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Assessment of macronutrients and soil fertility status of an *Inceptisol*: A review

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Abstract
Macronutrients (N, P, K) are important soil elements that control its fertility. Soil characterization in relation to evaluation of fertility status of the soil of an area or region is an important aspect in context of sustainable agriculture production. Because of imbalanced and inadequate fertilizers use and coupled with low efficiency of other inputs, the response (production) efficiency of chemical fertilizers (nutrients) declined tremendously under intensive cultivation in recent years. Variation in nutrients supply is a natural phenomenon and some of them may be sufficient where others deficient. Nitrogen being an essential constituent of protein is a vitally important plant nutrient. Nitrogen is one of the 17 essential plant nutrients indispensable for growth and development of crop plants. Phosphorus stands next in importance after N among the essential nutrients. Phosphorus, amongst NPK can be called "The master key" with respect to the yield crops. Potassium is essential for various metabolic activities of living cell, transformation of carbohydrates, reduction of nitrates, synthesis of protein and normal meristematic activities where it acts as a catalyst or as a co-factor in enzymatic reaction of living cells.

Keywords: Macronutrients, soil fertility, inceptisol and crop yields

1. Introductions
Soil, the source of infinite life is the most vital and precious natural resource, and not renewable in short time. Soil fertility is a dynamic natural property and it can change under the influence of natural and human induced factors. As human population continue to increase, human disturbance on the earth's ecosystem to produce food and fiber will place greater demand on soils to supply essential nutrients. Continuous cropping for enhanced yield removes substantial amounts of nutrients from soil. Imbalanced and inadequate use of chemical fertilizers, improper irrigation and various cultural practices also deplete the soil quality rapidly (Medhe *et al.*, 2012). Soil fertility is an important aspect of the soil-plant relationship. Fertility status of the soil is primarily dependent upon both the macro and micronutrient reserve of that soil. Continued removal of nutrients by crops, with little or no replacement increases the nutrient stress in plants and lowers the fertility of soil and ultimately the crop productivity. The fertility status of the soils also depends on the nature of vegetation, climate, topography, texture of soil and decomposition rate of organic matter. Optimum productivity of any cropping systems depends on adequate supply of plant nutrients.

Soil fertility status, resulting crop response to applied fertilizer nutrients and net profit that can be obtained, are the important constituents to be taken into consideration before arriving at any decision on judicious use of fertilizers. High yielding fertilizers responsive variety of crops and high cost of fertilizers have necessitated the development of a quantitative basis of making fertilizer recommendations for obtaining economic yield of crop (Anonymous 1968) [1]. Soil nutrients play a vital role in the growth, development and yield of plant and the information on the fertility status of an area can go a long way in planning judicious fertilizers and soil management practices to develop economically viable alternatives for the farming community (Singh 1995) [56].

Fertility status of a soil is known in terms of soil test values. The soil tests are calibrated into different fertility categories such as low, medium and high (Welch *et al.* 1987 and Rashid and Memon 1996) [50]. In general, the soils are Most of the fertilizer recommendations given out by soil testing laboratories in India are based on soil test ratings given 50 years ago based on very limited data. These rating limits are irrespective of crop and soils and too general to be useful now in present context of intensive agriculture high yielding verities of crop for real site specific nutrient recommendation.

Fertilizer recommendation can be provided to the farmers based on major soil types occurring in a particular area. Such soil map will integrate the effects of soil and fertilizer nutrient efficiencies and nutrient requirement parameters on fertilizer recommendation.

Soil test provides the most accurate information on the availability of various plant nutrients (Dahnke and Olsen, 1990) [11]. Soil testing not only group the soil into classes relative to the levels of nutrients for suggesting fertilizer practices but also help in predicting the probability of getting profitable responses, evaluating soil productivity and determining specific soil conditions like alkalinity, salinity and acidity which limits the crop yields. Soil testing plays crucial role in soil fertility maintenance and sustainable precision agriculture, in areas of organic farming, conservation agriculture, contaminated soil diagnosis and remediation for rainfed and irrigated areas.

1.1 Review of Literature

The sincere efforts were made to scan the literature on the related topic and after scanning, the available literatures are presented in this chapter under appropriate heads:-

2. Status of physico-chemical properties in soil

2.1 Soil reaction (pH)

Soil reaction (pH) is one of most important chemical characteristics of the soil solution that influence many physical, chemical and biological properties of soil. It affects the availability of several plant nutrients. It is also most important factor for evaluating its production potential for most crops. Soil reaction is an indication of the acidity or basicity of the soil and it has been classified into three groups: (1) Acidity, (2) Alkalinity and (3) Neutrality. Verma *et al.* (2005) reported that the soils of the study area are alkaline in reaction (pH >7.0). The distribution of samples in various pH ranges indicates that only 26% of total soil samples fall in the pH range from 8.00 to 8.75. The maximum number of soil samples (51%) fall in 8.75 to 9.00 pH range. However, it is startling to observe that a significant number of samples, *i.e.*, 23% have pH values ranging from 9.00 to 9.75. In soils of arid tract of Punjab. Nazif *et al.* (2006) [38] the observed that the majority of the soil sites were alkaline in nature. The soil pH ranged from 6.88 to 8.06 (average 7.56) in the micronutrient status of soils.

Meena *et al.* (2006) [34] found that soil pH varied from 7.1 to 8.6 with an average of 7.8. According to classification of soil reaction suggested by Brady (1985) [6], 14 samples were neutral (pH 6.6to 7.3), 44 samples were mildly alkaline (pH 7.4 to 7.8), 59 samples were moderately alkaline (pH 7.9 to 8.4) and 3 samples were strongly alkaline (pH 8.5 to 9.0). The minimum value of pH 7.1 was observed in Uniara, Bilota, Pagra and Khatholi and maximum value of pH 8.6 was observed in Rupwas village of Tonk district of Rajasthan. Sharma and Chaudhary (2007) reported that the soils were slightly acidic to neutral in reaction (pH 6.25 to 7.29) in the soil profiles of different soil series of lower Shiwaliks of Solan district in North–West Himalayas. Kumar *et al.* (2009) characterized the soils of Santhal Paraganas region of Jharkhand. And they reported that Dumaka soil series were found in low pH range (from 3.80 to 6.40) and Lachimpur series showed wide variation in pH (4.60 to 7.70). Nirawar *et al.* (2009) [39] stated the pH range from 6.56 to 8.5 indicating the neutral to slightly alkaline in reaction in soils of Ahemedpur tahsil of Latur district. Singh *et al.* (2009) noted that the surface and subsurface soils were normal to slightly alkaline with pH ranging between 7.1 to 8.6 in the soils of district Ghazipur, Utter Pradesh. Rajeswar *et al.* (2009) [48] observed that all the pedons were neutral (7.4) to moderately alkaline (8.7) in reaction (pH) in soils Lower pH values were recorded in the surface as compared to subsurface horizons.

2.2 Electrical Conductivity

The electrical conductivity (EC) is the principal parameter to measure a total soluble salt concentration in the soil. The readings are temperature dependent therefore measurements typically are corrected to an equivalent value at 25 ºC. The internationally accepted standard unit for reporting EC is decisiemens per meter (dS m^{-1}). Verma *et al.* (2005) observed that the electrical conductivity (EC) of the soils, varied from 0.07 to 0.77 with mean value of 0.32 dS m^{-1} in soils of arid tract of Punjab, India. The mean EC of soil samples indicates that EC of different blocks is of the order Jhunir > Bhikhi > Mansa > Sardulgarh > Budhlada. All the soil samples fall in the normal EC range indicating that salinity is not at all a problem in these soils. The lower values of electrical conductivity in these soils may be attributed to more macro pores, as majority of the soil samples in the area are light textured, resulting in free drainage conditions. Sharma and Chaudhary (2007) reported that available EC status in the soil profiles of different soil series ranged from 0.09 to 0.40 dS m^{-1} in lower Shiwaliks of Solan district in North–West Himalayas. Rajeswar *et al.* (2009) [48] studied in soils of Garikapadu of Krishna district of Andhra Pradesh and observed that the EC values varied from 0.10 to 0.32 dS m^{-1}. Singh *et al.* (2009) observed that electrical conductivity varied between 0.10 and 0.38 dS m^{-1} in the soils of district Ghazipur, Utter Pradesh.

2.3 Organic Carbon

Soil organic matter consists of decomposing plant and animal residues. In addition to those minerals, soil organic matter contains living and dead microbial cell, microbialy synthesised compounds and number of derivatives produced as a result of microbial activity. It is the store house of all essential plant nutrients. It protects soil against erosion and help to form good soil structure. It provides good aeration and better water movement by loosening the soil. It is a source of 90-95 percent of the nitrogen in unfertilized soils. It supplies available phosphorus, sulphur and some other micronutrients like Fe, Mn, Cu, Zn etc. to the soil and there by increases the nutrient regime as well as improve the soil health. Sharma and Chaudhary (2007) reported that the organic carbon content from 1.5 to 15.9 g kg^{-1} showed a considerable variation with depth in lower Shiwaliks of Solan district in North–West Himalayas. Sharma *et al.* (2008) revealed that the organic carbon (OC) in the soils ranged between 0.16 to 0.97% with an average value of 0.61%. Considering the soils having <0.4 as low , 0.4 -0.75% as medium and > 0.75% as high in OC status, the distribution of soil samples under these categories was 6.8 , 73.5 and 19.7%, respectively. Singh *et al.* (2009) observed that the soils had low organic carbon content ranging from 3.4 to 4.9 g kg^{-1} in the soils of district Ghazipur, Utter Pradesh. Kumar *et al.* (2009) reported that soils of Dumka series were characterized by organic corbon ranging from 2.53 to 7.80 g kg^{-1}.

3. Status of soil available macronutrients

Soil fertility is related to the amount of available nutrients which others measure it by the yield capacity, and still others look it to be a function of organic matter or even soil texture.

In brief, soil fertility refers to the available status of essential nutrients in the soil (Tisdale *et.al.,* 1993). Soil test-based fertility management is an effective tool for increasing productivity of agricultural soils that have high degree of spatial variability resulting from the combined effects of physical, chemical or biological processes (Goovaerts 1998) [20]. Nutrients like nitrogen (N), phosphorus (P) and potassium (K) are considered as primary nutrients. These nutrients help in proper growth, development and yield differentiation of plants and are generally required by plants in large quantity.

3.1 Available Nitrogen

Nitrogen is an integral component of many compounds including chlorophyll and enzyme essential for plant growth. It is an essential constituent for amino acids which is building blocks for plant tissue, cell nuclei and protoplasm. Chibba and Sekhon (1985) [8] observed that the available content of nitrogen ranged from 138 to 295 kg ha^{-1} found in acidic soils of Panchrukhi, Kangra, Baijnath and Dehra blocks in Kangra district of Punjab. Thakur and Bhandari (1986) [60] reported that available nitrogen content ranged from 120 to 200 kg ha^{-1} in sandy clay loam soils of Saproon valley of Himachal Pradesh. Singh and Dutta (1988) observed that in soils of order *Inceptisols* and *Ultisols* of Mizoram the available nitrogen content fluctuated from 115 to 507 ppm. Kanthaliya and Bhatt (1991) [23] estimated available nitrogen content varied from 112 to 431 kg ha^{-1}. Ramesh *et al.* (1994) [49] reported that in soils of Guntur district of Andhra Pradesh available content of nitrogen showed a variation from 85 to 282 kg ha^{-1}. Kumar *et al.* (1995) [28] noted that available nitrogen content ranged from 203.8 to 407.2 kg ha^{-1} in soils of Soan river valley of lower Shiwaliks.

Verma *et al.* (2005) found that the available nitrogen content 100 kg ha^{-1} in Soils of Arid Tract of Punjab, India. The data indicates that majority of the soil samples from all study blocks are low in available N content. The high temperature prevailing in the area is responsible for the rapid burning of organic matter, thus resulting in low organic carbon content of these soils. Since organic matter content is an indicator of available nitrogen status of soils, thus the soils of the area are also dominantly low in respect of their available nitrogen. Bajpai *et al.* (2006) [2] conducted a long term permanent plot field experiment at the Raipur *inceptisol* of Chhattisgarh and reported that the initial fertility status of nitrogen is 234 kg ha^{-1}. Almost similar available nitrogen content 231 kg ha^{-1} was found in deep Aquic Ustorthent in semi arid tropics region of Andhra Pradesh Surekha *et al.* (2004) [58] and Gupta *et al.* (2004) also reported available nitrogen content was 234 kg ha^{-1} of citrus orchard in the subtropical zone of Jammu region. Meena *et al.* (2006) [34] stated that the available N content varied from 125 to 555 kg ha^{-1} with an average value of 309 kg ha^{-1}. On the basis of the rating suggested by Subbiah and Asija (1956), 32% samples were Low (< 250 N kg ha^{-1}) 61% medium (250 to 500 N kg ha^{-1}) and only 7% sample were high (> 500 N kg ha^{-1}) in available N in soils of Tonk district of Rajasthan. Desai *et al.* (2009) [14] conducted a field experiment during seven consequentive years on Vertic Haplustepts of South Gujarat and reported that the available nitrogen content is 278 kg ha^{-1}. Kumar *et al.* (2009) observed that an available N content of Dumka and Lachimpur series varied from 125 to 310 kg ha^{-1} with a mean of 216 kg ha^{-1} and 210 to 545 kg ha^{-1} with a mean of 401 kg ha^{-1} in soils of Santhal Paraganas rgion of Jharkhand. About 40 to 50% soil samples in Dumka series were rated as low in available N. Gogoi *et al.* (2010) [19] conducted a long term permanent integrated nutrient management (INM) experiment at instructional-cum-research farm of Assam Agriculture University (AAU), Jorhat. And they reported that the available nitrogen content is 270 kg ha^{-1}.

3.2 Available Phosphorous

Phosphorus is important component of adenosine di-phosphate (ADP) andadenosine tri-phosphate (ATP), which involves in energy transformation in plant. It is essential component of deoxyribonucleic acid (DNA), the seat of genetic inheritance in plant and animal. Phosphorous take part in important functions like photosynthesis, nitrogen fixation, crop maturation, root development, strengthening straw in cereal crops etc. It develops resistance against certain diseases. The availability of phosphorous is restricted under acidic and alkaline soil reaction the foliage is sparse and restricted the development of lateral bud is suppressed. Under severe deficiency, the apical part of the leaves turns brown and then margine of the leaves may role. Available phosphorus content in *Inceptisol* of Chhattisgarh is varied from 10 to 15 kg ha^{-1}. Singh and Singh (1985) reported that in Beel soils of Assam, the available content of phosphorus ranged from 6.2 to 84.0 kg ha^{-1}. Thakur and Bhandari (1986) [60] noted that available content of phosphorous showed a variation from 10 to 50 kg ha^{-1} in sandy clay loam soils of Saproon Valley of Himachal Pradesh. Kanthaliya and Bhatt (1991) [23] claimed that available content of phosphorous showed a variation from 7.6 to 135.3 kg ha^{-1}, 9.1 to 132.2 kg ha^{-1} and 22.8 to 112.0 kg ha^{-1}.

Lyngdoh and Shukla (1993) [31] reported that the available content of phosphorous varied from traces to 5.7 kg ha^{-1}, from traces to 23.4 kg ha^{-1} and from 4 to 6.9 kg ha^{-1} in *Alfisols* of east khasi hills, west khashi hills and jaintia hills of Meghalaya, respectively. Ramesh *et al.* (1994) [49] reported that the available P content ranged from 5.0 to 38 kg ha^{-1} in Psamment soils of Guntur district of Andhra Pradesh. Kumar *et al.* (1995) [28] found that in soils of Soan river valley of Himachal Pradesh the available P content varied from 2.0 to 29.0 g kg^{-1}. Bharambe *et al.* (2004) [4] conducted a field experiment during three consequentive years on Parbhani clay soil. They reported that the available phosphorus content as 28 kg ha^{-1}. Surekha *et al.* (2004) [58] analyzed the available Phosphorus content is 120 kg ha^{-1} of deep Aquic Ustorthent in semi arid tropics region of Andhra Pradesh. Verma *et al.* (2005) reported that the available phosphorus content of these soils varied from 1.8 to 59.6 kg ha^{-1} with a mean value of 18.46 kg ha^{-1} in soils of arid tract of Punjab, India. In general, available P ranged from low to medium, but high values of available P are also found in some part of the area about 45% soil samples tested low, 17% medium and 38% soil samples tested high in available P content. Sanjay *et al.* (2005) stated that the available phosphorus ranged from 2.35 to 25.66 kg ha^{-1} in soils of Leh district and 2.5 to 137.4 kg ha^{-1} in soils Bajpai *et al.* (2006) [2] conducted a long term permanent plot field experiment at the Raipur *inceptisol* of Chhattisgarh and reported that the initial fertility status of phosphoras is 11.5 kg ha^{-1}. Meena *et al.* (2006) [34] observed the available phosphorus content varied from 9.2 to 65.2 kg ha^{-1} with a mean value of 25.2 kg ha^{-1}. On the basis of the limits suggested by Muhr *et al*. (1963) [36], 35% samples were low (<20 P_2O_5 kg ha^{-1}), 60% Medium (20 to 50 P_2O_5 kg ha^{-1}), and 5% were high (<50 P_2O_5 kg ha^{-1}) in available phosphorus in soils of Tonk district of Rajasthan. Sharma *et al.* (2006) [53] stated that the available phosphorus varied from 4.0 to 22.15 kg ha^{-1} in soils of Leh district in cold arid region of Ladakh.

Nirawar *et al.* (2009) [39] observed that an available Phosphorus content ranged from 7.65 to16.15 kg ha^{-1} (mean 11.89 kg ha^{-1}) in soils of Ahemedpur tahsil of Latur district. Rajeswar *et al.* (2009) [48] revealed that the available Phosphorus content in all the pedons varied from 5.3 to 33.4 kg ha^{-1}.However, the highest available P was observed in the surface horizons and decreased regularly with depth and higher P in the surface horizon distribution of available macronutrients in soils Garikapadu of Krishna district of Andhra Pradesh. Kumar *et al.* (2009) observed that an available P content in soils ranged from 5.60 to 14.20 and 7.00 to13.40 kg ha^{-1} with mean value of 10.00 and 9.00 kg ha^{-1} in Dumka and Lachimpur series, Desai *et al.* (2009) [14] conducted a field experiment during seven consecutive years on Vertic Haplustepts of South Gujarat and reported that the available Phosphorus content is 51.7 kg ha^{-1}. Gogoi *et al.* (2010) [19] conducted a long term permanent integrated nutrient management (INM) reported the available Phosphorus content is 12.1 kg ha^{-1}. Bali *et al.* (2010) [3] the indiscriminate use of fertilizers over a period of time has resulted in buildup of nutrient elements like phosphorus in many locations. Hence for sustainability of the present agricultural system and management of our soil resources, a spatial database regarding the fertility status of soils is required, Sharma (2004).

3.3 Available Potassium

Potassium is an activator of various enzymes responsible for plant processes like energy metabolism, starch synthesis, nitrate reduction and sugar degradation. It is extremely mobile in plant and help to regulate opening and closing of stomata in the leaves and uptake of water by root cells. A deficiency of potassium brings about chlorosis, *i.e*., yellowing of leaves and leaf scorch in the case of fruit trees. It is also responsible for „dying back tips‟ of shoots. The older leaves show the deficiency symptoms earlier. Available potassium content in *Inceptisol* of Chhattisgarh is varied from 200 to 350 kg ha^{-1}. Thakur and Bhandari (1986) [60] reported that in soils of Saprun Valley of Himachal Pradesh the available K content ranged from 30 to 159.8 mg kg^{-1} in Soan river valley soils of lower Shiwaliks. Ghosh and Mukhopadhyay (1996) [18] observed that available potassium content varied from 62 to 262 kg ha^{-1} and 52 to 386 kg ha^{-1} respectively in soils of Jagannathpur and Barakonda of West Bengal. The higher value of available potassium in the Barakonda series explained as intensive weathering leading to increased released of K to the exchange site of clay minerals. Bharambe *et al.*, (2004) [4] conducted a field experiment during three consequentive years on Parbhani clay soil. They reported that the available available Potassium content is 506 kg ha^{-1}. Sanjay *et al.* (2005) found that the range of available potassium was 11 to 496 kg ha^{-1} and 103 to 861 kg ha^{-1} in soil samples of Leh and kargil district, respectively. Verma *et al.* (2005) reported that the available potassium content of these soils is generally medium to high, and only 3% soil samples tested low in available Sharma *et al.* (2006) [53] reported that the available potassium varied from 23.5 to 496.2 kg ha^{-1} in soils of Leh district in cold arid region of Ladakh. Bajpai *et al.* (2006) [2] conducted a long term permanent plot field experiment at the Raipur *Inceptisol* of Chhattisgarh and reported that the initial fertility status of potassium is 280 kg ha^{-1}. Almost similar available potassium content 365 kg ha^{-1} was found in deep Aquic Ustorthent in semi arid tropics region of Andhra Pradesh Surekha *et al.* (2004) [58] and Gupta *et al.* (2004) also reported available potassium content was 177 kg ha^{-1} of citrus orchard in the subtropical zone of Jammu region. Meena *et al.* (2006) [34] stated that status of available potassium (K_2O) in the soils ranged from 105 to 1059 kg ha^{-1} with an average of 377 kg ha^{-1}. According to Muhr *et al.* (1963) [36] 2.5% samples were low (<125 K_2O kg ha^{-1}), 41% were medium (125 to 300 K_2O kg ha^{-1}) and 56.5% samples were high (>300 K_2O kg ha^{-1}) in potassium content in soils of Tonk district of Rajasthan. Sharma *et al.* (2009) found that the available K content ranged between 64 to 139 mg kg^{-1} with a mean of 113 mg kg^{-1} in surface soils of intermediate zone of Jammu region. Nirawar *et al.* (2009) [39] observed that the content of available K in soils of Takalgaon varied from 207 to 213 kg ha^{-1} with a mean value of 210 kg ha^{-1} and in Andori village varied from 352 to 654 kg ha^{-1} with a mean of 550 kg ha^{-1} in soils of Ahemedpur tahsil of Latur district. Desai *et al.* (2009) [14] conducted a field experiment during seven consequentive years on Vertic Haplustepts of South Gujarat and reported that the available potassium content is 290 kg ha^{-1}. Kumar *et al.* (2009) observed that the content of available K in soils of Dumka series varied from 111 to145 kg ha^{-1} with a mean value of 124 kg ha^{-1} and in Lachimpur series from 110 to 188 kg ha^{-1} with a mean of 134 kg ha^{-1} Gogoi *et al.* (2010) [19] conducted a long term permanent integrated nutrient management (INM) experiment at instructional-cum-research farm of Assam Agriculture University Jorhat and reported the available potassium content is 116.7 kg ha^{-1}. Bali *et al.* (2010) [3] reported that the available potassium ranged from 33.6 to 1192 kg ha-1 (mean 280.57 kg ha^{-1}).

4. Relationship between various soil properties and available macronutrients

4.1 Relationship between available Nitrogen and pH

Meena *et al.* (2006) [34] reported that available N was negatively correlated (r = -0.292**) with pH. In soils of Tonk district of Rajasthan. This might be due to increased rate of denitrification at lower pH values (Tisdale 1997). Kumar *et al.* (2009) showed that relationship between available N content was a non- significant and negative correlation with pH (r = -0.03 and r= -0.019) in Dumka Lachimpur series in soils of Santhal Paraganas region of Jharkhand.

4.2 Relationship between available nitrogen and organic carbon

Singh and Datta (1988) reported a significant positive correlation between available nitrogen and organic carbon level in soils of Mizoram, where r value was found 0.93. Similar relationship were obtained by Kanthaliya and Bhatt (1991) [23] in soils of Rajasthan, by Ramesh *et al.* (1994) [49] in soils of Guntur district of Andhra Pradesh, similar result was also obtained by Kumar *et al.* (1995) [28] in soils of Soan river valley of Himanchal Pradesh. Meena *et al.* (2006) [34] reported that a significant positive correlation (r = 0.639**) was found between organic carbon and available nitrogen in soils of Tonk district of Rajasthan. This relationship was found because most of the soil nitrogen is in organic forms. Similar results were also reported by Verma *et al.* (1980) [63], Kanthalia and Bhatt (1991) [23] and Paliwal (1996). Kumar *et al.* (2009) showed that relationship between available N content was a highly significant and positive correlation with organic carbon (r = 0.838**) in Lachimpur series in soils of Santhal Paraganas region of Jharkhand.

4.3 Relationship between available phosphorus and pH

Sharma *et al.* (2006) reported that a significant positive correlation between available phosphorus and pH in soils of

Leh district of cold arid region of Ladakh. Meena *et al.* (2006) [34] reported that available phosphorus was significant and negatively correlated with pH (r = -0.575**) in soils of Tonk district of Rajasthan. Because at higher pH calcium can precipitate with phosphorus as Ca-phosphate and reduce phosphorus availability (Tisdale *et al.* 1997). Similar results were also noted by Singh (1988) [57] in the soils of Udaipur. Kumar *et al.* (2009) showed that relationship between available P content was a non-significant, negative correlation (r = -0.003) with pH in soils of Dumka series. And found a non-significant positive correlation (r = 0.001) in Lachimpur series in soils of Santhal Paraganas region of Jharkhand.

4.4 Relationship between available phosphorus and organic carbon

Murthy and Shrivastava (1994) [37] observed a significant and positive correlation between available P and organic carbon level in moderately acidic soils of Majhera farm of Pantnagar University, Uttar Pradesh. Meena *et al.* (2006) [34] reported that a significant positive correlation (r = 0.797**) was observed between organic carbon and available phosphorous in soils of Tonk district of Rajasthan. This relationship might be due to the presence of more than 50% of phosphorus in organic forms and after the decomposition of organic matter as humus is formed which forms complex with Al and Fe that a protective cover for P fixation adsorption / phosphate fixation (Tisdale *et al.* 1997). Kumar *et al.* (2009) showed that relationship between available P content was a non-significant and positive correlation with organic carbon (r = 0.073 and 0.009) in Dumka and Lachimpur series in soils of Santhal Paraganas region of Jharkhand. Waghmare *et al.* (2009) [39] reported that a significant positive correlation (r = 0.34**) was observed between organic carbon and available phosphorous in some soil of Ausa tahsil of Latur district.

4.5 Relationship between available potassium and pH

Singh and Singh (1985) reported that a significant positive correlation between available K and pH in Beel soils of Assam. Pal and Mukhopadhyay (1992) [41] reported that a significant and positive correlation between available K and pH in in Inceptisol of West Bengal. Sharma *et al.* (2006) [56] reported that a significant positive correlation between available potassium and pH in soils of Leh district of cold arid region of Ladakh. Kumar *et al.* (2009) showed that relationship between available K content was a non-significant and negative correlation with pH (r = -0.027 and r = -0.125) in Dumka and Lachimpur series in soils of Santhal Paraganas region of Jharkhand.

4.6 Relationship between available potassium and organic carbon

Meena *et al.* (2006) [34] reported that a significant positive correlation (r = 0.420**) was observed between organic carbon and available K content in soils of Tonk district of Rajasthan. This might be due to creation of favourable soil environment with presence of high organic matter. Similar results were also reported by Paliwal (1996) and chouhan (2001) [10]. Sharma *et al.* (2009) found that the available K had positively and significantly correlated with organic carbon (r = 0.441**) in surface soils of intermediate zone of Jammu region. Kumar *et al.* (2009) showed that relationship between available K content was a non-significant and positive correlation with organic carbon (r= 0.136 and r = 0.124) in Dumka and Lachimpur series in soils of Santhal Paraganas region of Jharkhand**.** The present study was undertaken with a view to evaluate the fertility status of *Inceptisol* of Akaltara block, Janjgir district and its relationship with important physico chemical characteristics for identifying the location specific conditions.

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