

Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh

THESIS



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CERTIFICATE – I

This is to certify that the thesis entitled “**Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh**” submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (DEPARTMENT OF SOIL SCIENCE & AGRICULTURAL CHEMISTRY)** of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bonafied research work carried out by **Miss. Sonali Kamle**, under my guidance and supervision. The subject of the thesis has been approved by the Student’s Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published. All the assistance and help received during the course of the investigation has dully been acknowledged by her.

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ABBREVIATION

| S. No. | Legends | Description |
|--------|---|-------------------------------------|
| 1. | Avail.N | Available Nitrogen |
| 2. | Avail.P | Available Phosphorous |
| 3. | Avail.K | Available Potassium |
| 4. | BH | Bouyoucos Hydrometer |
| 5. | CaCO ₃ | Calcium Carbonate |
| 6. | cm | Centimeter |
| 7. | CC | Coefficient of Correlation |
| 8. | CR | Coefficient of Regression |
| 9. | dsm ⁻¹ | DesiSiements Per Meter 10 |
| 10. | EC | Electrical Conductivity |
| 11. | et.al. | Alied (and other) |
| 12. | Ex-K | Exchangeable Potassium |
| 13. | FAS | Ferrous Ammonium Sulphate |
| 14. | FPM | Flame Photometer |
| 15. | H ₂ SO ₄ | Sulphuric Acid |
| 16. | i.e. | That is (inference to) |
| 17. | K | Potassium |
| 18. | K ₂ Cr ₂ O ₇ | Potassium Dichromate |
| 19. | mg kg ⁻¹ | Mili Gram Per Kilogram |
| 20. | MSL | Mean Sea Level |
| 21. | No. | Number |
| 22. | Non Ex.-K | Non-exchangeable Potassium |
| 23. | OC | OC Organic Carbon |
| 24. | PC | Platinum Crucible |
| 25. | pH | Power of Hydrogen Ion Concentration |

| | | |
|-----|------|-----------------------------------|
| 26. | SCM | SCM Solubridge Conductivity meter |
| 27. | SHPM | SHPM Sodium Hexametaphosphate |
| 28 | ViZ | Wide List |
| 29. | WSK | Water Soluble Potassium |
| 30. | % | Percentage |

CHAPTER- I

INTRODUCTION

Potassium is one of the three major plant nutrient elements. Most of the soils have large contents of total K but relatively small amount of available K. The cumulative effect of many physiological reactions in plants, Potassium has an important role in plant growth and development. Plants are absorbed in large amounts of K, although total soil K content exceeds crop uptake during a growing season. In some cases, only a small fraction of it is available to plant. Fixation and release of K by 2:1 layer silicates are very important processes influencing the availability of K to plants. The release of K from clay minerals is influenced by particle size and chemical composition (Huang, 2005). Vermiculite and Illite tend to fix K best under wet condition while fixation by montmorillonite and interstratified minerals occurs under dry conditions. Ions like NH_4^+ and H^+ compete with K^+ for K fixing or binding sites. The edge of the particle is confined to the wedge zone, and only small amounts of K can be fixed (Sekhon *et al.*, 1992). Potassium release from the mineral lattice can occur from an exchange reaction of K^+ ions with H^+ ions (Srinivasrao *et al.*, 2006). The high K capacity of soils at various incubation periods could be attributed to the high levels of silt and clay contents. The degree of fixation depends on their charge density and the amount of K added. K is recovered at different incubation period increase, with increased level of K added, and the added K is recovered at 30 days of incubation in all the soils (Umoh *et al.*, 2017).

Potassium is present in soils in various forms and combination. The available potassium in soil is difficult to ascertain because of its interaction with various intrinsic and extrinsic properties of soil. The direction of rate of reactions determines the rate of applied K and release of non-exchangeable K (Singh *et al.*, 2004). A number of extractants have been used from time to time to assess quantitatively the available K. Potassium plays an important role in increasing the production and improving the quality of crops and vegetables.

In soils, potassium exists in different forms viz. water soluble, exchangeable, Non-exchangeable and lattice potassium. The water soluble and exchangeable together constitutes the plant available potassium. Plants take up K from soil solution, which is readily replenished by soil exchangeable K. Some non exchangeable K can become exchangeable when solution and exchangeable K are depleted by plant removal, leaching, or exchange reactions with other cations. However mineral K, which is the major proportion of total K in soils, can become available only very slowly through long-term soil weathering. Distribution of K among these forms also occurs as K is added to soil as fertilizer, manure, or crop residues. It has long been recognized that wetting-drying and freezing-thawing cycles influence transformations of K between non-exchangeable, exchangeable and solution phases. The potassium content of Indian soils varies from less than 0.5 % to 3.00 % (Mengel, 1987). In Indian soil the soluble K form is present in approximately 2% and insoluble are present in range of 98% in form of minerals like biotite, feldspar, mica, muscovite, vermiculite (Goldstein, 1994).

The study related to various forms of K in soils of Ujjain tehsil is lacking. So the present Study was conducted by taking soil samples from different villages. The GPS location was also noted from each soil samples site.

The study was planned to investigate the “**Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh**” with the following objectives:

1. To know the availability of K in soils of Ujjain Tehsil of Ujjain District.
2. To assess different fractions of K in soils.
3. To work out the relationship among different forms of K and different Physico-chemical soil properties (Texture, pH, EC, OC, N, P, K).

CHAPTER-II

REVIEW OF LITERATURE

A brief review of literature related to the present investigation is “**Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh**” presented in this chapter under the following heads.

2.1 Distribution of different forms of potassium (K) in soil

2.2 Inter-relationship amongst different forms of K

2.3 Relationship between K forms and soil properties

2.1 Distribution of different forms of potassium (K) in soil

Potassium is present in soils in four forms that occur as a structural component of primary minerals such as mica and potassium bearing feldspars which become available only upon decomposition of their minerals. Potassium is trapped between layers of expanding lattice clays such as illite and montmorillonite.

2.1.1 Water soluble potassium (K)

Dixit *et al.* (1993) studied the distribution of different K forms within horizons in ten established soil series of western U.P. The contents of water soluble K was varied from 1.09-60.38 mg kg⁻¹. Profile mean contents of water soluble, exchangeable, available, non exchangeable, and total K were highest in Tarai zone while that of lattice K was highest in alluvial zone. Highly significant positive correlation was found among different forms of K.

Bhalerao and Pharande (2003) reported that the average water soluble K in saline, saline-sodic and sodic soils are 11.6, 19.24, and 15.41 mg kg⁻¹ respectively.

Kaul and Gupta (2005) studied different forms of potassium in 50 surface and subsurface soils from various locations of Jammu region (Jammu and Kashmir State), representing four agro-climatic zones and ten great soil groups belonging to three orders. The average contents of water soluble forms of potassium irrespective of agro-climatic zones and great soil groups was 18,500 mg kg⁻¹ in surface and 20,000 mg kg⁻¹ in subsurface soils.

The water soluble K content in the soils of Khammam district of Andhra Pradesh was in the range of 11.3 and 46.2 mg kg⁻¹ (Chandrasekhara Rao and Krishnamurthy, 2007).

Wani and Kumar, R. (2008) studied the different forms of potassium in ten representative soils of different physiographic in lesser Himalayas. The result showed the water soluble-K ranged from 4.7 to 14.8 mg kg⁻¹ (mean value of 7.2 mg kg⁻¹).

A study was also carried out by Yadav *et al.* (2009) on the forms of potassium, their distribution and relationship with soil properties in four soil profiles of eastern plain of Rajasthan. The mean value of water soluble K was 10.29 mg kg⁻¹ of soil. Mean and the per cent contribution of these forms was 0.28 towards total K. Water soluble K decreased whereas exchangeable, available, non-exchangeable K, lattice K and total K increased with soil depth. Non-exchangeable K, lattice K and total K were mainly contributed by the clay fraction in soil.

Mandal *et al.* (2011) observed the forms of potassium and their distribution in rubber growing soils of Tripura. They found that the water soluble-K ranged from 2.5-35.2 mg kg⁻¹ of soil which contributes only 0.015 -0.24% of total-K.

Gurumurthy and Prakasha (2011) studied the different land use systems where the soil is loamy sand to sandy clay loam. The water soluble K content in surface soils varied from 10.06 to 16.66 mg kg⁻¹.

Jatav and Dewangan (2012) reported that the water soluble K in soils of Baloda block at Janjgir district of Chhattisgarh state ranged from 3.9 to 16 mg kg⁻¹.

Shelake (2013) observed potassium behavior in important soil series of Kolhapur Maharashtra found that the water soluble -K 0.26 % towards total -K.

Saini and Grewal(2014)studiedthevertical distribution of different forms of potassium and theirrelationship with different soil properties in some Haryana soil under different crop rotation. Results showed that thewater soluble K ranged from 8 to 58kg ha⁻¹.

An investigation carried out byJatev *et al.*(2014) for the distribution of different forms of potassium in potato growing soils of Jalandhar district of Punjab. Thewater soluble- Kvaried from 12.8 to 81.2 mg kg⁻¹ with a mean value of 31.3 mg kg⁻¹.

Kundu *et al.*(2014) observed different forms and distribution of potassium in some soils of Honghly district of west bengal.The distribution of the different forms of the K in these soils the water soluble K range from 15.4 to 48.2 mg kg⁻¹ for surface soil and 21.5 to 49.1 mg kg⁻¹ for sub-surface soil.

The water-soluble K ranged between 0.006 and 0.144 cmol (p+) kg⁻¹ in soils of different horizons in North Eastern region of India (Reza *et al.* 2014).

Behra *et al.*(2015) conducted a study on the different forms of potassium and their distribution in some soil seriesrepresentingPaschim Medinipurdistrict under Red and Laterite Zone ofWest Bengal. Their resultshowed in Jhargram soil series and saripabasa soil series the content of water soluble K rangefrom 1.01 to 1.31 and 2.42 to 3.54 mg kg⁻¹ respectively.

The average values of water soluble K in surface and sub-surface soils were 12.4 and 9.2 mg kg⁻¹ respectively in soil of SASRD Research farm of Nagaland (Odyuo *et al.* 2015).

Kulkarni (2017) investigated different form of K in black and red soil type. The result showed that the water soluble- K range from 0.008 - 0.051 me/100g with a mean value of 0.019 me/100g.

Dhakad *et al.* (2017) found the status and distribution of different forms of potassium in soils of Gwalior District (M.P.). The result show that the average water soluble-K was 15.1 mg kg⁻¹.

Kori *et al.* (2018) observed the status and distribution of different forms of potassium in soils of Ashoknagar district (M.P.) with an average values for water soluble-K was 17.6 mg kg⁻¹.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore (M.P.). The result showed that the water soluble K in surface and subsurface layers of these soils ranged from 4.20-36.0 and 3.60-36.2 mg kg⁻¹ with an average values of 14.77 and 15.94 mg kg⁻¹ respectively.

2.1.2 Exchangeable potassium (K)

Pharande and Sonar (1996) studied the distribution of different forms of potassium in some soil series from Vertisols of Maharashtra in relation to soil properties. The exchangeable soil K varied from 148 to 415 percent. Although these soils were rich in exchangeable K throughout the depth, the total K reserve was poor indicating low K bearing minerals in soils. The water soluble and exchangeable K poorly correlated with non-exchangeable, lattice and total K indicating difficulty in replenishment of available K from non-exchangeable and lattice K.

The exchangeable K content in the soils of Khammam district of Andhra Pradesh was in the range 10.2 to 358.9 mg kg⁻¹ (Chandrasekhara Rao and Krishnamurthy, 2007).

Wani and Kumar, R. (2008) investigated forms of potassium in ten representative soils of different physiographic in lesser Himalayas. The amount of exchangeable- K ranged from 49.9 to 154.8 mg kg⁻¹ (mean value of 71.8 mg kg⁻¹).

The amount of exchangeable K in the soils of Agra district varied in the range of 49 to 304.2 mg kg⁻¹ with a mean value of 93 mg kg⁻¹ which constituted 0.64 per cent of total K (Singh *et al.* 2010).

Mandal *et al.* (2011) studied the forms of potassium and their distribution in rubber growing soils of Tripura found that the exchangeable- K ranged from 22.5-136.2 mg kg⁻¹ with a mean value of 67.6 mg kg⁻¹, which accounted for 0.93 - 1.31% of total-K.

Gurumurthy and Prakasha (2011) studied the different land use systems where the soil is loamy sand to sandy clay loam. The exchangeable potassium content in surface soils varied from 50.1 to 152.6 mg kg⁻¹.

Jatav and Dewangan (2012) reported that the exchangeable K in soils of Baloda block at Janjgir district of Chhattisgarh state ranged from 44.1 to 153.7 mg kg⁻¹.

Shelake (2013) studied the potassium behavior in important soil series of Kolhapur district and found that exchangeable- K 2.94% towards total K.

Lungmuana *et al.* (2014) analyzed the soils for distribution and variation of potassium in rice growing soils of red and lateritic zone of West Bengal and observed the exchangeable-K content of the soils was 0.20 cmol (p⁺) kg⁻¹ with the surface and subsurface soils accounting for 0.15 cmol (p⁺) kg⁻¹ with a mean value of 0.18 cmol (p⁺) kg⁻¹.

Saini and Grewal(2014)studied theverticaldistribution of different forms of potassiumand theirrelationship with different soil properties in someHaryana soil under different crop rotation. Theexchangeable -K ranged from 127 to 263kg ha⁻¹.

Jatev *et al.*(2014) observed the distribution of different forms of potassium in potato growing soils of Jalandhar district of Punjab.Theexchangeable-K ranged from 9.4 to 186.9 mg kg⁻¹.

Kundu *et al.* (2014) studied theforms and distribution of potassium in some soils ofHonghly districtof west bengal.The distribution of exchangeable K ranged from68.9to80.9 mg kg⁻¹ for surface soil and 72.9 to 92.2 mg kg⁻¹ for sub-surface soil.

Reza *et al.*(2014)studied the relationship between the forms of K with agro-ecological regions and the association of K forms with soil properties in the North-Eastern region of India. The exchangeable-K ranged in 0.07 and 0.54 cmol (p+) kg⁻¹ in soils of different horizons.

Behra *et al.*(2015) studied the different forms of potassium and their distribution in some soil series representing Paschim Medinipur district under Red and Laterite Zone of West Bengal. Their result showed in Jhargram soil series and saripabasa soil series the content of exchangeable-K ranged from 5.46 to 7.89 and 15.67 to 54.22mg kg⁻¹respectively.

Odyuo *et al.* (2015) observed the potassium fraction of soils of SASRD Research farm of Nagaland University.The average values of exchangeable-K in surface and sub-surface soils were 156 mg kg⁻¹.

Bashir *et al.*(2016)studieddistribution of different forms of potassium undertemperate conditions of Kashmir. Their result showed the contentofexchangeable-K ranged from 0.124-0.275 [cmol(p+)kg⁻¹].

Kulkarni (2017) studied forms of K in black and red soil type and observed that the exchangeable-K ranged from 0.251 - 0.975 me/100g with a mean value of 0.550 me/100g.

Dhakad *et al.*(2017)studied different forms of potassium in soils of Gwalior District (M.P.).The average exchangeable-K was in the range of 230.5 mg/kg.

Kori *et al.*(2018)analyzed different forms of potassium in soils of Ashoknagar district (M.P.).The results showed that the average values for exchangeable -K was 161.1 mg/kg.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore(M.P.).The result showed that the exchangeable K in surface and sub-surface soils varied from 167.0-329.2 and 184.1-335.7 mg kg⁻¹ with an average of 256.1 and 250.89 mg kg⁻¹respectively.

2.1.3 Non-Exchangeable potassium (K)

Bhalerao and Pharande (2003) reported that the non-exchangeable K in saline, saline-sodic and sodic soils are 262, 300 and 330 mg kg⁻¹respectively.

The non exchangeable K content in the soils of Khammam district of Andhra Pradesh was in the range of 95 to 1806 mg kg⁻¹(Chandrasekhara Rao and Krishnamurthy, 2007).

Ingole (2007) reported that the 9.00, 8.85 and 8.61 per cent non-exchangeable K present in Vertisols, Inceptisols and Entisols, respectively on Agriculture farm at MPKV, Rahuri.

Wani and Kumar, R. (2008)studied the different forms of potassium in ten representative soils of different physiographic in lesser Himalayas. The amount of non exchangeable-K ranged from 551.9 to 917.7 mg kg⁻¹(mean value of 680.9 mg kg⁻¹).

Wani (2009) studied the kinetics of non-exchangeable potassium release from some soil and their separates of Himalayas of India at different altitude zone of Kashmir valley. Non-exchangeable-K value was higher at MSL 95.2 to 106.9, medium altitude 92.8 to 95.9 and low altitude 67.01 to 74.9 mg kg⁻¹.

Mandal *et al.*(2011) studied the forms of potassium and their distribution in rubber growing soils of Tripura. The Non exchangeable-K varied from 201.2-824.6 mg kg⁻¹ with a mean value of 476.8 mg kg⁻¹.

Jatav and Dewangan (2012) reported that the non-exchangeable K in soils of Baloda block at Janjgir district of Chhattisgarh state ranged from 177.3 to 456 mg kg⁻¹.

Shelake (2013) studied potassium behavior in important soil series of Kolhapur district and found that non exchangeable-K was 9.26 % towards total-K.

Saini and Grewal(2014)studied the vertical distribution of different forms of potassium and their relationship with different soil properties in some Haryana soil under different crop rotation. The Non exchangeable-K ranged from 442 to 828 kg ha⁻¹.

Jatev *et al.*(2014) studied the distribution of different forms of potassium in potato growing soils of Jalandhar district of Punjab. The Non exchangeable-K ranged from 285 to 3381 mg kg⁻¹ with a mean value of 1620 mg kg⁻¹.

Kundu *et al.*(2014) observed the forms and distribution of potassium in some soils of Hooghly district of west Bengal. The distribution of the different forms of the K in these soils the non exchangeable-K ranged from 658.9 to 764.5 mg kg⁻¹ for surface soil and 701.0 to 789.9 mg kg⁻¹ for sub surface soil.

Odyuo *et al.*(2015) potassium fraction of soils of SASRD Research farm of Nagaland University. The average values of non exchangeable K in surface and sub-surface soils were 879 and 918 mg kg⁻¹ respectively.

Bashir *et al.*(2016) studied the distribution of different forms of potassium under temperate conditions of Kashmir. Their result showed the content of non exchangeable- K ranged from 1.434-2.625 [cmol(p+)kg⁻¹].

Kulkarni (2017) studied forms of K in black and red soil type and observed that non exchangeable-K ranged from 0.625 - 2.987 me/100g with a mean value of 1.463 me/100g.

Dhakad *et al.*(2017) studied different forms of potassium in soils of Gwalior District (M.P.).The average value of non exchangeable-K in the range of 548.40 mg /kg.

Akbas *et al.*(2017) studied the variability of soil potassium and its relationship to land use and parent material.The non exchangeable-K (NEK) was 925 mg kg⁻¹ in surface layers and 167.2 mg kg⁻¹ in subsurface layers.

Kori *et al.*(2018) observed the status and distribution of different forms of potassium in soils of Ashoknagar district(M.P.).The results showed that the average values for non exchangeable-K was 614.8 mg /kg.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore(M.P.).The result showed that the non-exchangeable K varied from 180.4-430.4 and 208.8-396.8 mg kg⁻¹ with an average of 305.08 and 305.19 mg kg⁻¹ in surface and sub-surface soil layers, respectively.

2.1.4 Lattice potassium(K)

A laboratory study was carried out by Choudhary and Prasad (1997) indicated that on average lattice potassium contributed 92.3% to total soil potassium.

Shelake (2013) studied the potassium behaviour in important soil series of Kolhapur Maharashtra found that the Lattice K 87.54 % of total K.

Jatev *et al.*(2014) observed the distribution of different forms of potassium in potato growing soils of Jalandhar district of Punjab. The Lattice-K ranged from 186 to 19411 mg kg⁻¹.

Kundu *et al.*(2014) observed that the forms and distribution of potassium in some soils of Honghly district of West Bengal. The lattice-K ranged from 14801.3 to 16361.0 mg kg⁻¹ for surface soil and 14951.3 to 16378.4 mg kg⁻¹ for sub-surface soil.

Bashir *et al.*(2016) studied distribution of different forms of potassium under temperature conditions of Kashmir. The result showed that the content of Lattice-K ranged from 29.730-51.859 [cmol(p+) kg^{-1}].

Kulkarni (2017) the result showed that the lattice-K range from 21.818 - 45.883 me/100g with a mean value of 32.522 me/100g in black and red soil.

Dhakad *et al.*(2017) obtained an average value of lattice-K in the range of 1.403% in soils of Gwalior District (M.P.).

Kori *et al.*(2018) showed the average values for lattice- K was 1.334% in Ashoknagar district of M.P.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore(M.P.).The result showed that the lattice K varied from 8113.8-15823.6 and 8922.8-16172.2mg kg⁻¹ with an average of 12285.10 and 12142.70 mg kg⁻¹ in surface and sub-surface soil layers, respectively.

2.1.5 Available potassium (K)

Shilpa *et al.* (2007) studied the potassium fraction distribution and their interrelationship between forms of potassium in soils from five districts of Central and Eastern Vidarbha region of Maharashtra. The available K contributed 1.97 per cent towards total K.

The available potassium content of the surface soil samples varied from 135320 kg ha⁻¹ in different revenue villages of the Ramachandrapuram mandal in Chittoor district of Andhra Pradesh reported by Varaprasad *et al.* (2008).

Kundu *et al.*(2014) studied in some soils of Honghly district of West Bengal.The distribution of available-K ranged from the 86.9 to 132.4 mg kg⁻¹ for surface soil and 98.5 to 135.6 mg kg⁻¹ for sub surface soil.

Odyuo *et al.* (2015) studied the potassium fraction of soils of SASRD Research farm of Nagaland University.The available-K in surface and sub-surface soils were 171 and 165 mg kg⁻¹ respectively.

Bashir *et al.*(2016)studied the distribution of available potassium under temperate conditions of Kashmir. The result showed that the content of available-K ranged from 0.134-0.313 [cmol(p+)kg⁻¹].

Kulkarni (2017) observed the different form of K in black and red soil type. He showed that the available-K ranged from 0.266 - 1.012 me/100g with a mean value of 0.569 me/100g.

Akbas *et al.* (2017) studied the variability of soil potassium and its relationship to land use and parent material. The average plant available-K (PAK) was 152.8 mg kg⁻¹ in surface layers and 167.2 mg kg⁻¹ in subsurface layers.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore (M.P.). The result showed that the available K varied from 212.1-347.0 and 195.6-352.4 mg kg⁻¹ with an average of 271.86 and 266.82 mg kg⁻¹ in surface and sub-surface soil layers, respectively.

2.1.6 Total potassium (K)

Pharande and Sonar (1996) studied the distribution of different forms of potassium in some soil series from Vertisols of Maharashtra in relation to soil properties. The total soil K varied from 0.15 to 1.23 percent. Although these soils were rich in exchangeable K throughout the depth, the total K reserve was poor indicating low K bearing minerals in soils. The water soluble and exchangeable K poorly correlated with non-exchangeable, lattice and total K indicating difficulty in replenishment of available K from non-exchangeable and lattice K.

The distribution of different forms of potassium in 10 representative soil series of Gurgaon District, Haryana, India, in relation to soil properties was studied by Dinakaran *et al.* (2006). The total K ranged from 10500 to 19000 mg kg⁻¹.

Jatav *et al.* (2006) studied the distribution of different forms of potassium in surface soils from Lahaul Valley in the cold desert region of Himachal Pradesh, India. The mean value of total K 15564 ppm.

Wani and Kumar, R. (2008) studied total potassium in ten representative soils of different physiographic in lesser Himalayas. The amount of total potassium ranged from 12320.1 to 18154.5 mg kg⁻¹ with a mean value of 15412.8 mg kg⁻¹.

Mandal *et al.* (2011) observed that the forms of potassium and their distribution in rubber growing soils of Tripura. The result found that the total-K ranged from 0.26-1.35% with a mean value of 0.57%, indicating low to moderate reserve for K in rubber growing soils of Tripura.

Saini and Grewal (2014) studied the vertical distribution of different forms of potassium and their relationship with different soil properties in some Haryana soil under different crop rotation. The total-K ranged from 1.18 to 1.92%.

Jatev *et al.* (2014) observed total-K in range of 656 to 21406 mg kg⁻¹ in potato growing soils of Jalandhar district of Punjab.

Kundu *et al.* (2014) observed the total-K ranged from 15579.2 to 17250.2 mg kg⁻¹ for surface soil and 15753.5 to 17303.2 mg kg⁻¹ for sub surface soil of Hooghly district of West Bengal.

The total-K ranged from 17.4 to 63.6 cmol(p+)kg⁻¹ in soils of different horizons of North-Eastern region of India. (Reza *et al.* (2014)

Odyuo *et al.* (2015) analyzed the Potassium fractions of soils of SASRD Research farm of Nagaland University. The average values of total-K in surface and sub-surface soils were 24.0 and 25.0 mg kg⁻¹ respectively.

Bashir *et al.* (2016) observed total potassium under temperate conditions of Kashmir is 31.6054.50 [cmol(p+)kg⁻¹].

Kulkarni (2017) studied the different forms of K in black and red soil type. The result showed that the total-K ranged from 23.515 - 49.640 me/100g with a mean value of 34.574 me/100g.

Dhakad *et al.*(2017) observed the total-K of 1.482%in soils of Gwalior district M.P.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore(M.P.).The result showed that the total K varied from 8550.50-16490.60 and 9445.60-16785.60 mg kg⁻¹ with an average of 12855.24 and 12714.73 mg kg⁻¹ in surface and sub-surface soil layers, respectively.

2.2 INTER RELATIONSHIP AMONG DIFFERENT FORMS OF POTASSIUM

A laboratory study was carried out by Choudhary and Prasad (1997) indicated that on average, water soluble, exchangeable, available, non-exchangeable and lattice potassium contributed 0.09, 0.31, 0.40, 7.3 and 92.3% to total soil potassium, respectively. Water soluble K showed a significantly positive correlation with exchangeable K ($r=0.776$). Available K was significantly and positively correlated with water soluble K ($r=0.850$) and with exchangeable K ($r=0.997$). Non-exchangeable K was positively and significantly correlated with lattice K ($r=0.747$) and total soil potassium ($r=0.842$). Lattice K had a positive and significant correlation with total soil potassium ($r=0.987$).

Das *et al.* (2000) studied the distribution of different forms of potassium in some typical soil profiles occurring on varied landforms under red and laterite ecosystem of West Bengal, India and reported that surface soils contained less amount of all forms of K than subsurface soils except water soluble K. The surface and subsurface soils of most profiles were sufficient in available K. Significant positive correlations were observed amongst different forms.

Gangopadhyay *et al.*(2005) obtained non-exchangeable K had significant positive correlation with lattice- K ($r=0.61^{**}$) and total- K ($r=0.67^{**}$) while lattice-K had significant positive correlation with total-K ($r=0.99^{**}$).

Shilpa *et al.* (2007) studied the potassium fraction distribution and their interrelationship between forms of potassium in soils from five districts of Central and Eastern Vidarbha region of Maharashtra. The available, water soluble, exchangeable, non-exchangeable and lattice K contributed 1.97, 0.12, 1.88, 11.25 and 86.76 per cent towards total K. The increase in available K significantly correlated with exchangeable K ($r=0.9964^{**}$) in Central Vidarbha whereas total and lattice K was highly significant and positively correlated with each other in Vidarbha ($r=0.9954^{**}$) and Eastern Vidarbha ($r=0.9946^{**}$).

Sharma *et al.*(2009) reported that the water soluble K showed significant and positive correlation with exchangeable K ($r=0.762^{**}$) but non significantly correlated with mineral and total K. Non-exchangeable K had highly significant and positive relationship with mineral ($r=0.458^{**}$) and total K ($r=0.551^{**}$).

Mandal *et al.*(2011) noticed that the exchangeable K was positively and significantly correlated with non exchangeable K and total K. non exchangeable K was also positively and significantly correlated with total K suggesting that all these forms of K were in dynamic equilibrium in the soil solution.

Jatav and Dewangan (2012) observed that the significant and positive correlations were observed among different soil K fraction. The order of dominance of different forms of soil potassium was non-exchangeable K > exchangeable K > available K > water-soluble K.

Jatav *et al.*(2014) noticed the positive coefficients of correlation amongst the forms of K and suggested that the different potassium forms are present in dynamic equilibrium under potato growing areas of Jalandhar district of Punjab.

Kulkarni CP (2017) indicated that all the forms of potassium found higher in black soils compared to red soils. The water soluble and exchangeable K was higher in surface sample compared to sub surface in both the soil type. Whereas, non-exchangeable, lattice and total K was higher in sub surface than the surface in both the soil types.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore(M.P.). Exchangeable K showed a significant positive relation with non-exchangeable K, lattice K and total K in surface and subsurface soil samples. Similarly, nonexchangeable K also showed a significant positive correlation with lattice K ($r=0.322^*$) and total K ($r=0.347^*$) in surface soil samples, whereas, positive correlation with lattice K ($r=0.237$) and total K ($r=0.253$) in sub surface soil samples. A significant positive relationship was obtained between lattice K and total K in surface and sub-surface soil samples ($r=0.999^{**}$).

2.3 Relationship between K forms and soil properties

Muhr *et al.* (1965) conducted a study on different types of soils for organic carbon rating and observed rating limit, 63, 56 and 91% of soils are low (<0.50%), 37, 44 and 9% in medium (0.50-0.75%) and none of the soil samples were found in high (>0.75%) in OC content in alluvial, medium black and ravenous land, respectively. FAO (1973) also proposed the limit for calcareous soils as CaCO_3 content greater than 5%.

Vertical distribution of different forms of K in five Vertisols and four Alfisols soil series of Western Maharashtra, India was studied by Raskar and Pharande (1997). The physico-chemical properties of Vertisols and Alfisols were correlated with different forms of potassium. The amount of water soluble, exchangeable, non-exchangeable, lattice and total K in profiles of different Vertisol soil series ranged from 3-31.8, 54-278, 83-787, 1243-7387 mg kg^{-1} and 0.14-0.82%, respectively. The soil pH, EC, CaCO_3 and organic carbon content in Vertisol showed positive relationship with all the forms of K.

Nayan and Walia (1999) studied the profile distribution of various forms of potassium in some landforms of Bundelkhand region, Uttar Pradesh. Total K was positively correlated with the coarse and medium sand fraction. Exchangeable K was correlated highly with the silt, clay, cation exchange capacity, organic carbon and pH of the soils. The non-exchangeable fraction of K varied due to difference in silt and clay content and mineralogy. It showed a positive correlation with the silt and clay fractions as well as the exchangeable K fraction in soils.

Meena *et al.* (2006) obtained a significant positive correlation of available nitrogen with organic carbon status of the soil. Available N was negatively and non-significantly correlated with CaCO₃ content of the soil. This was reflected in low content of available N in soil and loss of N through denitrification. Calcium is precipitates in high pH soils and reduce the P availability also.

Patra *et al.* (2006) studied the distribution of various forms of K at different depths of four representative soil profiles from the Tarai acid soil zone of West Bengal, India. The total K, HCl extractable K and nonexchangeable K consistently increased with increasing depth of profile, whereas the available and exchangeable K stepwise decreased with depth. The water soluble K was relatively more in the surface (13.6-26.1 mg kg⁻¹) and immediate subsurface layer (13.6-22.4 mg kg⁻¹) than the soils underneath (10.1-18.2 mg kg⁻¹).

Singh *et al.* (2009) reported that the surface and subsurface soils were normal to slightly alkaline in reaction ranging between 7.1 to 8.6 in the soils of District Ghazipur, Uttar Pradesh.

Sharma *et al.* (2009) reported that the water soluble K was significantly and positively correlated with organic carbon ($r = 0.628^*$) exchangeable K and available K had positive and significant correlation with organic carbon ($r=0.441^{**}$ & $r=0.506^{**}$) and clay content ($r=0.352^{**}$ & $r=0.326^{**}$), respectively. Highly significant negative relationship of exchangeable K ($r=-0.373^{**}$) and available K ($r=-0.320^{**}$) was observed with sand.

Athokpam *et al.*(2010) collected twenty-five surface soil (0-15 cm) samples from different districts of the valley and hills of Manipur, India, to assess the relationships of various forms of potassium (K) with physicochemical properties of the acidic soils occurring in the State. A highly significant correlation was observed with pH, EC, CEC, organic carbon, available N and clay, and negatively correlated with sand.

Vertical distribution of different forms of potassium in major soils of Haryana was investigated by Kaliramana and Pannu (2011). Correlation study showed that all the forms of potassium were positively significant correlated with O.C, CEC, silt, clay content of soil and sand showed negative correlation with all forms of K except water soluble-K. The different forms of potassium were positive and significant correlation among themselves. The potassium content decreased with the increase in particle size fractions.

Mandal *et al.*(2011) reported that the exchangeable K was significant and positively correlated with clay, OC of soil. However, silt and clay fraction of soils significantly correlated with non- exchangeable K.

Jatav and Dewangan (2012) noticed that the soil pH showed positive and significant correlation with water soluble, exchangeable and available-K. OC exhibited significant and positive correlation with water soluble and exchangeable-K and negative correlation with non exchangeable K.

Kundu *et al.* (2014) observed that the various forms of K were positively and significantly correlated amongst themselves and with CEC, clay and silt content of the soils and negatively correlated with sand content of the soils spreading over seventeen blocks of the Hooghly district of West Bengal.

Reza *et al.*(2014) studied the relationship between the forms of K (K forms) with agro-ecological regions and the association of K forms with soil properties in the North-Eastern region of India. Exchangeable K showed higher correlation with clay ($r=0.519^{**}$), while fixed K with organic carbon ($r=0.390^{*}$).

Fertility status of alluvial and medium black soils and ravenous land, and their correlation studies were carried out by Singh *et al.* (2014) for Chambal region of Madhya Pradesh. The alluvial and medium black soils were neutral to alkaline, whereas ravenous land was more or less neutral. Available N, P and K were negatively and significantly correlated with pH. Available K increased with increasing EC. Available K also increased with increasing levels of organic carbon and silt plus clay. As per nutrient index, available K was high in alluvial, medium black soils and ravenous land and index values were 2.63, 2.55 and 2.81, respectively.

Saini and Grewal (2014) showed that the different forms of potassium were positively and significantly correlated with organic carbon, silt and clay content of the soils. They were negatively correlated with sand content. The different forms of potassium were positively and significantly correlated among themselves.

Bashir *et al.* (2016) associated available potassium was positively and significantly correlated with organic carbon ($r=0.960^*$), cation exchangeable capacity ($r=0.874^*$) and clay ($r=0.642^{**}$) and was negatively correlated with CaCO_3 ($r=0.740^*$), sand ($r=-0.365^*$) and silt ($r=-0.734^*$).

Shinde *et al.* (2016) conducted a study during the year 2015-2016 at Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dhule with an aim to know the fertility status of soils of Agriculture College Farm, Nandurbar. The EC varied from 0.08 to 0.89 dS m^{-1} .

Dhakad *et al.* (2017) studied status and distribution of different forms of potassium in soils of Gwalior District (M.P.). The result showed that the Correlation of different forms of potassium was positively correlated with OC, EC, and clay content. Similarly highly significant and positive relationship was observed between different forms of K.

Anupama *et al.* (2018) observed the fractions of potassium in soils of Agriculture College Research Farm, Indore(M.P.).The exchangeable K ($r=-0.006$) and Nonexchangeable K ($r=-0.096$) showed negative relationship with OC but all the forms of potassium were not reached up to the level of significance. In subsurface soil samples, coefficient of correlation between organic carbon content and exchangeable, available, lattice and total forms of potassium were showed negative relationship and nonsignificant. On the other hand, water soluble ($r=0.073$) and non-exchangeable ($r=0.111$) forms of potassium showed positive but non-significant relationship with OC in subsurface soil samples.

CHAPTER – III

MATERIAL AND METHODS

This chapter deals with concise description of the materials used and the techniques adopted during the investigation entitled **“Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh”** under the following appropriate heads.

3.1 Experimental site

The study was carried out in Ujjain tehsil. Ujjain is situated on the Malwa Plateau in Central India. Mostly soils are black in colour & rich in clay content. The vegetation is typical of arid regions with thorny tree like babul and acacia dominating the landscape. Soybean, wheat, jawar and bajra are the main crops grown.

3.2 Location, climate and general description of the area

3.2.1 Geographical location of the Ujjain tehsil

The Ujjain tehsil is towards north of Ghatiya, which is surrounded by Indore in south, Dewas, in east and Badnagar on the western side. This Tehsil comes under the Ujjain district of Madhya Pradesh state. Ujjain is situated on the bank of Kshipra river and located in between $23^{\circ}10'45.4800''$ N latitude and $75^{\circ}47'5.6832''$ E longitude. (Fig 3.1)

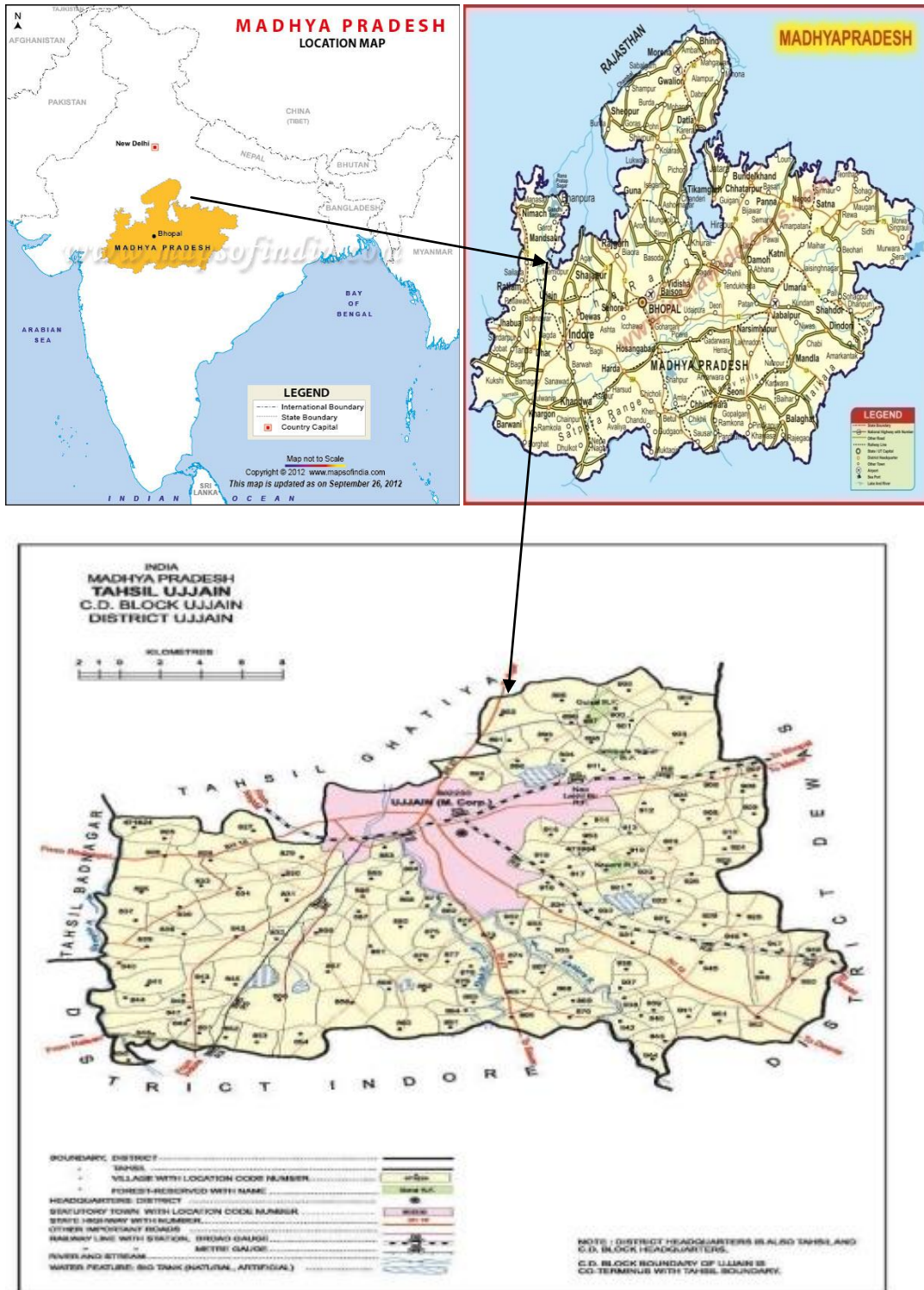


Fig3.1: Location of Ujjain Tehsil

3.2.2 Geographical extent

| | |
|-------------------------|-----------------------------|
| Total geographical area | 60987.4 ha |
| Areas under cultivation | 49607.1 ha |
| Area under irrigation | 25837.0 ha |
| Grazing land | 3149 ha |
| Total village | 131 |
| Kharif crops | Soybean, Maize, Sorghum etc |
| Rabi crops | Wheat, Gram, Musturd etc |

3.3.3 Climate

The climate here is tropical. In winter, there is much less rainfall in Ujjain than summer. In Ujjain, the average annual temperature is 25.2°C. precipitation here average 892 mm.

3.3.4 Soils

The soils of the area are developed from the basalt parent material under the warm sub-humid climate soil developed in situ and those of local alluviam origin.

3.4 Collection and preparation of soil samples

Total 150 surface soil samples collected from the Ujjain Tehsil of Ujjain district and their geographical position was recorded with the help of GPS (Appendix I). These soil samples were air dried, crushed in wooden mortal and pastel and passed through 2 mm plastic sieve for physico-chemical analysis using following standard procedures.

3.5 Analysis of soil samples

3.5.1 Mechanical composition of soil

The sand, silt and clay were determined by mechanical analysis of soil. All the collected samples were analyzed by Bouyoucos Hydrometer method (Bouyoucos, 1962).

In this analysis, 50 gm soil was treated with 100 ml of 5% solution of sodium hexa meta phosphate. Percentage of silt and clay was estimated with the help of hydrometer while the percentage of sand was calculated by subtracting percentage of silt and clay from 100.

3.5.2 Chemical properties of soil

3.5.2.1 Soil reaction (pH)

10gm soil was taken in a 50 ml beaker to which 20 ml distilled water was added. The content was stirred with a glass rod for half an hour to attain equilibrium. pH of soil:water suspension (1:2) was determined by pH meter (Piper, 1966).

3.5.2.2 Electrical conductivity (dSm^{-1})

Electrical conductivity of soil samples was determined in 1:2 Soil: Water suspension using electrical conductivity meter and expressed in dSm^{-1} at 25°C (Piper, 1966).

3.5.2.3 Organic carbon

Organic carbon was estimated by the Walkley and Black (1934) method. In this method, organic matter in the soil is oxidized with a mixture of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) and concentrated H_2SO_4 utilizing the heat of dilution of H_2SO_4 . Unused normal $\text{K}_2\text{Cr}_2\text{O}_7$ is back titrated with N/2 ferrous ammonium sulphate using diphenyl amine as indicator.

3.5.2.4 Available nitrogen

Soil available nitrogen was estimated by alkaline permanganate method as suggested by Subbiah and Asija (1956).

3.5.2.5 Available phosphorus

The determination of available phosphorus was done by using Olsen's reagent (0.5 N sodium bicarbonate solution of pH 8.5) as extractant and stannous chloride was used which reduced to blue color by the method outlined by Olsen *et al.* (1954).

3.6 Method of analysis of different forms of K

3.6.1 Available potassium

Available potassium was determined by using neutral normal ammonium acetate solution as extractant and K was determined using flame photometer as described by Jackson (1973).

3.6.2 Water soluble potassium

Water soluble potassium was estimated in 1:2 soil water suspension using flame photometer as described by Hanway and Heidal (1952).

3.6.3 Exchangeable potassium

Exchangeable potassium was calculated by subtracting water soluble K from available K.

3.6.4 Non-exchangeable potassium

1N boiling HNO₃ extractable potassium was estimated by using flame photometer in 1:10, soil:acid suspension boiled for 10 minutes as described by Black (1965). The results were expressed in mg kg⁻¹.

3.6.5 Total potassium

Total potassium was estimated by using flame photometer. In this digested the soil sample with hydrofluoric (48%) and perchloric acid (70-72%) in platinum crucible by the method outlined by Black (1965). The results were expressed in mg kg^{-1} .

3.6.6 Lattice potassium

Lattice potassium was calculated by subtracting water soluble K, exchangeable K and Non-exchangeable K from Total K.

3.7 Statistical analysis

The statistical analysis to understand correlation among different forms of potassium and with soil properties was done as suggested by Panse and Sukhatme (1954).

CHAPTER-IV

RESULTS

In the present study was carried out to investigate “**Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh**”. In this study, 150 soil samples were collected from Ujjain tehsil and analyzed for different forms of potassium and physical as well as chemical characteristics. Results of the investigation are described under the following heads.

- 4.1 General properties of soils
- 4.2 Physical and Chemical Characteristic of soils
- 4.3 Status of different forms of potassium
- 4.4 Correlation between soil properties and forms of potassium
- 4.5 Inter-relationship among different forms of potassium

4.1 General properties of soils

The soils of the area are developed from the basalt parent material under the warm sub-humid climate. Ujjain is situated on the Malwa Plateau in Central India.

4.2 Physical and Chemical Characteristic of soil

4.2.1 Mechanical composition of soils

The texture of the soils of Ujjain tehsil collected from different fields varied from silty clay to clay (appendix II-IV). The mechanical composition in respect of sand, silt and clay per cent in collected surface soil samples were in the range of 9.15-24.06, 24-41.55 and 40.2-58.6 with the mean value of 16.34, 34, and 49.78 per cent respectively in the surface soil.

4.2.2 Soil pH

The pH values of soil samples were found in the range of 7.01-8.15 under different fields with the mean value of 7.61. Maximum value of soil pH (8.15) was observed in 28th field whereas minimum surface soil pH (7.01) was noticed in 147th field. About 26.67 % and 73.33 % surface soil samples were found in medium and high pH values respectively (Appendix V).

4.2.3 Electrical Conductivity (dSm⁻¹)

Electrical conductivity (EC) status of soil samples collected from Ujjain tehsil (Appendix VI) was found in the range of 0.1-0.79 with an average value of 0.28 (dSm⁻¹). Maximum value of surface soil EC (0.79) was observed in soil collected from the 26th field, whereas minimum value (0.1) was noted in 60th field. It is evident from that 100 % surface soil samples of Ujjain tehsil were in low range of the electrical conductivity.

4.2.4 Organic carbon (%)

Organic carbon status of Ujjain tehsil soil (Appendix VII) was noticed in the range of 0.30-0.60 % under different fields with the mean value of 0.48 %. Maximum value of organic carbon (0.60 %) in the soil was observed in 43th field, whereas minimum value (0.30 %) in 62th field. It is clear from the table that 56 % soil samples belongs to low status and 66% soil samples were in medium status of organic carbon.

4.2.5 Available Nitrogen (kg ha⁻¹)

Available Nitrogen status in the soils of Ujjain tehsil (Appendix VIII) was in the range of 139-235 under different fields with the mean value of 198.27. Maximum value of available nitrogen (235 kg ha⁻¹) in the surface soil was observed in 84th field, whereas minimum available nitrogen (139 kg ha⁻¹) was noted in 60th field. It is evident from that 100.00% soil samples of Ujjain tehsil come in low range of available nitrogen.

4.2.6 Available Phosphorous (kg ha⁻¹)

Available phosphorus (P) status of soil samples (Appendix IX) were in the range of 8-25.6 kg ha⁻¹ with mean value of 15.08 kg ha⁻¹. Maximum value of available P (25.6 kg ha⁻¹) in soil was observed in 14th field, where as minimum value (8.0 kg ha⁻¹) was noticed in 21st field. About 14 % of soil samples were found in low status of available P. 76 % of soil samples comes under medium range of available phosphorous and 10 % soil samples were under high range of available P.

4.3 Status of different forms of potassium (K)

4.4.1 Water soluble K (mg kg^{-1})

Status of water soluble K in Ujjain tehsil (Table 4.1) was found in the range of $3.1\text{-}24\text{mg kg}^{-1}$ under different fields with the mean of 11.47mg kg^{-1} . Maximum value of water soluble K in soil (24mg kg^{-1}) was observed in 90th field. The minimum value of water soluble K in soil (3.1mg kg^{-1}) was noticed in 60th field.

Table 4.1 Distribution of samples under different levels of W.S.K

| S.No. | Water soluble K (mg kg^{-1}) | No of samples | % samples |
|-------|---|---------------|-----------|
| 1 | Low <10 | 56 | 37.33 |
| 2 | Medium 10-25 | 94 | 62.67 |
| 3 | High >25 | Nil | Nil |
| | Total | 150 | 100 |

General statistics:

| | |
|-------|--------|
| Range | 3.1-24 |
| Mean | 11.47 |
| SD | 4.43 |
| CV% | 39.67 |

4.4.2 Exchangeable K (mg kg^{-1})

Exchangeable K status of soil samples collected from Ujjain tehsil (Table 4.2) was found in the range of $118.38\text{-}196.12\text{mg kg}^{-1}$ with an average value of 148.67mg kg^{-1} . Maximum value of exchangeable K (196.12mg kg^{-1}) was observed in soil collected from the 1st field, whereas minimum value (118.38mg kg^{-1}) was noted in 114th field.

Table 4.2 Distribution of samples under different levels of Ex. K

| S.No. | Exchangeable K (mg kg^{-1}) | No of samples | % samples |
|-------|--|---------------|-----------|
| 1 | Low <100 | Nil | Nil |
| 2 | Medium 100-250 | 150 | 100 |
| 3 | High >250 | Nil | Nil |
| | Total | 150 | |

General statistics:

| | |
|-------|---------------|
| Range | 118.38-196.12 |
| Mean | 148.67 |
| SD | 16.70 |
| CV% | 11.23 |

4.4.3 Available K (mg kg⁻¹)

Available K status of soil samples collected from Ujjain tehsil (Table 4.3) was found in the range of 129.95-206.7mg kg⁻¹ with the mean value of 160.11mg kg⁻¹. Maximum value of soil available K (206.70mg kg⁻¹) was observed in soil collected from the 24th field whereas, minimum value (129.95 mg kg⁻¹) was noted in 57th field.

Table 4.3 Distribution of samples under different levels of Avail.- K

| S.No. | Available K (mg kg ⁻¹) | No of samples | % samples |
|-------|------------------------------------|---------------|-----------|
| 1 | Low <125 | Nil | Nil |
| 2 | Medium 125-200 | 147 | 98 |
| 3 | High>200 | 3 | 2 |
| | Total | 150 | |

General statistics:

| | |
|-------|---------------|
| Range | 129.95-206.70 |
| Mean | 160.11 |
| SD | 16.37 |
| CV% | 10.22 |

4.4.4 Non-exchangeable K (mg kg⁻¹)

Non-exchangeable K status of soil samples collected from Ujjain tehsil (Table 4.4) was found in the range of 200-411mg kg⁻¹ with the mean value of 333.13 mg kg⁻¹. Maximum value of surface soil non-exchangeable K (411mg kg⁻¹) was observed in soil collected from the 73th field, whereas minimum value (200mg kg⁻¹) was noted in 110th field.

Table 4.4 Distribution of samples under different levels of Non- Ex.- K

| S.No. | Non-Ex. K (mg kg ⁻¹) | No of samples | % samples |
|-------|----------------------------------|---------------|-----------|
| 1 | Low <200 | 1 | 0.67 |
| 2 | Medium 200-350 | 84 | 56 |
| 3 | High>350 | 65 | 43.33 |
| | Total | 150 | |

General statistics:

| | |
|--------------------|---------|
| Range | 200-411 |
| Mean | 335.13 |
| Standard deviation | 16.41 |
| CV% | 15.14 |

4.4.5 Lattice K (mg kg⁻¹)

Status of soil Lattice K in Ujjain tehsil (Table 4.5) was found in the range of 7888.50-17515.71mg kg⁻¹ under different fields with the mean of 12396.85mg kg⁻¹. Maximum value of surface soil lattice K (17516 mg kg⁻¹) was observed in 52th field, minimum value of surface (7943.8 mg kg⁻¹) soil lattice K were noticed in 1st field.

Table 4.5 Distribution of samples under different levels of Lattice-K

| S.No. | Lattice K (mg kg ⁻¹) | No of samples | % samples |
|-------|----------------------------------|---------------|-----------|
| 1 | Low <10000 | 38 | 25.33 |
| 2 | Medium 10000-12000 | 27 | 18 |
| 3 | High>12000 | 85 | 56.67 |
| | Total | 150 | |

General statistics:

| | |
|-------|------------------|
| Range | 7888.50-17515.71 |
| Mean | 12396.85 |
| SD | 2435.04 |
| CV% | 19.64 |

4.4.6 Total K (mg kg⁻¹)

Total K status of soil samples collected from Ujjain tehsil (Table 4.6) was found in the range of 8500-18000mg kg⁻¹ with the mean value of 12963mg kg⁻¹. Maximum value of surface soil Total K (18000 mg kg⁻¹) was observed in soil collected from the 52th field whereas, minimum value (8500 mg kg⁻¹) was noted in 15th field.

Table 4.6 Distribution of samples under different levels of Total-K

| S.no. | Total K (mg kg ⁻¹) | No of samples | % samples |
|-------|--------------------------------|---------------|-----------|
| 1 | Low <10000 | 21 | 14 |
| 2 | Medium 10000-12000 | 29 | 19.33 |
| 3 | High>12000 | 100 | 66.67 |
| | Total | 150 | |

General statistics

| | |
|-------|------------|
| Range | 8500-18000 |
| Mean | 12968 |
| SD | 2340.80 |
| CV% | 18.04 |

4.5 Correlation between soil properties and forms of potassium

The results of correlation study (coefficient of correlation) between different forms of potassium with soil properties are presented in the table.

Table 4.7 Correlation between soil properties and forms of potassium

| | EC | pH | OC | N | P | Sand (%) | Silt (%) | Clay (%) |
|------------------|--------|---------|-------|-------|----------|----------|----------|----------|
| W.S.K. | 0.005 | -0.110 | 0.113 | 0.128 | -0.198* | 0.021 | 0.211** | 0.045 |
| Ex.K. | 0.168* | 0.047 | 0.039 | 0.021 | -0.160* | -0.157* | 0.052 | 0.105 |
| avail. K | 0.172* | 0.018 | 0.071 | 0.056 | -0.216** | -0.155* | 0.110 | 0.119 |
| Non-ex. K | 0.097 | 0.218** | 0.035 | 0.071 | -0.089 | 0.223** | 0.242** | 0.028 |
| Lattice K | 0.004 | -0.135* | 0.091 | 0.062 | 0.180* | 0.204* | -0.231** | 0.308** |
| total K | 0.004 | -0.132 | 0.092 | 0.064 | 0.177* | 0.199* | -0.227** | 0.311** |

*. Test of significance of Correlation at 148 DF for 5% ($r=0.134$)

** . Test of significance of Correlation at 148 DF for 1% ($r=0.208$)

4.5.1 Soil pH

The results (Table 4.7) indicate that, in surface soil the soil pH showed positive relationship with exchangeable K ($r=0.047$) and available K ($r=0.018$) and non exchangeable K ($r= 0.218^{**}$). Negative relationship with water soluble ($r=-0.101$), lattice K ($r= -0.135^*$) and total K ($r=-0.132$). The coefficient of correlation of pH with non-exchangeable K ($r= 0.218^{**}$) was positive and significant at 1% level of significance. The coefficient of correlation of pH with lattice K ($r= -0.135^*$) was negative and significant at 5 % level of significance. whereas, all the forms of potassium except non-exchangeable K and lattice K were not reached up to the level of significance.

4.5.2 Electrical Conductivity (EC)

In general, electrical conductivity (EC) of surface soil showed positive relationship with all the forms of potassium (Table 4.7). All the forms of potassium were not reached up to the level of significance except exchangeable K ($r= 0.168^*$) and available K ($r=0.172^*$) which were significant at 5 % level of significance.

4.5.3 Organic Carbon (OC)

The organic carbon (OC) content of surface samples showed positive relationship with all the forms of potassium. The water soluble K ($r= 0.113$), exchangeable K ($r=0.039$), available K ($r= 0.071$), non exchangeable K ($r= 0.035$), lattice K ($r= 0.091$) and total K ($r=0.092$) (Table 4.7) showed positive relationship with OC but all the forms of potassium were not reached up to the level of significance.

4.5.4 Available Nitrogen

The available Nitrogen content of surface samples showed positive relationship with all the forms of potassium but relationship could not reach to the level of significance.

4.5.5 Available Phosphorus

In general available phosphorous content of the surface soil showed positive coefficient of correlation with lattice K ($r= 0.180^*$) and total K ($r= 0.177^*$) and were significant at 5% level. With water soluble K ($r= -0.198^*$) and exchangeable K ($r=-0.160^*$) negative and significant at 5% level of significance. Available phosphorus content of the surface soil (Table 4.7) showed negative relationship with avail. K ($r= -0.216^{**}$) was significant at 1 % level of significance. Non-exchangeable K ($r= -0.089$) was negative relationship with P but relationship could not reach to the level of significance.

4.5.6 Sand

The results (Table 4.7) indicate that the sand particle contents showed (Table 4.7) positive relationship with water soluble K ($r= 0.021$), lattice K ($r= 0.204^*$) and total K ($r= 0.199^*$). Exchangeable K ($r=-0.157^*$), available K ($r= -0.155^*$) and non-exchangeable K ($r= -0.223^{**}$) showed negative relationship with sand particles. The coefficients of correlation of sand content of surface soils with available K, exchangeable K, Lattice K and total K were significant at 5% level of significance and non-exchangeable K was significant at 1% level of significance.

4.5.7 Silt

The silt particles of the surface soils of Ujjain tehsil indicated positive relationship with all the forms of potassium except lattice and total K (Table 4.7). The coefficients of correlation of silt content of surface soil with water soluble K ($r= 0.211^{**}$), non-exchangeable K ($r=0.242^{**}$), lattice K ($r= -0.231^{**}$) and total K ($r= -0.227^{**}$) were significant at 1% level of significance. Exchangeable K and available K were not reached up to the level of significance.

4.5.8 Clay

The results (Table 4.7) indicate that the clay particles of the surface soil showed positive relationship with all the forms of potassium. The coefficient of correlation of clay content with all the forms of potassium were non-significant except lattice K ($r = 0.308^{**}$) and total K ($r = 0.311^{**}$) which were significant at 1% level of significance.

4.6 Inter-relationship among different forms of potassium.

The results of correlation study (coefficient of correlation) between different forms of potassium are presented in table (4.8).

Table 4.8 Inter-relationship among different forms of potassium in soil

| Forms of K | Ex. K | Non-ex. K | Lattice K | total K |
|------------|-------|-----------|-----------|---------|
| W.S.K | 0.059 | -0.108 | 0.129 | 0.120 |
| Ex. K | | 0.135* | 0.801** | 0.820** |
| Non-ex. K | | | 0.182* | 0.205* |
| Lattice K | | | | 0.98** |

*. Test of significance of Correlation at 148 DF for 5% ($r = 0.134$)

** . Test of significance of Correlation at 148 DF for 1% ($r = 0.208$)

4.6.1 Water soluble K

The results (Table 4.8) indicate that in surface soil, water soluble K showed a positive and non significant relationship with exchangeable K ($r = 0.059$), lattice K ($r = 0.129$) and total K ($r = 0.120$). Negative and non significant relationship with non exchangeable K ($r = -0.108$).

4.6.2 Exchangeable K

Exchangeable K (4.8) showed a significant positive correlation with non-exchangeable K ($r = 0.135^*$) at 5% level and significant positive correlation with lattice K ($r = 0.801^{**}$) and total K ($r = 0.820^{**}$) at 1% level.

4.6.3 Non-exchangeable K

The results (Table 4.8) indicate that in surface soil, non-exchangeable K had significant and positive correlation with lattice K ($r = 0.182^*$) and total K ($r = 0.205^*$) at 5% level of significance.

Among different K forms, water soluble K showed positive correlation with exchangeable K($r= 0.059$), lattice K ($r= 0.129$) and total K ($r= 0.120$). But it showed negative correlation with non exchangeable K($r= -0.108$). Non-exchangeable K had a positive relation with lattice K ($r= 0.182^*$) and total K ($r= 0.205^*$).

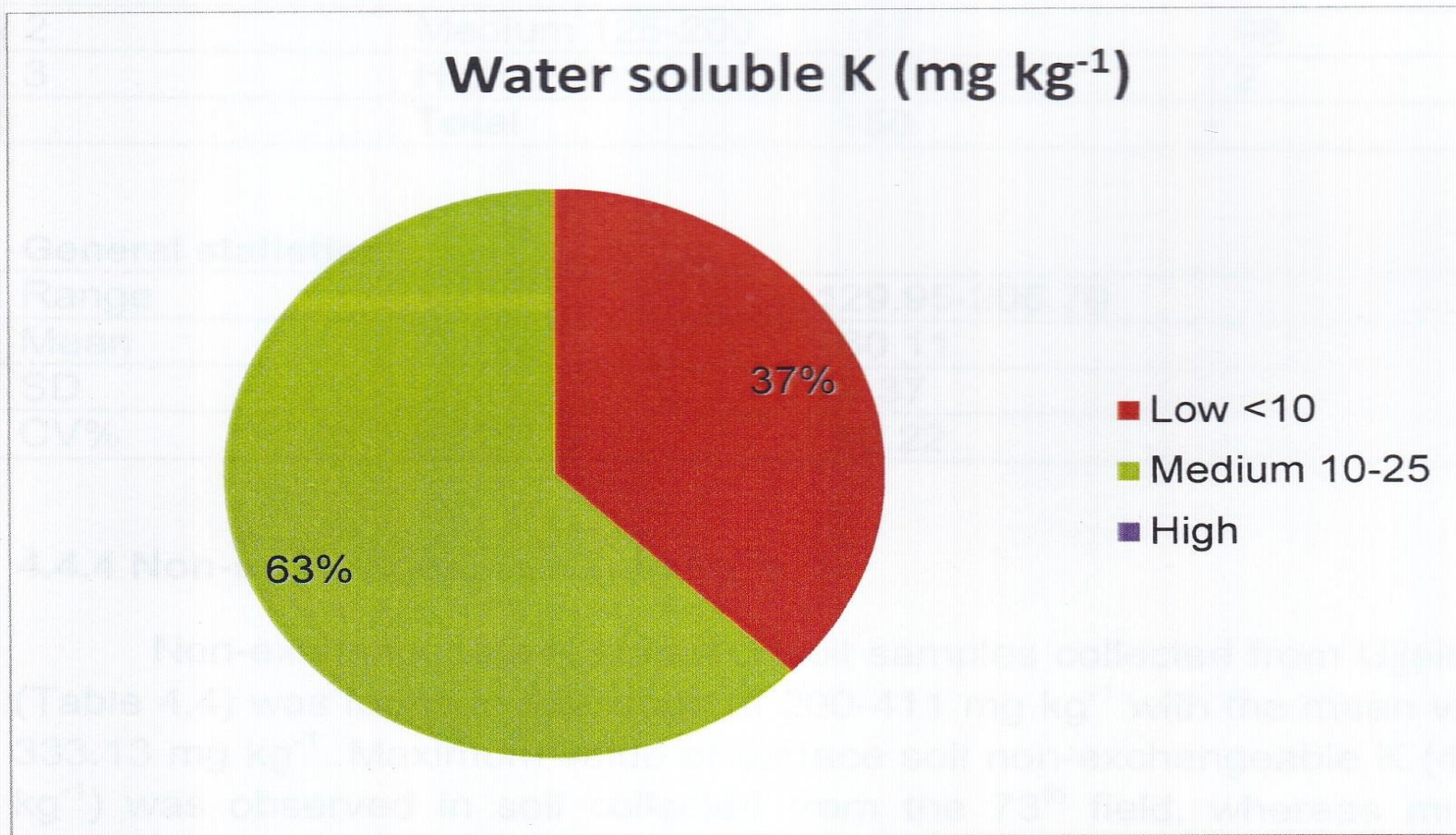


Fig.4.1 Available W.S.K in Soils of Ujjain Tehsil

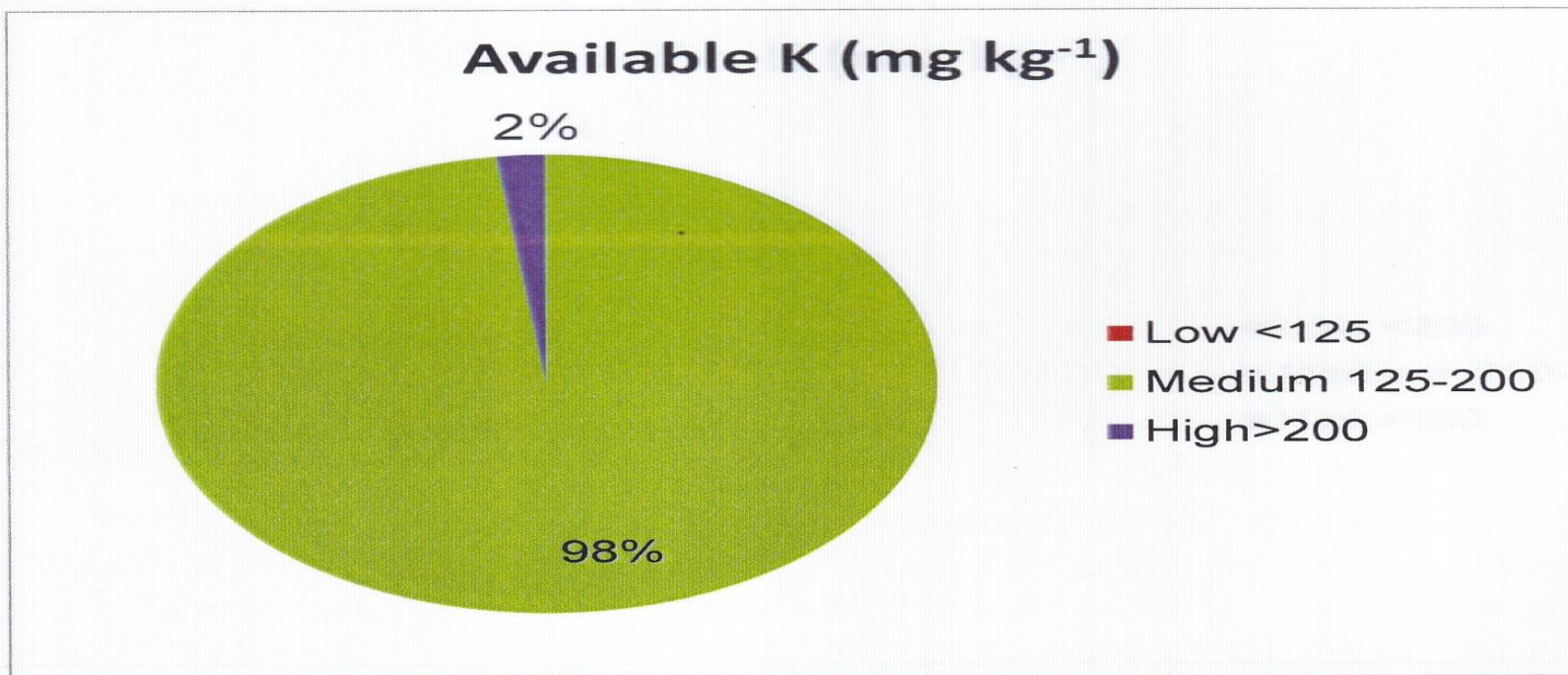


Fig.4.2 Available K in Soils of Ujjain Tehsil

| S.No. | Total K (mg kg ⁻¹) | No. of samples | % samples |
|--------------|--------------------------------|----------------|-----------|
| 1 | Low <200 | 1 | 1.37 |
| 2 | Medium 200-350 | 12 | 16.27 |
| 3 | High >350 | 67 | 92.36 |
| Total | | | |

| General statistics | |
|--------------------|----------|
| Range | 200-3500 |
| Mean | 1963 |
| SD | 1000 |
| CV% | 51 |

| 4.4.6 Total K | |
|---------------|---|
| Total K | collected from Ujjain Tehsil (Table 4.3) was found in the range of 200-3500 mg kg ⁻¹ with the mean value of 1963 mg kg ⁻¹ . Maximum value of 3500 mg kg ⁻¹ of Total K was observed in soil collected from the village of ... minimum value (200 mg kg ⁻¹) was noted. |

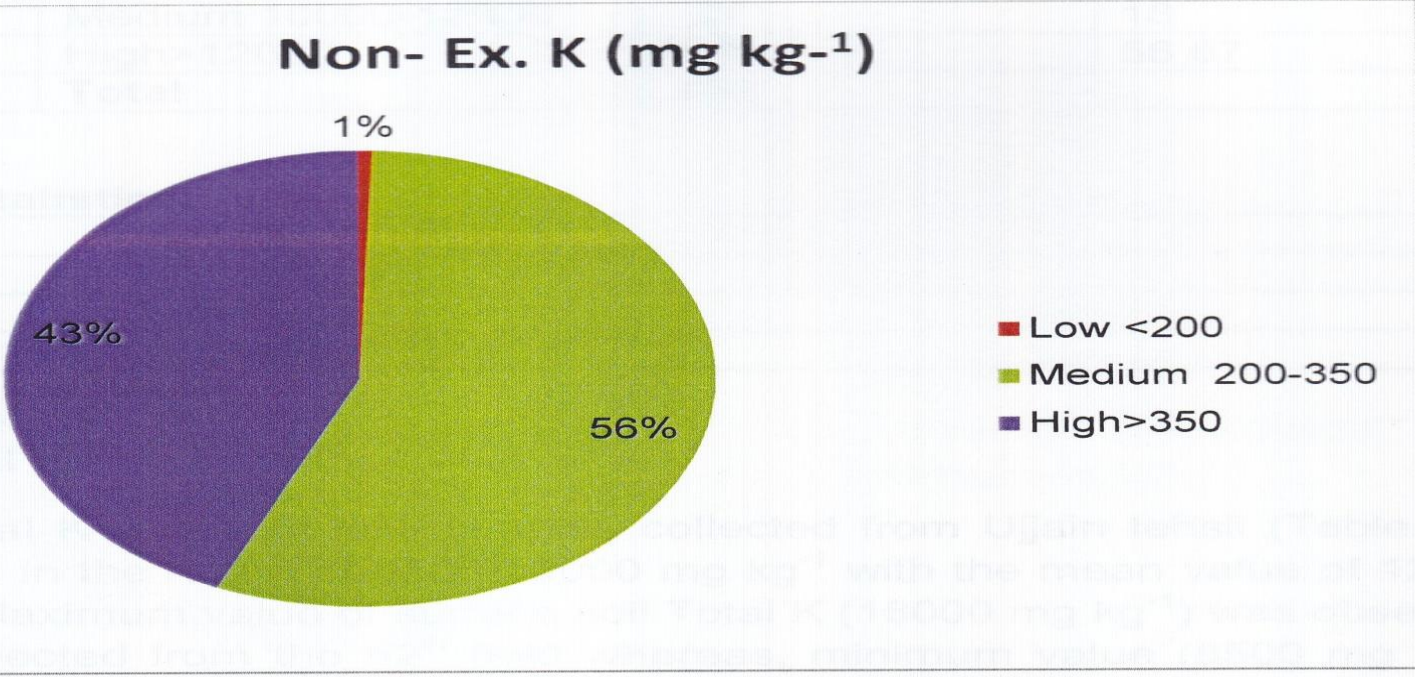


Fig.4.3 Non-Ex. K in Soils of Ujjain Tehsil

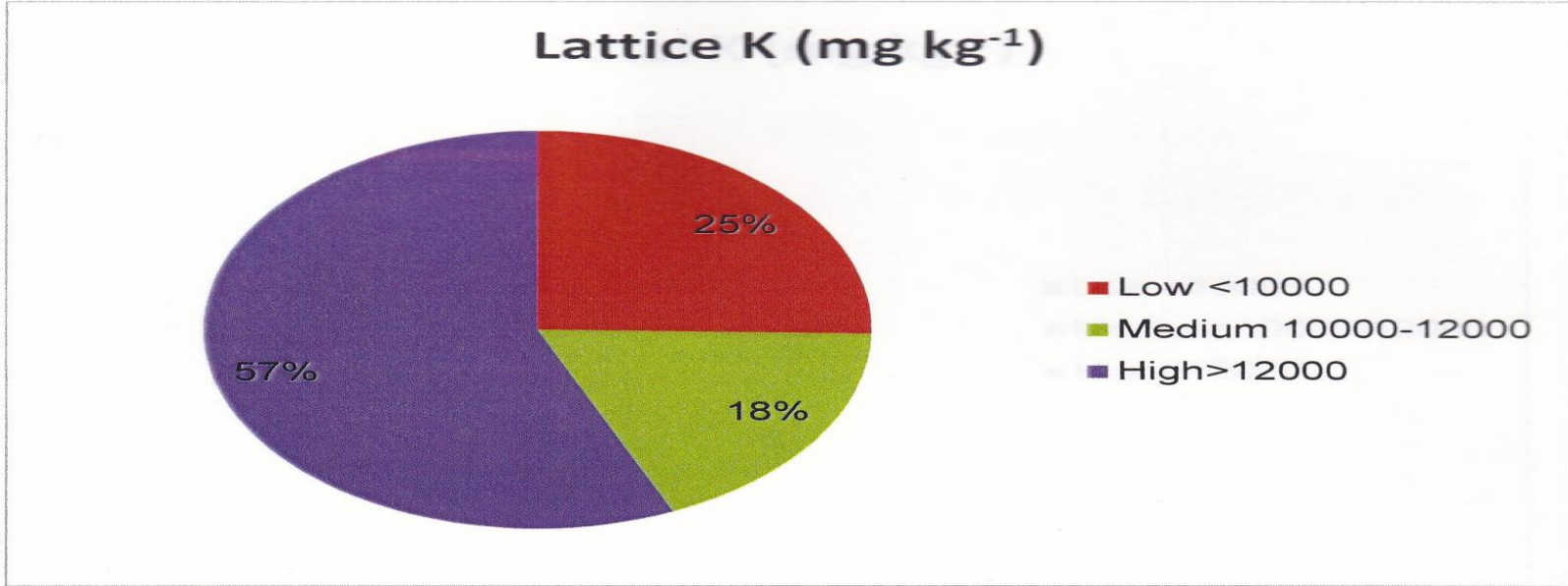


Fig.4.4 Lattice K in Soils of Ujjain Tehsil

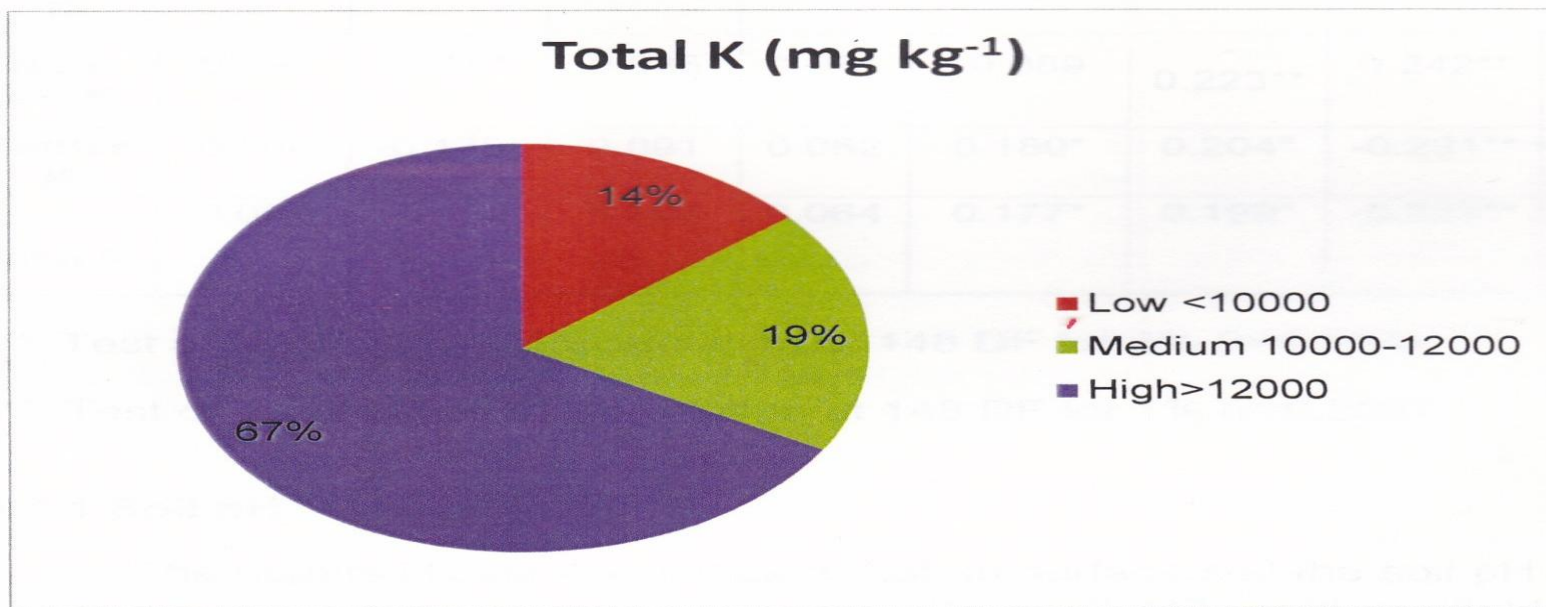


Fig.4.5 Total K in Soils of Ujjain Tehsil

CHAPTER - V

DISCUSSION

The present study was carried out on the topic “**Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh**” to find out the pattern of different forms of K in Ujjain tehsil soil. The obtained results were discussed in the present chapter with the support of the data, scientific facts and views of the other researcher. In this study, total 150 soil samples were collected from 150 fields of Ujjain tehsil (M.P.), and their geographical position were recorded with help of GPS.

During the course of discussion an effort has been made to establish the distribution of different forms of K and their relationship with important physico-chemical properties of soils of Ujjain tehsil. However, on the basis of findings an attempt has been made in the foregoing pages to explain the possible reason of variability obtained due to physicochemical properties of soils. Wherever necessary findings of other workers have also quoted to support the result of the present investigation.

5.1 Soil properties

Detailed analysis of soils was carried out in order to know their physical and chemical characteristics and their effect on the availability of different forms of K. Relationship between different forms of K and soil properties were also worked out.

5.1.1 Mechanical composition of soils

The texture of the soils of Ujjain tehsil varied from silty clay to clay (Appendix II-IV). The sand, silt and clay per cent were observed in the range of 9.15-24.06, 24-41.55, and 32.05-55.6 with the mean value of 16.34, 33.98, and 48.46 percent respectively in the surface soil. In general the clay content was higher in the soil samples. Singh *et al.* (2014) also noticed that the medium black soils are rich in clay content.

5.1.2 Soil pH

Surface soil pH of Ujjain tehsil (Appendix V) was found in the range of 7.01-8.15 under different fields with the mean value of 7.61. About 26.67% of samples were found in normal (7-7.5) and 73.33% were found in slightly higher level (>7.5) of soil pH in soil. Similar findings were also reported by Singh *et al.* (2009). Because these soils are generally formed from the basic parent material like basalt and having higher pH values. The higher pH could be due to increase in accumulation of exchangeable sodium and calcium carbonate.

5.1.3 Electrical Conductivity (dSm^{-1})

Electrical conductivity (Appendix VI) status of surface soil samples was found in the range of 0.10-0.79 with mean value of 0.29 dSm^{-1} . Similar findings were also reported

by Shinde *et al.* (2016). Surface soil samples from the fields (100 %) were recorded in safe limits ($<0.8 \text{ dSm}^{-1}$). On the basis of EC data it could be said that the soils of the Ujjain tehsil are good and can be used for cultivation of crops.

5.1.4 Organic carbon (%)

Surface soil organic carbon was found in the range of 0.30-0.60 % under different fields with the mean value of 0.48 %. It is clear from the results, that 56 % surface soil samples belong to low status and 44 % surface soils samples shows medium status of organic carbon (Appendix VII). According to Muhr *et al.* (1965) rating limits 56 % of soils are low ($<0.5 \%$), 44 % in medium (0.5-0.75 %) and none of the soil samples were found in high ($>0.75 \%$) in organic carbon content in medium black soils. The low organic carbon content in these soils may be attributed to the high rate of organic matter decomposition under hyperthermic temperature regime which leads to extremely high oxidizing conditions. Low organic carbon content in these soils may also be due to intensive cultivation throughout the year.

5.1.5 Available Nitrogen (kg ha^{-1})

Available nitrogen status in the surface soils was found in the range of 139-235 kg ha^{-1} under different fields with the mean value of 198.25 kg ha^{-1} (Appendix VIII). It is evident from the results that 100 % surface soil samples were come with low range of available nitrogen (Table 4.1). The low availability of nitrogen in these soils might be due to increased rates of denitrification. Similar results were also reported by Meena *et al.* (2006).

5.1.6 Available Phosphorus (kg ha^{-1})

Available phosphorus status of surface soil samples was found in the range of 8.0-25.60 with mean value of 15.10 kg ha^{-1} . About 14 % of surface soil samples were found in low status of available phosphorous. 76 % of surface soil samples comes under medium range of available phosphorous (Appendix IX) and 10 % surface soil samples comes under high range of available phosphorous. Low to medium content of P in soil might be due to the higher pH of the study soil. In such types of soil calcium precipitates P as Ca-phosphate and reduce P availability. Similar findings were made by Meena *et al.* (2006).

5.2 Status of different forms of potassium

5.2.1 Water soluble K

Status of surface soil water soluble K in Ujjain tehsil was found in the range of 3.1-24 mg kg^{-1} in different samples with the mean of 11.47 mg kg^{-1} (Appendix X). This form represented 7.71, 7.16, 3.42, 0.09 and 0.089% of exchangeable, available, non-

exchangeable, lattice and total K respectively. Results on the same line with different soil types have also been reported by Dixit *et al.* (1993) and Yadav and Meena (2009).

5.2.2 Exchangeable K

Exchangeable K status of surface soil samples was found in the range of 118.38-196.12 mg kg⁻¹ with the average value of 148.67 mg kg⁻¹ (Appendix X), contributed 1.15% of total K. Pharande and Sonar (1996) also reported the similar findings related to exchangeable K and total K. The variation in exchangeable potassium content among the soil samples may be attributed to differential release of potassium from non-exchangeable and lattice potassium as well as variation in labile pool due to potassium fertilization.

5.2.3 Available K

Available K status of surface soil was found in the range of 129.95-206.70 mg kg⁻¹ with the mean value of 160.07 mg kg⁻¹ (Appendix X). This form contributes 1.24 % of total K in surface soil. Shilpa *et al.* (2007) also reported that available K contributed 1.97 % towards total K in soils.

5.2.4 Non-exchangeable K

Non-exchangeable K status of surface soil samples was found in the range of 200-411 mg kg⁻¹ with the mean value of 335.13 mg kg⁻¹ (Appendix X) contributed 2.59 % towards total K (Appendix X). Anupama *et al.* (2018) also reported 305.08 mg kg⁻¹ of non-exchangeable K in soils of Ujjain tehsil.

5.2.5 Lattice K

Status of surface soil Lattice K was found in the range of 7943.75-17515.71 mg kg⁻¹ under different fields with the mean of 12478.11 mg kg⁻¹ (Appendix X) contributed 96.25 % of total K. Choudhary and Prasad (1997) also reported that Lattice K contributed 92.3% towards total K in soils.

5.2.6 Total K

Total K status of surface soil samples was found in the range of 8500-18000 mg kg⁻¹ with the mean value of 12968.96 mg kg⁻¹ (Appendix X). These results are in agreement with the findings of Dinakaran *et al.* (2006) and Jatav *et al.* (2006).

5.3 Relationship between soil properties and forms of potassium

In general, electrical conductivity (EC) of surface soil showed positive relationship with all the forms of potassium. It seems that soluble salts of potassium may contribute to EC.

These results are in agreement with the findings of Raskar and Pharande (1997) and Athokpam *et al.* (2010).

The organic carbon (OC) content of surface samples showed positive relationship with all the forms of potassium. Similar relationship was also reported by Dhakad *et al.* (2017), Raskar and Pharande (1997).

The available Nitrogen content of surface samples showed positive relationship with all the forms of potassium.

Clay content of the surface soil showed positive relationship with all the forms of potassium. Similar relationship was also reported by Nayan and Walia (1999), Sharma *et al.* (2009)

5.4 Interrelationship among different forms of potassium

5.4.1 Available K

Water soluble K showed a negative and non significant correlation with nonexchangeable K (-0.108 *). Exchangeable K showed significant positive correlation with non-exchangeable K ($r = 0.320^{**}$), Yadav *et al.* (1999) also reported that the exchangeable K show positive and significant relationship between nonexchangeable and total K, indicates that the existence of dynamic equilibrium between these forms of K. These results are in agreement with the findings of Das *et al.* (2000) and Kaliramana and Pannu (2011).

5.4.2 Non-exchangeable K

It is clear from the Table(4.8) that non-exchangeable K had significant positive correlation with lattice K ($r = 215^{**}$) and total K ($r = 224^{**}$). These relationships indicate that these soils contain significant amount of potash bearing minerals which might have materially contributed to its large K reserve. Similar relationship was also reported by Choudhary and Prasad (1997).

5.4.3 Total K

A highly significant (0.98^{**}) and positive correlation was also found between lattice K and total K in soils (Table 4.8), indicates an equilibrium between these forms of K and depletion of one is instantly replenished by one or more of the other forms of K. Shilpa *et al.* (2007) also reported highly significant and positive correlation between total K and lattice K.

CHAPTER - VI
SUMMARY, CONCLUSION AND SUGGESTION
FOR FURTHER WORK

6.1 Summary

Potassium (K) is known as quality element and also an essential macro nutrient required for the proper growth and development of plants. Different forms of K are in dynamic equilibrium and any depletion in a given form is likely to shift in the direction to replenish it. The study of various forms of K in black soils region of Ujjain tehsil is scanty. Therefore, the study related to such aspect is essential to know the concentration of different K forms viz., water soluble, exchangeable, non exchangeable and as a part of mineral lattice and their correlation study between these forms in soils.

The thesis topic entitled “**Soil Potassium, its Different Forms in Ujjain Tehsil of Madhya Pradesh**” was selected for the present study. This study was carried out by taking total 150 soil samples from the Ujjain tehsil. The objectives of the study were as follows:

1. To know the availability of K in soil of Ujjain Tehsil of Ujjain District.
2. To assess different fraction of K in soil.
3. To work out the relationship among different forms of K and different Physico-chemical soil properties (Texture, pH, EC, OC, N, P, K).

The findings of the present experiment are summarized as under:

- The texture of the soils of Ujjain tehsil varied from silty clay to clay. The mean values of percent sand, silt and clay were 16.34, 33.98, and 48.46 percent in the surface soil samples.
- The mean values of pH were 7.61 for surface soil samples. These values showed the soils are alkaline in reaction. About 73.33% soil samples were found in slightly higher pH level (> 7.5) in surface soil.
- The mean values of EC were 0.29dSm^{-1} for surface soils.
- As far the OC is concerned, it is clear that 56% surface soil samples belonged to low status (< 0.5%).
- The nitrogen (N) status was also low in surface soil samples ($139\text{-}235 \text{ kg ha}^{-1}$).
- About 76% of surface soil samples come under medium range of available phosphorous ($8\text{-}25.6 \text{ kg ha}^{-1}$).
- The mean values of water soluble, exchangeable, available, nonexchangeable, lattice and total K in $11.47, 148.67, 160.11, 335.13, 12396.85$ and $12892.29 \text{ mg kg}^{-1}$ in surface soils of Ujjain tehsil. It can be concluded that soils are poor in exchangeable K and fixed K and needs adequate K application.

- In general, electrical conductivity (EC) of surface soil showed positive relationship with all the forms of potassium. Exchangeable K ($r= 0.168^*$) and available K ($r= 0.172^*$) were significant at 5 % level of significance.
- Soil pH showed positive relationship with exchangeable K ($r=0.047$) and available K ($r=0.018$). But negative relationship with water soluble ($r= -0.110$), lattice K ($r= -0.135^*$) and total K ($r=-0.132$). The coefficient of correlation of pH with non-exchangeable K ($r=0.218^{**}$) was positive and significant at 1% level of significance. Water soluble K showed a significant positive correlation with exchangeable K (0.059).

Conclusion

- Soils of Ujjain tehsil were slightly alkaline in reaction and safe limit of EC.
- Most of the fields were low in organic carbon and available nitrogen
- Low to medium status of available phosphorous was observed in surface soils under different fields of Ujjain tehsil.
- More than half of the soil samples were in medium range of water soluble K, exchangeable K and non- exchangeable K content.
- Water soluble K showed positive and significant relationship with also exchangeable K, lattice and total K.

Suggestions for further research work

- Soil test crop response studies may be conducted according to potassium present in soils of Ujjain tehsil.
- Adsorption and desorption studies on potassium may be conducted in these soils, to know the fixation capacity of the soil.

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Appendix I: Location of soil sampling site through GPS

| S. No. | Village | GPS Location | |
|--------|------------|---------------|--------------|
| | | Latitude | Longitude |
| 1 | Ramvasa | 22° 42' 17" N | 75° 53' 55"E |
| 2 | Tawakheda | 23° 9' 28" N | 75° 47' 26"E |
| 3 | Dabla | 23° 10' 31" N | 75° 47' 24"E |
| 4 | Ujjain | 23° 11' 1" N | 75° 47' 5"E |
| 5 | Surasa | 23° 14' 5" N | 75° 48' 35"E |
| 6 | Mangrola | 23° 9' 37" N | 75° 43' 52"E |
| 7 | Mullapura | 23° 11' 7" N | 75° 44' 40"E |
| 8 | Ninora | 23° 5' 28" N | 75° 49' 5"E |
| 9 | Mullapura | 23° 11' 11" N | 75° 44' 26"E |
| 10 | Mohanpura | 23° 11' 3" N | 75° 43' 26"E |
| 11 | Nijampura | 23° 11' 24" N | 75° 46' 53"E |
| 12 | Bamora | 23° 8' 3" N | 75° 41' 47"E |
| 13 | Jamalkhedi | 23° 10' 42" N | 75° 47' 16"E |
| 14 | Fajalpura | 23° 10' 42" N | 75° 47' 16"E |
| 15 | Devrakhedi | 23° 10' 35" N | 75° 47' 19"E |
| 16 | Samdiya | 23° 7' 49" N | 75° 39' 10"E |
| 17 | Mohanpura | 23° 11' 2" N | 75° 43' 26"E |
| 18 | Mohanpura | 23° 11' 2" N | 75° 43' 20"E |
| 19 | Chintaman | 23° 9' 33" N | 75° 44' 38"E |
| 20 | Nalwa | 23° 9' 11" N | 75° 39' 0"E |

| | | | |
|----|---------------|---------------|--------------|
| 21 | Nalwa | 23° 9' 11" N | 75° 38' 54"E |
| 22 | Jeewankhedi | 23° 9' 0" N | 75° 46' 47"E |
| 23 | Chandukhedi | 23° 9' 25" N | 75° 41' 5"E |
| 24 | Kharet | 23° 10' 20" N | 75° 49' 8"E |
| 25 | Jamalkheda | 23° 9' 31" N | 75° 39' 48"E |
| 26 | Jamalkheda | 23° 9' 39" N | 75° 39' 51"E |
| 27 | Nalwa | 23° 9' 11" N | 75° 39' 0"E |
| 28 | Jeewankhedi | 23° 9' 5" N | 75° 46' 56"E |
| 29 | Kharet | 23° 10' 37" N | 75° 47' 19"E |
| 30 | Chandukhedi | 23° 9' 36" N | 75° 41' 10"E |
| 31 | Fajalpur | 23° 10' 46" N | 75° 38' 48"E |
| 32 | Kharet | 23° 9' 31" N | 75° 39' 48"E |
| 33 | Datana | 23° 6' 9" N | 75° 53' 28"E |
| 34 | Matana | 23° 3' 51" N | 75° 51' 28"E |
| 35 | Datana | 23° 6' 10" N | 75° 53' 28"E |
| 36 | Chandesra | 23° 6' 37" N | 75° 51' 2"E |
| 37 | Kalyanpur | 23° 4' 5" N | 75° 52' 1"E |
| 38 | Semlyakhedi | 23° 22' 24" N | 75° 40' 13"E |
| 39 | Kundukhedi | 23° 9' 23" N | 75° 41' 5"E |
| 40 | Patpala | 23° 11' 52" N | 75° 52' 4"E |
| 41 | Harsodan | 23° 11' 17" N | 75° 54' 20"E |
| 42 | Tajpur | 23° 13' 31" N | 75° 54' 11"E |
| 43 | Masoda | 23° 12' 47" N | 75° 54' 35"E |
| 44 | Masoda | 23° 12' 55" N | 75° 54' 38"E |
| 45 | Umriya | 23° 1' 6" N | 75° 25' 25"E |
| 46 | Piplahaniya | 23° 15' 25" N | 75° 54' 44"E |
| 47 | Gunai | 23° 11' 39" N | 75° 54' 34"E |
| 48 | Jambara | 23° 12' 49" N | 75° 54' 35"E |
| 49 | Bakniya | 23° 15' 56" N | 75° 51' 23"E |
| 50 | Sayarkhedi | 23° 15' 4" N | 75° 51' 24"E |
| 51 | Badodiyabhand | 23° 12' 9" N | 75° 53' 38"E |
| 52 | Badarkha | 23° 13' 40" N | 75° 51' 44"E |
| 53 | Sahadkhedi | 23° 11' 34" N | 75° 50' 22"E |
| 54 | Ujjain | 23° 11' 36" N | 75° 48' 24"E |
| 55 | Narvar | 23° 5' 7" N | 75° 55' 44"E |
| 56 | Bolasa | 23° 3' 12" N | 75° 53' 59"E |
| 57 | Bavri | 23° 41' 2" N | 75° 53' 45"E |
| 58 | Bavri | 23° 31' 1" N | 75° 53' 48"E |
| 59 | Bavri | 23° 41' 6" N | 75° 53' 49"E |
| 60 | Premnagar | 23° 10' 27" N | 75° 46' 47"E |
| 61 | Pawasa | 23° 11' 37" N | 75° 50' 5"E |
| 62 | Bhavari | 23° 3' 42" N | 75° 53' 28"E |
| 63 | Bhavari | 23° 3' 47" N | 75° 53' 23"E |
| 64 | Shakkarwasa | 23° 7' 56" N | 75° 47' 59"E |
| 65 | Hamukhedi | 23° 7' 34" N | 75° 48' 58"E |

| | | | |
|-----|-----------------|---------------|---------------|
| 66 | Hamukhedi | 23° 7' 36" N | 75° 48' 56"E |
| 67 | Mindiya | 23° 7' 5" N | 75° 48' 14"E |
| 68 | Mindiya | 23° 7' 12" N | 75° 48' 7"E |
| 69 | Pipliyaragho | 23° 5' 30" N | 75° 47' 28"E |
| 70 | Pipliyaragho | 23° 5' 33" N | 75° 47' 31"E |
| 71 | Gangedi | 23° 6' 24" N | 75° 46' 40"E |
| 72 | Gangedi | 23° 6' 28" N | 75° 46' 46"E |
| 73 | Hajyakhedi | 23° 6' 2" N | 75° 45' 30"E |
| 74 | Hasampura | 23° 6' 22" N | 75° 44' 24"E |
| 75 | Hasampura | 23° 6' 36" N | 75° 44' 34"E |
| 76 | Gondiya | 23° 4' 48" N | 75° 44' 35"E |
| 77 | Gondiya | 23° 4' 54" N | 75° 44' 53"E |
| 78 | Lekota | 23° 3' 39" N | 75° 42' 12"E |
| 79 | Lekota | 23° 3' 46" N | 75° 42' 11"E |
| 80 | Lekota | 23° 3' 54" N | 75° 42' 9"E |
| 81 | Lekota | 23° 4' 0" N | 75° 42' 3"E |
| 82 | Hamirkhedi | 23° 2' 40" N | 75° 38' 28"E |
| 83 | Hamirkhedi | 23° 2' 50" N | 75° 38' 29"E |
| 84 | Hamirkhedi | 23° 2' 59" N | 75° 38' 34"E |
| 85 | Hamirkhedi | 23° 3' 1" N | 75° 38' 25"E |
| 86 | Hamirlhedi | 23° 3' 8" N | 75° 38' 18"E |
| 87 | Fatehabad | 23° 0' 49" N | 75° 40' 33"E |
| 88 | Chandrawatiganj | 23° 0' 37" N | 75° 40' 20"E |
| 89 | Chandrawatiganj | 23° 0' 40" N | 75° 40' 10"E |
| 90 | Kankariya | 23° 1' 45" N | 75° 43' 42"E |
| 91 | Kankariya | 23° 1' 35" N | 75° 43' 39" E |
| 92 | Kankariya | 23° 1' 35" N | 75° 44' 3" E |
| 93 | Nagjhiri | 23° 19' 53" N | 75° 28' 20" E |
| 94 | Kuwariya | 23°6' 52" N | 75°49'59" E |
| 95 | Karadiya | 23°6'7" N | 75°49'7" E |
| 96 | Karadiya | 23°6'23" N | 75°49'30" E |
| 97 | Chandeshra | 23°6'37" N | 75°51'2" E |
| 98 | Chandeshra | 23°6'26" N | 75°50'53" E |
| 99 | Chandesari | 23°7'21" N | 75°51'23" E |
| 100 | Chandesari | 23°7'5" N | 75°51'43" E |
| 101 | Matanakala | 23°8'13" N | 75°51'5" E |
| 102 | Silarkhedi | 23°6'56" N | 75°5'31" E |
| 103 | Matanakala | 23°7'51" N | 75°50'47" E |
| 104 | Ingori | 23°9'26" N | 75°34'6" E |
| 105 | Ingori | 22°42'15" N | 75°53'53" E |
| 106 | Jawasikumar | 23°9'7" N | 75°51'32" E |
| 107 | Datarawada | 23°10'35" N | 75°47'19" E |
| 108 | Datarawada | 23°10'42" N | 75°47'17" E |
| 109 | Lalpura | 23°10'47" N | 75°47'4" E |
| 110 | Lalpura | 23°10'46" N | 75°47'3" E |

| | | | |
|-----|-----------------|-------------|-------------|
| 111 | Surjanwasa | 23°10'15" N | 75°52'25" E |
| 112 | Surjanwasa | 23°10'25" N | 75°52'23" E |
| 113 | Jawantarpur | 23°10'45" N | 75°48'13" E |
| 114 | Jawantarpur | 23°10'25" N | 75°52'23" E |
| 115 | Hakkanipura | 23°13'2" N | 75°48'35" E |
| 116 | Padaiyakhedi | 23°11'19" N | 75°49'5" E |
| 117 | Madhopura | 23°8'29" N | 75°16'37" E |
| 118 | Pawasa | 23°11'40" N | 75°50'3" E |
| 119 | Shankarpur | 23°11'48" N | 75°50'28" E |
| 120 | Bhorukhedi | 23°9'23" N | 75°41'5" E |
| 121 | Ninora | 23°5'37" N | 75°49'2" E |
| 122 | Kithodarav | 23°11'0" N | 75°47'4" E |
| 123 | Kithidarav | 23°11'6" N | 75°47'21" E |
| 124 | Ranabad | 23°6'5" N | 75°43'11" E |
| 125 | Talod | 23°5'58" N | 75°41'14" E |
| 126 | Takwasa | 23°3'21" N | 75°37'45" E |
| 127 | Tankariya kazi | 23°9'53" N | 75°56'15" E |
| 128 | Tankariya panth | 23°42'40" N | 75°53'28" E |
| 129 | Manpura | 23°8'22" N | 75°51'2" E |
| 130 | Nogawan | 23°7'9" N | 75°56'57" E |
| 131 | Nikewadi | 23°42'42" N | 75°53'29" E |
| 132 | Kasampura | 23°2'4" N | 75°54'28" E |
| 133 | Kesoni | 23°9'50" N | 75°53'39" E |
| 134 | Bakaniya | 23°15'56" N | 75°51'33" E |
| 135 | Chandmukh | 23°7'54" N | 75°45'46" E |
| 136 | Jaiwantpur | 23°10'58" N | 75°52'46" E |
| 137 | Kadchha | 23°7'4" N | 75°55'53" E |
| 138 | Nahariya | 23°14'28" N | 75°50'51" E |
| 139 | Pingleshwar | 23°13'2" N | 75°52'28" E |
| 140 | Sabalpur | 23°6'37" N | 75°39'31" E |
| 141 | Palkhedi | 23°7'10" N | 75°45'27" E |
| 142 | Kuwariya | 23°6'52" N | 75°49'59" E |
| 143 | Madhopura | 23°8'29" N | 75°16'37" E |
| 144 | Amirpur | 23°10'44" N | 75°38'49" E |
| 145 | Tajpur | 23°13'31" N | 75°54'8" E |
| 146 | Banskhedi | 23°19'17" N | 75°53'28" E |
| 147 | Bodani | 23°32'53" N | 75°18'31" E |
| 148 | Kachnariya | 23°24'59" N | 75°57'49" E |
| 149 | Jarkhoda | 23°2'24" N | 75°46'51" E |
| 150 | Fatehabad | 23°0'49" N | 75°40'32" E |

Appendix II: Sand (%) in the soils of Ujjain Tehsil

| S. No. | Sand (%) | S. No. | Sand (%) | S. No. | Sand (%) | S. No. | Sand (%) | S. No. | Sand (%) |
|--------|----------|--------|----------|--------|----------|--------|----------|--------------|-------------------|
| 1 | 20.20 | 31 | 13.18 | 61 | 17.35 | 91 | 16.14 | 121 | 14.20 |
| 2 | 18.40 | 32 | 15.10 | 62 | 24.05 | 92 | 20.14 | 122 | 13.22 |
| 3 | 17.40 | 33 | 12.17 | 63 | 24.06 | 93 | 20.08 | 123 | 13.30 |
| 4 | 13.40 | 34 | 14.70 | 64 | 23.10 | 94 | 18.08 | 124 | 9.30 |
| 5 | 21.00 | 35 | 14.16 | 65 | 23.10 | 95 | 16.09 | 125 | 9.28 |
| 6 | 16.00 | 36 | 10.95 | 66 | 22.08 | 96 | 16.20 | 126 | 9.30 |
| 7 | 13.00 | 37 | 19.00 | 67 | 19.00 | 97 | 16.30 | 127 | 9.40 |
| 8 | 16.60 | 38 | 15.10 | 68 | 19.10 | 98 | 14.20 | 128 | 19.40 |
| 9 | 14.36 | 39 | 19.00 | 69 | 19.20 | 99 | 14.40 | 129 | 19.35 |
| 10 | 13.82 | 40 | 20.00 | 70 | 14.00 | 100 | 14.10 | 130 | 19.14 |
| 11 | 9.75 | 41 | 12.04 | 71 | 14.20 | 101 | 14.20 | 131 | 19.05 |
| 12 | 11.28 | 42 | 20.02 | 72 | 14.40 | 102 | 14.30 | 132 | 19.20 |
| 13 | 14.37 | 43 | 18.00 | 73 | 19.00 | 103 | 16.30 | 133 | 19.25 |
| 14 | 15.37 | 44 | 18.00 | 74 | 19.10 | 104 | 17.40 | 134 | 19.00 |
| 15 | 14.63 | 45 | 19.02 | 75 | 23.20 | 105 | 19.40 | 135 | 18.10 |
| 16 | 16.26 | 46 | 19.47 | 76 | 23.10 | 106 | 19.40 | 136 | 19.20 |
| 17 | 9.53 | 47 | 9.15 | 77 | 23.10 | 107 | 19.05 | 137 | 17.50 |
| 18 | 15.40 | 48 | 15.53 | 78 | 21.10 | 108 | 19.07 | 138 | 17.30 |
| 19 | 13.28 | 49 | 17.78 | 79 | 20.20 | 109 | 13.41 | 139 | 12.30 |
| 20 | 12.72 | 50 | 10.25 | 80 | 15.10 | 110 | 21.40 | 140 | 14.40 |
| 21 | 13.23 | 51 | 16.42 | 81 | 15.00 | 111 | 21.40 | 141 | 16.50 |
| 22 | 10.89 | 52 | 12.34 | 82 | 15.30 | 112 | 22.42 | 142 | 19.50 |
| 23 | 11.54 | 53 | 16.00 | 83 | 15.40 | 113 | 15.10 | 143 | 17.50 |
| 24 | 15.86 | 54 | 21.10 | 84 | 15.40 | 114 | 12.10 | 144 | 19.25 |
| 25 | 15.48 | 55 | 14.02 | 85 | 15.30 | 115 | 14.05 | 145 | 19.40 |
| 26 | 10.39 | 56 | 14.03 | 86 | 15.20 | 116 | 14.06 | 146 | 20.50 |
| 27 | 15.20 | 57 | 19.10 | 87 | 15.16 | 117 | 14.35 | 147 | 9.20 |
| 28 | 15.80 | 58 | 19.10 | 88 | 15.16 | 118 | 20.35 | 148 | 11.22 |
| 29 | 15.20 | 59 | 21.10 | 89 | 16.14 | 119 | 18.15 | 149 | 13.18 |
| 30 | 11.70 | 60 | 23.50 | 90 | 15.20 | 120 | 16.05 | 150 | 13.14 |
| | | | | | | | | Range | 9.15-24.06 |
| | | | | | | | | Mean | 16.34 |

Appendix III : Silt (%) in the soils of Ujjain Tehsil

| S. No. | Silt (%) | S. No. | Silt (%) | S. No. | Silt (%) | S. No. | Silt (%) | S. No. | Silt (%) |
|--------|----------|--------|----------|--------|----------|--------|----------|--------------|-----------------|
| 1 | 30.40 | 31 | 35.20 | 61 | 32.00 | 91 | 35.66 | 121 | 40.40 |
| 2 | 36.30 | 32 | 32.80 | 62 | 30.65 | 92 | 34.66 | 122 | 38.39 |
| 3 | 24.00 | 33 | 34.20 | 63 | 29.64 | 93 | 34.67 | 123 | 38.35 |
| 4 | 34.00 | 34 | 34.80 | 64 | 29.50 | 94 | 35.67 | 124 | 40.35 |
| 5 | 28.00 | 35 | 35.04 | 65 | 29.49 | 95 | 36.66 | 125 | 39.40 |
| 6 | 34.00 | 36 | 35.70 | 66 | 29.52 | 96 | 36.60 | 126 | 38.40 |
| 7 | 32.40 | 37 | 30.40 | 67 | 30.40 | 97 | 35.50 | 127 | 35.30 |
| 8 | 32.20 | 38 | 32.70 | 68 | 31.30 | 98 | 35.60 | 128 | 30.30 |
| 9 | 35.20 | 39 | 25.60 | 69 | 31.25 | 99 | 35.50 | 129 | 32.35 |
| 10 | 32.18 | 40 | 31.20 | 70 | 30.40 | 100 | 35.60 | 130 | 34.40 |
| 11 | 35.14 | 41 | 35.23 | 71 | 31.30 | 101 | 40.50 | 131 | 40.50 |
| 12 | 34.12 | 42 | 29.10 | 72 | 32.20 | 102 | 40.50 | 132 | 40.40 |
| 13 | 35.40 | 43 | 33.40 | 73 | 35.50 | 103 | 37.50 | 133 | 35.35 |
| 14 | 32.40 | 44 | 35.60 | 74 | 34.40 | 104 | 36.60 | 134 | 29.40 |
| 15 | 35.17 | 45 | 35.66 | 75 | 32.40 | 105 | 35.35 | 135 | 30.40 |
| 16 | 34.58 | 46 | 30.34 | 76 | 31.41 | 106 | 36.25 | 136 | 35.30 |
| 17 | 38.32 | 47 | 35.65 | 77 | 30.40 | 107 | 30.10 | 137 | 36.30 |
| 18 | 34.20 | 48 | 34.17 | 78 | 31.30 | 108 | 29.09 | 138 | 37.40 |
| 19 | 36.12 | 49 | 33.59 | 79 | 29.30 | 109 | 32.09 | 139 | 32.40 |
| 20 | 35.18 | 50 | 35.25 | 80 | 34.30 | 110 | 28.10 | 140 | 31.30 |
| 21 | 36.37 | 51 | 33.36 | 81 | 34.40 | 111 | 28.20 | 141 | 30.20 |
| 22 | 35.61 | 52 | 35.26 | 82 | 34.30 | 112 | 28.19 | 142 | 30.25 |
| 23 | 36.16 | 53 | 33.75 | 83 | 35.20 | 113 | 39.40 | 143 | 31.25 |
| 24 | 33.67 | 54 | 29.60 | 84 | 35.30 | 114 | 38.20 | 144 | 30.25 |
| 25 | 34.20 | 55 | 35.73 | 85 | 36.40 | 115 | 37.85 | 145 | 32.20 |
| 26 | 34.81 | 56 | 34.65 | 86 | 36.60 | 116 | 37.74 | 146 | 32.10 |
| 27 | 34.12 | 57 | 35.40 | 87 | 36.66 | 117 | 35.45 | 147 | 35.60 |
| 28 | 32.82 | 58 | 35.50 | 88 | 35.66 | 118 | 39.45 | 148 | 34.59 |
| 29 | 30.70 | 59 | 29.70 | 89 | 34.66 | 119 | 40.55 | 149 | 33.61 |
| 30 | 34.72 | 60 | 28.00 | 90 | 35.40 | 120 | 41.55 | 150 | 34.63 |
| | | | | | | | | Range | 24-41.55 |
| | | | | | | | | Mean | 33.98 |

Appendix IV : Clay (%) in the soils of Ujjain Tehsil

| S. No. | Clay (%) | S. No. | Clay (%) | S. No. | Clay (%) | S. No. | Clay (%) | S. No. | Clay (%) |
|--------|----------|--------|----------|--------|----------|--------|----------|--------------|--------------------|
| 1 | 49.40 | 31 | 41.23 | 61 | 50.65 | 91 | 48.20 | 121 | 45.40 |
| 2 | 45.30 | 32 | 46.55 | 62 | 45.30 | 92 | 45.20 | 122 | 48.39 |
| 3 | 32.80 | 33 | 53.63 | 63 | 46.30 | 93 | 45.25 | 123 | 48.35 |
| 4 | 51.60 | 34 | 38.50 | 64 | 47.40 | 94 | 46.25 | 124 | 50.35 |
| 5 | 35.04 | 35 | 34.58 | 65 | 47.41 | 95 | 47.25 | 125 | 51.32 |
| 6 | 50.00 | 36 | 38.90 | 66 | 48.40 | 96 | 47.20 | 126 | 52.30 |
| 7 | 51.60 | 37 | 50.60 | 67 | 50.60 | 97 | 48.20 | 127 | 55.30 |
| 8 | 40.23 | 38 | 52.20 | 68 | 49.60 | 98 | 50.20 | 128 | 50.30 |
| 9 | 40.44 | 39 | 55.40 | 69 | 49.65 | 99 | 50.10 | 129 | 48.30 |
| 10 | 52.00 | 40 | 49.80 | 70 | 55.60 | 100 | 50.30 | 130 | 46.46 |
| 11 | 53.30 | 41 | 52.75 | 71 | 54.50 | 101 | 45.30 | 131 | 40.45 |
| 12 | 54.60 | 42 | 51.88 | 72 | 53.40 | 102 | 45.20 | 132 | 40.40 |
| 13 | 38.00 | 43 | 48.60 | 73 | 45.50 | 103 | 46.20 | 133 | 45.40 |
| 14 | 52.23 | 44 | 46.40 | 74 | 46.50 | 104 | 46.10 | 134 | 51.60 |
| 15 | 32.05 | 45 | 45.32 | 75 | 44.40 | 105 | 45.25 | 135 | 51.50 |
| 16 | 49.17 | 46 | 50.19 | 76 | 45.49 | 106 | 44.35 | 136 | 55.50 |
| 17 | 52.15 | 47 | 55.20 | 77 | 46.50 | 107 | 50.85 | 137 | 46.20 |
| 18 | 35.80 | 48 | 50.30 | 78 | 47.60 | 108 | 51.84 | 138 | 45.30 |
| 19 | 51.60 | 49 | 49.63 | 79 | 50.50 | 109 | 54.50 | 139 | 55.30 |
| 20 | 53.10 | 50 | 54.50 | 80 | 50.60 | 110 | 50.50 | 140 | 54.30 |
| 21 | 50.40 | 51 | 50.28 | 81 | 50.50 | 111 | 50.40 | 141 | 53.30 |
| 22 | 52.50 | 52 | 51.40 | 82 | 50.40 | 112 | 49.39 | 142 | 50.25 |
| 23 | 49.30 | 53 | 50.25 | 83 | 49.40 | 113 | 45.50 | 143 | 51.25 |
| 24 | 50.47 | 54 | 49.30 | 84 | 49.30 | 114 | 49.60 | 144 | 50.50 |
| 25 | 53.32 | 55 | 50.25 | 85 | 48.30 | 115 | 48.10 | 145 | 48.40 |
| 26 | 54.80 | 56 | 51.32 | 86 | 48.20 | 116 | 48.20 | 146 | 47.40 |
| 27 | 40.00 | 57 | 45.50 | 87 | 48.18 | 117 | 50.20 | 147 | 55.20 |
| 28 | 51.38 | 58 | 45.40 | 88 | 49.18 | 118 | 40.20 | 148 | 54.19 |
| 29 | 54.10 | 59 | 49.20 | 89 | 49.20 | 119 | 41.30 | 149 | 53.21 |
| 30 | 53.60 | 60 | 48.50 | 90 | 49.40 | 120 | 42.40 | 150 | 52.23 |
| | | | | | | | | Range | 32.05-55.60 |
| | | | | | | | | Mean | 48.46 |

Appendix V : pH in the soils of Ujjain Tehsil

| S. No. | pH (1:2) | S. No. | pH (1:2) | S. No. | pH (1:2) | S. No. | pH (1:2) | S. No. | pH (1:2) |
|--------|----------|--------|----------|--------|----------|--------|----------|--------------|------------------|
| 1 | 7.50 | 31 | 7.77 | 61 | 7.80 | 91 | 7.61 | 121 | 7.36 |
| 2 | 7.53 | 32 | 7.68 | 62 | 7.85 | 92 | 7.62 | 122 | 7.62 |
| 3 | 7.48 | 33 | 7.50 | 63 | 7.80 | 93 | 7.63 | 123 | 7.64 |
| 4 | 7.45 | 34 | 7.74 | 64 | 7.84 | 94 | 7.67 | 124 | 7.48 |
| 5 | 7.58 | 35 | 7.83 | 65 | 7.74 | 95 | 7.70 | 125 | 7.77 |
| 6 | 7.45 | 36 | 7.67 | 66 | 7.65 | 96 | 7.71 | 126 | 7.73 |
| 7 | 7.60 | 37 | 7.68 | 67 | 7.70 | 97 | 7.69 | 127 | 7.9 |
| 8 | 7.70 | 38 | 7.72 | 68 | 7.80 | 98 | 7.72 | 128 | 7.81 |
| 9 | 7.90 | 39 | 7.71 | 69 | 7.60 | 99 | 7.76 | 129 | 7.84 |
| 10 | 7.93 | 40 | 7.20 | 70 | 7.50 | 100 | 7.78 | 130 | 7.86 |
| 11 | 7.85 | 41 | 7.10 | 71 | 7.30 | 101 | 7.10 | 131 | 7.85 |
| 12 | 7.71 | 42 | 7.30 | 72 | 7.50 | 102 | 7.11 | 132 | 7.75 |
| 13 | 7.61 | 43 | 7.40 | 73 | 7.74 | 103 | 7.33 | 133 | 7.93 |
| 14 | 7.64 | 44 | 7.50 | 74 | 7.71 | 104 | 7.45 | 134 | 7.9 |
| 15 | 7.37 | 45 | 7.42 | 75 | 7.60 | 105 | 7.70 | 135 | 7.67 |
| 16 | 7.62 | 46 | 7.45 | 76 | 7.65 | 106 | 7.71 | 136 | 7.72 |
| 17 | 7.75 | 47 | 7.25 | 77 | 7.69 | 107 | 7.84 | 137 | 7.3 |
| 18 | 7.85 | 48 | 7.10 | 78 | 7.72 | 108 | 7.52 | 138 | 7.71 |
| 19 | 7.70 | 49 | 7.12 | 79 | 7.74 | 109 | 7.20 | 139 | 7.6 |
| 20 | 7.85 | 50 | 7.21 | 80 | 7.76 | 110 | 7.06 | 140 | 7.58 |
| 21 | 7.80 | 51 | 7.70 | 81 | 7.78 | 111 | 7.11 | 141 | 7.56 |
| 22 | 7.65 | 52 | 7.80 | 82 | 7.72 | 112 | 7.59 | 142 | 7.4 |
| 23 | 7.50 | 53 | 7.90 | 83 | 7.68 | 113 | 7.50 | 143 | 7.11 |
| 24 | 7.74 | 54 | 7.71 | 84 | 7.65 | 114 | 7.55 | 144 | 7.71 |
| 25 | 7.65 | 55 | 7.85 | 85 | 7.61 | 115 | 7.70 | 145 | 7.86 |
| 26 | 7.84 | 56 | 8.00 | 86 | 7.65 | 116 | 7.80 | 146 | 7.1 |
| 27 | 7.73 | 57 | 7.93 | 87 | 7.63 | 117 | 7.68 | 147 | 7.01 |
| 28 | 8.15 | 58 | 7.70 | 88 | 7.70 | 118 | 7.36 | 148 | 7.13 |
| 29 | 7.59 | 59 | 7.80 | 89 | 7.71 | 119 | 7.40 | 149 | 7.16 |
| 30 | 7.70 | 60 | 7.90 | 90 | 7.60 | 120 | 7.85 | 150 | 7.21 |
| | | | | | | | | Range | 7.01-8.15 |
| | | | | | | | | Mean | 7.61 |

Appendix VI : EC in the soils of Ujjain Tehsil

| S. No. | EC (dSm ⁻¹) | S. No. | EC (dSm ⁻¹) | S. No. | EC (dSm ⁻¹) | S. No. | EC (dSm ⁻¹) | S. No. | EC (dSm ⁻¹) |
|--------|-------------------------|--------|-------------------------|--------|-------------------------|--------|-------------------------|--------------|-------------------------|
| 1 | 0.24 | 31 | 0.21 | 61 | 0.14 | 91 | 0.22 | 121 | 0.32 |
| 2 | 0.21 | 32 | 0.23 | 62 | 0.13 | 92 | 0.35 | 122 | 0.37 |
| 3 | 0.24 | 33 | 0.37 | 63 | 0.22 | 93 | 0.26 | 123 | 0.34 |
| 4 | 0.25 | 34 | 0.19 | 64 | 0.17 | 94 | 0.24 | 124 | 0.20 |
| 5 | 0.32 | 35 | 0.16 | 65 | 0.17 | 95 | 0.19 | 125 | 0.15 |
| 6 | 0.25 | 36 | 0.17 | 66 | 0.27 | 96 | 0.30 | 126 | 0.14 |
| 7 | 0.34 | 37 | 0.26 | 67 | 0.31 | 97 | 0.19 | 127 | 0.12 |
| 8 | 0.14 | 38 | 0.30 | 68 | 0.17 | 98 | 0.15 | 128 | 0.22 |
| 9 | 0.17 | 39 | 0.34 | 69 | 0.18 | 99 | 0.48 | 129 | 0.55 |
| 10 | 0.26 | 40 | 0.23 | 70 | 0.15 | 100 | 0.15 | 130 | 0.22 |
| 11 | 0.28 | 41 | 0.33 | 71 | 0.37 | 101 | 0.39 | 131 | 0.25 |
| 12 | 0.23 | 42 | 0.27 | 72 | 0.47 | 102 | 0.28 | 132 | 0.16 |
| 13 | 0.21 | 43 | 0.22 | 73 | 0.16 | 103 | 0.18 | 133 | 0.15 |
| 14 | 0.16 | 44 | 0.24 | 74 | 0.25 | 104 | 0.26 | 134 | 0.28 |
| 15 | 0.20 | 45 | 0.20 | 75 | 0.22 | 105 | 0.35 | 135 | 0.78 |
| 16 | 0.34 | 46 | 0.24 | 76 | 0.59 | 106 | 0.24 | 136 | 0.77 |
| 17 | 0.23 | 47 | 0.17 | 77 | 0.33 | 107 | 0.18 | 137 | 0.75 |
| 18 | 0.26 | 48 | 0.26 | 78 | 0.31 | 108 | 0.41 | 138 | 0.62 |
| 19 | 0.77 | 49 | 0.32 | 79 | 0.67 | 109 | 0.27 | 139 | 0.34 |
| 20 | 0.30 | 50 | 0.27 | 80 | 0.33 | 110 | 0.22 | 140 | 0.23 |
| 21 | 0.27 | 51 | 0.17 | 81 | 0.21 | 111 | 0.28 | 141 | 0.20 |
| 22 | 0.36 | 52 | 0.17 | 82 | 0.19 | 112 | 0.31 | 142 | 0.21 |
| 23 | 0.35 | 53 | 0.44 | 83 | 0.49 | 113 | 0.36 | 143 | 0.43 |
| 24 | 0.26 | 54 | 0.41 | 84 | 0.32 | 114 | 0.33 | 144 | 0.22 |
| 25 | 0.35 | 55 | 0.23 | 85 | 0.20 | 115 | 0.24 | 145 | 0.37 |
| 26 | 0.79 | 56 | 0.24 | 86 | 0.27 | 116 | 0.37 | 146 | 0.24 |
| 27 | 0.36 | 57 | 0.24 | 87 | 0.34 | 117 | 0.19 | 147 | 0.19 |
| 28 | 0.77 | 58 | 0.29 | 88 | 0.17 | 118 | 0.15 | 148 | 0.16 |
| 29 | 0.76 | 59 | 0.14 | 89 | 0.14 | 119 | 0.16 | 149 | 0.18 |
| 30 | 0.45 | 60 | 0.10 | 90 | 0.15 | 120 | 0.34 | 150 | 0.17 |
| | | | | | | | | Range | 7.01-8.15 |
| | | | | | | | | Mean | 7.61 |

Appendix VII : OC(%) in the soils of Ujjain Tehsil

| S. No. | OC (%) | S. No. | OC (%) | S. No. | OC (%) | S. No. | OC (%) | S. No. | OC (%) |
|--------|--------|--------|--------|--------|--------|--------|--------|--------------|-----------|
| 1 | 0.50 | 31 | 0.50 | 61 | 0.35 | 91 | 0.55 | 121 | 0.45 |
| 2 | 0.45 | 32 | 0.59 | 62 | 0.30 | 92 | 0.48 | 122 | 0.42 |
| 3 | 0.50 | 33 | 0.45 | 63 | 0.40 | 93 | 0.53 | 123 | 0.43 |
| 4 | 0.47 | 34 | 0.45 | 64 | 0.55 | 94 | 0.45 | 124 | 0.46 |
| 5 | 0.41 | 35 | 0.59 | 65 | 0.47 | 95 | 0.48 | 125 | 0.50 |
| 6 | 0.57 | 36 | 0.49 | 66 | 0.42 | 96 | 0.36 | 126 | 0.60 |
| 7 | 0.52 | 37 | 0.49 | 67 | 0.40 | 97 | 0.43 | 127 | 0.40 |
| 8 | 0.50 | 38 | 0.31 | 68 | 0.52 | 98 | 0.58 | 128 | 0.60 |
| 9 | 0.45 | 39 | 0.36 | 69 | 0.40 | 99 | 0.58 | 129 | 0.37 |
| 10 | 0.41 | 40 | 0.38 | 70 | 0.30 | 100 | 0.60 | 130 | 0.45 |
| 11 | 0.42 | 41 | 0.51 | 71 | 0.56 | 101 | 0.57 | 131 | 0.42 |
| 12 | 0.41 | 42 | 0.56 | 72 | 0.50 | 102 | 0.49 | 132 | 0.47 |
| 13 | 0.45 | 43 | 0.60 | 73 | 0.57 | 103 | 0.48 | 133 | 0.50 |
| 14 | 0.38 | 44 | 0.53 | 74 | 0.45 | 104 | 0.42 | 134 | 0.40 |
| 15 | 0.41 | 45 | 0.49 | 75 | 0.50 | 105 | 0.41 | 135 | 0.50 |
| 16 | 0.50 | 46 | 0.45 | 76 | 0.42 | 106 | 0.46 | 136 | 0.60 |
| 17 | 0.53 | 47 | 0.48 | 77 | 0.50 | 107 | 0.51 | 137 | 0.52 |
| 18 | 0.49 | 48 | 0.54 | 78 | 0.49 | 108 | 0.52 | 138 | 0.56 |
| 19 | 0.48 | 49 | 0.39 | 79 | 0.48 | 109 | 0.50 | 139 | 0.57 |
| 20 | 0.47 | 50 | 0.46 | 80 | 0.50 | 110 | 0.50 | 140 | 0.45 |
| 21 | 0.47 | 51 | 0.43 | 81 | 0.53 | 111 | 0.49 | 141 | 0.47 |
| 22 | 0.40 | 52 | 0.48 | 82 | 0.43 | 112 | 0.48 | 142 | 0.60 |
| 23 | 0.46 | 53 | 0.51 | 83 | 0.44 | 113 | 0.47 | 143 | 0.47 |
| 24 | 0.50 | 54 | 0.56 | 84 | 0.60 | 114 | 0.44 | 144 | 0.52 |
| 25 | 0.55 | 55 | 0.55 | 85 | 0.53 | 115 | 0.58 | 145 | 0.60 |
| 26 | 0.46 | 56 | 0.43 | 86 | 0.50 | 116 | 0.56 | 146 | 0.60 |
| 27 | 0.57 | 57 | 0.41 | 87 | 0.48 | 117 | 0.39 | 147 | 0.57 |
| 28 | 0.45 | 58 | 0.40 | 88 | 0.49 | 118 | 0.38 | 148 | 0.55 |
| 29 | 0.55 | 59 | 0.40 | 89 | 0.48 | 119 | 0.49 | 149 | 0.50 |
| 30 | 0.43 | 60 | 0.46 | 90 | 0.60 | 120 | 0.50 | 150 | 0.55 |
| | | | | | | | | Range | 0.30-0.60 |
| | | | | | | | | Mean | 0.48 |

Appendix VIII : Available N in the soils of Ujjain Tehsil

| S.No. | Avail. N (Kg ha ⁻¹) | S.No. | Avail. N (Kg ha ⁻¹) | S.No. | Avail. N (Kg ha ⁻¹) | S.No. | Avail. N (Kg ha ⁻¹) | S. No. | Avail. K (Kg ha ⁻¹) |
|-------|------------------------------------|-------|------------------------------------|-------|------------------------------------|-------|------------------------------------|--------------|------------------------------------|
| 1 | 200.00 | 31 | 200.00 | 61 | 162.00 | 91 | 218.00 | 121 | 190.00 |
| 2 | 190.00 | 32 | 231.60 | 62 | 143.00 | 92 | 196.00 | 122 | 184.00 |
| 3 | 200.00 | 33 | 190.00 | 63 | 180.00 | 93 | 209.18 | 123 | 186.00 |
| 4 | 194.00 | 34 | 190.00 | 64 | 218.00 | 94 | 190.00 | 124 | 192.00 |
| 5 | 182.00 | 35 | 231.60 | 65 | 194.00 | 95 | 196.00 | 125 | 200.00 |
| 6 | 224.80 | 36 | 198.00 | 66 | 184.00 | 96 | 165.60 | 126 | 235.00 |
| 7 | 207.20 | 37 | 198.00 | 67 | 180.00 | 97 | 186.00 | 127 | 180.00 |
| 8 | 200.00 | 38 | 146.80 | 68 | 207.20 | 98 | 228.20 | 128 | 235.00 |
| 9 | 190.00 | 39 | 165.60 | 69 | 180.00 | 99 | 228.20 | 129 | 169.20 |
| 10 | 182.00 | 40 | 172.80 | 70 | 143.00 | 100 | 235.00 | 130 | 190.00 |
| 11 | 184.00 | 41 | 203.60 | 71 | 221.40 | 101 | 224.80 | 131 | 184.00 |
| 12 | 182.00 | 42 | 221.40 | 72 | 200.00 | 102 | 198.00 | 132 | 194.00 |
| 13 | 190.00 | 43 | 235.00 | 73 | 224.80 | 103 | 196.00 | 133 | 200.00 |
| 14 | 172.80 | 44 | 210.80 | 74 | 190.00 | 104 | 184.00 | 134 | 180.00 |
| 15 | 182.00 | 45 | 198.00 | 75 | 200.00 | 105 | 182.00 | 135 | 200.00 |
| 16 | 200.00 | 46 | 190.00 | 76 | 184.00 | 106 | 192.00 | 136 | 235.00 |
| 17 | 210.80 | 47 | 196.00 | 77 | 200.00 | 107 | 203.60 | 137 | 207.20 |
| 18 | 198.00 | 48 | 214.40 | 78 | 198.00 | 108 | 207.20 | 138 | 221.40 |
| 19 | 196.00 | 49 | 176.40 | 79 | 196.00 | 109 | 200.00 | 139 | 224.80 |
| 20 | 194.00 | 50 | 192.00 | 80 | 200.00 | 110 | 200.00 | 140 | 190.00 |
| 21 | 194.00 | 51 | 186.00 | 81 | 210.80 | 111 | 198.00 | 141 | 194.00 |
| 22 | 180.00 | 52 | 196.00 | 82 | 186.00 | 112 | 196.00 | 142 | 235.00 |
| 23 | 192.00 | 53 | 203.60 | 83 | 188.00 | 113 | 194.00 | 143 | 194.00 |
| 24 | 200.00 | 54 | 221.40 | 84 | 235.00 | 114 | 188.00 | 144 | 207.20 |
| 25 | 218.00 | 55 | 218.00 | 85 | 210.80 | 115 | 228.20 | 145 | 235.00 |
| 26 | 192.00 | 56 | 186.00 | 86 | 200.00 | 116 | 221.40 | 146 | 235.00 |
| 27 | 224.80 | 57 | 182.00 | 87 | 196.00 | 117 | 176.40 | 147 | 224.80 |
| 28 | 190.00 | 58 | 180.00 | 88 | 198.00 | 118 | 172.80 | 148 | 218.00 |
| 29 | 218.00 | 59 | 180.00 | 89 | 196.00 | 119 | 198.00 | 149 | 200.00 |
| 30 | 186.00 | 60 | 139.00 | 90 | 235.00 | 120 | 200.00 | 150 | 218.00 |
| | | | | | | | | Range | 139-235 |
| | | | | | | | | Mean | 198.25 |

Appendix IX : Available P in the soils of Ujjain Tehsil

| S. No. | Avail P (Kg ha ⁻¹) | S. No. | Avail P (Kg ha ⁻¹) | S. No. | Avail P (Kg ha ⁻¹) | S. No. | Avail P (Kg ha ⁻¹) | S. No. | Avail P (Kg ha ⁻¹) |
|--------|--------------------------------|--------|--------------------------------|--------|--------------------------------|--------|--------------------------------|--------------|--------------------------------|
| 1 | 11.20 | 31 | 15.60 | 61 | 19.20 | 91 | 9.60 | 121 | 11.20 |
| 2 | 8.00 | 32 | 16.80 | 62 | 11.20 | 92 | 11.20 | 122 | 9.60 |
| 3 | 15.60 | 33 | 16.00 | 63 | 15.60 | 93 | 11.20 | 123 | 15.60 |
| 4 | 16.00 | 34 | 15.60 | 64 | 19.20 | 94 | 11.20 | 124 | 16.00 |
| 5 | 16.80 | 35 | 16.00 | 65 | 11.20 | 95 | 16.00 | 125 | 11.20 |
| 6 | 15.60 | 36 | 9.60 | 66 | 9.60 | 96 | 16.80 | 126 | 15.60 |
| 7 | 11.20 | 37 | 11.20 | 67 | 15.60 | 97 | 19.20 | 127 | 16.00 |
| 8 | 9.60 | 38 | 16.00 | 68 | 9.60 | 98 | 11.20 | 128 | 16.80 |
| 9 | 8.00 | 39 | 16.00 | 69 | 11.20 | 99 | 9.60 | 129 | 16.00 |
| 10 | 15.60 | 40 | 16.80 | 70 | 16.00 | 100 | 15.60 | 130 | 16.80 |
| 11 | 19.20 | 41 | 19.20 | 71 | 16.80 | 101 | 15.60 | 131 | 15.60 |
| 12 | 21.60 | 42 | 11.20 | 72 | 19.20 | 102 | 16.00 | 132 | 16.00 |
| 13 | 23.20 | 43 | 11.20 | 73 | 21.60 | 103 | 16.80 | 133 | 19.20 |
| 14 | 25.60 | 44 | 15.60 | 74 | 23.20 | 104 | 19.20 | 134 | 21.60 |
| 15 | 21.60 | 45 | 15.60 | 75 | 16.80 | 105 | 21.60 | 135 | 23.20 |
| 16 | 19.20 | 46 | 11.20 | 76 | 16.20 | 106 | 16.00 | 136 | 16.80 |
| 17 | 16.80 | 47 | 9.60 | 77 | 11.20 | 107 | 15.60 | 137 | 16.00 |
| 18 | 15.60 | 48 | 16.00 | 78 | 15.60 | 108 | 11.20 | 138 | 15.60 |
| 19 | 11.60 | 49 | 16.00 | 79 | 9.60 | 109 | 15.60 | 139 | 11.20 |
| 20 | 9.60 | 50 | 11.20 | 80 | 16.00 | 110 | 15.60 | 140 | 16.00 |
| 21 | 8.00 | 51 | 21.60 | 81 | 15.60 | 111 | 15.60 | 141 | 16.80 |
| 22 | 8.00 | 52 | 23.20 | 82 | 8.00 | 112 | 11.20 | 142 | 16.00 |
| 23 | 11.20 | 53 | 25.60 | 83 | 8.00 | 113 | 16.00 | 143 | 15.60 |
| 24 | 9.60 | 54 | 21.60 | 84 | 19.20 | 114 | 16.80 | 144 | 15.60 |
| 25 | 15.60 | 55 | 15.60 | 85 | 16.00 | 115 | 16.80 | 145 | 15.60 |
| 26 | 9.60 | 56 | 19.20 | 86 | 16.00 | 116 | 19.20 | 146 | 11.20 |
| 27 | 15.60 | 57 | 16.00 | 87 | 15.60 | 117 | 21.60 | 147 | 16.00 |
| 28 | 11.20 | 58 | 21.60 | 88 | 11.20 | 118 | 11.20 | 148 | 15.60 |
| 29 | 9.60 | 59 | 15.60 | 89 | 19.20 | 119 | 9.60 | 149 | 16.80 |
| 30 | 11.20 | 60 | 16.00 | 90 | 11.20 | 120 | 9.60 | 150 | 16.00 |
| | | | | | | | | Range | 8.0-25.60 |
| | | | | | | | | Mean | 15.10 |

Appendix X : Status of different forms of potassium (mg kg⁻¹) in soils of Ujjain Tehsil

| S. No. | W.S.K (mg kg ⁻¹) | Ex. K (mg kg ⁻¹) | Avail. K (mg kg ⁻¹) | Non-ex. K (mg kg ⁻¹) | Lattice K (mg kg ⁻¹) | Total K (mg kg ⁻¹) |
|--------|------------------------------|------------------------------|---------------------------------|----------------------------------|----------------------------------|--------------------------------|
| 1 | 10.13 | 196.12 | 206.25 | 350.00 | 7943.75 | 8500.00 |
| 2 | 8.32 | 158.48 | 166.80 | 325.00 | 7888.50 | 8380.30 |
| 3 | 5.25 | 145.77 | 151.02 | 220.00 | 9625.98 | 9997.00 |
| 4 | 10.25 | 168.79 | 179.04 | 345.00 | 9601.21 | 10125.25 |
| 5 | 8.25 | 130.45 | 138.70 | 350.00 | 8957.61 | 9446.31 |
| 6 | 10.25 | 130.79 | 141.04 | 389.00 | 8927.71 | 9457.75 |
| 7 | 15.46 | 136.15 | 151.61 | 400.00 | 9225.18 | 9776.79 |
| 8 | 9.25 | 144.73 | 153.98 | 365.00 | 9335.27 | 9854.25 |
| 9 | 6.25 | 141.82 | 148.08 | 345.00 | 7895.00 | 8388.08 |
| 10 | 10.35 | 154.77 | 165.12 | 378.00 | 9121.96 | 9665.08 |
| 11 | 11.10 | 163.50 | 174.60 | 325.00 | 9231.25 | 9730.85 |
| 12 | 10.00 | 160.13 | 170.13 | 370.00 | 9339.27 | 9879.40 |
| 13 | 8.32 | 152.54 | 160.86 | 342.00 | 8869.00 | 9371.86 |
| 14 | 10.08 | 129.65 | 139.73 | 365.00 | 9127.27 | 9632.00 |
| 15 | 6.30 | 147.72 | 154.02 | 385.00 | 9282.98 | 9822.00 |
| 16 | 7.45 | 156.84 | 164.29 | 348.00 | 9361.71 | 9874.00 |
| 17 | 8.20 | 177.07 | 185.27 | 260.00 | 9979.73 | 10425.00 |
| 18 | 4.35 | 185.38 | 189.73 | 385.00 | 9670.27 | 10245.00 |
| 19 | 8.50 | 174.54 | 183.04 | 362.00 | 9943.96 | 10489.00 |
| 20 | 9.00 | 174.93 | 183.93 | 384.00 | 9910.07 | 10478.00 |
| 21 | 12.00 | 189.79 | 201.79 | 337.00 | 10148.21 | 10687.00 |
| 22 | 15.00 | 174.73 | 189.73 | 364.00 | 11931.27 | 12485.00 |
| 23 | 16.11 | 190.59 | 206.70 | 345.00 | 11923.30 | 12475.00 |
| 24 | 15.00 | 167.59 | 182.59 | 358.00 | 9588.90 | 10129.49 |
| 25 | 12.00 | 170.14 | 182.14 | 372.00 | 13034.86 | 13589.00 |
| 26 | 14.00 | 165.46 | 179.46 | 389.00 | 12902.54 | 13471.00 |
| 27 | 5.08 | 173.49 | 178.57 | 373.00 | 12906.43 | 13458.00 |
| 28 | 7.50 | 170.18 | 177.68 | 375.00 | 12995.32 | 13548.00 |
| 29 | 6.50 | 165.82 | 172.32 | 352.00 | 10733.68 | 11258.00 |
| 30 | 7.00 | 161.75 | 168.75 | 360.00 | 10728.25 | 11257.00 |
| 31 | 8.50 | 150.43 | 158.93 | 367.00 | 10899.07 | 11425.00 |
| 32 | 5.00 | 150.36 | 155.36 | 373.00 | 11164.64 | 11693.00 |
| 33 | 10.00 | 154.73 | 164.73 | 342.00 | 10978.27 | 11485.00 |
| 34 | 12.00 | 142.02 | 154.02 | 290.00 | 10802.98 | 11247.00 |
| 35 | 10.50 | 128.79 | 139.29 | 382.00 | 8596.00 | 9117.29 |
| 36 | 12.16 | 130.70 | 142.86 | 250.00 | 9877.50 | 10270.36 |

| | | | | | | |
|----|-------|--------|--------|--------|----------|----------|
| 37 | 11.40 | 142.62 | 154.02 | 324.00 | 11996.98 | 12475.00 |
| 38 | 10.00 | 146.25 | 156.25 | 280.00 | 12202.75 | 12639.00 |
| 39 | 10.38 | 152.57 | 162.95 | 365.00 | 11830.05 | 12358.00 |
| 40 | 9.50 | 162.38 | 171.88 | 245.00 | 12058.13 | 12475.00 |
| 41 | 10.07 | 179.66 | 189.73 | 333.50 | 13865.27 | 14388.50 |
| 42 | 15.00 | 168.04 | 183.04 | 326.00 | 14563.96 | 15073.00 |
| 43 | 17.00 | 164.25 | 181.25 | 319.00 | 14352.75 | 14853.00 |
| 44 | 20.00 | 165.27 | 185.27 | 223.00 | 14443.73 | 14852.00 |
| 45 | 22.37 | 155.31 | 177.68 | 278.00 | 14507.32 | 14963.00 |
| 46 | 18.00 | 156.11 | 174.11 | 300.00 | 14882.89 | 15357.00 |
| 47 | 15.50 | 161.29 | 176.79 | 320.00 | 14872.21 | 15369.00 |
| 48 | 7.34 | 157.39 | 164.73 | 295.00 | 14888.27 | 15348.00 |
| 49 | 6.20 | 153.62 | 159.82 | 310.00 | 14897.18 | 15367.00 |
| 50 | 8.30 | 145.72 | 154.02 | 325.00 | 16062.98 | 16542.00 |
| 51 | 7.34 | 137.75 | 145.09 | 350.00 | 16400.91 | 16896.00 |
| 52 | 6.34 | 157.95 | 164.29 | 320.00 | 17515.71 | 18000.00 |
| 53 | 5.50 | 163.25 | 168.75 | 325.00 | 16405.25 | 16899.00 |
| 54 | 10.00 | 142.68 | 152.68 | 203.00 | 14879.32 | 15235.00 |
| 55 | 10.00 | 124.50 | 134.50 | 243.00 | 14984.38 | 15361.87 |
| 56 | 10.13 | 119.82 | 129.95 | 282.00 | 15006.18 | 15418.13 |
| 57 | 10.13 | 128.86 | 138.99 | 337.00 | 13778.14 | 14254.13 |
| 58 | 12.50 | 144.64 | 157.14 | 372.00 | 13993.86 | 14523.00 |
| 59 | 3.10 | 159.85 | 162.95 | 350.00 | 15744.05 | 16257.00 |
| 60 | 7.80 | 152.02 | 159.82 | 332.00 | 16046.18 | 16538.00 |
| 61 | 5.25 | 152.44 | 157.69 | 337.00 | 14846.96 | 15341.65 |
| 62 | 5.12 | 152.82 | 157.94 | 233.00 | 13865.18 | 14256.12 |
| 63 | 8.50 | 156.23 | 164.73 | 305.00 | 15784.27 | 16254.00 |
| 64 | 3.21 | 156.17 | 159.38 | 313.00 | 11885.63 | 12358.00 |
| 65 | 5.20 | 139.89 | 145.09 | 330.00 | 11999.91 | 12475.00 |
| 66 | 8.12 | 135.18 | 143.30 | 356.00 | 11989.70 | 12489.00 |
| 67 | 8.50 | 150.43 | 158.93 | 365.00 | 14003.07 | 14527.00 |
| 68 | 9.20 | 150.62 | 159.82 | 290.00 | 11909.18 | 12359.00 |
| 69 | 7.40 | 128.31 | 135.71 | 310.00 | 13101.29 | 13547.00 |
| 70 | 10.00 | 126.61 | 136.61 | 325.00 | 14862.39 | 15324.00 |
| 71 | 8.00 | 128.61 | 136.61 | 243.00 | 13896.39 | 14276.00 |
| 72 | 6.38 | 129.33 | 135.71 | 411.00 | 14246.29 | 14793.00 |
| 73 | 12.00 | 127.29 | 139.29 | 231.00 | 14418.71 | 14789.00 |
| 74 | 10.00 | 130.63 | 140.63 | 270.00 | 14152.38 | 14563.00 |
| 75 | 13.00 | 128.07 | 141.07 | 285.00 | 13826.93 | 14253.00 |
| 76 | 15.00 | 140.36 | 155.36 | 320.00 | 13209.64 | 13685.00 |

| | | | | | | |
|-----|-------|--------|--------|--------|----------|----------|
| 77 | 12.00 | 156.75 | 168.75 | 342.00 | 12075.25 | 12586.00 |
| 78 | 12.50 | 152.23 | 164.73 | 289.00 | 11891.27 | 12345.00 |
| 79 | 14.00 | 145.82 | 159.82 | 285.00 | 12344.18 | 12789.00 |
| 80 | 14.73 | 139.29 | 154.02 | 290.00 | 12011.98 | 12456.00 |
| 81 | 15.00 | 149.29 | 164.29 | 340.00 | 11618.71 | 12123.00 |
| 82 | 17.00 | 153.54 | 170.54 | 345.00 | 11853.46 | 12369.00 |
| 83 | 20.00 | 139.82 | 159.82 | 400.00 | 12896.18 | 13456.00 |
| 84 | 4.60 | 140.49 | 145.09 | 410.00 | 13233.91 | 13789.00 |
| 85 | 5.50 | 154.32 | 159.82 | 396.00 | 12900.18 | 13456.00 |
| 86 | 12.00 | 146.04 | 158.04 | 320.00 | 13644.96 | 14123.00 |
| 87 | 5.00 | 138.30 | 143.30 | 350.00 | 14295.70 | 14789.00 |
| 88 | 7.80 | 147.56 | 155.36 | 345.00 | 11857.64 | 12358.00 |
| 89 | 24.00 | 140.29 | 164.29 | 356.00 | 13714.71 | 14235.00 |
| 90 | 20.00 | 125.09 | 145.09 | 350.00 | 14873.91 | 15369.00 |
| 91 | 22.00 | 133.36 | 155.36 | 365.00 | 14737.64 | 15258.00 |
| 92 | 15.00 | 149.73 | 164.73 | 358.00 | 14624.27 | 15147.00 |
| 93 | 16.00 | 167.04 | 183.04 | 348.00 | 14715.96 | 15247.00 |
| 94 | 12.00 | 175.50 | 187.50 | 369.00 | 15196.50 | 15753.00 |
| 95 | 10.00 | 174.38 | 184.38 | 358.00 | 15308.63 | 15851.00 |
| 96 | 8.50 | 172.75 | 181.25 | 345.00 | 15219.75 | 15746.00 |
| 97 | 6.20 | 174.60 | 180.80 | 375.00 | 16276.20 | 16832.00 |
| 98 | 8.30 | 179.20 | 187.50 | 354.00 | 15278.50 | 15820.00 |
| 99 | 17.00 | 162.46 | 179.46 | 358.00 | 9720.54 | 10258.00 |
| 100 | 14.00 | 165.02 | 179.02 | 359.00 | 9936.98 | 10475.00 |
| 101 | 13.00 | 168.25 | 181.25 | 345.00 | 9720.75 | 10247.00 |
| 102 | 12.20 | 177.53 | 189.73 | 342.00 | 9726.27 | 10258.00 |
| 103 | 16.00 | 139.36 | 155.36 | 362.00 | 9718.64 | 10236.00 |
| 104 | 22.00 | 137.82 | 159.82 | 359.00 | 9850.18 | 10369.00 |
| 105 | 21.00 | 137.93 | 158.93 | 347.00 | 10730.07 | 11236.00 |
| 106 | 19.00 | 138.14 | 157.14 | 352.00 | 10725.86 | 11235.00 |
| 107 | 14.00 | 146.27 | 160.27 | 387.00 | 10710.73 | 11258.00 |
| 108 | 15.00 | 157.77 | 172.77 | 324.00 | 10978.23 | 11475.00 |
| 109 | 10.00 | 145.36 | 155.36 | 200.00 | 11998.64 | 12354.00 |
| 110 | 8.50 | 155.79 | 164.29 | 201.00 | 12003.71 | 12369.00 |
| 111 | 7.23 | 137.86 | 145.09 | 203.00 | 12237.91 | 12586.00 |
| 112 | 14.00 | 120.82 | 134.82 | 305.00 | 12107.18 | 12547.00 |
| 113 | 16.00 | 118.38 | 134.38 | 358.00 | 11982.63 | 12475.00 |
| 114 | 12.00 | 124.16 | 136.16 | 341.00 | 12007.84 | 12485.00 |
| 115 | 11.20 | 153.53 | 164.73 | 387.00 | 12988.27 | 13540.00 |
| 116 | 14.25 | 142.89 | 157.14 | 397.00 | 9703.86 | 10258.00 |

| | | | | | | |
|----------------|--------------|---------------|---------------|---------------|-----------------|-----------------|
| 117 | 18.20 | 146.09 | 164.29 | 378.00 | 8907.71 | 9450.00 |
| 118 | 20.00 | 121.07 | 141.07 | 356.00 | 8953.93 | 9451.00 |
| 119 | 21.00 | 119.63 | 140.63 | 374.00 | 8937.38 | 9452.00 |
| 120 | 18.00 | 124.41 | 142.41 | 371.00 | 9006.59 | 9520.00 |
| 121 | 12.50 | 129.02 | 141.52 | 341.00 | 9077.48 | 9560.00 |
| 122 | 4.50 | 150.86 | 155.36 | 356.00 | 9350.64 | 9862.00 |
| 123 | 5.62 | 148.84 | 154.46 | 325.00 | 9178.54 | 9658.00 |
| 124 | 7.00 | 157.73 | 164.73 | 331.00 | 9161.27 | 9657.00 |
| 125 | 8.50 | 151.77 | 160.27 | 369.00 | 9718.73 | 10248.00 |
| 126 | 12.50 | 158.48 | 170.98 | 357.00 | 9719.02 | 10247.00 |
| 127 | 14.00 | 127.52 | 141.52 | 345.00 | 9767.48 | 10254.00 |
| 128 | 13.20 | 129.21 | 142.41 | 371.00 | 9731.59 | 10245.00 |
| 129 | 15.00 | 125.63 | 140.63 | 398.00 | 11506.38 | 12045.00 |
| 130 | 16.00 | 138.02 | 154.02 | 354.00 | 11526.98 | 12035.00 |
| 131 | 12.00 | 143.36 | 155.36 | 320.00 | 12000.64 | 12476.00 |
| 132 | 10.00 | 144.46 | 154.46 | 310.00 | 12118.54 | 12583.00 |
| 133 | 8.00 | 137.09 | 145.09 | 325.00 | 14285.91 | 14756.00 |
| 134 | 9.50 | 135.14 | 144.64 | 347.00 | 14360.36 | 14852.00 |
| 135 | 10.20 | 154.53 | 164.73 | 314.00 | 14390.27 | 14869.00 |
| 136 | 13.00 | 149.95 | 162.95 | 368.00 | 13997.05 | 14528.00 |
| 137 | 11.00 | 151.50 | 162.50 | 304.00 | 14061.50 | 14528.00 |
| 138 | 13.20 | 151.09 | 164.29 | 304.00 | 13789.71 | 14258.00 |
| 139 | 16.00 | 143.82 | 159.82 | 358.00 | 14010.18 | 14528.00 |
| 140 | 19.50 | 139.88 | 159.38 | 359.00 | 14767.63 | 15286.00 |
| 141 | 15.00 | 142.14 | 157.14 | 369.00 | 14842.86 | 15369.00 |
| 142 | 12.00 | 147.82 | 159.82 | 387.00 | 14822.18 | 15369.00 |
| 143 | 10.20 | 134.89 | 145.09 | 345.00 | 16041.91 | 16532.00 |
| 144 | 13.00 | 132.54 | 145.54 | 347.00 | 15831.46 | 16324.00 |
| 145 | 12.00 | 134.88 | 146.88 | 345.00 | 15850.13 | 16342.00 |
| 146 | 15.00 | 129.20 | 144.20 | 368.00 | 16228.80 | 16741.00 |
| 147 | 14.00 | 133.32 | 147.32 | 342.00 | 16362.68 | 16852.00 |
| 148 | 12.50 | 123.21 | 135.71 | 341.00 | 16486.29 | 16963.00 |
| 149 | 10.00 | 126.16 | 136.16 | 320.00 | 16075.84 | 16532.00 |
| 150 | 12.00 | 124.16 | 136.16 | 310.00 | 16006.84 | 16453.00 |
| Min. | 3.10 | 118.38 | 129.95 | 200.00 | 7888.50 | 8380.30 |
| Max. | 24.00 | 196.12 | 206.70 | 411.00 | 17515.71 | 18000.00 |
| Average | 11.47 | 148.67 | 160.11 | 335.13 | 12396.85 | 12892.29 |

Vita

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She is going to complete his master degree programme requirement by submission of this thesis.

Date :-

Sonali Kamle

