal	15.40	22.90	11.80
	24	Diver	15.50	19.60	11.30
	25	Wadipora	14.60	19.60	10.50
	26	Turkpora	14.30	18.60	11.90
	27	Patal	13.80	16.90	8.60
	28	Kulangam	13.70	17.90	9.40
	29	Kulangam	11.60	14.50	7.40

	30	Gangbuk	10.30	15.80	7.70
	Mean		15.45	20.51	11.91
	Range		10.30-19.20	14.50-26.80	7.40-18.20
pH>7.50	31	Samboora	16.90	23.80	12.20
	32	Patal	15.80	24.50	13.60
	33	Chandhara	14.60	20.50	12.80
	34	Dusu	14.60	17.40	11.50
	35	Samboora	14.60	19.60	11.80
	36	Chandhara	14.40	25.80	11.90
	37	Dusu	13.80	15.40	10.50
	38	Dusu	12.90	15.80	8.60
	39	Patal	12.60	18.60	7.80
	40	Chandhara	12.60	19.70	9.80
	41	Bandi	12.40	18.80	9.40
	42	Kalsan	12.40	16.80	10.60
	43	Samboora	9.90	14.80	6.30
	44	Lethpora	9.30	12.50	6.40
	45	Chandhara	7.60	18.90	12.70
	Mean		12.96	18.86	10.39
	Range		7.60-16.90	12.50-25.80	6.30-13.60
Overall	Mean		15.66	22.15	12.65
	Range		7.60-22.40	12.50-34.60	6.30-19.20

Table 4.13: Comparison among different extractants for available Iron (mg/kg)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
CaCl₂-DTPA	18.58 ^b	15.45 ^b	12.96 ^b
AB-DTPA	27.03 ^a	20.51 ^a	18.86 ^a
AAAc-EDTA	15.64 ^c	11.91 ^c	10.39 ^c

Different letters in columns express significant difference at $\alpha \leq 0.05$

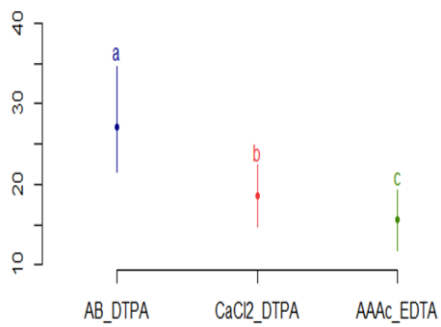


Fig. 4.5: (a)

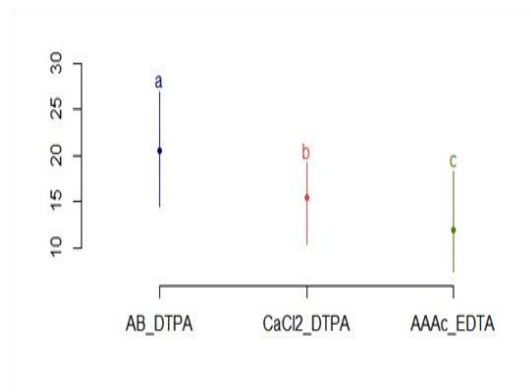


Fig. 4.5: (b)

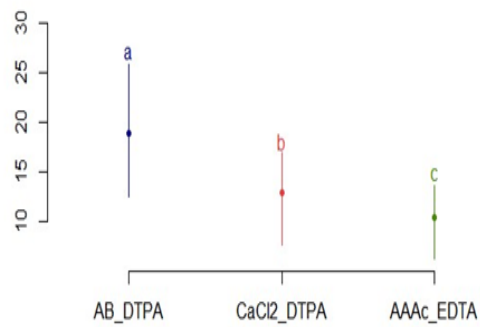


Fig. 4.5: (c)

Fig. 4.5: Comparison among different methods of iron at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50

4.2.6 Available Copper (mg/kg)

The overall data for available copper is presented in table 4.14. The results reveal that on an average the power of extraction of the different extractants was as follows: AB-DTPA > AAAC-EDTA > CaCl₂-DTPA and available copper extracted ranged from 0.90 to 3.80, 0.90 to 3.10 and 0.20 to 2.50, respectively. As for pH < 6.50 it was observed that available copper for CaCl₂-DTPA, ABDTPA and AAAC-EDTA ranged from 0.80 to 2.50, 2.10 to 3.80 and 1.40 to 3.10, for pH range between 6.50 to 7.50 the available copper extracted by above three methods ranged from 0.20 to 1.80, 0.90 to 2.50 and 1.10 to 2.30 and for pH > 7.50 available copper extracted by above three methods ranged from 0.20 to 1.10, 1.30 to 2.80 and 0.90 to 1.90, respectively.

The data for comparison of different extractants for extracting available copper at different pH ranges is presented in table 4.15 and Fig. 4.6: (a, b, c). The data revealed that, at all three pH ranges, the extracting power of different extractants was as follows: AB-DTPA > AAAC-EDTA > CaCl₂-DTPA. At pH < 6.5 the mean values according to the extracting power of extractants were 3.16, 2.46 and 1.53, respectively. For pH range 6.50 to 7.50 for above methods the mean values were 1.82, 1.55 and 0.86, respectively. For pH > 7.50 the mean values for above three methods were 1.77, 1.33 and 0.63, respectively. At pH range between 6.50 to 7.50 AB-DTPA and AAAC-EDTA were at par with each other and for other two categories of pH all the methods were statistically significant.

Table 4.14: Available copper in soil (mg/kg) as obtained with different extractants

Category	S.No.	Location	CaCl ₂ -DTPA	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	1.30	3.50	2.80
	2	Ratnipora	1.30	3.10	1.90
	3	Chawalgam	2.50	3.80	3.10
	4	Nisarabad	1.10	3.10	2.50
	5	Yaripora	2.10	3.50	2.90
	6	Kadoorah	1.60	3.20	2.80
	7	Daran	1.70	3.20	2.50
	8	Ashmuji	0.90	2.10	1.60
	9	Shurat	1.40	3.10	2.20
	10	Nisarabad	0.80	2.10	1.40
	11	Parigam	1.30	3.10	2.30
	12	Chanser	1.80	3.60	2.90
	13	Khokharhama	1.70	3.30	2.50
	14	Adigan	1.10	2.90	2.40
	15	Ashmuji	2.30	3.80	3.01
	Mean		1.53	3.16	2.46
	Range		0.80-2.50	2.10-3.80	1.40-3.10
pH 6.50-7.50	16	Chollen	1.40	2.10	1.90
	17	Turkpora	1.80	2.50	2.10
	18	Nambla	0.60	1.80	1.40
	19	Dooniwari	0.40	1.60	1.11
	20	Dawaran	0.60	1.50	1.10
	21	Chotipora	1.30	2.30	1.80
	22	Dorusa	0.20	0.90	1.20
	23	Patal	0.30	1.90	2.10
	24	Diver	0.60	1.70	1.10
	25	Wadipora	0.80	1.90	1.40
	26	Turkpora	0.80	1.90	1.30
	27	Patal	0.70	2.10	1.40
	28	Kulangam	1.30	2.30	1.90

	29	Kulangam	1.60	1.30	2.30
	30	Gangbuk	0.50	1.50	1.10
	Mean		0.86	1.82	1.55
	Range		0.20-1.80	0.90-2.50	1.10-2.30
pH>7.50	31	Samboora	0.50	1.80	1.30
	32	Patal	0.70	1.70	1.80
	33	Chandhara	0.40	1.40	1.10
	34	Dusu	0.80	2.80	1.40
	35	Samboora	0.60	2.10	1.50
	36	Chandhara	0.80	1.90	1.30
	37	Dusu	0.90	2.10	1.50
	38	Dusu	0.30	1.30	0.90
	39	Patal	0.90	2.30	1.50
	40	Chandhara	0.60	1.50	1.20
	41	Bandi	0.70	1.70	1.30
	42	Kalsan	0.60	1.30	1.10
	43	Samboora	0.40	1.90	1.20
	44	Lethpora	0.20	1.30	0.90
	45	Chandhara	1.10	1.40	1.90
	Mean		0.63	1.77	1.33
Range		0.20-1.10	1.30-2.80	0.90-1.90	
Overall	Mean		1.01	2.25	1.78
	Range		0.20-2.50	0.90-3.80	0.90-3.10

Table 4.15: Comparison among different extractants for available copper (mg/kg)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
CaCl₂-DTPA	1.53 ^c	0.86 ^b	0.63 ^c
AB-DTPA	3.16 ^a	1.82 ^a	1.77 ^a
AAAc-EDTA	2.46 ^b	1.55 ^a	1.33 ^b

Different letters in columns express significant difference at $\alpha \leq 0.05$

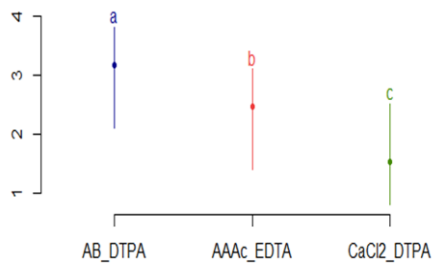


Fig. 4.6: (a)

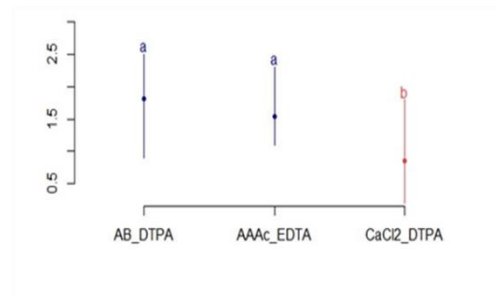


Fig. 4.6: (b)

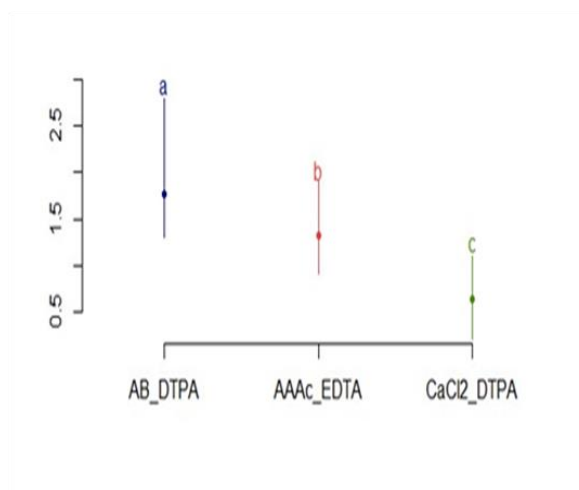


Fig. 4.6: (c)

Fig. 4.6: Comparison among different methods of copper at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50

4.2.7 Available Manganese (mg/kg)

The overall data for available manganese is presented in table 4.16. The results reveal that on an average the power of extraction of the different extractants was as follows: AAAC-EDTA > AB-DTPA > CaCl₂-DTPA and available manganese extracted ranged from 10.60 to 35.40, 9.20 to 27.80 and 4.20 to 19.20, respectively. As for the pH < 6.50 it was observed that available copper for CaCl₂-DTPA, ABDTPA and AAAC-EDTA ranged from 13.80 to 19.20, 10.90 to 27.80 and 11.70 to 35.40, respectively. For pH range between 6.50 to 7.50, available manganese extracted by above three methods ranged from 4.70 to 13.60, 9.30 to 18.50 and 14.30 to 23.93, respectively and for pH > 7.50 available manganese extracted by above three methods ranged from 4.20 to 14.30, 9.20 to 20.60 and 10.60 to 28.70, respectively.

The data comparing different extractants for extracting available manganese at different pH ranges is presented in table 4.17 and Fig. 4.7: (a, b, c). The data revealed that, at all three pH ranges, the extracting power of different methods was as follows: AAAC-EDTA > AB-DTPA > CaCl₂-DTPA. At pH < 6.5 the mean values according to the extracting power of extractants were 29.37, 22.01 and 16.75, respectively. For pH range 6.50 to 7.50 the mean values were 18.91, 14.63 and 10.37, respectively and for pH > 7.50 the mean values were 19.59, 14.58 and 9.57, respectively. At all pH ranges, all the methods were statistically significant with each other.

Table 4.16: Available manganese in soil (mg/kg) as obtained with different extractants

Category	S.No.	Location	CaCl ₂ -DTPA	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	16.30	22.30	31.60
	2	Ratnipora	18.80	23.70	31.80
	3	Chawalgam	16.20	21.60	32.70
	4	Nisarabad	18.60	25.30	33.90
	5	Yaripora	14.70	19.40	25.60
	6	Kadoorah	16.20	22.40	31.70
	7	Daran	14.40	20.20	24.30
	8	Ashmuji	18.50	23.50	32.60
	9	Shurat	15.80	19.70	26.50
	10	Nisarabad	13.80	10.90	11.70
	11	Parigam	19.20	27.80	35.40
	12	Chanser	15.70	20.60	23.80
	13	Khokharhama	18.40	25.60	33.20
	14	Adigan	17.40	23.60	32.60
	15	Ashmuji	17.30	23.60	33.10
	Mean		16.75	22.01	29.37
	Range		13.80-19.20	10.90-27.80	11.70-35.40
pH 6.50-7.50	16	Chollen	9.90	12.60	15.40
	17	Turkpora	10.30	15.40	19.20
	18	Nambla	13.60	17.50	23.30
	19	Dooniwari	11.40	15.30	19.20
	20	Dawaran	13.20	16.40	19.90
	21	Chotipora	9.80	13.60	17.50
	22	Dorusa	9.40	13.60	16.20
	23	Patal	9.90	11.60	14.30
	24	Diver	8.20	15.40	21.90
	25	Wadipora	12.50	16.40	21.20
	26	Turkpora	12.70	18.50	23.20
	27	Patal	8.60	15.40	19.90
	28	Kulangam	10.80	14.20	18.50

	29	Kulangam	4.70	9.30	14.70
	30	Gangbuk	10.60	14.30	19.20
	Mean		10.37	14.63	18.91
	Range		4.70-13.60	9.30-18.50	14.30-23.93
pH>7.50	31	Samboora	13.70	20.60	26.90
	32	Patal	4.20	9.20	10.60
	33	Chandhara	9.40	14.40	20.30
	34	Dusu	10.50	15.70	21.90
	35	Samboora	12.40	18.90	22.50
	36	Chandhara	6.20	13.60	18.20
	37	Dusu	8.80	14.60	19.40
	38	Dusu	6.30	11.70	17.40
	39	Patal	11.20	17.50	22.80
	40	Chandhara	8.30	11.50	17.20
	41	Bandi	12.20	15.40	18.20
	42	Kalsan	11.30	13.50	17.80
	43	Samboora	14.30	20.30	28.70
	44	Lethpora	9.20	12.50	19.50
	45	Chandhara	5.60	9.30	12.50
	Mean		9.57	14.58	19.59
Range		4.20-14.30	9.20-20.60	10.60-28.70	
Overall	Mean		12.23	17.08	22.62
	Range		4.20-19.20	9.20-27.80	10.60-35.40

Table 4.17: Comparison among different extractants for available manganese (mg/kg)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
CaCl₂-DTPA	16.75 ^c	10.37 ^c	9.57 ^c
AB-DTPA	22.01 ^b	14.63 ^b	14.58 ^b
AAAc-EDTA	29.37 ^a	18.91 ^a	19.59 ^a

Different letters in columns express significant difference at $\alpha \leq 0.05$

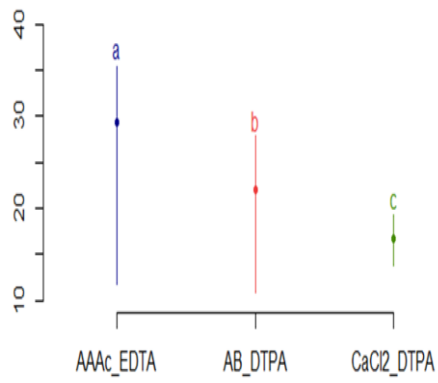


Fig. 4.7: (a)

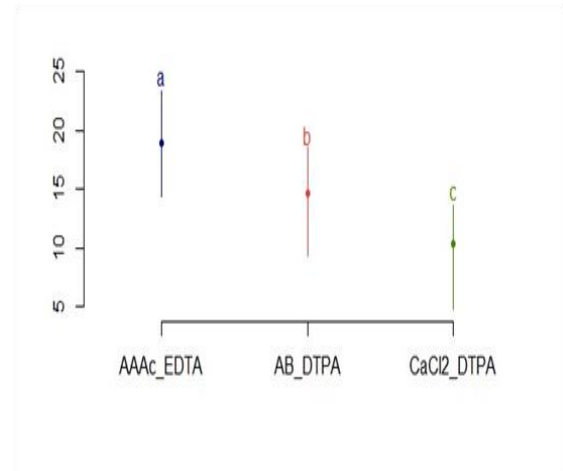


Fig. 4.7: (b)

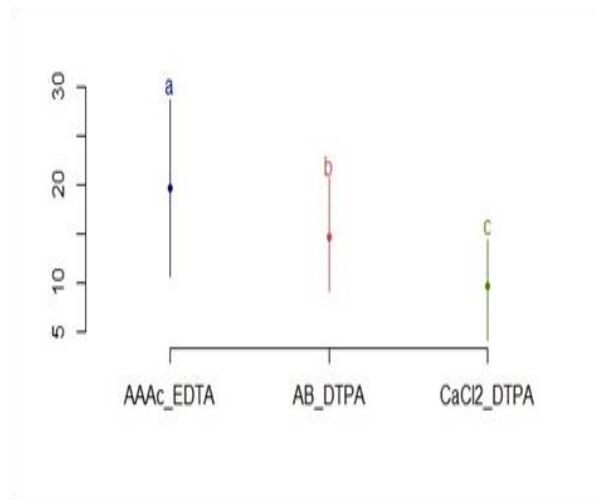


Fig. 4.7: (c)

Fig. 4.7: Comparison among different methods of manganese at a) pH <6.50, b) pH 6.50 to 7.50, c) pH > 7.50

4.2.8 Available Zinc (mg/kg)

The overall data for available manganese is presented in table 4.18. The results reveal that on an average the power of extraction of the different extractants was as follows: $\text{CaCl}_2\text{-DTPA} > \text{AB-DTPA} > \text{AAAc-EDTA}$ and available zinc extracted ranged from 0.90 to 3.60, 1.10 to 3.70 and 0.60 to 2.60, respectively. As for $\text{pH} < 6.50$ it was observed that available zinc for $\text{CaCl}_2\text{-DTPA}$, ABDTPA and AAAc-EDTA ranged from 0.90 to 3.50, 1.90 to 3.50 and 1.20 to 2.50, respectively. For pH range between 6.50 to 7.50 available zinc extracted by above three methods ranged from 1.90 to 3.10, 1.30 to 3.70 and 0.80 to 2.60, respectively and for $\text{pH} > 7.50$ the available zinc for above three methods ranged from 1.50 to 3.60, 1.10 to 2.90 and 0.60 to 2.40, respectively.

The data comparing different extractants for extracting available zinc at different pH ranges is presented in table 4.19 and Fig. 4.8: (a, b, c). The data revealed that, at $\text{pH} < 6.50$ power of different methods was as follows: $\text{AB-DTPA} > \text{CaCl}_2\text{-DTPA} > \text{AAAc-EDTA}$ with mean values of 2.56, 2.49, 1.73, respectively. Also, AB-DTPA and $\text{CaCl}_2\text{-DTPA}$ methods were at par with each other. At pH ranges 6.50 to 7.50 and > 7.50 , the extracting power of different methods was as follows: $\text{CaCl}_2\text{-DTPA} > \text{AB-DTPA} > \text{AAAc-EDTA}$ with mean values of 2.49, 2.15, 1.71 for pH range 6.50 to 7.50 whereas for $\text{Ph} > 7.50$ mean values ranged from 2.63, 2.06, 1.57, respectively. At pH range of 6.50 to 7.50 AB-DTPA and $\text{CaCl}_2\text{-DTPA}$ were at par with each other whereas, for $\text{pH} > 7.50$ all the methods were statistically significant.

Table 4.18: Available Zinc in soil (mg/kg) as obtained with different extractants

Category	S.No.	Location	CaCl ₂ -DTPA	AB-DTPA	AAAc-EDTA
pH<6.50	1.	Chambgund	1.20	3.50	1.60
	2	Ratnipora	3.30	2.90	2.40
	3	Chawalgam	2.30	1.90	1.30
	4	Nisarabad	1.10	3.30	1.30
	5	Yaripora	3.10	2.30	1.80
	6	Kadoorah	3.30	2.90	2.30
	7	Daran	2.90	2.10	1.60
	8	Ashmuji	2.90	2.10	1.50
	9	Shurat	2.50	2.10	1.50
	10	Nisarabad	1.80	2.20	1.50
	11	Parigam	3.50	3.10	2.10
	12	Chanser	2.90	2.30	1.90
	13	Khokharhama	3.10	2.90	2.50
	14	Adigan	0.90	2.90	1.20
	15	Ashmuji	2.50	1.90	1.40
	Mean		2.49	2.56	1.73
	Range		0.90-3.50	1.90-3.50	1.20-2.50
pH 6.50-7.50	16	Chollen	3.10	2.40	2.10
	17	Turkpora	2.40	1.90	1.60
	18	Nambla	2.60	2.10	1.70
	19	Dooniwari	2.30	1.90	1.60
	20	Dawaran	2.50	1.90	1.50
	21	Chotipora	2.90	2.30	1.90
	22	Dorusa	2.80	2.30	1.80
	23	Patal	1.90	3.70	2.50
	24	Diver	2.30	1.90	1.40
	25	Wadipora	2.10	1.50	1.20
	26	Turkpora	1.90	1.30	0.80
	27	Patal	2.10	1.60	1.20
	28	Kulangam	3.10	2.90	2.60

	29	Kulangam	3.10	2.60	2.20
	30	Gangbuk	2.20	1.90	1.50
	Mean		2.49	2.15	1.71
	Range		1.90-3.10	1.30-3.70	0.80-2.60
pH>7.50	31	Samboora	2.50	1.90	1.40
	32	Patal	2.20	1.50	1.30
	33	Chandhara	2.70	2.10	1.70
	34	Dusu	3.60	2.90	2.40
	35	Samboora	3.60	2.80	2.10
	36	Chandhara	2.50	1.90	1.40
	37	Dusu	1.50	1.10	0.60
	38	Dusu	2.80	2.30	1.90
	39	Patal	2.90	2.80	1.70
	40	Chandhara	1.90	1.30	0.90
	41	Bandi	2.10	1.60	1.10
	42	Kalsan	3.20	2.70	2.30
	43	Samboora	3.50	2.30	1.80
	44	Lethpora	2.30	1.90	1.60
	45	Chandhara	2.20	1.80	1.30
	Mean		2.63	2.06	1.57
Range		1.50-3.60	1.10-2.90	0.60-2.40	
Overall	Mean		2.54	2.26	1.67
	Range		0.90-3.60	1.10-3.70	0.60-2.60

Table 4.19: Comparison among different extractants for available Zinc (mg/kg)

Methods	Categories		
	pH<6.50	pH 6.50 to 7.50	pH> 7.50
CaCl₂-DTPA	2.49 ^a	2.49 ^a	2.63 ^a
AB-DTPA	2.56 ^a	2.15 ^a	2.06 ^b
AAAc-EDTA	1.73 ^b	1.71 ^b	1.57 ^c

Different letters in columns express significant difference at $\alpha \leq 0.05$

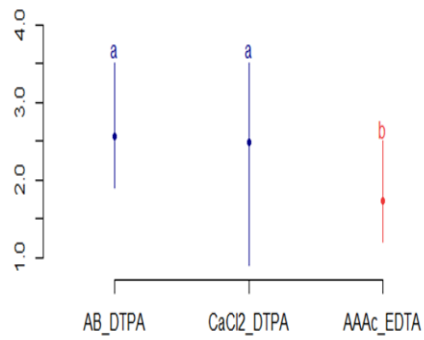


Fig 4.8: (a)

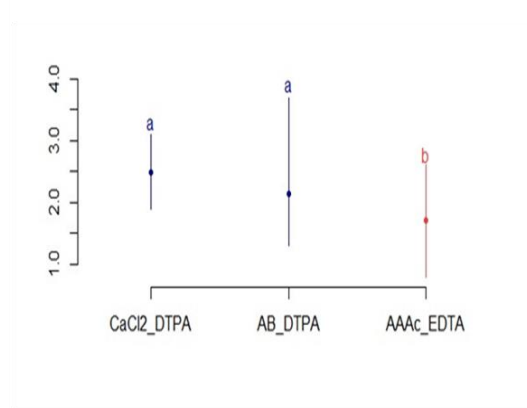


Fig. 4.8: (b)

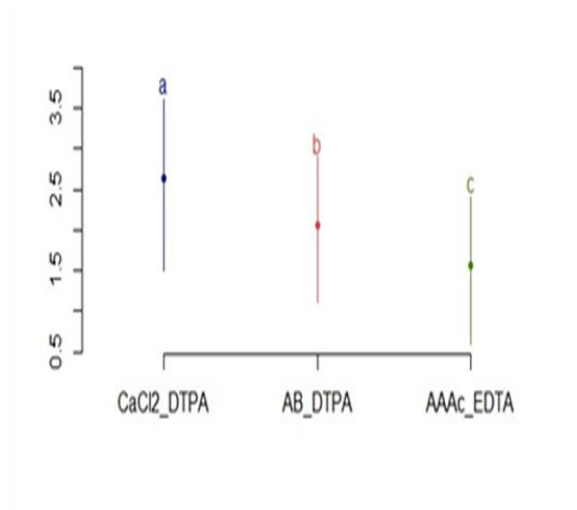


Fig. 4.8: (c)

Fig. 4.8: Comparison of different methods of zinc at a) pH <6.50, b) pH 6.50 to 7.50, c) pH > 7.50

4.3 Correlation Studies

The relationships of the extracted quantity found for particular nutrient under multi-nutrient extractant with standard methods were studied following correlation analysis and have been discussed in subsequent sections.

4.3.1 Relationship between the available nutrients and physico-chemical properties and relation among different methods of extraction

i. Phosphorous

The coefficients of correlation between available phosphorus and physico-chemical properties are shown in Fig. 4.9: (a, b, c, d). When soil samples having different pH ranges were considered separately, a non-significant relationship existed between all P extraction methods (Olsen, Bray, AB-DTPA and AAAC-EDTA) and physico chemical properties. However, when all pH ranges were considered together, Bray, AB-DTPA and AAAC-EDTA were having negative and highly significant relation with pH, EC. In addition, Bray was also negatively correlated with CaCO_3 .

As shown in Fig 4.9: (a), 4.9: (b) and 4.9: (c) at $\text{pH} < 6.50$, $6.50- 7.50$ and > 7.50 AB-DTPA and AAAC-EDTA were highly correlated with the standard methods i.e., Olsen and Bray. Also, it was found that AAAC-EDTA is more closely related to the standard methods. Same results were found when all the samples were taken together irrespective of pH (Fig. 4.9: (d)).

ii. Potassium

The coefficients of correlation between available potassium and physico-chemical properties are shown in Fig. 4.10: (a, b, c, d). When soil samples having different pH ranges were considered separately, a non-significant relationship existed between the potassium extracted by all the three methods (Ammonium Acetate, AB-DTPA, AAAC-EDTA) with pH, EC, organic carbon, CEC and CaCO_3 . However, when all pH ranges were considered together, AB-DTPA method had

positive and significant relation with CaCO_3 and for AAAC-EDTA a positive and significant correlation was found with pH and CaCO_3 .

As shown in Fig 4.10: (a, b, c) at all the pH ranges AB-DTPA and AAAC-EDTA were highly correlated with the standard method ammonium acetate. Also, it was found that AB-DTPA is more closely related to the standard method. Same results were found when all the samples were taken together irrespective of pH (Fig.4.10: (d)).

iii. Calcium

The coefficients of correlation between exchangeable calcium and physico-chemical properties are shown in Fig. 4.11: (a, b, c, d). At pH <6.50 and 6.50-7.50, highly significant relationship existed between Ca extracted by all the three methods with organic carbon and CEC and a non-significant relation existed with other soil properties. However, at pH > 7.50 all the three methods were highly significant with CEC and a non-significant relation existed between the methods and other soil properties but AB-DTPA method had positive and significant relation with organic carbon. Also, a positive and significant correlation was found with CEC and organic carbon when all the samples were taken into consideration irrespective of pH.

As shown in Fig 4.11: (a, b, c) at all pH ranges, AB-DTPA and AAAC-EDTA were highly correlated with the standard method Versenate Titration Method. Also, it was found that AAAC-EDTA is more closely related to the standard method. Same results were found when all the samples were taken together irrespective of pH (Fig.4.11: (d)).

iv. Magnesium

The coefficients of correlation between exchangeable magnesium and physico-chemical properties are shown in Fig. 4.12: (a, b, c, d). At pH <6.50 highly significant relationship existed between magnesium extracted by all the three methods with organic carbon and CEC and a non-significant relation existed with other soil properties, at pH range of 6.50-7.50, highly significant relationship existed between Ca extracted by all the three methods with organic carbon, Versenate titration method and AB-DTPA were highly correlated with CEC but AAAC-EDTA had a non-significant relation with CEC and also a non-significant relation existed with other soil properties. However, at pH > 7.50 all the three methods were highly significant with CEC and a non-significant relation existed between the methods and other soil properties. Also, a positive and significant correlation was found with CEC and organic carbon except for AB-DTPA had non-significant relation with CEC when all the samples were taken into consideration irrespective of pH.

As shown in Fig 4.12: (a, b, c) at all pH ranges, AB-DTPA and AAAC-EDTA were highly correlated with the standard method (Versenate Titration Method). Also, it was found that AAAC-EDTA is more closely related to the standard method. Same results were found when all the samples were taken together irrespective of pH (Fig.4.12: (d)).

v. Iron

The coefficients of correlation for relationship between available iron and physico-chemical properties are shown in Fig. 4.13: (a, b, c, d). At pH <6.50 CaCl₂-DTPA and AAAC-EDTA had a significant but negative relation with pH. A significant but negative correlation was found between all the three methods with pH at pH ranges between 6.50-7.50 and > 7.50. However, all three methods had highly significant but negative correlation with pH, EC and CaCO₃ and highly significant and positive relation with organic carbon and CEC except for AB-DTPA

which had a non-significant relation with CEC when all the samples were taken into consideration irrespective of pH.

As shown in Fig. 4.13: (a, b, c) at all the pH ranges, AB-DTPA and AAAC-EDTA were correlated with the standard method CaCl_2 -DTPA. Same results were found when all the samples were taken together irrespective of pH (Fig. 4.13: (d)).

vi. Copper

The coefficients of correlation between available copper and physico-chemical properties are shown in Fig. 4.14: (a, b, c, d). A non-significant relationship existed between the copper extracted by all the three methods (CaCl_2 -DTPA, AB-DTPA, AAAC-EDTA) with pH, EC, organic carbon, CEC and CaCO_3 when soil samples having different pH ranges were considered. However, all the above three methods had highly significant but negative correlation with pH, EC and CaCO_3 and a significant and positive relation with organic carbon when all the samples were taken into consideration irrespective of pH.

As shown in Fig 4.14(a), at $\text{pH} < 6.50$ it was found that all the methods were highly correlated with standard method CaCl_2 -DTPA. At $\text{pH} 6.50$ - 7.50 (Fig. 4.14: (b)) all the methods were correlated with each other and at $\text{pH} > 7.50$ (Fig. 4.14: (c)) AB-DTPA had a non-significant relation with the standard method. Also, it was found that all the methods were highly correlated with standard methods and AAAC-EDTA was more closely related to the standard method when all the samples were taken together irrespective of pH (Fig.4.14: (d)).

vii. Manganese

The coefficients of correlation between available manganese and physico-chemical properties are shown in Fig. 4.15: (a, b, c, d). At $\text{pH} < 6.50$ AAAC-EDTA had positive and significant relation with CEC and non- significant relation with other properties and for samples having pH range between 6.50 - 7.50 all the three methods had negative but significant relation with EC and non-significant relation

with other soil properties. Whereas, for $\text{pH} > 7.50$ a non-significant relationship existed between the manganese extracted by all the three methods with the soil properties. However, all the above three methods had highly significant but negative relation with pH , EC and CaCO_3 and significant and positive relation with organic carbon and CEC when all the samples were taken into consideration irrespective of pH .

As shown in Fig 4.15: (a, b, c) at all the pH ranges, AB-DTPA and AAAC-EDTA were highly correlated with the standard method CaCl_2 -DTPA. Also, it was found that AB-DTPA is more closely related to the standard method. Same results were found when all the samples were taken together irrespective of pH (Fig.4.15: (d)).

viii. Zinc

The coefficients of correlation between available zinc and physico-chemical properties are shown in Fig. 4.16: (a, b, c, d). A non-significant relationship existed between the zinc extracted by all the three methods viz., (CaCl_2 -DTPA, AB-DTPA, AAAC-EDTA) with pH , EC , organic carbon, CEC and CaCO_3 when soil samples having different pH ranges were considered. Also, all the above three methods had a non-significant relation with the soil properties when all the samples were taken into consideration irrespective of pH .

As shown in Fig 4.16: (a) at $\text{pH} < 6.50$, it was found that AAAC-EDTA was correlated with standard method CaCl_2 -DTPA but AB-DTPA had a non-significant relation with standard method. Same trend was followed in pH range between 6.50 to 7.50 (Fig.4.16: (b)). At pH range > 7.50 (Fig. 4.16: (c)) all the methods were highly correlated with the standard method. Also, it was found that AAAC-EDTA was highly correlated to the standard method while AB-DTPA had a non-significant relation with the standard method when all the samples were taken together irrespective of pH (Fig. 4.16:(d)).

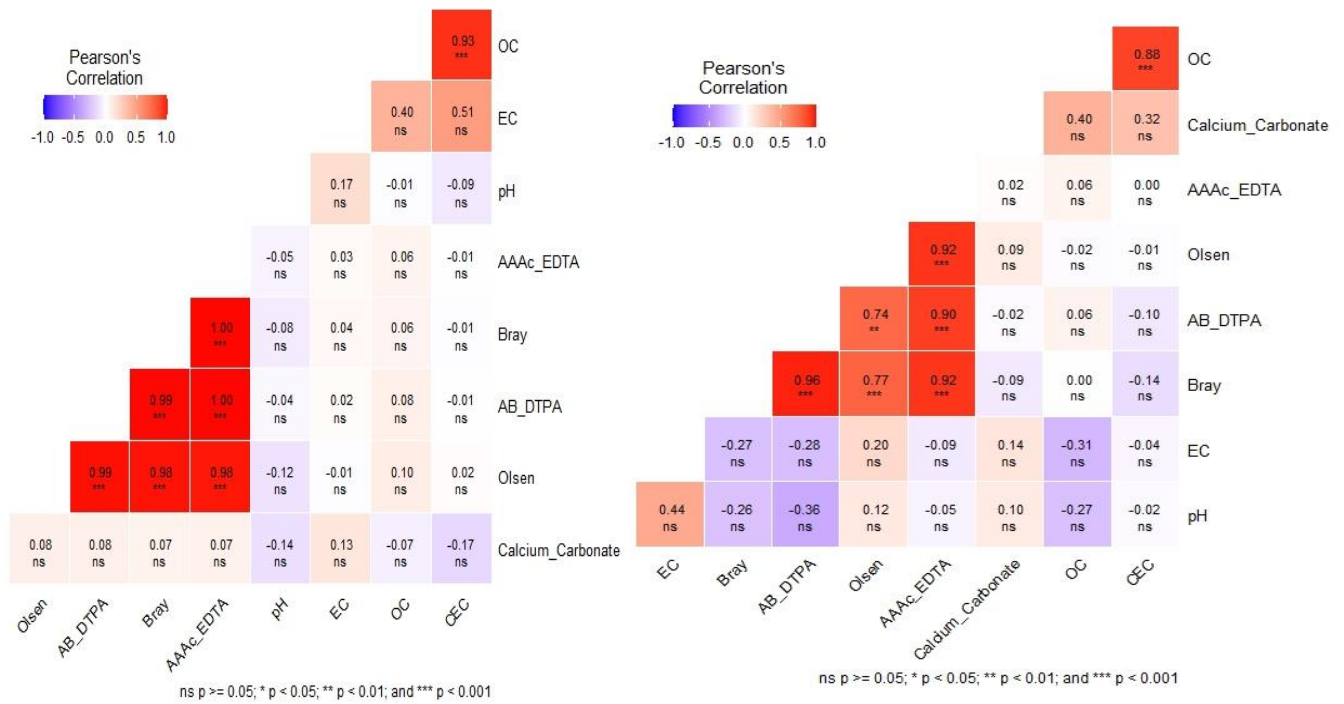


Fig 4.9(a)

Fig. 4.9(b)

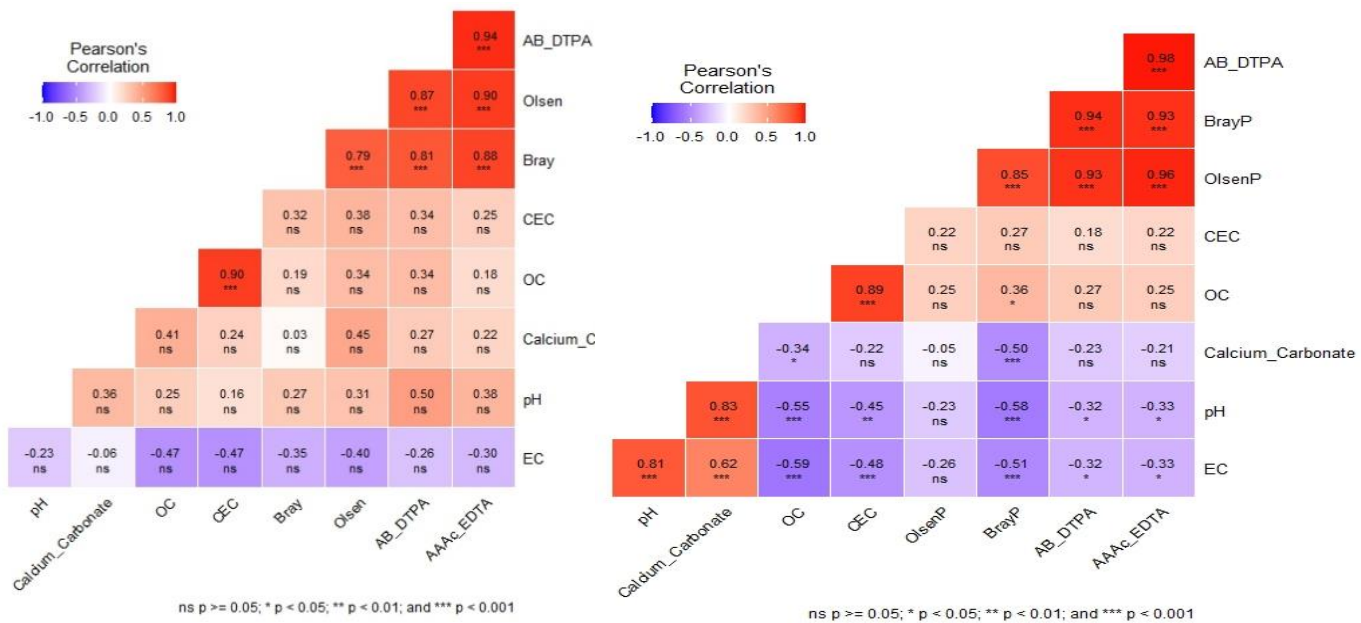


Fig 4.9(c)

Fig. 4.9(d)

Fig.4.9: Correlation of different methods of phosphorous with physico-chemical properties and correlation between different methods at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50, d) Overall

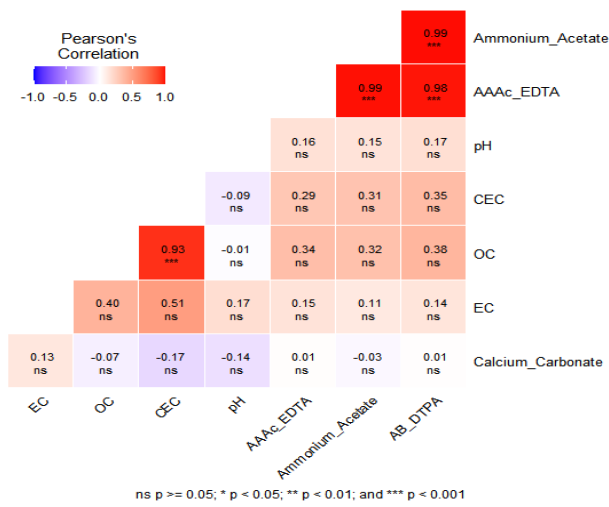


Fig. 4.10: (a)

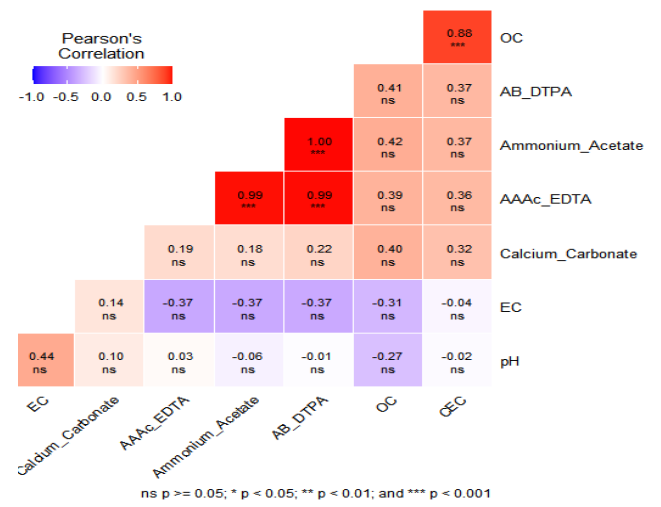


Fig. 4.10: (b)

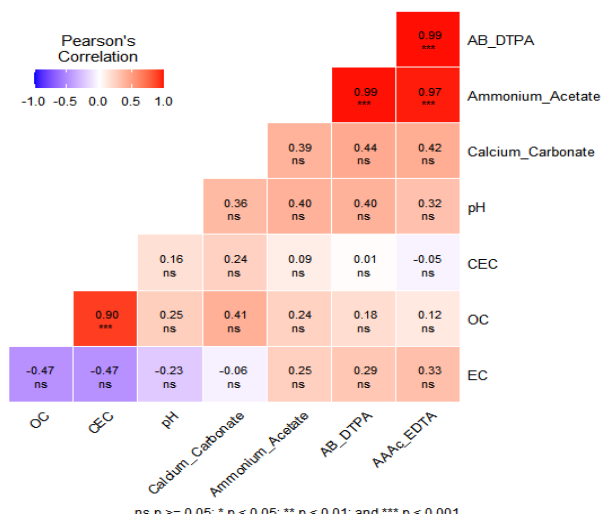


Fig. 4.10: (c)

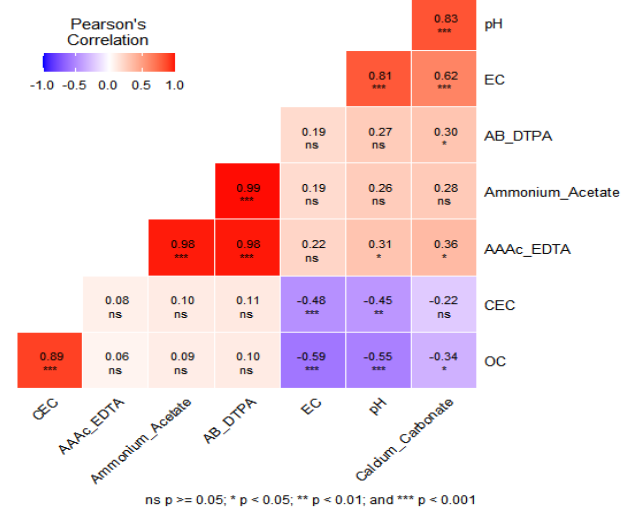


Fig.4.10: (d)

Fig. 4.10: Correlation of different methods of potassium with physico-chemical properties and correlation between different methods at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50, d) Overall

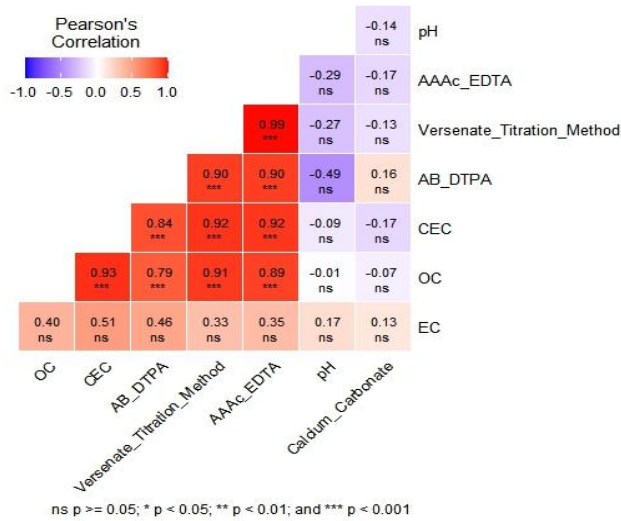


Fig. 4.12: (a)

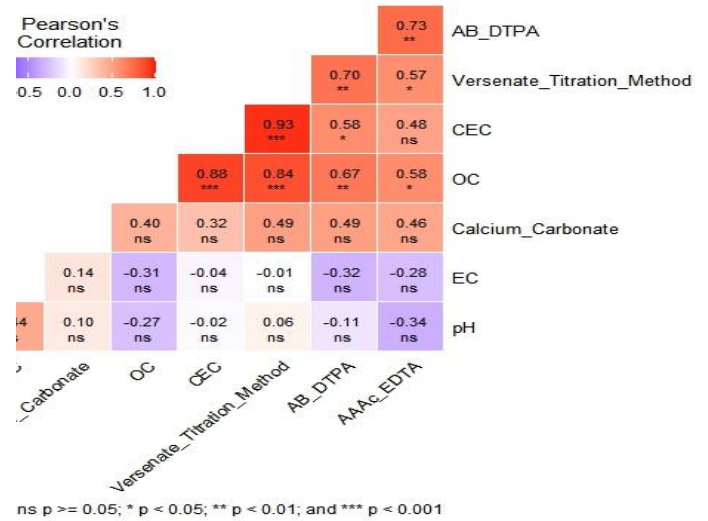


Fig 4.12: (b)

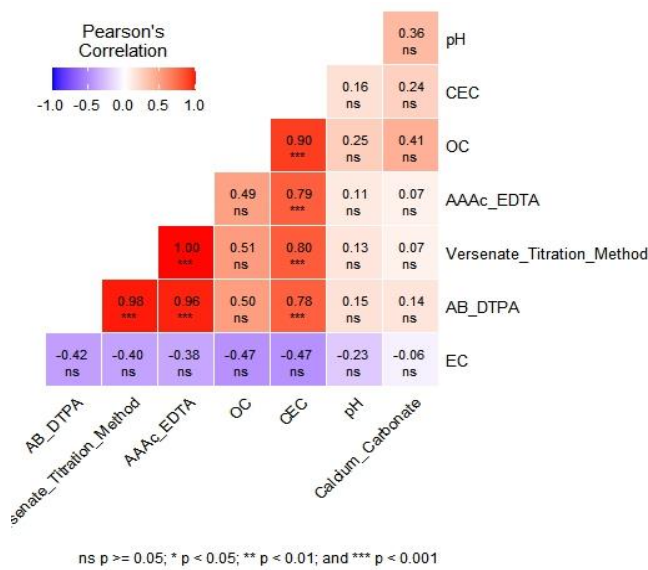


Fig 4.12: (c)

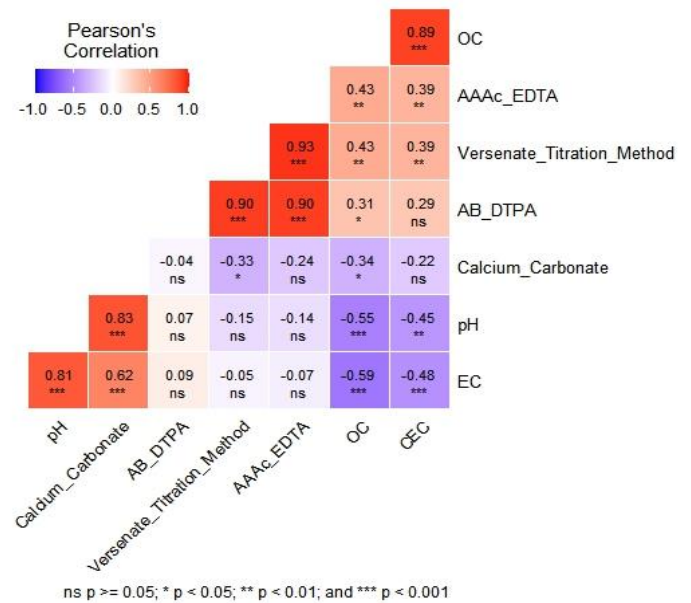


Fig 4.12: (d)

Fig. 4.12: Correlation of different methods of magnesium with physico-chemical properties and correlation between different methods at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50, d) Overall

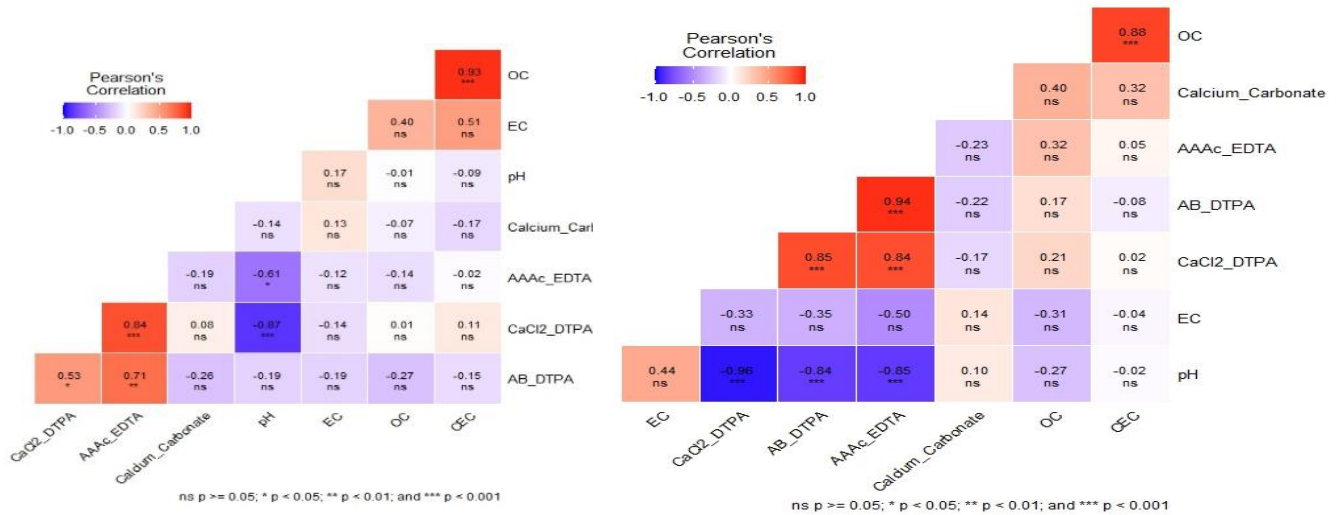


Fig 4.13: (a)

Fig 4.13: (b)

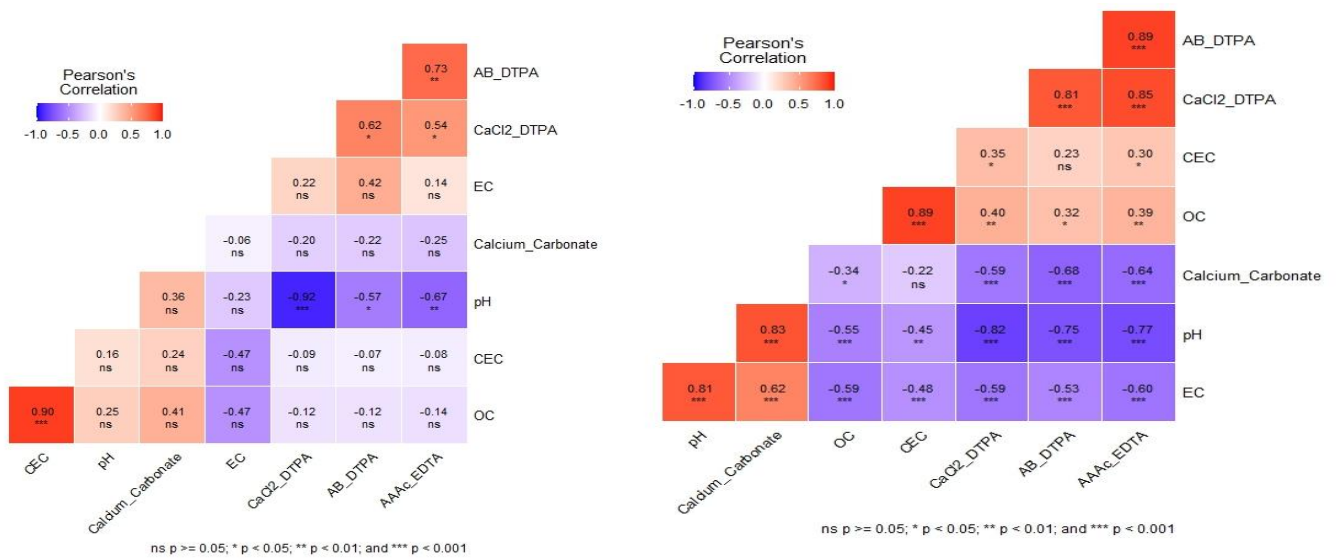


Fig. 4.13: (c)

Fig. 4.13: (d)

Fig. 4.13: Correlation of different methods of iron with physico-chemical properties and correlation between different methods at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50, d) Overall

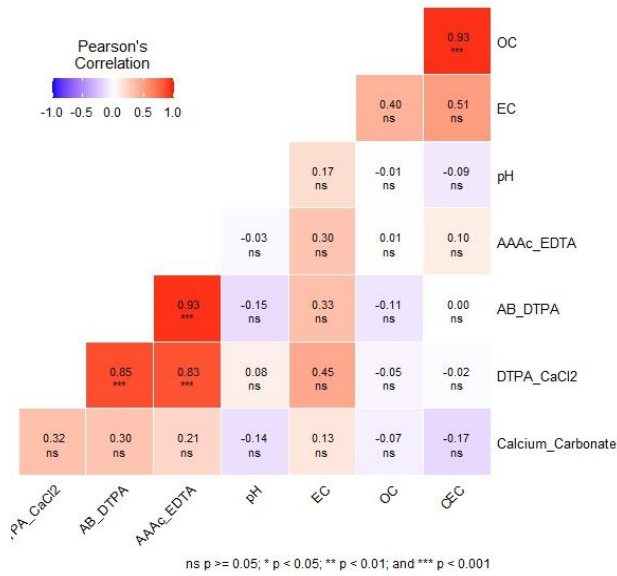


Fig. 4.14: (a)

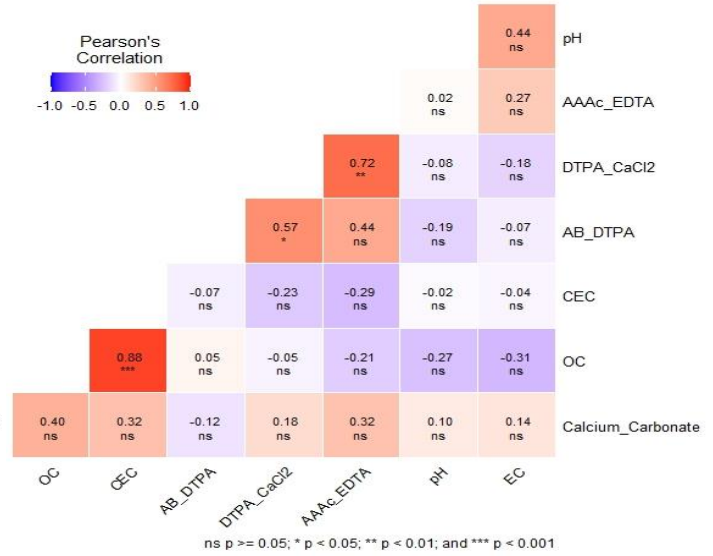


Fig. 4.14: (b)

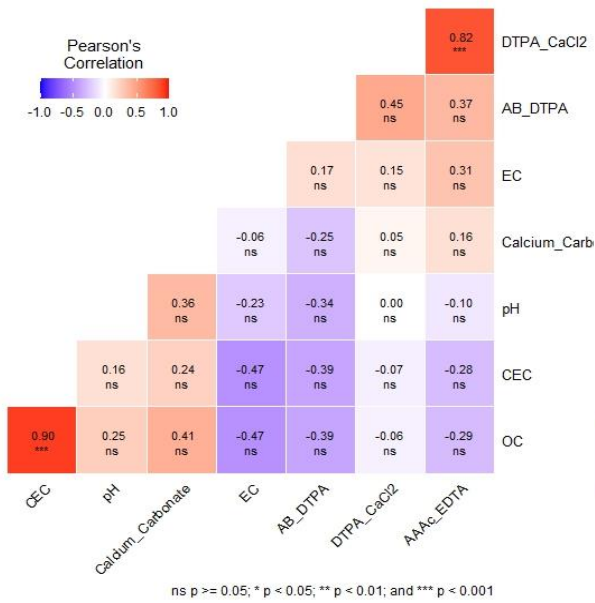


Fig. 4.14: (c)

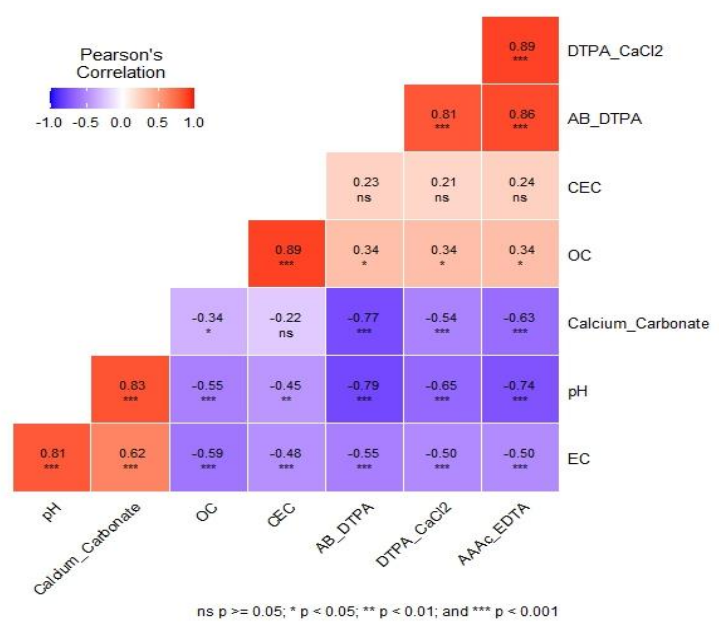


Fig 4.14: (d)

Fig. 4.14: Correlation of different methods of copper with physico-chemical properties and correlation between different methods at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50, d) Overall

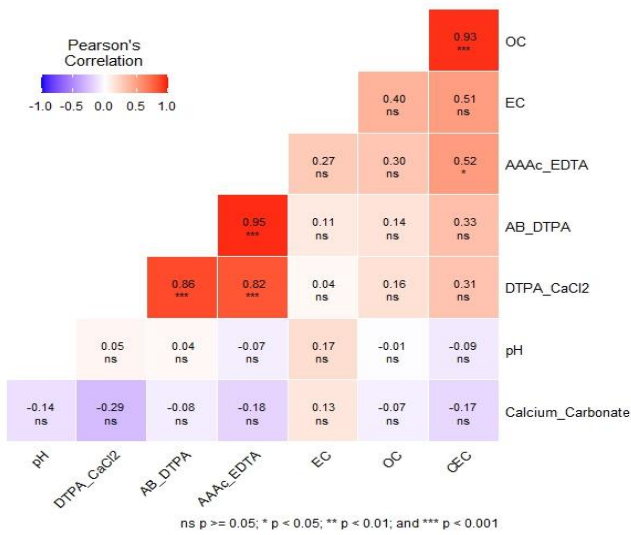


Fig. 4.15: (a)

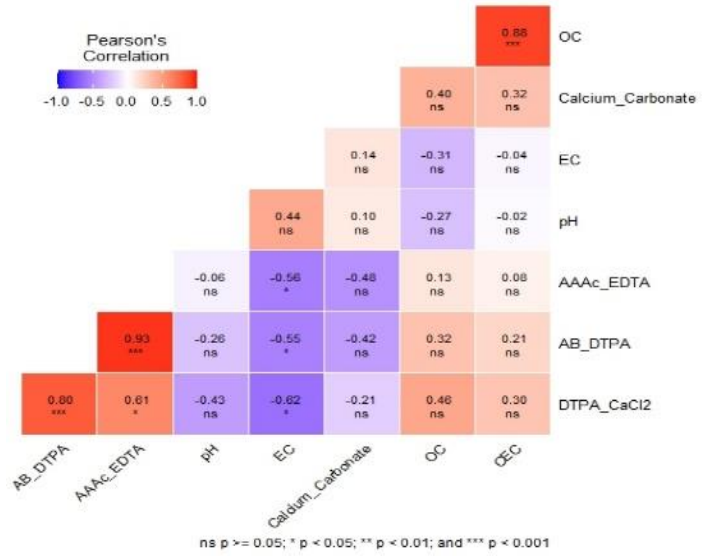


Fig. 4.15: (b)

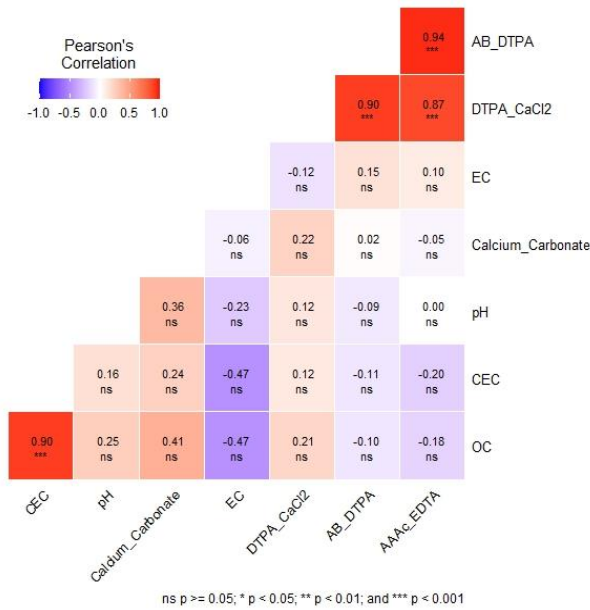


Fig 4.15: (c)

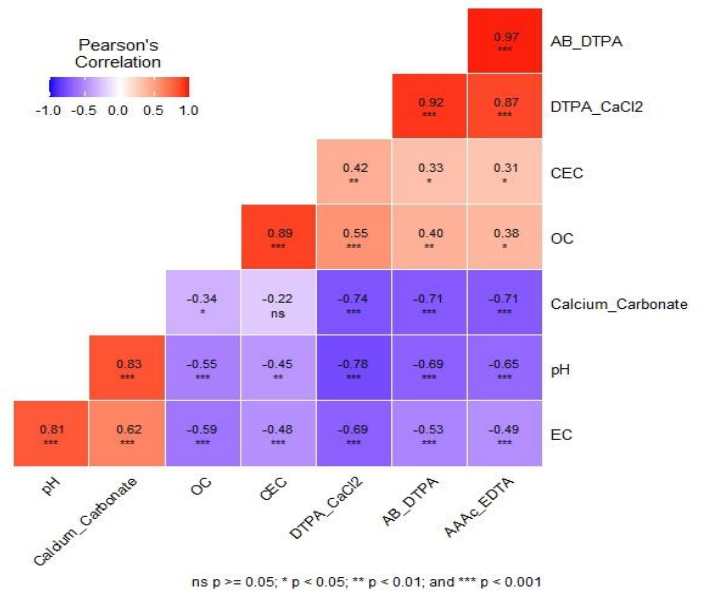


Fig. 4.15: (d)

Fig. 4.15: Correlation of different methods of manganese with physico-chemical properties and correlation between different methods at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50, d) Overall

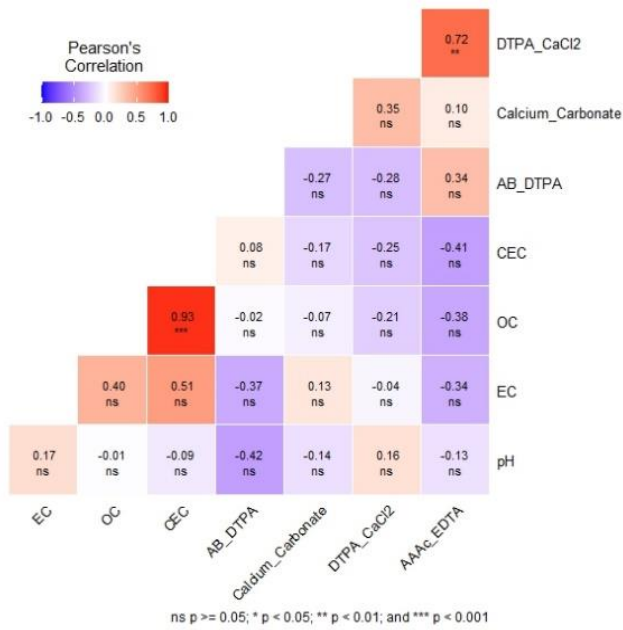


Fig. 4.16: (a)

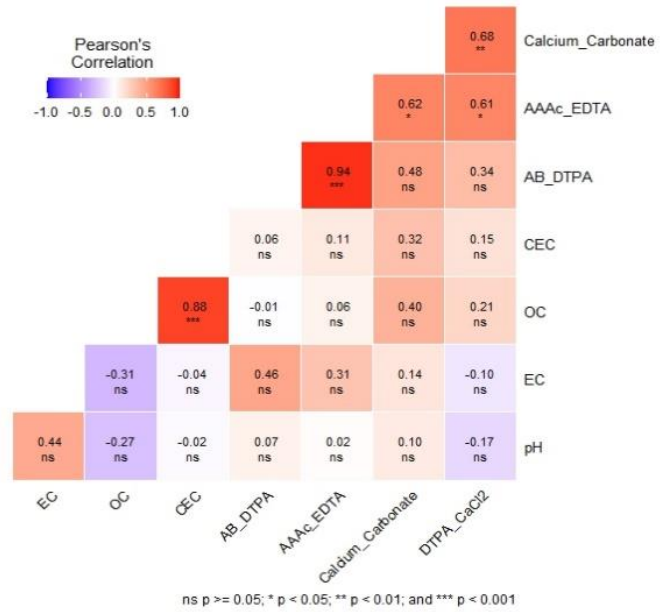


Fig. 4.16: (b)

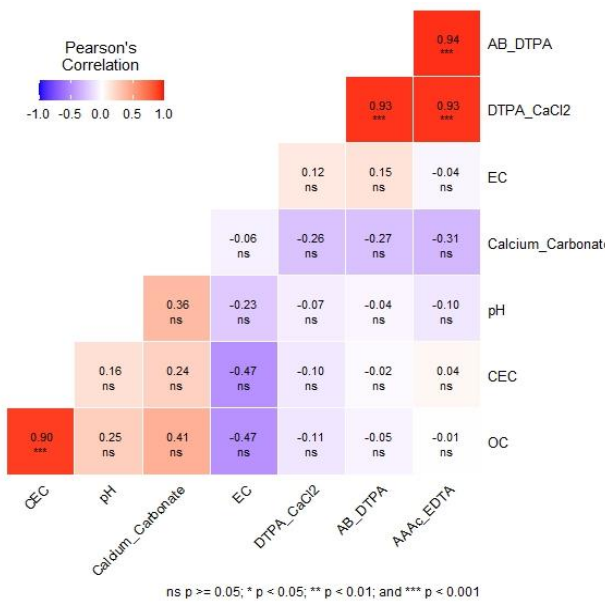


Fig. 4.16: (c)

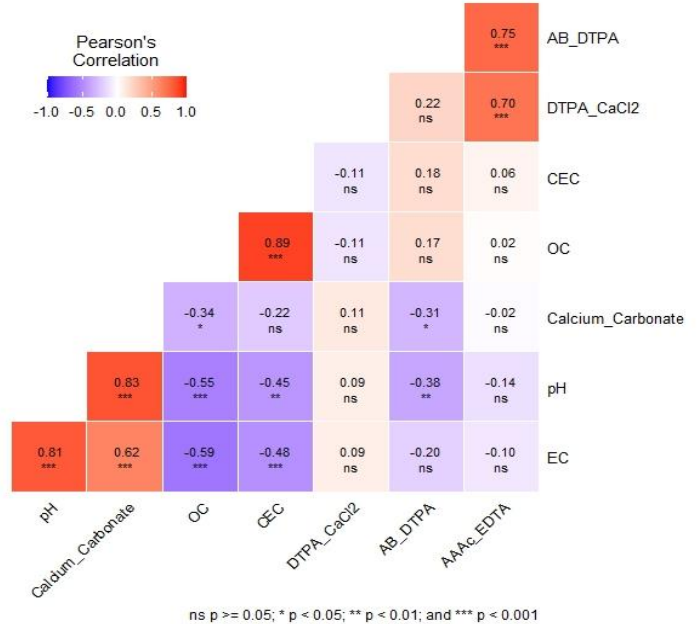


Fig. 5.16: (d)

Fig. 4.16: Correlation of different methods of zinc with physico-chemical properties and correlation between different methods at a) pH < 6.50, b) pH 6.50 to 7.50, c) pH > 7.50, d) Overall

Chapter-5

DISCUSSION

The results pertaining to the observed parameters in accordance with the objectives of current work has been discussed with proper reasoning and supported by the relevant literature in this chapter under the following heads:

5.1 Physico-chemical properties of soils

5.2 Available macro and micronutrient cations

5.3 Correlation studies

5.1 Physico-chemical properties of soils

5.1.1 Mechanical Analysis

The data presented in table 4.1 with regard to soil separates indicates that the soil texture varied from loam, clay loam, silty clay loam, sandy clay loam and silt loam. This is in conformity with the results of Maqbool *et al.* (2017), who have classified the soils as clay loam, silt loam, sandy loam in district Ganderbal of J&K and Mahapatra *et al.* (2000) who classified soils of sub-humid ecosystems of Kashmir region as loamy skeletal to silty clay loam.

5.1.2 Soil pH

The data related to soil reaction is shown in table 4.2. It can be inferred from the data that a wide range of soil pH occurs in Kashmir valley. The soils could be easily divided into pH range of 4.90 to 5.90 (first category), 6.60 to 7.40 (second category) and 7.60 to 7.90 (third category). This wide variation in soil pH may be due to the difference in parent material, vegetation and topography. The findings are in conformity with Alaie and Guptha (2019).

5.1.3 Electrical conductivity

The data presented in table 4.2 shows a wide variation in electrical conductivity of soils, the electrical conductivity ranged from 0.23 to 0.04 for pH

range of < 6.50, 0.11 to 0.43 for pH range of 6.50-7.50 and 0.21 to 0.64 for soils having PH >7.50. The overall EC ranged from 0.04 to 0.64. Also, all the samples were found under the normal range (<0.8 dS/m) for growing different crops. The values recorded for EC in this study are in conformity with the ranges reported by Shafi *et al.* (2018) and Abad *et al.* (2014).

5.1.5 Organic Carbon

Data related to organic carbon (Table 4.3) showed that organic carbon ranged from 0.62 to 1.89 per cent in soils having pH values less than 6.5, 0.21 to 1.54 per cent in soils having pH values ranging from 6.5 to 7.5 and 0.12 to 1.92 per cent in soils having pH values greater than 7.5. The overall organic carbon ranged from 0.12 to 1.92 per cent. The reason for lower organic carbon of the soil samples from District Pulwama (saffron soils) may be due to the less vegetative cover and faster degradation of organic matter with little or no addition of organic manures. The readings are in conformity with those of Mahpatra *et al.* (2000).

5.1.5 Cation Exchange Capacity

It is apparent from the data presented in table 4.3 that the CEC ranged from 8.90 to 13.80 cmol(c)/kg in soils having pH values less than 6.50, 7.20 to 16.20 cmol(c)/kg in soils having pH between 6.50 to 7.50 and 7.10 to 13.60 cmol(c)/kg in soils having pH greater than 7.50. The overall CEC ranged from 7.10 to 16.20 cmol(c)/kg. These differences in CEC may be due to difference in organic carbon, the higher cation exchange capacity in some soils may be due to higher organic matter. These findings corroborate with Shafi *et al.* (2018), Wani *et al.* (2010) and Bashir *et al.* (2016)

5.1.6 Calcium Carbonate

The data for calcium carbonate is shown in table 4.3. The data shows that the calcium carbonate ranged from 0.10 to 0.90 per cent in soils having pH less than 6.50, 1.70 to 3.00 per cent in soils having pH between 6.50 to 7.50 and 1.30 to 2.50 per cent in soils having pH greater than 7.50. The overall calcium carbonate ranged

from 0.10-3.00 per cent. The low content of calcium carbonate can be due to the leaching down of calcium carbonate to the lower surfaces. Similar findings were reported by Shafi *et al.* (2018), Kirmani (2004), Ramzan *et al.* (2014) and Bashir *et al.* (2016).

5.2 Available macro and Micro-nutrient Cations

5.2.1 Available Phosphorous

The data for the comparison of different extractants for extracting available phosphorous at different pH ranges is presented in table 4.5. The results revealed that, at pH <6.50 the extracting power of different methods was as follows; Bray> Olsen> AAAC-EDTA>AB-DTPA. Similar results were found by Sharma *et al.* (2018), Elrashidi *et al.* (2003), who also reported higher phosphorous extraction by using the Bray method in comparison to Olsen and AB-DTPA extractants. Phosphorus extracted by Bray method in acid soils was higher than that extracted by other methods, it might be due to presence of Al and Fe bound phosphorous in acid soils which can be extracted by combination of HCl with ammonium fluoride which is used as an extractant in Bray method and extracts acid soluble phosphorous bound with Fe and Al (Lindsay 1979). The lower quantity of P extracted by AB-DTPA and Olsen extractant when compared with Bray may be due to the reason that both Olsen and AB-DTPA method extract soil phosphorous with HCO_3^- ions and mainly from Ca-phosphates (Elrashidi *et al.*, 2003). For pH range 6.50 to 7.50 and > 7.50 the extracting power of the extractants for available phosphorous was as follows: Olsen> AAAC-EDTA> Bray> AB-DTPA. Similar results were reported by Malathi and Stalin (2018) for neutral and alkaline soils where Olsen extracted highest amount of phosphorous than other methods. Due to the multi-dentate character of the EDTA, a relatively higher amount of phosphorus was extracted with AAAC-EDTA than AB-DTPA. In addition to the EDTA fraction, the ammonium ion (NH_4^+), which can be displaced and replaced, is also present Njukeng *et al.* (2013).

5.2.2 Available potassium

The data comparing different extractants for extracting available potassium at different pH ranges is presented in table 4.7. The data revealed that, at all three pH ranges, the extracting power of different extractants was as follows: Ammonium Acetate > AB-DTPA > AAAC-EDTA. Similar findings were reported by Sharma *et al.* (2018). Comparatively more potassium was extracted using ammonium acetate than with AB-DTPA or AAAC-EDTA, this was likely caused by the fact that the ammonium acetate method had a larger concentration of NH_4^+ ions than the other two procedures. The ratio of soil to solution for potassium extraction could be another factor. Ammonium acetate required 5.0 g of soil to be extracted with 25 ml of extractant, AB-DTPA required 10.0 g of soil to be extracted with 20 ml of extractant, and AAAC-EDTA required 10.0 g of soil to be extracted with 25 ml of extractant. The quantity of extractant was more in Ammonium acetate, which had more contact with soil (Khan 2008). Similar findings were reported by Soltanpour and Schwab (1985) while comparing AB- DTPA with standard method.

5.2.3 Exchangeable calcium and magnesium

The data comparing different extractants for extracting exchangeable calcium and magnesium at different pH ranges is presented in table 4.9 and 4.11. The data revealed that, at all three pH ranges, the extracting power of different methods for calcium and magnesium was as follows: AAAC-EDTA > Versenate method > AB-DTPA. The lower quantity of calcium and magnesium extracted by AB-DTPA may be attributed to the reason that calcium and magnesium are precipitated as carbonate salts due to rise in pH during shaking process (Malathi and Stalin 2018; Soltanpour and Schwab 1985). Similar results were reported by Elrashidi (2003) and Madurapperuma and Kumaragamage (2008).

5.2.4 Available Iron

The data comparing different extractants for extracting available iron at different pH ranges is presented in table 4.13. The results revealed that, at all three pH ranges, the extracting power of different methods was as follows: AB-DTPA > CaCl₂-DTPA > AAAC-EDTA. These results are in conformity with the findings of Maurico *et al.* (2012). Similar results were recorded by Elrashidi *et al.* (2003) while comparing AB DTPA and DTPA extractable iron. Also, the availability of NH₄⁺ in the AB-DTPA mixture to replace the micro nutrients in the exchange complex might have extracted more iron (Ayed and Chaudary 1989).

5.2.5 Available copper

The data comparing different extractants for extracting available copper at different pH ranges is presented in table 4.15. The results revealed that, at all three pH ranges, the extracting power of different methods was as follows: AB-DTPA > AAAC-EDTA > CaCl₂-DTPA. These results are in conformity with Ayed and Chaudhary (1989), Maurico *et al.* (2012), Elrashidi *et al.* (2003) who also recorded higher amount of copper with AB-DTPA in comparison to DTPA.

5.2.6 Available manganese

The data for comparison of different extractants for extracting available manganese at different pH ranges is presented in table 4.17. The results revealed that, at all three pH ranges, the extracting power of different methods was as follows: AAAC-EDTA > AB-DTPA > CaCl₂-DTPA.

5.2.7 Available Zinc

The data comparing different extractants for extracting available zinc at different pH ranges is presented in table 4.19. The results revealed that, at pH < 6.50 power of different methods was as follows: AB-DTPA > CaCl₂-DTPA > AAAC-EDTA. Higher quantity of zinc extracted by AB-DTPA in comparison to other extractants in the present study are in conformity with the results of Abadia *et al.* (1980), Ayed and Chaudary (1989), Elrashidi *et al.* (2003), Maftoun *et al.*

(2003), Takrattanasaran *et al.* (2010). At pH ranges 6.50 to 7.50 and > 7.50, the extracting power of different methods was as follows: CaCl₂-DTPA > AB-DTPA > AAAC-EDTA.

5.3 Correlation studies

5.3.1 Relationship between the available nutrients and physico-chemical properties and relation among different methods of extraction

i. Phosphorous

As shown in Fig. 4.9: (a, b, c, d) the relationships between the quantity of phosphorus extracted using different methods of extraction (Olsen, Bray, AB-DTPA, AAAC-EDTA) with pH, EC, organic carbon, CEC, and CaCO₃ in samples having pH <6.50, 6.50-7.50 and > 7.50, a non-significant correlation existed between the P extracted by all the four methods with above mentioned soil properties. The results are in conformity with the findings of Sharma *et al.*, (2018) for pH <6.5. Similar findings were also reported by Hossain *et al.* (2014) for organic carbon and pH. However, when all the samples were taken into consideration irrespective of pH, Bray method had negative but highly significant relation with pH, EC and CaCO₃ and for AB-DTPA and AAAC-EDTA a significant but negative correlation was found with pH and EC.

As shown in Fig. 4.9: (a, b, c) at pH < 6.50, 6.50- 7.50 and > 7.50 AB-DTPA and AAAC-EDTA were highly correlated with the standard methods, i.e., Olsen and Bray. Same results were found when all the samples were taken together irrespective of pH (Fig. 4.9: (d)). The findings are in conformity with Sharma *et al.* (2018), Madurapperuma and Kumaragamage (1999), Soltanpour and Schuwab (1977), Njukeng *et al.* (2013).

ii. Potassium

As evident from Fig. 4.10: (a, b, c, d) a non-significant relationship existed between the potassium extracted by all the three methods (Ammonium Acetate,

AB-DTPA, AAAC-EDTA) with pH, EC, OC, CEC and CaCO₃ in samples having pH <6.50, 6.50-7.50 and > 7.50. The results are in conformity with the findings of Hossain *et al.* (2014) and Sharma *et al.* (2018) for organic carbon, pH and EC. However, AB-DTPA method had positive and significant relation with CaCO₃ and for AAAC-EDTA a positive and significant correlation was found with pH and CaCO₃ when all the samples were taken into consideration irrespective of pH.

As shown in Fig. 4.10: (a, b, c) at pH < 6.50, 6.50- 7.50 and > 7.50 AB-DTPA and AAAC-EDTA were highly correlated with the standard method Ammonium Acetate. Same results were found when all the samples were taken together irrespective of pH (Fig. 4.10: (d)). These results were in conformity with Sharma *et al.*, (2018), Madurapperuma and Kumaragamage (1999), Soltanpour and Schuwab (1977), Njukeng *et al.* (2013).

iii. Calcium

As evident from Fig. 4.11(a, b, c, d) a highly significant relationship existed between Ca extracted by all the three methods with organic carbon and CEC and a non-significant relation existed with other soil properties in samples having pH <6.50 and 6.50-7.50. However, at pH > 7.50 all the three methods were highly significant with CEC and a non-significant relation existed between the methods and other soil properties but AB-DTPA method had positive and significant relation with organic carbon. Also, a positive and significant correlation was found with CEC and organic carbon when all the samples were taken into consideration irrespective of pH.

The relationships between the amounts of calcium extracted by different methods (Versenate Titration Method, AB-DTPA, AAAC-EDTA) with pH, EC, OC, CEC and CaCO₃.

As shown in Fig 4.11(a, b, c) at pH < 6.50, 6.50-7.50 and > 7.50 AB-DTPA and AAAC-EDTA were highly correlated with the standard method, versenate Titration Method. Same results were found when all the samples were taken

together irrespective of pH (Fig.4.11: (d)). Similar results were recorded by Madurapperuma and Kumaragamage (1999) for Versenate titration method and AB-DTPA.

iv. Magnesium

As evident from Fig. 4.12: (a., b, c, d) the relationships between the amounts of magnesium extracted by different methods (Versenate Titration Method, AB-DTPA, AAAC-EDTA) with pH, EC, OC, CEC and CaCO₃ in samples having pH <6.50 highly significant relationship existed between Mg extracted by all the three methods with organic carbon and CEC and a non-significant relation existed with other soil properties, at pH range of 6.50-7.50, highly significant relationship existed between Mg extracted by all the three methods with organic carbon, Versenate titration method and AB-DTPA were highly correlated with CEC but AAAC-EDTA had a non-significant relation with CEC and also a non-significant relation existed with other soil properties. However, at pH > 7.50 all the three methods were highly significant with CEC and a non-significant relation existed between methods and other soil properties.

As shown in Fig. 4.12: (a, b, c) at pH< 6.50, 6.50- 7.50 and > 7.50 AB-DTPA and AAAC-EDTA were highly correlated with the standard method Versenate Titration Method. Same results were found when all the samples were taken together irrespective of pH (Fig. 4.12: (d)). Similar results were recorded by Madurapperuma and Kumaragamage (1999) for Versenate titration method and AB-DTPA.

v. Iron

As evident from Fig. 4.13: (a), the relationships between the amounts of iron extracted by different methods (CaCl₂-DTPA, AB-DTPA, AAAC-EDTA) with pH, EC, organic carbon, CEC and CaCO₃ in samples having pH <6.50, CaCl₂-DTPA and AAAC-EDTA had a significant but negative relation with pH. A significant but negative correlation was found between all the three methods with pH at pH ranges

between 6.50-7.50 and > 7.50 (Fig. 4.13: (b, c)). However, all the above three methods had highly significant but negative correlation with pH, EC and CaCO_3 and highly significant and positive relation with organic carbon and CEC except for AB-DTPA which had a non-significant relation with CEC when all the samples were taken into consideration (Fig.4.13: (d)).

As shown in Fig 4.13: (a, b, c) at all the pH ranges, AB-DTPA and AAAC-EDTA were correlated with the standard method CaCl_2 -DTPA. Same results were found when all the samples were taken together irrespective of pH (Fig. 4.13: (d)). The above results are in conformity with the findings recorded by Malathi and Stalin (2018) and Sharma *et al.* (2018).

vi. Copper

As evident from Fig. 4.14:(a, b, c, d) the relationships between the amounts of copper extracted by different methods (CaCl_2 -DTPA, AB-DTPA, AAAC-EDTA) with pH, EC, organic carbon, CEC and CaCO_3 in samples having pH < 6.50 , 6.50-7.50 and > 7.50 a non-significant relationship existed between the P extracted by all the four methods with above mentioned soil properties. However, all the above three methods had highly significant but negative relation with pH, EC and CaCO_3 and significant and positive relation with organic carbon when all the samples were taken into consideration. These results are in conformity with the findings of Sharma *et al.*, (2018). Similar results were reported by Khalifa *et al.* (1996), Nazif *et al.* (2006) and Rajakumar *et al.* (1996).

As shown in Fig 4.14: (a, b) and 4.46 at pH < 6.50 and 6.50- 7.50 it was found that all the methods were positively correlated with standard method CaCl_2 -DTPA. The results are in conformity with those of Malathi and Stalin (2018) and Sharma *et al.*, (2018). For pH range > 7.50 (Fig. 4.14: (c)) AB-DTPA had a non-significant relation with the standard method. Also, it was found that all the methods were highly correlated with standard methods when all the samples were taken

together (Fig.4.14:(d)). The results were similar to the findings of Malathi and Stalin (2018) and Sharma *et al.* (2018).

vii. Manganese

As evident from Fig. 4.15:(a, b, c, d) the relationships between the amounts of manganese extracted by different methods (CaCl₂-DTPA, AB-DTPA, AAAC-EDTA) with pH, EC, organic carbon, CEC and CaCO₃ in having pH <6.50 AAAC-EDTA had positive and significant relation with CEC others being non- significant, for samples 6.50-7.50 all the three methods had negative but significant relation with EC and others being non-significant, for pH > 7.50 a non-significant relationship existed between the Mn extracted by all the three methods with above mentioned soil properties. However, all the above three methods had highly significant but negative relation with pH, EC and CaCO₃ and significant and positive relation with organic carbon and CEC when all the samples were taken into consideration. These results are in conformity with the findings of Sharma *et al.*, (2018). Similar results were reported by Khalifa *et al.* (1996), Nazif *et al.* (2006) and Rajakumar *et al.* (1996).

As shown in Fig 4.15: (a, b, c) at pH < 6.50, 6.50- 7.50 and > 7.50 AB-DTPA and AAAC-EDTA were highly correlated with the standard method CaCl₂-DTPA. Same results were found when all the samples were taken together (Fig.4.15: (d)). These results are in conformity to the findings of Madurapperuma and Kumaragamage (1999), Malathi and Stalin (2018) and Sharma *et al.*, (2018).

viii. Zinc

As shown in Fig. 4.16: (a, b, c, d) the relationships between the amounts of zinc extracted by different methods (CaCl₂-DTPA, AB-DTPA, AAAC-EDTA) with pH, EC, organic carbon, CEC and CaCO₃ in samples having pH <6.50, 6.50-7.50 and > 7.50, a non-significant relationship existed between the Zn extracted by all the three methods with above mentioned soil properties. Also, all the above three

methods had a non-significant relation with the mentioned soil properties when all the samples were taken into consideration.

As shown in Fig 4.16: (a, b) at pH < 6.50 and 6.50-7.50 it was found that AAAC-EDTA was correlated with standard method CaCl₂-DTPA but AB-DTPA had a non-significant relation with standard method. At pH range > 7.50 (Fig. 4.16:(c)) all the methods were highly correlated with the standard method. The findings were in conformity with Madurapperuma and Kumaragamage (1999), Malathi and Stalin (2018) and Sharma *et al.*, (2018). Also, it was found that AAAC-EDTA was highly correlated to the standard method while AB-DTPA had a non-significant relation with the standard method when all the samples were taken together (Fig.4.16:(d)).

Chapter -6

SUMMARY AND CONCLUSION

The present study entitled “**Evaluation of Different Extractants for Determination of Available P, K, Ca, Mg and Micronutrient Cations in soils of Kashmir Valley**” was undertaken to study the effectiveness and usefulness of different soil multinutrient extractants for determining the availability of nutrients in soils under different pH ranges. In order to achieve the required objectives, the amount of P, K, Ca, Mg and micronutrient cations extracted by AB-DTPA and AAAC-EDTA were compared with that extracted by commonly adopted standard methods, namely Olsen and Bray for extractable P, Ammonium acetate for extractable K, Versenate titration method for Ca and Mg and CaCl_2 -DTPA for extractable micronutrients (Fe, Cu, Mn and Zn).

The important findings of present investigation are summarized in this chapter:

6.1 Physico-chemical properties of soil

On the basis of texture, soils of areas under investigation were classified as loam, clay loam, silty clay loam, sandy clay loam and silt loam. The soil reaction ranged from acidic to alkaline and were divided into three categories (pH < 6.5, 6.5 to 7.5 and > 7.5). The overall electrical conductivity of studied samples was in normal range. Soil organic carbon ranged from 0.62 to 1.89 per cent in soils having pH values less than 6.5, 0.21 to 1.54 per cent in soils having pH values ranging from 6.5 to 7.5 with and 0.12 to 1.92 per cent in soils having pH values greater than 7.5. The CEC ranged from 8.90 to 13.80 cmol(c)/kg in soils having pH values less than 6.50, 7.20 to 16.20 cmol(c)/kg in soils having pH between 6.50 to 7.50 and 7.10 to 13.60 cmol(c)/kg in soils having pH greater than 7.50. The calcium carbonate ranged from 0.10 to 0.90 per cent in soils having pH less than 6.50, 1.70 to 3.00 per cent in soils having pH between 6.50 to 7.50 and 1.30 to 2.50 per cent in soils having pH greater than 7.50.

6.2 Comparative efficiency of different multinutrient and standard extractants in extracting soil available nutrients

At pH <6.50 the extracting power of different extractants for phosphorus extraction followed the order: Bray> Olsen> AAAC-EDTA>AB-DTPA. For pH range 6.50 to 7.50 as well as > 7.5, the extracting power of the extractants for available phosphorous was Olsen> AAAC-EDTA> Bray> AB-DTPA. In case of potassium, at all the three pH ranges, the extracting power of different extractants followed the order Ammonium Acetate> AB-DTPA> AAAC- EDTA and in case of calcium and magnesium at all the three pH ranges, the extracting power of different extractants was as follows: AAAC-EDTA> Versenate method> AB-DTPA.

At all three pH ranges, the extracting power of different extractants for iron was AB-DTPA> CaCl₂-DTPA> AAAC-EDTA. In case of copper, at all three pH ranges, the extracting power of different extractants was AB-DTPA> AAAC-EDTA > CaCl₂-DTPA. In case of manganese, at all three pH ranges, the extracting power of different extractants was AAAC-EDTA > AB-DTPA > CaCl₂-DTPA and in case of zinc, at pH < 6.50 power of extraction of different extractants was AB-DTPA > CaCl₂-DTPA> AAAC-EDTA. At pH ranges 6.50 to 7.50 and > 7.50, the extracting power of different methods was as follows CaCl₂-DTPA > AB-DTPA > AAAC-EDTA.

6.3 Correlation studies

Bray method of phosphorous had negative but highly significant relation with pH, EC and CaCO₃ while as AB-DTPA and AAAC-EDTA had a significant but negative correlation with pH and EC. Also, AB-DTPA and AAAC-EDTA were highly correlated with the standard methods i.e., Olsen and Bray at all pH ranges. A positive and significant correlation was found between the different methods of potassium quantification with pH and CaCO₃. Also, AB-DTPA and AAAC-EDTA were highly correlated with the standard method ammonium acetate at all pH ranges. A positive and significant correlation was found between different methods

of calcium quantification with CEC and organic carbon. Also, AB-DTPA and AAAC-EDTA were highly correlated with the standard method, Versenate Titration Method at all pH ranges. A positive and significant correlation was found for different methods of magnesium quantification with CEC and organic carbon except for AB-DTPA which had non-significant relation with CEC. Also, AB-DTPA and AAAC-EDTA were highly correlated with the standard Versenate Titration Method at all pH ranges.

For determination of micronutrient cations (Fe, Cu and Mn) all three methods had highly significant but negative correlation with pH, EC and CaCO_3 and highly significant and positive relation with organic carbon and CEC irrespective of pH except for copper which had non-significant relation with CEC. Also, AB-DTPA and AAAC-EDTA were positively correlated with the standard method CaCl_2 - DTPA. In case of zinc, all the three methods had a non-significant relation with the soil properties when all the samples were taken into consideration irrespective of pH. Also, AB-DTPA and AAAC-EDTA were positively correlated with the standard method CaCl_2 - DTPA.

CONCLUSIONS

The results of this investigation led to the following conclusions:

- Olsen performed best at pH 6.5-7.5 and >7.5, followed by AAAC-EDTA, Bray 1 and AB-DTPA. At pH 6.5, Bray 1 extractant estimated more P than AAAC-EDTA, followed by Olsen and AB-DTPA.
- At all pH ranges, ammonium acetate extracted more potassium (K) than any other extractant, followed by AB-DTPA and AAAC-EDTA.
- With the exception of Mg at pH 6.5-7.5, AAAC-EDTA was statistically at par with Versenate titration method and extracted more Ca and Mg than any other extractant at all pH ranges.

- Fe and Cu were extracted more by AB-DTPA at all pH ranges under investigation, whereas Mn was estimated more by AAAC-EDTA and AB-DTPA extracted more Zn at all pH ranges.
- Since AAAC-EDTA shows positive correlation with all commonly adopted standard methods at all pH ranges under study, it can be used as alternative for estimation of P, K, Ca, Mg and micro-nutrient cations.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by external examiner **Dr. Mohammad Amin Bhat** (Soil Scientist), Regional Research Station, PAU, Ballawal Saunkhri, Takarla, Balachaur Punjab during thesis Viva-Voce examination held on **03-12-2022** have been incorporated in the final manuscript entitled “**Evaluation of Different Extractants for Estimation of P, K, Ca, Mg & Micro-nutrient Cations in Soils of Kashmir Valley**” submitted by **Ms. Syed Andleeba Jan (MSA-2020-1383)**.

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