CHAPTER-V

DISCUSSION

Results obtained by analysing different physical and chemical properties viz. sand, silt, clay, texture, soil colour, bulk density, particle density, porosity, pH, EC, CaCO3, organic carbon, available nutrients status viz. N, P, K, exchangeable Ca, Mg, available S and DTPA Fe, Mn, Cu and Zn etc. are discussed in this chapter under following heads.

5.1 Soil

5.1.1 Physical properties of soil from irrigated and non irrigated farmland.

5.1.2 Chemical properties of soil from irrigated and non irrigated farmland.

5.1.3 Macro nutrients and micro nutrient status in soil from irrigated and non irrigated farmland.

5.1.4 Soil nutrients index value (NIV).

5.1.5 Correlation of physico-chemical properties with nutrient availability.

5.2 Water

5.2.1 Physico-chemical properties of water from irrigated and non irrigated farmland.

5.2.2 Correlation of water parameters with soil parameters.

5.1. Soil

5.1.1. Physical properties of soil from irrigated and non irrigated farm land

1) Irrigated

Out of 150 soil samples collected, 75 soils samples each were grouped under irrigated and non irrigated farmlands. 75 soil samples each collected from irrigated and non irrigated farmlands were sub-grouped under season viz. monsoon, winter and summer. The data on some physical properties of these soil samples are presented in Table 1.
The data on physical properties of soil from irrigated farmland of study area is presented in Table 1. The data revealed that out of 25 soil samples collected from irrigated farmland, the particle density of these soils ranged from 2.40 to 2.80 mg m$^{-3}$ with mean value 2.67 mg m$^{-3}$. The lowest particle density 2.40 mg m$^{-3}$ was found in sample S10 where as highest particle density 2.80 mg m$^{-3}$ was found in sample S16.

Bulk density of soil sample ranged from 1.34 to 1.43 mg m$^{-3}$ with mean value 1.41 mg m$^{-3}$. The minimum 1.34 mg m$^{-3}$ and maximum 1.43 mg m$^{-3}$ bulk density of these soil samples were found in sample S14 and S2.

The porocity of these soil samples ranged from 45.04 to 61.50 per cent with mean value 49.70 per cent. The lowest porocity was found in sample S17 whereas highest porocity was recorded in sample S10.

Soil from study area show dominant spectral wavelength of munsell colour i.e. Hue 10 YR. Soil show variation in value and chroma also. The value varied between 2-5 and chroma i.e. purity of colour varied between 0-3. According to munsell colour chart, soil from irrigated farmland are black to very dark brown to very dark gray in colour.

The data on soil texture revealed that all soil samples were clay in texture. The sand per cent ranged from 15.8 to 26.1 percent, silt per cent ranged from 22.3 to 29.8 per cent and clay per cent ranged from 48.00 to 58.20 per cent in soil samples from irrigated farmlands.

2) Non Irrigated

The data on some physical properties of these soil samples from non irrigated farmlands are presented in Table 6.

The data revealed that out of 25 soil samples collected from irrigated farmland, the particle density of these soils ranged from 2.44 to 2.79 mg m$^{-3}$ with mean value 2.67 mg m$^{-3}$. The lowest particle density 2.44 mg m$^{-3}$ was found in sample S7 where as highest particle density 2.79 mg m$^{-3}$ was found in sample S10.
Bulk density of soil samples ranged from 1.41 to 1.61 mg m\(^{-3}\) with mean value 1.53 mg m\(^{-3}\). The minimum 1.52 mg m\(^{-3}\) and maximum 1.61 mg m\(^{-3}\) bulk density of these soil were found in sample S2 and S9.

The porosity of these soil samples ranged from 46.76 to 55.53 per cent with mean value 50.63 per cent. The lowest porosity was found in sample S24 whereas highest porosity was recorded in sample S14.

Soil from study area show dominant spectral wavelength of munsell colour i.e. Hue 10 YR. Soil show variation in value and chroma also. The value varied between 2-5 and chroma i.e. purity of colour varied between 0-3. According to munsell colour chart, soils from irrigated farmland are black to very dark brown.

The data on soil texture indicate that all soil clayey in texture. The sand per cent ranged from 14.8 to 34.3 per cent, silt per cent ranged from 17.8 to 32.4 per cent and clay per cent ranged from 47.90 to 57.80 per cent in soil samples from non irrigated farmlands.

This little variation in colour value because of assemblage of minerals derived from basaltic trap rock and black brown colour of soil associated with titaniferous composition and humas content. Black to dark brown colour of soil was also recorded by Yadav (2005), Kalbhor (2007) and Patil (2008).

Since the basalt is parent material of these soils and on weathering this produces high amount of clay minerals (Jibhakate, 2009).

Variation in bulk density value may be due to dispersion and migration of clay and clogging of pores. Similar results were reported by Yadav (2005).

5.1.2 Chemical properties of soil from irrigated and non irrigated farmlands.

Data on chemical properties of soil from irrigated and non irrigated farmlands are presented in Table 2, 3, 4, 5 and 7, 8, 9, 10 respectively.

1) pH

Irrigated Farms

The data on physico-chemical characteristics of soil from irrigated farmland of study area is presented in Table 2. The result in nutshell indicated that the pH ranged
from 7.09 to 7.94 with average value of 7.45 in monsoon season. The soil sample S10 showed lowest pH (7.09) while highest pH (7.94) was observed in soil sample S22.

Out of 25 soil samples in monsoon season the pH of 15 soil sample (60 %) were normal, 10 soil samples (40%) were found alkaline in reaction. Thus the soil samples were found neutral to alkaline in nature.

The data on physico-chemical properties of soils grouped under winter season (Table 3) revealed that, out of 25 soil samples, 13 soil samples were neutral in reaction (pH 6.5 - 7.5 ) and 12 soil samples were alkaline in reaction (7.5 - 8.9). The pH varied from 7.21 to 7.93 with a mean value of 7.48. The lowest pH 7.21 was recorded in soil sample S15 while the soil S21 showed highest (7.93) followed by S4 (7.43). Out of 25 soil samples (52%) soil samples were found neutral in reaction and (48%) soil samples were alkaline in reaction.

Physico-chemical properties of soils in summer season from non irrigated farm land are presented in Table 4. The data indicated that the pH of these soil samples were varied from 7.20 to 7.94 with a mean value of 7.54. The lowest pH (7.20) was found in soil sample S16 and the highest pH (7.94) was found in soil sample S23 followed by S21 (7.93).

It was revealed from the data (Table 4) that out of 25 samples 44 per cent soil samples were neutral and 56 per cent soils samples were alkaline in reaction.

**Non Irrigated Farms:**

The data on physioc-chemical characteristics of soil is presented in Table 7. The results in nutshell indicated that the pH ranged from 6.94 - 7.96 with an average value of 7.30 in monsoon season. The soil sample S14 showed lowest pH 6.94, while the highest pH 7.96 was observed in soil sample S9 followed by pH 7.94 from soil sample S14.

Out of 25 soil samples of monsoon, the pH of 19 soil samples (76%) were normal, 06 soil samples (24%) were found alkaline in reaction. Thus, the soils were neutral to alkaline in nature.

The data on physico-chemical properties of soils grouped under inceptisol (Table 8) revealed that, out of 25 soil samples, 18 soil samples were neutral in reaction (pH 6.5 - 7.5 ) and 7 soil samples were alkaline in reaction (7.5 - 8.9). The
pH varied from 7.11 to 7.90 with a mean value of 7.37. The lowest pH 7.11 was recorded in soil sample S12 while the soil S9 showed highest (7.90) followed by S18 (7.68). Out of 25 soil samples (72%) soil samples were found neutral in reaction and (28%) soil samples were alkaline in reaction.

Physico-chemical properties of soils in summer season from non irrigated farm land are presented in Table 9. The data indicated that the pH of these soil samples were varied from 7.10 to 7.89 with a mean value of 7.59. The lowest pH (7.10) was found in soil sample S19 and the highest pH (7.89) was found in soil sample S1 followed by S10 (7.88).

It was revealed from the data (Table 9) that out of 25 samples 28 per cent soil sample were neutral and 72 per cent soils samples were alkaline in reaction.

The data narrated indicated that, pH of these soil samples were found to be maximum alkaline in summer and neutral in monsoon from both irrigated and nonirrigated farmlands of study area. The values indicated that, soils of study area were neutral to alkaline in soil reaction. The relative high content of pH in these soil samples might be due to presence of high degree of base saturation. Padole and Mahajan (2003) reported that the pH of swell shrink soil of Vidharba region was ranged from 7.1 to 8.0. The low pH might be due to when H⁺ ion form predominant absorbed cations on soil colloids make the soil acidic. These results are in accordance with the result reported by Waikar et al. (2003).

**EC**

1) Irrigated farm land:

The EC of these soils in monsoon season (irrigated) were ranged from 0.124 to 0.626 dSm⁻¹ with mean value of 0.26 dSm⁻¹. The lowest EC (0.124) was found in soil sample S8 where as highest EC 0.626 was recorded in soil sample S16 followed by 0.476 dSm⁻¹ in soil sample S12. Thus EC of their soil were in the normal range.

The EC of these soils in winter season (irrigated) varied from 0.156 to 0.761 dSm⁻¹ with a mean value of 0.33 dSm⁻¹. The lowest EC (0.156 dSm⁻¹) was observed in soil S2 and highest EC (0.761 dSm⁻¹) was observed in soil sample S16 followed by S12 (0.563 dSm⁻¹). Thus all the soils grouped under winter season were in normal EC.

The data further indicated that EC of these soilin summer season (irrigated) ranged from 0.208 to 0.832 dSm⁻¹ with a mean value of 0.44 dSm⁻¹. The lowest EC
(salt concentration) 0.208 dSm$^{-1}$ was recorded in soils S1 and highest EC (0.832 dSm$^{-1}$) was found in S9 followed by S16 (0.780 dSm$^{-1}$). The soils were in normal salt concentration.

2) Non Irrigated farmland:

The EC of these soils were ranged from 0.133 to 0.467 dSm$^{-1}$ with a mean value of 0.26 dSm$^{-1}$. The lowest EC (0.133 dSm$^{-1}$) was found in the soil sample S3. Whereas, highest EC (0.467 dSm$^{-1}$) was recorded in soil sample S16 followed by S1 EC 0.463 dSm$^{-1}$. Thus, the EC of these soils were in the normal range.

The EC of these soils winter varied from 0.197 to 0.563 dSm$^{-1}$ with a mean value of 0.37 dSm$^{-1}$. The lowest EC (0.197 dSm$^{-1}$) was observed in soil S9 and highest EC (0.563 dSm$^{-1}$) was observed in soil sample S5 followed by S1 (0.56 dSm$^{-1}$). Thus all the soils grouped under winter season were in normal EC.

The data further indicated that EC of these soil samples ranged from 0.219 to 0.631 dSm$^{-1}$ with a mean value of 0.45 dSm$^{-1}$. The lowest EC (salt concentration) 0.219 dSm$^{-1}$ was recorded in soils S9 and highest EC (0.631) was found in S5 followed by S1 (0.614 dSm$^{-1}$). The soils were in normal salt concentration.

The EC of these soil samples (Fig. 2, 5) were 99 per cent safe and less than 1 per cent normal. Among three categorizations in three seasons, it showed that safe EC was found in monsoon (100%) and winter (100%) and summer (96%) while normal EC was found in summer (4%). Further the data indicated that the soils of study area were safe limit in EC. The low EC in these soils might be due to proper management of soil and there by leaching of salts take place from surface to surface. These results are in confirmatory with results reported by Joshi and Kadrekar (1988) in salt affected soil of Maharashtra. Similar finding were also reported by Mali et al. (2012) and Waiker et al. (2003) in soils from Barhanpur, Maharashtra.

3) Organic carbon

1) Irrigated farmland:

The data on organic carbon (Table 2) showed that the soil in monsoon (irrigated) were very low in organic carbon. The content of organic carbon ranged from 0.27 to 0.99 per cent with mean value of 0.56 per cent in monsoon season. The
soil sample S21 showed lowest organic carbon (0.27 %) while the maximum content of organic carbon 0.99 per cent was recorded in soil sample S11 followed by soil sample S13 (0.94 %). In monsoon out of 25 soil samples 48 per cent were low, 28 per cent were medium and 24 per cent were high in organic carbon.

The organic carbon content of soils grouped under winter (irrigated) ranged from 0.11 to 1.00 per cent with a mean value of 0.46 per cent. The lowest organic carbon (0.11 %) was observed in soils S12, whereas the highest organic carbon (1.00 %) was observed in soil S10 followed by S7 (0.81 %). Out of 25 soil samples, 64, 28 and 8 per cent were low, medium and high in organic carbon content, respectively.

Soil under summer (irrigated) had organic carbon content ranged from 0.14 to 0.89 per cent with a mean value of 0.40 per cent. The soil sample S14 collected had lowest organic carbon content i.e. 0.14 per cent, while the soil sample S10 collected had highest organic carbon i.e. 0.89 per cent followed by soil sample S7 (0.68 %). Thus, the soil from summer season showed lower status of organic carbon than recorded in monsoon and winter.

2) Non Irrigated farmland:

The data on organic carbon content (Table 7) showed that the soils in monsoon (non irrigated) were very low to high in organic carbon. The content of organic carbon ranged from 0.24 to 0.85 per cent with a mean value of 0.40 per cent in monsoon. The soil sample S9 showed lowest organic carbon (0.24 %), while the maximum content of organic carbon 0.85 per cent was recorded in soil sample S1 followed by soil sample S25 (0.55 %).

The organic carbon content of soils grouped under winter (non irrigated) ranged from 0.18 to 0.61 per cent with a mean value of 0.30 per cent. The lowest organic carbon (0.18 %) was observed in soils S3, whereas the highest organic carbon (0.61 %) was observed in soil S1 followed by S22 (0.58 %). Out of 25 soil samples, 92 and 8 per cent were low and medium in organic carbon content, respectively.

Soil under summer season (non irrigated) had organic carbon content ranged from 0.11 to 0.51 per cent with a mean value of 0.24 per cent. The sample S3 collected had lowest organic carbon content i.e. 0.11 per cent, while the soil sample S1 collected had highest organic carbon i.e. 0.51 per cent followed by soil sample S25
Thus the soil from summer season showed lower status of organic carbon than recorded in monsoon and winter.

The organic carbon contents of soils from irrigated farmlands were 48 per cent low, 32 per cent medium and 20 per cent high category in monsoon, 52 per cent low, 40 per cent medium and 8 per cent high in winter and 68 per cent low category, 28 per cent medium and 4 per cent high in summer while from non irrigated farmlands were 84 per cent low, 12 per cent medium and 4 per cent high in monsoon, 92 per cent low and 8 per cent medium in winter season and summer season. The value indicated that soils were low to medium in organic carbon status.

The high content of organic carbon might be due to addition of organic matter through either artificially or naturally and its subsequent decomposition. This result was in confirmatory with results reported by More *et al.* (1987) in soils from salt affected area of Purna command area in Marathwada region. Whereas low to medium content of organic carbon in soil resemblance with poor management and higher temperature. Bacchewar and Gajbhiye (2011) reported that the organic carbon content in soil of Latur district, Maharashtra ranged from 0.21 to 1.28 per cent with an average of 0.75 per cent and also by Raut and Mali (2003).

4) Calcium carbonate

1) Irrigated farmland:

As regards the data on calcium carbonate Table 2, the CaCO$_3$ ranged from 1.20 to 8.00 per cent with average value 3.04 per cent in monsoon season. The soil sample S1 showed lowest calcium carbonate 1.20 per cent while maximum content of CaCO$_3$ 8.00 per cent was recorded in soil sample S7 followed by soil sample S17 (7.50 %). It was also revealed that all soil samples of study area in monsoon season were calcareous to non-calcareous in nature.

The CaCO$_3$ in the soil under winter season varied from 1.20 to 7.80 per cent with an average value of 3.27 per cent. The lowest CaCO$_3$ (1.20 per cent) in the soil was recorded in S1. Whereas, highest CaCO$_3$ (7.80 per cent) was observed in S7 followed by S8 (7.30 per cent). From the data it was revealed that, soils from study area were non-calcareous to calcareous in nature.
As regards the CaCO$_3$ content (Table 4) of soils from summer season observed that CaCO$_3$ content of soils varied from 1.30 to 8.10 per cent with an average value of 3.72 per cent. The soil S1 showed the lowest CaCO$_3$ (0.30 %), whereas the soil S17 showed the highest CaCO$_3$ content (8.10 %) followed by S10 (7.80 %). It was also revealed that all soil samples of study area in a summer season were non-calcareous to calcareous in nature.

2) Non Irrigated farmland:

As regards the data on calcium carbonate (Table 7), the CaCO$_3$ ranged from 1.60 to 4.60 per cent with an average 1.75 per cent in monsoon. The soil sample S3 showed lowest calcium carbonate content (1.60 %), while the maximum content of calcium carbonate 4.60 per cent was recorded in soil S1 followed by soil sample S7 (1.90 %). Thus soil is non calcareous in nature.

The CaCO$_3$ in the soil under winter season varied from 1.20 to 4.90 per cent with an average value of 1.75 per cent. The lowest CaCO$_3$ (1.20 %) in the soil was recorded in S11. Whereas, highest CaCO$_3$ (4.90 %) was observed in S1 followed by S7 (1.90 %). From the data it was revealed that, all soil samples were non-calcareous in nature.

As regards the CaCO$_3$ content (Table 9) of soils from summer season observed that CaCO$_3$ content of soils varied from 1.10 to 5.60 per cent with an average value of 1.74 per cent. The soil S16 showed the lowest CaCO$_3$ (1.10 %), whereas the soil S1 showed the highest CaCO$_3$ content (5.60 %) followed by S2 (1.60 %). It was also revealed that all soil samples of summer season were non-calcareous in nature.

The soils of study area were 72 per cent low and 28 per cent medium and 0 per cent in high in CaCO$_3$ content. The data indicated that the soils of study area were low to medium in CaCO$_3$ content.

The low to medium CaCO$_3$ content in these soils might be due to fact that the presence of CaCO$_3$ in powdery form and hyperthermic temperature regime of study area. Padole and Mahajan (2003) reported that the CaCO$_3$ content of swell shrink soils of Vidharbha region (Maharashtra) were ranged from 1.34 to 15.56 per cent. Sharma et al. (2003) reported that the CaCO$_3$ content of calcareous and saline-alkaline soils of
East U.P. were ranged from 0.25 to 4 per cent and also by Bacchewar and Gajbhiye (2011).

Data on CEC revealed that the soils in the area can be texturally classified as clay loams to clayey. It is further observed that the values of CEC are very low as compared to the total exchangeable cations. This variation may possibly be due to the clay and organic matter content of soil (Daji, 1985). However, in general CEC value in present soil are high, as compared to the range of 3 to 15 me/100 gm expected from CEC can be considered indicative of halloysite to montmorillouite clay bearing soils that can be categorized silty loam to organic soil.

In general, more the clay and organic matter, higher the CEC in the soil clay content is important because these small particle have a high ratio of surface area to volume. Different types of clay also vary in CEC. Smetites and montmosillite have highest CEC (80-100 me/100 gm) followed by illites (15-40 meg/100 gm) Kaolinites (3-15 meq/100 gm).

4.2 Status of available primary micronutrient

1) Nitrogen (N)

1) Irrigated farmland:

The data on status of N, P and K and their categorization in soils of monsoon season (irrigated) (Table 11 & 14) revealed that the available N content of these soils were ranged from 33.40 to 201.30 kg ha\(^{-1}\) with a mean value of 121.52 kg ha\(^{-1}\). The lowest N content (37.40 kg ha\(^{-1}\)) was observed in soils S14, whereas the highest N content (201.30 kg ha\(^{-1}\)) was recorded in soils S14 followed by S9 (171.00 kg ha\(^{-1}\)). Out of 25 soil samples, all soil samples were in low (< 250 kg ha\(^{-1}\)) in available N content.

Among the 25 soil samples grouped under winter (irrigated) (Table 12 & 14), the available nitrogen content ranged from 35.00 to 189.21 kg ha\(^{-1}\) with a mean value of 104.32 kg ha\(^{-1}\).The lowest available nitrogen (35.00 kg ha\(^{-1}\)) was found in soil sample S14 whereas highest available nitrogen (189.21 kg ha\(^{-1}\)) was observed in soil sample S10 followed by S11 (161.20 kg ha\(^{-1}\)).
Among 25 soil samples of winter all soil samples were low in available nitrogen content.

The data from Table 13 & 14 revealed that the available N content in soils group under summer season (irrigated) ranged from 33.10 to 170.50 kg ha$^{-1}$ with the average value of 98.46 kg ha$^{-1}$. The lowest available N (33.10 kg ha$^{-1}$) was found in soils of S14 and the highest available N (170.50 kg ha$^{-1}$) was observed from soil S10 followed by S13 (218.59 kg ha$^{-1}$).

The data also revealed that out of 25 soil samples grouped under summer all sample were low in nitrogen content.

2) Non Irrigated farmland:

The data on status of N, P and K and their categorization in soils of monsoon season (non irrigated) (Table 15 & 18) revealed that the available N content of these soils were ranged from 58.50 to 133.02 kg ha$^{-1}$ with a mean value of 97.90 kg ha$^{-1}$. The lowest N content (58.50 kg ha$^{-1}$) was observed in soils S20, whereas the highest N content (133.02 kg ha$^{-1}$) was recorded in soils S1 followed by S2 (124.26 kg ha$^{-1}$). Out of 25 soil samples, all soil samples were in low (< 250 kg ha$^{-1}$) in available N content.

Among the 25 soil samples grouped under winter (non irrigated) (Table 16&18), the available nitrogen content ranged from 46.37 to 123.40 kg ha$^{-1}$ with a mean value of 88.44 kg ha$^{-1}$. The lowest available nitrogen (46.37 kg ha$^{-1}$) was found in soil sample S3 whereas highest available nitrogen (123.40 kg ha$^{-1}$) was observed in soil sample S1 followed by S2 (119.20 kg ha$^{-1}$).

Among 25 soil samples of winter all soil samples were low in available nitrogen content.

The data from Table 17 & 18 N, P, K of soil in summer season (non irrigated) revealed that the available N content in soils group under summer season ranged from 40.19 to 115.18 kg ha$^{-1}$ with the average value of 73.84 kg ha$^{-1}$. The lowest available N (40.19 kg ha$^{-1}$) was found in soils S3 and the highest available N (115.18 kg ha$^{-1}$) was observed from soil S1 followed by S2 (93.13 kg ha$^{-1}$).
The data also revealed that out of 25 soil samples grouped under summer all sample were low.

The N, P and K are the key nutrients which required for plant metabolism. Due to imbalance supply and faulty management practices, decrease the availability of these nutrients. Hence it causes wide spread deficiency of N, P and K in soil of irrigated and non irrigated farmlands undertaken for study.

The results in nutshell indicated that the soils of study area were low in available N content. The variation in available N content in soil could be due to regular management like organic matter application, application of fertilizers and inherent soil properties and season temperature variation etc. (Jayaprakash et al., 2012, Patil et. al., 2014). The difference in there physiography, differential cultivation and management practices of these soils but also removal of N by the crop, losses through leaching, denitrification and fixation and volatization take place. Some nitrogen is immobilised by soil microbes, this results in low availability of N in the soil. Ashok Kumar (2010) reported that available N content in soils of Ahmednagar district of Maharashtra varied from 47.00 to 228.9 kg ha\(^{-1}\) Chalwade (2006) also reported that five talukas of Maharashtra Viz. Gangakhed, Palam, Ahmedpur, Loha and Kandhar of Parbhani and Nanded districts were low in available nitrogen content.

2) Phosphorous (P)

1) Irrigated

The available phosphorus content in these soil samples were varied from 8.66 to 57.21 kg ha\(^{-1}\) with a mean value of 21.13 kg ha\(^{-1}\). The lowest P (8.66 kg ha\(^{-1}\)) content was found in soil sample S14 and the highest P content (57.21 kg ha\(^{-1}\)) was recorded in soil sample S13 followed by S16 (34.43 kg ha\(^{-1}\)).

Among 25 soil samples of monsoon collected from study area, 1 sample were low in P content (<10 kg ha\(^{-1}\)), 19 samples were medium in P content (10-25 kg ha\(^{-1}\)) and 5 samples were high in P content (>25 kg ha\(^{-1}\)).

As regard the available phosphorus content in winter the available P content varied from 6.92 to 45.61 kg ha\(^{-1}\) with an average value of 18.22 kg ha\(^{-1}\). The lowest available phosphorus (6.92 kg ha\(^{-1}\)) was found in soil sample S15 and the highest
available phosphorus (45.61 kg ha\(^{-1}\)) was found in soil sample S13 followed by S4 (26.36 kg ha\(^{-1}\)).

Out of 25 soil samples of winter, 01 sample was categorized as low, 21 samples were medium and 3 samples were high in P content.

The available P content in these soils ranged from 6.67 to 36.97 kg ha\(^{-1}\) with an average value of 24.76 kg ha\(^{-1}\). Soil sample S15 showed the lowest available P (6.67 g kg\(^{-1}\)), whereas soil samples S13 showed the highest available P (36.97 kg ha\(^{-1}\)) followed by sample S16 (32.15 kg ha\(^{-1}\)).

Out of 25 soil samples from study area grouped under summer 16 per cent samples were low, 76 per cent samples were medium and 8 per cent sample were high in available P content.

2) Non Irrigated farmland:

The available phosphorus content in these soil samples were varied from 10.2 to 30.6 kg ha\(^{-1}\) with a mean value of 17.22 kg ha\(^{-1}\). The lowest P (10.20 kg ha\(^{-1}\)) content was found in soil sample S9 and the highest P content (30.6 kg ha\(^{-1}\)) was recorded in soil sample S16 followed by S15 (27.21 kg ha\(^{-1}\)).

Among 25 soil samples of monsoon collected from study area 0 samples were categorized as low in P content (<10 kg ha\(^{-1}\)), 22 samples were medium (10-25 kg ha\(^{-1}\)) and 3 samples were high (>25 kg ha\(^{-1}\)) in P content.

As regard the available phosphorus content in winter the available P content varied from 8.02 to 26.82 kg ha\(^{-1}\) with an average value of 14.38 kg ha\(^{-1}\). The lowest available phosphorus (8.02 kg ha\(^{-1}\)) was found in soil sample S10 and the highest available phosphorus (26.82 kg ha\(^{-1}\)) was found in soil sample S3 followed by S18 (22.26 kg ha\(^{-1}\)).

Out of 25 soil samples of winter, 9 samples were categorized as low, 15 samples were medium and 1 sample was high in P content.

The available P content in these soils ranged from 4.81 to 23.38 kg ha\(^{-1}\) with an average value of 12.13 kg ha\(^{-1}\). Soil sample S1 showed the lowest available P (4.81 g kg\(^{-1}\)), whereas soil samples S18 showed the highest available P (23.38 kg ha\(^{-1}\)) followed by sample S11 (18.36 kg ha\(^{-1}\)).
Out of 25 soil samples from study area grouped under summer 52% samples were categorized as low and 48% samples were medium in available P content.

From the data, it was observed that soils of study area were low to medium in available phosphorus content. Variation in availability of phosphorus might be due to variation in soil properties viz. pH, Calcareousness, organic matter content, texture and various soil management and agronomic practices Gajbe et al. (1976) reported that the available P content in the soils of Marathwada region were varied from 25.6 to 51.2 kg ha\(^{-1}\). Ashok Kumar et al. (2010) reported that soil of some typical sugarcane growing areas of Ahmednagar district of Maharashtra were low in P which ranged 0.6 to 28.6 kg ha\(^{-1}\).

3) Potassium (K)

1) Irrigated farmland:

The available K were ranged from 224.15 to 1058.10 kg ha\(^{-1}\) with a mean value of 513.44 kg ha\(^{-1}\). The lowest available K was found in soil sample S7 while highest available K was observed in soil sample S10.

Out of 25 soil samples of monsoon season, 0 samples were categorized as low in available K content (< 150 kg ha\(^{-1}\)), 3 samples were categorized as medium (150-300 kg ha\(^{-1}\)) and 22 samples were high (> 300 kg ha\(^{-1}\)) in available K content.

The available potassium content in soils of study area grouped under winter ranged from 206.16 kg ha\(^{-1}\) to 725.61 kg ha\(^{-1}\) with an average value of 444.95 kg ha\(^{-1}\). The lowest available K (206.16 kg ha\(^{-1}\)) was found in soil sample S7 while the highest available K (725.61 kg ha\(^{-1}\)) was found in soil sample S18 followed by S11 (712.16 kg ha\(^{-1}\)).

Out of the 25 soil samples of winter season (0%) soil sample were low in available K, (12%) soil sample were medium and (88%) soil samples were high in available K.

The available K content in soils grouped under summer ranged from 204.85 to 1036.5 kg ha\(^{-1}\) with a mean value of 469.50 kg ha\(^{-1}\). Soil sample S7 showed the lowest available K 204.85 kg ha\(^{-1}\), whereas the highest available K content (1036.5 kg ha\(^{-1}\)) was found in soil sample S13 followed by S10 (830.38 kg ha\(^{-1}\)).
Out of 25 soil samples of summer 0% soil sample was found to be categorized as low, 16% soil samples were medium and 84% soil samples were found high in available K content.

2) Non Irrigated

The available K were ranged from 214.30 to 493.41 kg ha\(^{-1}\) with a mean value of 307.58 kg ha\(^{-1}\). The lowest available K was found in soil sample S18 while highest available K was observed in soil sample S11.

Out of 25 soil samples of monsoon season, 0 samples were low in available K content (< 150 kg ha\(^{-1}\)), 13 samples were categorized as medium (150-300 kg ha\(^{-1}\)) and 12 samples were high (> 300 kg ha\(^{-1}\)) in available K content.

The available potassium content in soils of study area grouped under winter ranged from 177.15 kg ha\(^{-1}\) to 980.88 kg ha\(^{-1}\) with an average value of 324.21 kg ha\(^{-1}\). The lowest available K (177.15 kg ha\(^{-1}\)) was found in soil sample S6 while the highest available K (980.88 kg ha\(^{-1}\)) was found in soil sample S10 followed by S16 (467.43 kg ha\(^{-1}\)).

Out of the 25 soil samples of winter season 0% soil sample were low in available K, 52% soil sample were medium and 48% soil samples were high in available K.

The available K content in soils grouped under summer ranged from 182.80 to 444.28 kg ha\(^{-1}\) with a mean value of 284.44 kg ha\(^{-1}\). Soil sample S6 showed the lowest available K (182.80 kg ha\(^{-1}\)), whereas the highest available K content (444.28 kg ha\(^{-1}\)) was found in soil sample S2 followed by S1 (410.42 kg ha\(^{-1}\)).

Out of 25 soil samples of summer 0% soil sample was found to be categorized as low, 56% soil samples were medium and 44% soil samples were found high in available K content.

From the above data, it showed that the soil of study area were medium to high in K content. The high content of K might be due to presence of smectite type of silicate clay minerals, it may also be due to the presence of K bearing mineral like feldspar and mica in the parent material and also due to creation of favourable environment with presence of high organic matter. Malewar et al. (1995) reported that the available K\(_2\)O content in soils Maharashtra were varied from 318.00 to 616 kg ha\(^{-1}\).
Waikar *et al.* (2003) analysed the soils of Marathwada region and reported that the available K content was ranged from 303 to 512 kg ha\(^{-1}\). More and Gavali (2000) reported that the available potassium in swell shrink soils of different talukas of Parbhani Maharashtra ranged from 120 to 370 mg kg\(^{-1}\) with mean value of 228.00 mg kg\(^{-1}\). Similar finding was also reported by Meena *et al.* (2006).

### 4.3 Status of available Secondary macronutrients Ca, Mg and S:

#### 1) Sulphur (S)

##### 1) Irrigated farmland:

The data on status available S, exchangeable Ca++ and Mg++ of soils of study area are presented in Table 19 and 22. The available sulphur contents in soils of study area grouped under monsoon season (irrigated) were ranged from 3.42 to 14.55 mg kg\(^{-1}\) with an average value of 8.09 mg kg\(^{-1}\). The lowest available S (3.42 mg kg\(^{-1}\)) was recorded in soils S15, while highest available S (14.55 mg kg\(^{-1}\)) followed by S13 (11.55 mg kg\(^{-1}\)).

Out of 25 soil samples grouped under monsoon 8% samples were categorized as low, 72% samples were medium and 20% samples were found high in available S content.

The data on status of available S, exchangeable Ca++ and Mg++ of soils of study area are presented in Table 20 and 22. The available sulphur content in soils of study area grouped under winter (irrigated) were ranged from 2.82 to 10.20 mg kg\(^{-1}\) with an average value of 6.97 mg kg\(^{-1}\). The lowest value of S (2.82 mg kg\(^{-1}\)) was recorded in soil sample S15 while highest value of S content (10.20 mg kg\(^{-1}\)) was recorded in soil sample S4 followed by S3 (9.19 mg kg\(^{-1}\)).

Out of 25 soil samples, 0 per cent samples were low, 96 per cent soil samples were medium and 4 per cent samples were high in available sulphur content.

The data on status of available S, exchangeable Ca++ and Mg++ in soils of study area summer season (irrigated) are presented in Table 21 and 22. The available sulphur content in soils of study area were ranged from 2.22 to 16.90 mg kg\(^{-1}\) with an average value of 6.40 mg kg\(^{-1}\). The lowest S (2.22 mg kg\(^{-1}\)) was recorded in soils
samples S15 while highest value of S (16.90 mg kg\(^{-1}\)) was recorded in soil sample S13 followed by S16 (11.19 mg kg\(^{-1}\)).

Among the 25 soil samples grouped under summer 24 per cent samples were low, 68 per cent samples were medium and 8 per cent samples were high in available sulphur content.

2) Non Irrigated farmland:

The data on status available S, exchangeable Ca++ and Mg++ of soils of study area are presented in Table 23 and 26. The available sulphur contents in soils of study area grouped under monsoon season (non irrigated) were ranged from 3.67 to 12.80 mg kg\(^{-1}\) with an average value of 6.17 mg kg\(^{-1}\). The lowest available S (3.67 mg kg\(^{-1}\)) was recorded in soils S16, while highest available S (12.80 mg kg\(^{-1}\)) was recorded in soil S3 followed by S1 (11.39 mg kg\(^{-1}\)).

Out of 25 soil samples grouped under monsoon (64%) samples were low, (24%) samples were medium and (8%) samples were found high in available S content.

The data on status of available S, exchangeable Ca++ and Mg++ of soils of study area are presented in Table 24 and 26. The available sulphur content in soils of study area grouped under winter (non irrigated) were ranged from 2.89 to 10.10 mg kg\(^{-1}\) with an average value of 5.37 mg kg\(^{-1}\). The lowest value of S (2.89 mg kg\(^{-1}\)) was recorded in soil sample S16 while highest value of S content (10.10 mg kg\(^{-1}\)) was recorded in soil sample S1 followed by S2 (9.36 mg kg\(^{-1}\)).

Out of 25 soil samples, 72 per cent samples were categorized as low, 24 per cent soil samples were medium and 4 per cent samples were high in available sulphur content.

The data on status of available S, exchangeable Ca++ and Mg++ in soils of study area in summer season (non irrigated) are presented in Table 25 and 26. The available sulphur content in soils of study area were ranged from 2.21 to 10.00 mg kg\(^{-1}\) with an average value of 4.76 mg kg\(^{-1}\). The lowest S (2.21 mg kg\(^{-1}\)) was recorded in soils samples S9 while highest value of S (10.00 mg kg\(^{-1}\)) was recorded in soil sample S1 followed by S3 (8.81 mg kg\(^{-1}\)).
Among the 25 soil samples grouped under summer, 24 per cent samples were categorized as low, 60 per cent samples were medium, and 16 per cent samples were high in available sulphur content.

The soils from irrigated farmlands were 8 per cent low, 72 per cent medium and 20 per cent high in available S content in monsoon. 8 per cent low, 88 per cent medium and 4 per cent high in winter season and 24 per cent low, 68 per cent medium and 8 per cent high in summer season. While soils from non-irrigated farmlands were 60 per cent low, 24 per cent medium and 4 per cent high in monsoon, 72 per cent low, 24 per cent medium and 4 per cent high in winter and 68 per cent low, 24 per cent medium and 8 per cent high in summer season. The value indicated that the soil of study area were low to medium in available S content. This could be attributed due to medium to high amount of clay content in soils, which can absorb varying amount of S. This might be expected due to presence of Fe and Al oxides in surface soils Singh et al. (2006). Lande et al. (1977) reported that the available sulphur in normal soils of Marathwada inclined towards depletion, which ranged from 8.2 to 42 mg kg\(^{-1}\) but more availability of sulphur 117.6 to 144 mg kg\(^{-1}\) was recorded in saline soil.

2) Ca and Mg

Data on status exchangeable Ca++ and Mg++ of soil of study area are presented Table No. 19, 20, 21 and 22.

1) Irrigated farmland:

The data further revealed that the exchangeable Ca++ content of these soils were ranged from 17.90 to 49.00 Cmol(P+) kg\(^{-1}\) with an average value of 31.00 Cmol(P+) kg\(^{-1}\). The lowest exchangeable Ca++ (17.90 Cmol(P+) kg\(^{-1}\)) was recorded in soils S19, whereas highest exchangeable Ca++ (49.00 Cmol(P+) kg\(^{-1}\)) was observed in soils S5 followed by S3 (48.50 Cmol(P+) kg\(^{-1}\)).

All 25 soil samples grouped under monsoon were high in exchangeable Ca++ content.

The exchangeable Mg++ content in soils of study area were varied from 6.90 to 19.80 Cmol(P+) kg\(^{-1}\) with a mean value of 14.93 Cmol(P+) kg\(^{-1}\). The lowest value of exchangeable Mg++ (6.90 Cmol (P+) kg\(^{-1}\)) was observed in soil sample S14 while
highest value of exchangeable Mg++ (19.80 Cmol (P+) kg\(^{-1}\)) was recorded in soil sample S2 followed by S10 (19.00 Cmol(P+) kg\(^{-1}\)).

The data revealed that all of the 25 soil samples grouped under monsoon were high in exchangeable Mg++.

The data revealed that the exchangeable Ca++ content (Table 20) of these soils were ranged from 26.60 to 61.30 Cmol(P+) kg\(^{-1}\) with an average value of 43.06 Cmol(P+) kg\(^{-1}\). The lowest exchangeable Ca++ (26.60 Cmol(P+) kg\(^{-1}\)) was recorded in soils S1, while highest exchangeable Ca++ content (61.30 Cmol(P+) kg\(^{-1}\)) was observed in soils S12 followed by S11 (61.00 cmol(P+) kg\(^{-1}\)).

The data revealed that all the 25 soil samples of study area contain high exchangeable Ca++.

The exchangeable Mg++ content in soils of study area were varied from 8.70 to 28.60 Cmol(P+) kg\(^{-1}\) with a mean value of 15.85 Cmol(P+) kg\(^{-1}\). The lowest Mg++ content (8.70 Cmol(P+) kg\(^{-1}\)) was recorded in soils samples S14, while highest Mg++ content (28.60 Cmol(P+) kg\(^{-1}\)) was recorded in soil sample S7 followed by S17 (22.10 Cmol(P+) kg\(^{-1}\)). All the 25 soil samples of study area grouped under winter contain high exchangeable Mg++.

From the data presented in Table 21 it was revealed that the exchangeable Ca++ content of these soils in summer season (irrigated) were ranged from 17.80 to 48.90 Cmol(P+) kg\(^{-1}\) with an average value of 31.10 Cmol(P+) kg\(^{-1}\). The lowest values of exchangeable Ca++ (17.80 Cmol(P+) kg\(^{-1}\)) was recorded in soils S19, while highest exchangeable Ca++ (48.90 Cmol(P+) kg\(^{-1}\)) was observed in soils S5 followed by S3 (47.80 Cmol(P+) kg\(^{-1}\)). All 25 soil samples grouped under summer showed high content of exchangeable Ca++.

The data presented in Table 21 also revealed that the exchangeable Mg++ content in soils of study area grouped under summer season (irrigated) ranged from 6.80 to 19.30 Cmol(P+) kg\(^{-1}\) with a mean value of 14.79 Cmol(P+) kg\(^{-1}\). The lowest Mg++ (6.80 Cmol(P+) kg\(^{-1}\)) was observed in soils S14 while the highest Mg++ (19.30 Cmol(P+) kg\(^{-1}\)) was recorded in soils S7 followed by S5 (19.20 Cmol(P+) kg\(^{-1}\)). All the 25 soil samples grouped under summer showed high content of exchangeable Mg++.
2) Non Irrigated farmland:

The data on status of exchangeable Ca++ and Mg++ of soil of non irrigated farmlands of study area are presented in Table 23, 24, 25 & 26.

The data further revealed that the exchangeable Ca++ content of these soils in monsoon season (non irrigated) were ranged from 21.20 to 29.60 Cmol (P+) kg$^{-1}$ with an average value of 26.26 Cmol (P+) kg$^{-1}$. The lowest exchangeable Ca++ (21.20 Cmol (P+) kg$^{-1}$) was recorded in soils S10, whereas highest exchangeable Ca++ (29.60 Cmol(P+) kg$^{-1}$) was observed in soils S10 followed by S1 (28.90 Cmol(P+) kg$^{-1}$).

All 25 soil samples grouped under monsoon were high in exchangeable Ca++ content.

The exchangeable Mg++ content in soils of study area were varied from 12.00 to 17.50 Cmol(P+) kg$^{-1}$ with a mean value of 14.94 Cmol(P+) kg$^{-1}$. The lowest value of exchangeable Mg++ (12.00 Cmol(P+) kg$^{-1}$) was observed in soil sample S10 while highest value of exchangeable Mg++ (17.50 Cmol(P+) kg$^{-1}$) was recorded in soil sample S2 followed by S3 (16.50 Cmol(P+) kg$^{-1}$).

The data revealed that all of the 25 soil samples grouped under monsoon were high in exchangeable Mg++.

The data presented in Table 24 revealed that the exchangeable Ca++ content of these soils in winter season (non irrigated) were ranged from 33.10 to 48.30 Cmol(P+) kg$^{-1}$ with an average value of 39.48 Cmol(P+) kg$^{-1}$. The lowest exchangeable Ca++ (33.10 Cmol(P+) kg$^{-1}$) was recorded in soils S15, while highest exchangeable Ca++ content (48.30 Cmol(P+) kg$^{-1}$) was observed in soils S4 followed by S3 (47.10 Cmol(P+) kg$^{-1}$).

The data revealed that all the 25 soil samples of study area contain high exchangeable Ca++.

The exchangeable Mg++ content in soils of study area were varied from 11.80 to 28.60 Cmol(P+) kg$^{-1}$ with a mean value of 17.11 Cmol(P+) kg$^{-1}$. The lowest Mg++ content (11.80 Cmol(P+) kg$^{-1}$) was recorded in soil sample S1, while highest Mg++ content (28.60 Cmol(P+) kg$^{-1}$) was recorded in soil sample S7 followed by S10 (21.30
Cmol(P+) kg\(^{-1}\)). All the 25 soil samples of study area grouped under winter contain high exchangeable Mg++.

From the data presented in Table 25 it was revealed that the exchangeable Ca++ content of these soils in summer season (non irrigated) were ranged from 20.20 to 27.10 Cmol (P+) kg\(^{-1}\) with an average value of 24.82 Cmol(P+) kg\(^{-1}\). The lowest values of exchangeable Ca++ (20.20 Cmol(P+) kg\(^{-1}\)) was recorded in soils S10, while highest exchangeable Ca++ (27.10 Cmol(P+) kg\(^{-1}\)) was observed in soils S2 followed by S1 (26.80 Cmol(P+) kg\(^{-1}\)). All 25 soil samples grouped under summer showed high content of exchangeable Ca++.

The data presented in Table 25 also revealed that the exchangeable Mg++ content in soils of study area grouped under summer ranged from 9.10 to 16.80 Cmol(P+) kg\(^{-1}\) with a mean value of 13.95 Cmol(P+) kg\(^{-1}\). The lowest Mg++ (9.10 Cmol(P+) kg\(^{-1}\)) was observed in soils S23 while the highest Mg++ (16.80 Cmol(P+) kg\(^{-1}\)) was recorded in soils S2 followed by S3 (15.80 Cmol(P+) kg\(^{-1}\)). All the 25 soil samples grouped under summer showed high content of exchangeable Mg++.

The soil of study area was high in exchangeable Ca and Mg content. The data narrated that the maximum calcium and magnesium found in monsoon 100 per cent, winter 100 per cent and summer 100 %. The values indicated that all the soils of study area were high in exchangeable Ca and Mg. This might be due to more content of CaCO\(_3\) and organic matter. Bacchewar and Gajbhiye (2011) reported that exchangeable calcium content in the soils of Latur district, Maharashtra ranged from 13.00 to 52.00 cmol kg\(^{-1}\) with mean value of 37.8 cmol kg\(^{-1}\). Singh et al. (2004) reported that Mg content in acid soils of Manipur varied from 0.4 to 8.5 mg kg\(^{-1}\).

5.1. Status of available micronutrients (Fe, Cu, Mn & Zn) in soil of irrigated and non irrigated farmland

1) Iron (Fe)

1) Irrigated farmland:

The data on DTPA (Diethylene Triamine Pentacetic acid) extractable Fe, Cu, Mn and Zn and their categorization were tabulated in Table 27 and 30. The DTPA extractable Fe content of these soil samples were varied from 2.024 to 4.82 mg kg\(^{-1}\).
with an average value of 3.19 mg kg\(^{-1}\). The lowest DTPA extractable Fe content (2.024 mg kg\(^{-1}\)) was recorded in soil sample S9, while highest DTPA extractable Fe content (4.82 mg kg\(^{-1}\)) was observed in soil sample S24 followed by S17 (3.838 mg kg\(^{-1}\)).

Out of 25 soil samples 5 samples were categorized as low, 18 samples were medium and 2 samples were high in DTPA extractable Fe content.

The data presented in Table 28 and 30 indicated that the DTPA extractable Fe content of these soils were ranged from 2.001 to 4.81 mg kg\(^{-1}\) with an average value of 3.09 mg kg\(^{-1}\). The lowest DTPA extractable Fe (2.01 mg kg\(^{-1}\)) found in soil sample S3 while highest content of DTPA extractable Fe (4.81 mg kg\(^{-1}\)) was observed in soil S17 followed by S21 (4.102 mg kg\(^{-1}\)).

Out of 25 soil samples grouped under winter 03 samples was low (<2.5 mg kg\(^{-1}\)), 22 samples were medium (2.5 to 4.5 mg kg\(^{-1}\)) and none of the samples were high (> 4.5 mg kg\(^{-1}\)) in DTPA extractable Fe content.

The data presented in Table 29 to 30 indicated that the DTPA extractable Fe content of these soils were ranged from 1.881 to 4.071 mg kg\(^{-1}\) with an average value of 2.84 mg kg\(^{-1}\). The lowest DTPA extractable Fe (1.881 mg kg\(^{-1}\)) content was found in soil sample S4, while highest (4.071 mg kg\(^{-1}\)) content was observed in soil S15 followed by S14 (4.001 mg kg\(^{-1}\)).

Out of 25 soil samples, 8 samples were low (<2.5 mg kg\(^{-1}\)), 16 samples were medium (2.5 to 4.5 mg kg\(^{-1}\)) and none of the samples (> 4.5 mg kg\(^{-1}\)) were high in DTPA extractable Fe content.

2) Non Irrigated farmland:

The data on DTPA Fe, Cu, Mn and Zn and their categorization were tabulated in Table 31 and 34. The DTPA extractable Fe content of these soil samples were varied from 2.052 to 4.354 mg kg\(^{-1}\) with an average value of 2.85 mg kg\(^{-1}\). The lowest DTPA extractable Fe content (2.052 mg kg\(^{-1}\)) was recorded in soil sample S2, while highest DTPA extractable Fe content (4.354 mg kg\(^{-1}\)) was observed in soil sample S7 followed by S4 (3.838 mg kg\(^{-1}\)).
Out of 25 soil samples 11 samples were low and 14 samples were medium in DTPA extractable Fe content.

The data presented in Table 32 and 34 indicated that the DTPA extractable Fe content of these soils were ranged from 1.603 to 4.012 mg kg\(^{-1}\) with an average value of 2.68 mg kg\(^{-1}\). The lowest DTPA extractable Fe (1.603 mg kg\(^{-1}\)) found in soil sample S18 while highest content of DTPA extractable Fe (4.012 mg kg\(^{-1}\)) was observed in soil S4 followed by S10 (3.998 mg kg\(^{-1}\)).

Out of 25 soil samples grouped under winter 15 samples was low (<2.5 mg kg\(^{-1}\)), 10 samples were medium (2.5 to 4.5 mg kg\(^{-1}\)) and none of the samples were high (> 4.5 mg kg\(^{-1}\)) in DTPA extractable Fe content.

The data presented in Table 33 to 34 indicated that the DTPA extractable Fe content of these soils were ranged from 1.01 to 6.210 mg kg\(^{-1}\) with an average value of 2.62 mg kg\(^{-1}\). The lowest DTPA extractable Fe (1.01 mg kg\(^{-1}\)) was found in soil sample S11, while highest (6.210 mg kg\(^{-1}\)) was observed in soil S13 followed by S12 (6.010 mg kg\(^{-1}\)).

Out of 25 soil samples, 13 samples were low (<2.5 mg kg\(^{-1}\)), 7 samples were medium (2.5 to 4.5 mg kg\(^{-1}\)) and 5 samples (> 4.5 mg kg\(^{-1}\)) were high in DTPA extractable Fe content.

The soils of study area were found low to medium in DTPA Fe content. This low to moderate DTPA Fe content in soil may be due to absence of mineral like feldspar, magnetite, Hematite and Limonite which together constitute bulk of trap rack in these soils. It is also due uptake by high yielding crop varieties under intensive cropping. Malewar and Ismail (1999) reported that the DTPA Fe content of Marathwada soil samples were ranged from 0.36 to 25.15 mg kg\(^{-1}\). Dhange \textit{et al.} (2000) reported that DTPA - Fe of soils of Shevgaon Tahsil of Ahmadnagar district Maharashtra were ranged between 2.22 to 9.06 ppm. Gupta (2005) reported that 11.2 per cent of Indian soils are deficient in DTPA extractable iron.

2) Zinc (Zn)

1) Irrigated farmland:

The data revealed that the DTPA extractable Zn in these soil samples were ranged from 0.25 to 1.224 mg kg\(^{-1}\) with a mean value of 0.49 mg kg\(^{-1}\). The lowest
DPTA extractable Zn content (0.25 mg kg⁻¹) was observed in soil sample S25, while highest DPTA extractable Zn content (1.224 mg kg⁻¹) was recorded in soil sample S22 followed by S4 (0.878 mg kg⁻¹).

Among 25 soil samples, 18 samples were low (< 0.6), 7 samples were moderate (0.6 to 1.2) and 0 samples was categorized in high (>1.2) DTPA extractable Zn content.

The data presented in Table 28 and 30 revealed that the data revealed that the DTPA extractable Zn content in soils of study area were ranged from 0.217 to 1.221 mg kg⁻¹ with a mean value of 0.53 mg kg⁻¹. The lowest DTPA extractable Zn (1.221 mg kg⁻¹) was recorded in soil S15. While highest DTPA extractable Zn (0.889 mg kg⁻¹) was observed in soils S17 followed by soil sample S22 (0.889 mg kg⁻¹).

Out of 25 soil samples, 19 samples were in low (< 0.60 mg kg⁻¹), 6 samples were medium (0.60 to 1.12 mg kg⁻¹) and none of the sample showed high in DTPA extractable Zn content.

The data presented in Table 29 and 30 indicated that the DTPA extractable Zn content in soils of study area were ranged from 0.200 to 0.981 mg kg⁻¹ with a mean value of 0.48 mg kg⁻¹. The lowest DTPA extractable Zn content (0.200 mg kg⁻¹) was recorded in soils sample S7, while highest DTPA extractable Zn content (0.981mg kg⁻¹) was observed in soils S16 followed by soil sample S22 (0.893 mg kg⁻¹).

Out of 25 soil samples, 18 samples were low (<0.60 mg kg⁻¹), 7 samples were medium (0.62 to 1.12 mg kg⁻¹) and none of the samples was categorized under high (>1.2 mg kg⁻¹) in DTPA extractable Zn content.

2) Non Irrigated farmland:

The data presented in Table 31 and 34 revealed that the DTPA extractable Zn in these soils were ranged from 2.392 to 7.15 mg kg⁻¹ with a mean value of 0.56 mg kg⁻¹. The lowest DPTA extractable Zn content (0.276 mg kg⁻¹) was observed soil sample S5, while highest DPTA extractable Zn content (0.732 mg kg⁻¹) was recorded in soil sample S18 followed by S6 (0.640 mg kg⁻¹).
Among 25 soil samples, 16 samples were categorized as low (< 0.6), 9 samples were moderate (0.6 to 1.2) and 0 samples was categorized in high (>1.2) DTPA extractable Zn content.

The data presented in Table 32 and 34 revealed that the DTPA extractable Zn content in soils of study area were ranged from 0.239 to 0.669 mg kg\(^{-1}\) with a mean value of 0.46 mg kg\(^{-1}\). The lowest DTPA extractable Zn (0.239 mg kg\(^{-1}\)) was recorded in soil S12. While highest DTPA extractable Zn (0.669 mg kg\(^{-1}\)) was observed in soils S2 followed by soil sample S4 (0.601 mg kg\(^{-1}\)).

Out of 25 soil samples, 20 samples were in low (< 0.60 mg kg\(^{-1}\)), 5 samples were medium (0.60 to 1.12 mg kg\(^{-1}\)) and none of the sample showed high in DTPA extractable Zn content.

The data presented in Table 33 and 34 indicated that the DTPA extractable Zn content in soils of study area were ranged from 0.231 to 0.900 mg kg\(^{-1}\) with a mean value of 0.76 mg kg\(^{-1}\). The lowest DTPA extractable Zn content (0.231 mg kg\(^{-1}\)) was recorded in soils sample S12, while highest DTPA extractable Zn content (0.900mg kg\(^{-1}\)) was observed in soils S8 followed by soil sample S15 (0.693 mg kg\(^{-1}\)).

Out of 25 soil samples, 22 samples were low (<0.60 mg kg\(^{-1}\)), 3 samples were medium (0.62 to 1.12 mg kg\(^{-1}\)) and none of the samples was categorized under high (>1.2 mg kg\(^{-1}\)) in DTPA extractable Zn content.

DTPA Zn content in soils of study area was low to medium. Majority of these soils were marginal or poor in DTPA Zn content. This might be due to fact that under alkaline condition, the zinc cations are changed largely to their oxides or hydroxide and their by lower the availability of zinc. Kadao et al. (2002) reported that banana growing soils of Wardha district, Maharashtra, the DTPA extractable Zn content varied from 0.15 to 0.58 mg kg\(^{-1}\). Nazif et al. (2006) reported that soils of district Ithimber (Azad Jammu and Kashmir) the DTPA extractable Zn ranged from 0.74 to 2.08 mg kg\(^{-1}\). The low content of DTPA Zn might be due to low organic matter and high CaCO\(_3\) content in these soil samples.
3) Manganese (Mn)

1) Irrigated farmland:

The data of DTPA Mn and their categorization are presented in Table 27 and 30. Further data revealed that the available DTPA extractable Mn content in these soils was varied from 2.74 to 9.156 mg kg\(^{-1}\) with a mean value of 3.65 mg kg\(^{-1}\). The lowest DTPA extractable Mn content (2.24 mg kg\(^{-1}\)) was recorded in soils S23 while highest DPTA extractable Mn content (9.156 mg kg\(^{-1}\)) was found in soils S6 followed by S13 (5.726 mg kg\(^{-1}\)).

Among the 25 soil samples, 0 sample showed low (<2 mg kg\(^{-1}\)), 21 samples were medium (2-5 mg kg\(^{-1}\)) and 4 sample were (> 5 mg kg\(^{-1}\)) in DTPA extractable Mn content.

The DTPA extractable Mn content of these soil samples were varied from 1.013 to 5.078 mg kg\(^{-1}\) with a mean value of 2.74 mg kg\(^{-1}\). The lowest DTPA extractable Mn content (1.013 mg kg\(^{-1}\)) was recorded in soil S7, while highest DTPA extractable Mn (5.078 mg kg\(^{-1}\)) content was observed in S13 followed by S11 (4.998 mg kg\(^{-1}\)).

Out of 25 soil samples, 6 samples were low (< 5 mg kg\(^{-1}\)), 18 samples were medium (2 to 5 mg kg\(^{-1}\)) and 1 samples were high (> 5 mg kg\(^{-1}\)) in DTPA extractable Mn content.

The DTPA extractable Mn content of these soil samples were varied from 1.001 to 7.261 mg kg\(^{-1}\) with a mean value of 2.84 mg kg\(^{-1}\). The lowest DTPA extractable Mn (0.491 mg kg\(^{-1}\)) was recorded in soil S7, while highest DTPA extractable Mn content (7.261 mg kg\(^{-1}\)) was observed in soil sample S6 followed by S13 (4.91 mg kg\(^{-1}\)).

Out of 25 soil samples, 9 samples were categorized as low, (< 2 mg kg\(^{-1}\)), 15 samples were medium (2 to 5 mg kg\(^{-1}\)) and 01 samples were high (> 5 mg kg\(^{-1}\)) in DTPA extractable Mn content.

2) Non Irrigated farmland:

The data of DTPA Mn and their categorization are presented in Table 31 and 34. Further data revealed that the available DTPA extractable Mn content in these
soils was varied from 2.392 to 7.15 mg kg\(^{-1}\) with a mean value of 4.14 mg kg\(^{-1}\). The lowest DTPA extractable Mn content (1.392 mg kg\(^{-1}\)) was recorded in soils S21 while highest DTPA extractable Mn content (7.150 mg kg\(^{-1}\)) was found in soils S6 followed by S8 (6.430 mg kg\(^{-1}\)).

Among the 25 soil samples, 0 sample showed low (<2 mg kg\(^{-1}\)), 15 samples were medium (2-5 mg kg\(^{-1}\)) and 10 samples were high (> 5 mg kg\(^{-1}\)) in DTPA extractable Mn content.

The DTPA extractable Mn content of these soil samples were varied from 2.21 to 6.714 mg kg\(^{-1}\) with a mean value of 4.14 mg kg\(^{-1}\). The lowest DTPA extractable Mn content (2.21 mg kg\(^{-1}\)) was recorded in soil S1, while highest DTPA extractable Mn (6.714 mg kg\(^{-1}\)) content was observed in S2 followed by S3 (6.661 mg kg\(^{-1}\)).

Out of 25 soil samples, 0 samples were low (<5 mg kg\(^{-1}\)), 17 samples were medium (2 to 5 mg kg\(^{-1}\)) and 8 samples were high (> 5 mg kg\(^{-1}\)) in DTPA extractable Mn content.

The DTPA extractable Mn content of these soil samples were varied from 2.017 to 6.171 mg kg\(^{-1}\) with a mean value of 3.47 mg kg\(^{-1}\). The lowest DTPA extractable Mn (2.017 mg kg\(^{-1}\)) was recorded in soil S1, while highest DTPA extractable Mn content (6.171 mg kg\(^{-1}\)) was observed in soil sample S6 followed by S2 (4.617 mg kg\(^{-1}\)).

Out of 25 soil samples, 0 samples were categorized as low (< 2 mg kg\(^{-1}\)), 24 samples were medium (2 to 5 mg kg\(^{-1}\)) and 01 samples were high (> 5 mg kg\(^{-1}\)) in DTPA extractable Mn content.

The data on DTPA Mn content in soils of study area were low to high. The high status of DTPA Mn in the soils might be due to the fact that lower oxidation (reduced) status of DTPA Mn is more soluble than higher oxidation state at normal pH range of soil. Oxidation of divalent Mn\(^{++}\) to trivalent, Mn\(^{+++}\) by certain fungi and bacteria, also some organic compounds synthesised by micro organism or released by plants as root exudates have oxidizing or reducing power. These result in confirmatory with Takale et al. (1977). Saraswat et al. (2005) reported that DTPA extractable Mn of these soil samples were ranged from 2.4 to 6.4 mg kg\(^{-1}\).
4) Copper (Cu)

1) Irrigated farmland:

The data of DTPA Cu and their categorization are presented in Table 27 and 30. The DTPA-Cu content grouped under monsoon (irrigated) in the soils of study area was ranged from 0.102 to 5.418 mg kg\(^{-1}\) with a mean value of 2.86 mg kg\(^{-1}\). The lowest DTPA-Cu content (0.102 mg kg\(^{-1}\)) was observed in soils S11 whereas, highest DTPA-Cu content (5.418 mg kg\(^{-1}\)) was found in soils S1 followed by S7 (4.85 mg kg\(^{-1}\)).

Out of 25 soil samples from study area 1 soil sample was low and remaining 24 soil samples were categorized under high DTPA-Cu content. The data of DTPA Cu and their categorization are presented in Table 28 and 30. The DTPA-Cu contents in soils of study area grouped under winter (irrigated) were ranged from 1.613 to 4.612 mg kg\(^{-1}\) with an average value of 2.46 mg kg\(^{-1}\). The lowest value of DTPA-Cu (1.613 mg kg\(^{-1}\)) content was recorded in soil sample S25, whereas highest DTPA-Cu (4.612 mg kg\(^{-1}\)) was recorded in soils samples S4 followed by S7 (3.911 mg kg\(^{-1}\)). All soil samples 25 showed high content of DTPA-Cu.

The data of DTPA Cu and their categorization are presented in Table 29 and 30. The DTPA-Cu contents of study area soils in summer season (irrigated) were ranged from 0.670 to 4.981 mg kg\(^{-1}\) with an average value of 2.19 mg kg\(^{-1}\). The lowest DTPA-Cu content (0.670 mg kg\(^{-1}\)) was recorded in soil sample S11, whereas highest value of DTPA-Cu (4.981 mg kg\(^{-1}\)) was recorded in soils S1 followed by S7 (3.610 mg kg\(^{-1}\)).

Out of 25 soil samples, all samples were high in DTPA-Cu content.

2) Non Irrigated farmland:

The data of DTPA Cu and their categorization are presented in Table 31 and 34. The DTPA-Cu content grouped under monsoon (non irrigated) in the soils of study area was ranged from 0.676 to 6.746 mg kg\(^{-1}\) with a mean value of 2.58 mg kg\(^{-1}\). The lowest DTPA-Cu content (0.676 mg kg\(^{-1}\)) was observed in soils S3 whereas, highest DTPA-Cu content (6.741 mg kg\(^{-1}\)) was found in soils S18 followed by S1 (4.488 mg kg\(^{-1}\)).
Out of 25 soil samples from study area all 25 soil samples were categorized under high DTPA-Cu content.

The data of DTPA Cu and their categorization are presented in Table 32 and 34. The DTPA-Cu contents in soils of study area grouped under winter (non irrigated) were ranged from 1.631 to 4.017 mg kg\(^{-1}\) with an average value of 2.90 mg kg\(^{-1}\). The lowest value of DTPA-Cu (1.631 mg kg\(^{-1}\)) content was recorded in soil sample S7, whereas highest DTPA-Cu (4.017 mg kg\(^{-1}\)) was recorded in soils samples S5 followed by S2 (3.861 mg kg\(^{-1}\)). All 25 soil samples showed high content of DTPA-Cu.

The data of DTPA Cu and their categorization are presented in Table 33 and 34. The DTPA-Cu contents of study area soils in summer season (non irrigated) were ranged from 0.348 to 4.117 mg kg\(^{-1}\) with an average value of 2.30 mg kg\(^{-1}\). The lowest DTPA-Cu content (0.348 mg kg\(^{-1}\)) was recorded in soil sample S4, whereas highest value of DTPA-Cu (4.117 mg kg\(^{-1}\)) was recorded in soils S5 followed by S2 (3.691 mg kg\(^{-1}\)).

Out of 25 soil samples, all samples were high in DTPA-Cu content.

As regards to DTPA Cu content, the soil samples of study area were 0.33 per cent low, 0 per cent medium and 99.66 per cent high in DTPA Cu content. The high content of DTPA Cu in these soils was might be due to presence of Cu minerals like cuprites and chalcocite etc. in the parent material. Dhage et al. (2000) reported that DTPA Cu content in the soil of Shevgaon tahsil of Ahmadnagar district, Maharashtra were ranged from 2.04 to 11.38 mg kg\(^{-1}\). Balpande et al. (2007) found that the DTPA Cu contents in grape growing soils of Nasik district of Maharashtra were ranged from 1.16 to 22.00 mg kg\(^{-1}\). Kirmani et al. (2011) reported that soils of Budgam district of Jammu and Kashmir the available Cu content ranged from 0.98 to 14.36 ppm with mean value of 6.15 ppm.

**Derived parameters**

**SAR (Irrigated farmlands)**

Data on SAR value of soil from irrigated farmlands of study area is presented in Table No. 35, 36 & 37. The data indicated that SAR value ranged from 0.77 to 2.00 with an average value 1.37 in monsoon, it ranged from 0.74 to 1.75 with average
value 1.20 in winter season and in summer season it ranged from 0.91 to 1.92 with an average value 1.41.

**ESP (Irrigated farmlands)**

Data on ESP value of soil from non irrigated farmlands of study area is presented in Table No. 35, 36 & 37. The data indicated that ESP value ranged from -0.24 to 1.59 with average value 0.62 in monsoon, it ranged from -0.29 to 1.22 with average value 0.41 in winter season and in summer season it ranged from -0.03 to 1.67 with average value 0.71.

**SAR (Non-Irrigated farmlands)**

Data on SAR value of soil from irrigated farmlands of study area is presented in Table No. 35, 36 & 37. The data indicated that SAR value ranged from 0.85 to 2.07 with average value 1.41 in monsoon, it ranged from 0.82 to 1.86 with average value 1.20 in winter season and in summer season it ranged from 0.92 to 1.97 with average value 1.49.

**ESP (Non-Irrigated farmlands)**

Data on ESP value of soil from non irrigated farmlands of study area is presented in Table No. 35, 36 & 37. The data indicated that ESP value ranged from -0.118 to 1.71 with average value 0.71 in monsoon, it ranged from -0.23 to 1.38 with average value 0.41 in winter season and in summer season it ranged from -0.02 to 1.55 with average value 0.83.

Data on SAR values of soils indicated that all SAR value are low (<10). It is safe. The SAR indicates the tendency of soil to become exchangeable with sodium. Therefore higher SAR values means higher ESP and hence lower soil permeability (Donahue et al., 1987).

The ESP values of 15 are considered as boundary between saline and alkali soils (USDA 1954). Therefore ESP value greater than 15 can be considered indicative of the presence of alkali and those below this value reflects non alkali nature of the soils of study area when prevelage of sodium increase, the soil become none alkaline in reaction. In case of five textured soils with montmorillonite clays, an ESP of 15 is good approximation at which dispersion occurs. However, Kaolinte bearing soils
ESP value may approach 45 to 50 before dispersion is serious (Bauder and Brock, 2001). The soil can be suitable for plant growth if salt content, pH and ESP are low. But when salts accumulate in the soil and sodium salt became more greater quantity of sodium will adsorbed by soil (Yaron, 1981).

### 4.1.10 Soil Nutrient Index

The nutrient index value of primary nutrient, secondary nutrient and some micronutrients viz. Fe, Cu, Mn and Zn of study area represented in Table No. 38, 39 & 40.

The nutrient index value for soil of the study area was low for nitrogen, low for phosphorus and medium to high with respect to potassium, the value worked out from nutrient index for nitrogen, phosphorus and potassium are 1.00, 1.20 & 2.68 respectively against the nutrient index value < 1.67 for low, 1.67 to 2.33 for medium and > 2.33 for high fertility status of area. The high fertility status for magnesium and calcium both are 3.00, while medium in irrigated farmlands and low in non-irrigated farmlands for sulphur. The fertility status of iron and zinc were low, for manganese it is low to medium and for copper it was high the values worked out from nutrient index for Fe, Cu, Mn, Zn are 1.20, 2.98, 1.92 & 1.22 respectively.

### 4.1.11 Correlation between physico-chemical properties and available nutrients in soil (Irrigated)

Various soil properties are associated with the availability of nutrient. Soil characteristics play an important role in the transformation of nutrients. Soil reaction is one of the important soil properties that affect the plant growth and soil organic carbon content is generally considered as the index of soil fertility and sustainability.

The data on correlation between physico-chemical and available nutrients in soil of study area is reported in Table 41. The soil pH \( r=-0.158 \) showed negative non significant correlation with available nitrogen. EC \( r=0.112 \) and CaCO\(_3\) \( r=0.294 \) was found positive correlation with available nitrogen but organic carbon \( r= 0.844^{**} \) showed significant available nitrogen and organic carbon may be due to association of nitrogen with organic carbon, adsorption of N with organic matter and adsorption of ammonical N by humus complex in soil (Kanthaliya and Bhatt, 1991).
The available phosphorus was negatively correlated with pH \( r=-0.255 \), CaCO\(_3\) \( r=-0.052 \) and organic carbon \( r=-0.128 \) whereas it showed significant positive correlation with EC \( r=0.579^{**} \).

The available potassium showed positive correlation with EC \( r=0.337 \) and organic carbon \( r=0.076 \) but it showed negative correlation with pH \( r=-0.032 \) and CaCO\(_3\) \( r=-0.014 \).

The available sulphur showed positive correlation with CaCO\(_3\) \( r=0.201 \) and organic carbon \( r=0.016 \) but it showed significant positive correlation with EC \( r=0.414^{*} \). This might be due to effect of soil pH on availability of sulphur when pH of soil increased, the availability of sulphur decreases. Similar results were also reported by Mali and Raut (2003).

The exchangeable calcium in these soil samples were positive correlated with pH \( r=0.184 \), EC \( r=0.040 \), CaCO\(_3\) \( r=0.103 \) and organic carbon \( r=0.260 \). Similar results were reported by Lande et al. (1977).

The exchangeable magnesium in these soils were positively and significantly correlated with CaCO\(_3\) \( r=0.640^{**} \), organic carbon \( r=0.533^{**} \) and positive correlation with pH \( r=0.217 \) but negatively correlated with EC \( r=-0.059 \) . Similar results were reported by Bachewar and Gujbiye (2011).

The DTPA Fe in these soils were positively correlated with pH\( r=0.236 \) and CaCO\(_3\) \( r=0.107 \) where as it showed negative non significant correlation with EC \( r=-0.264 \) and organic carbon \( r=-0.161 \).

The DTPA Cu showed positive correlation with pH \( r=0.240 \), CaCO\(_3\) \( r=0.194 \) and organic carbon \( r=0.194 \) but show negative correlation with EC \( r=-0.240 \).

The DTPA Zn content in these soils were positively correlated with EC \( r=0.150 \) and negatively correlated with pH \( r=-0.034 \), CaCO\(_3\) \( r=-0.343 \) and organic carbon \( r=-0.116 \).

The DTPA Mn show positive correlation with pH \( r=0.021 \), EC \( r=0.272 \) and CaCO\(_3\) \( r=0.048 \) but negative correlation with organic carbon \( r=-0.231 \).
4.1.11 Correlation between physico-chemical properties and available nutrients in soil (Non Irrigated)

The data on correlation between physicochemical properties and available nutrient in soil is presented in Table 42. The soil pH ($r=0.465^*$), EC ($r=0.453^*$), CaCO$_3$ ($r=0.490^{**}$) and organic carbon ($r=0.628^{**}$) positive significant correlation with nitrogen. The available nitrogen showed close relationship with organic carbon may be due to association of nitrogen with organic matter, adsorption of N with organic matter and adsorption of amonical of N with organic matter and adsorption of amonical N by humus complex in the soil (Kanthalliya and Bhatt, 1991).

The negative correlation of available P with found with soil pH ($r = -0.288$), EC ($r=-0.061$). The available P showed positive correlation with CaCO$_3$ ($r=0.293$) and organic carbon ($r=0.193$). This might be due to the fact that, at high pH calcium can precipitate with phosphorus in Ca-phosphate and reduce phosphorus availability. Similar results were also noted by Meena et al. (2006).

The available potassium showed positive non significant relationship with soil characteristics viz. soil pH ($r=0.047$), EC ($r=0.122$), CaCO$_3$ ($r=0.291$) and organic carbon ($r=0.313$). Similar report were also reported by More and Gavali (2000).

The available sulphur status in soil of study area showed negative correlation with pH ($r=-0.193$) and positive correlation with EC ($r=0.142$), CaCO$_3$ ($r=0.472^*$) and organic carbon ($r=0.308$).

The exchangeable calcium show negative correlation with pH ($r=-0.276$) and positive correlation with EC ($r=0.011$), CaCO$_3$ ($r=0.277$) and organic carbon ($r=0.266$). These results are in confirmatory with result obtained by Khalid et al. (2011).

The exchangeable magnesium show positive relationship with EC ($r=0.124$) and organic carbon ($r=0.011$) and showed negative relationship with pH ($r=-0.075$) and CaCO$_3$ ($r=-0.298$).

The DTPA Fe content in soil of study area negatively correlated with pH ($r=-0.290$), EC ($r=-0.205$), CaCO$_3$ ($r=-0.326$) and organic carbon ($r=-0.545$). The negative relationship of CaCO$_3$ with available Fe might be due to fact that increase in CaCO$_3$
content favors the precipitation of Fe\(^{2+}\) to Fe\(^{3+}\) oxide or transformation of available Fe in to carbonates or bicarbonates present in soil. These results are similar with result reported by Malewar (2004) and Mahashabde et al. (2012).

The negatively correlation was observed between DTPA Mn and pH (r=-0.374), EC (r=-0.211), CaCO\(_3\) (r=-0.285), organic carbon (r=-0.281). Similar results were reported by Sharma et al. (2003).

The DTPA Zn showed negative correlation with soil pH (r=-0.190) and CaCO\(_3\) (r=-0.146) and it showed positive correlation with EC (r=0.178) and organic carbon (r=0.041).

The DTPA Zn in these soil were negatively correlated with pH (r=0.144) and positive correlated with EC (r=0.301), CaCO\(_3\) (r=0.251) and organic carbon (r=0.275). The similar findings were reported by Kadao et al. (2002).

Water

4.2.1 pH

a) Irrigated farmlands

Analytical results of the chemical properties of the irrigation water from irrigated farmlands study area are presented in Table No. 47, 48 & 49. The data indicated that the pH value ranged from 7.05 to 7.56 with average value 7.33 in monsoon season, 7.04 to 7.54 with average value 7.30 in winter season and 7.20 to 7.89 with average value 7.47 in summer season.

b) Non-Irrigated farmlands

Analytical results of the chemical properties of the irrigation water from irrigated farmlands of study area are presented in Table No. 50, 51 & 52. The data indicated that the pH value ranged from 7.05 to 7.49 with average value 7.30 in monsoon season, 7.04 to 7.51 with average value 7.31 in winter season and 7.31 to 7.91 with average value 7.57 in summer season.

Overall data indicated that the pH of these water samples were slightly alkaline in all season viz. monsoon, winter and summer. Further data revealed that the pH of water sample in summer season was higher than in winter and monsoon. This
increase in pH of water sample in summer season might be due to increase in concentration of sodium dominated with carbonates and bicarbonates as compare to monsoon and winter seasons. Lal et al. (1998) reported the pH of irrigation water samples collected from Bikaner district of Rajasthan was alkaline and ranged from 7.10 to 8.8. Similar results were also reported by Mohandas and Marimuthu (2002), Verma et al. (2003) and Khodapanah et al. (2009).

4.2.2 EC

a) Irrigated farmlands:

   The most important water quality guideline crop productivity is the water salinity hazards as measured by electrical conductivity. The data presented in Table No. 47, 48 & 49 revealed that the EC values of irrigation water samples from irrigated farmland were ranged from 0.34 to 0.65 dSm\(^{-1}\) with the average value 0.55 dSm\(^{-1}\) in monsoon season, 0.36 to 0.97 dSm\(^{-1}\) with the average value 0.63 dSm\(^{-1}\) in winter and 0.41 to 0.87 dSm\(^{-1}\) with the average value 0.75 dSm\(^{-1}\) in summer season.

b) Non-Irrigated farmlands

   The data presented in Table No. 50, 51 & 52 revealed that the EC values of irrigation water samples from non irrigated farmland were ranged from 0.34 to 0.65 dSm\(^{-1}\) with the average value 0.52 dSm\(^{-1}\) in monsoon season, 0.36 to 0.69 dSm\(^{-1}\) with the average value 0.54 dSm\(^{-1}\) in winter and 0.41 to 0.87 dSm\(^{-1}\) with the average value 0.75 dSm\(^{-1}\) in summer season.

   It is observed from data that the EC of water sample was higher in summer season as compared to monsoon and winter season. Out of 60 samples, 45 samples were categorized in good quality and 15 samples were categorized in permissible salinity. Further data revealed that 0 per cent of water samples were safe for irrigation, while 75 per cent water samples were safe for irrigation but need moderate leaching and 25 per cent water samples were fairly suitable and cannot be used on soils with restricted drainage.

   In summer season the concentration of EC was higher than in monsoon and winter because in summer season the evaporation rate is higher than winter season that causes decrease in the dilution of water and also due to accumulation of more
soluble salts in irrigation water. Chilkar (2011), Masal (2011) and Patil (2011) Lamture et al. (2014) recorded the EC were high in summer as compared to monsoon. Mahmud et al. (2007), reported the EC value of water sample were ranged from 196 to 483 μScm⁻¹ indicate low C1 and medium C2 salinity classes.

4.2.3 Cations concentration

The concentration of different soluble cations viz. calcium, magnesium, sodium and potassium in irrigation water samples from irrigated and non irrigated farmlands in study area are presented in Table 47, 48, 49 and 50, 51, 52 respectively.

1) Sodium

a) Irrigation farmlands

The data revealed that the Na⁺ content of irrigation water samples from irrigated farmlands were ranged from 0.67 to 1.70 mgL⁻¹ with the average value 1.183 mgL⁻¹ in monsoon season, 0.78 to 1.8 mgL⁻¹ with the average value 1.26 mgL⁻¹ in winter and 1.12 to 2.61 mgL⁻¹ with the average value 1.731 mgL⁻¹ in summer season.

b) Non-Irrigation farmlands

The data revealed that the Na⁺ content of irrigation water samples from non irrigated farmlands were ranged from 0.67 to 1.78 mgL⁻¹ with the average value 1.075 mgL⁻¹ in monsoon season, 0.77 to 1.93 mgL⁻¹ with the average value 1.144 mgL⁻¹ in winter and 1.14 to 2.23 mgL⁻¹ with the average value 1.47 mgL⁻¹ in summer season.

Further data revealed that the Na content of irrigation water samples were higher in summer season as compared to monsoon and winter. Shahid et al. (2008) observed that the concentration in the water sample from Julana block of Jind district, Haryana had a wider range of Na from 0.55 to 63.30 me L⁻¹ with mean value of 17.01 me L⁻¹. Similar results were also reported by Khodapanah et al. (2009), Dahiphale (2010) and Patil (2010).

2) Potassium

a) Irrigation farmlands

The data revealed that the K⁺ content of irrigation water samples (irrigated) were ranged from 2.70 to 4.83 mg L⁻¹ with the average value 3.99 mg L⁻¹ in monsoon
season, 3.00 to 5.01 mg L\(^{-1}\) with the average value 4.07 mg L\(^{-1}\) in winter and 2.89 to 5.13 mg L\(^{-1}\) with the average value 4.28 mg L\(^{-1}\) in summer season.

b) Non-Irrigation farmlands

The data revealed that the K\(^+\) content of irrigation water samples (non irrigated) were ranged from 2.70 to 8.69 mg L\(^{-1}\) with the average value 4.37 mg L\(^{-1}\) in monsoon season, 3.76 to 8.80 mg L\(^{-1}\) with the average value 4.85 mg L\(^{-1}\) in winter and 2.89 to 8.99 mg L\(^{-1}\) with the average value 4.78 mg L\(^{-1}\) in summer season.

Data indicated that K concentration of irrigation water samples was higher during summer season than monsoon and winter season. Singh and Bishnoi (2004) studied that the potassium content in water of Muktsar district of Punjab were ranged from 0.07 to 2.95 me L\(^{-1}\). Similar results were also reported by Mahmad et al. (2007) and Shahid et al. (2008).

3) Calcium :

a) Irrigation farmlands

The data revealed that the Ca\(^{++}\) content of irrigation water samples (irrigated) were ranged from 1.60 to 20.00 me L\(^{-1}\) with the average value 11.21 me L\(^{-1}\) in monsoon season, 6.40 to 26.00 me L\(^{-1}\) with the average value 13.79 me L\(^{-1}\) in winter and 6.50 to 29.00me L\(^{-1}\) with the average value 16.03 me L\(^{-1}\) in summer season.

b) Non-Irrigation farmlands

The data revealed that the Ca\(^{++}\) content of irrigation water samples (non irrigated) were ranged from 1.60 to 9.20 me L\(^{-1}\) with the average value 6.71 me L\(^{-1}\) in monsoon season, 1.40 to 11.00me L\(^{-1}\) with the average value 8.44me L\(^{-1}\) in winter and 2.60 to 14.10me L\(^{-1}\) with the average value 9.51me L\(^{-1}\) in summer season.

Data revealed that Ca content of irrigation water sample in summer were higher than monsoon and winter. Lal et al. (1976) studied that Ca content in irrigation water of Gyanpur Tahsil Dist. Varanasi ranged from 1.02 to 3.3 me L\(^{-1}\). Similar finding were also reported by Mahmud et al. (2007) and Shahid et al. (2008).
4) Magnesium:

a) Irrigation farmlands

The data revealed that the Mg$^{++}$ content of irrigation water samples (irrigated) were ranged from 7.20 to 24.80 me L$^{-1}$ with the average value 16.64 me L$^{-1}$ in monsoon season, 9.10 to 23.10 me L$^{-1}$ with the average value 16.72 me L$^{-1}$ in winter and 9.10 to 21.40 me L$^{-1}$ with the average value 15.70 me L$^{-1}$ in summer season.

b) Non-Irrigation farmlands

The data revealed that the Mg$^{++}$ content of irrigation water samples (non irrigated) were ranged from 8.80 to 22.20 me L$^{-1}$ with the average value 14.38 me L$^{-1}$ in monsoon season, 7.20 to 17.50 me L$^{-1}$ with the average value 11.72 me L$^{-1}$ in winter and 9.10 to 19.10 me L$^{-1}$ with the average value 13.40 me L$^{-1}$ in summer season.

Further data revealed that the Mg$^{++}$ content in irrigation water sample was lower in summer season than in monsoon and winter. Singh et al. (2006) reported that the irrigation water of Degana tahsil of Nagaur district (Rajsthan) Mg$^{++}$ content ranged from 1.1 to 12.1 me L$^{-1}$. Similar results were also reported by Savalia et al. (2006), Mahmud et al. (2007) and Shahid et al. (2008).

In summer season, the concentration of cations are higher than winter and monsoon because in summer season the evaporation rate is higher than winter and monsoon season, that causes decrease in the dilution of water. Increase in the depth of ground water was also responsible for increase in concentration of cations in irrigation water as well as rainfall was usually high as compare to winter and monsoon seasons that lead to decrease the concentration of cations in irrigation water.

4.2.4 Anions concentration:

The concentration of different soluble anions viz. carbonate, bicarbonate, chloride and sulphate in irrigation water samples of irrigated and non irrigated farmlands in study area are presented in Table 47, 48, 49 and 50, 51, 52 respectively.

1) Carbonate:

a) Irrigation farmlands:

The data revealed that the CO$_3^{-}$ content of irrigation water samples (irrigated) were nil in all sample.
b) Non-Irrigation farmlands:

The data revealed that the CO$_3^{2-}$ content of irrigation water samples (non irrigated) were nil in all sample.

The carbonates are generally absent or seldom occurred in more than 0.1 me L$^{-1}$ in water reported by Gupta (2005). He reported that the carbonates content of water in Talwandi Sabo tahsil of Bathinda district (Punjab) were ranged from 0 to 3.2 meL$^{-1}$. Similar results were also reported by Emangholizadeh (2008), Jivane (2009) and Dahiphale (2010).

2) Bicarbonate:

a) Irrigation farmlands:

The data revealed that the HCO$_3$ content of irrigation water samples (irrigated) were ranged from 7.10 to 10.80 me L$^{-1}$ with the average value 8.60 me L$^{-1}$ in monsoon season, 6.00 to 10.40 me L$^{-1}$ with the average value 8.29 me L$^{-1}$ in winter and 6.00 to 10.50 me L$^{-1}$ with the average value 8.86 me L$^{-1}$ in summer season.

b) Non-Irrigation farmlands:

The data revealed that the HCO$_3$ content of irrigation water samples (non irrigated) were ranged from 6.00 to 9.20 with the average value 7.83 in monsoon season, 6.00 to 8.40 with the average value 7.44 in winter and 6.00 to 10.50 with the average value 7.86 in summer season.

It was observed from the data that the HCO$_3$ content of irrigation water samples were higher in summer than in monsoon and winter Singh and Bishnoi (2005) reported that the bicarbonate in water of Ferozpur district of Punjab ranged from 0.8 to 18 me L$^{-1}$. Similar finding were noted by Brar et al. (2002), Mahmud et al. (2007) and Bharadwaj et al. (2010).

3) Chloride:

a) Irrigation farmlands:

The data revealed that the Cl content of irrigation water samples (irrigated) were ranged from 4.40 to 8.40 me L$^{-1}$ with the average value 6.35 me L$^{-1}$ in monsoon
season, 4.30 to 8.80me L\(^{-1}\) with the average value 6.58 me L\(^{-1}\) in winter and 4.60 to 8.80me L\(^{-1}\) with the average value 6.84me L\(^{-1}\) in summer season.

b) Non-Irrigation farmlands:

The data revealed that the Cl content of irrigation water samples (non irrigated) were ranged from 5.60 to 8.40 me L\(^{-1}\) with the average value 6.40me L\(^{-1}\) in monsoon season, 5.60 to 8.80 me L\(^{-1}\) with the average value 6.76me L\(^{-1}\) in winter and 5.90 to 8.80 me L\(^{-1}\) with the average value 7.15me L\(^{-1}\) in summer season.

Further data revealed that Cl content of irrigation water sample were higher in summer season then monsoon and winter season. Singh and Bishnoi (2005) reported that the chloride content in water smaples of Malout Block of Muktsar District of Punjab were ranged from 0.8 to 42.7 me L\(^{-1}\). Similar results were also reported by Mahmud et al. (2007), Emamgholizadeh (2008) and Bharadwaj et al. (2010).

4) Sulphate

a) Irrigation farmlands

The data revealed that the SO\(_4^{2-}\) content of irrigation water samples (irrigated) were ranged from 0.63 to 1.87 me L\(^{-1}\) with the average value 1.17me L\(^{-1}\) in monsoon season, 0.64 to 1.89me L\(^{-1}\) with the average value 1.17me L\(^{-1}\) in winter and 0.91 to 2.43 me L\(^{-1}\) with the average value 1.596me L\(^{-1}\) in summer season.

b) Non-Irrigation farmlands

The data revealed that the SO\(_4^{2-}\) content of irrigation water (non irrigated) samples were ranged from 0.67 to 1.29 me L\(^{-1}\) with the average value 1.03 me L\(^{-1}\) in monsoon season, 0.78 to 1.35 me L\(^{-1}\) with the average value 1.089me L\(^{-1}\) in winter and 1.20 to 1.90 me L\(^{-1}\) with the average value 1.49me L\(^{-1}\) in summer season.

Data revealed that the sulphate content of irrigation water sample were higher in summer than monsoon and winter. Lal et al. (1998) reported that sulphate content in water sample Bikaner tahsil dist. Bikaner (Rajasthan) were ranged from 0 to 31.9 me L\(^{-1}\). Similar results were also reported by Mahmud et al. (2007).

4.2.5 Characteristic Indices and ratio of water

Sodium absorption ratio (SAR), Residual sodium carbonate (RSC), SSP, KI, SCI of irrigated water samples are presented in Table 53, 54.
1) SAR (Sodium absorption ratio)

**Irrigated**

SAR of water sample from study area are presented in Table 53, 54, 55. It is observed from data that SAR of irrigation water sample were ranged from 0.13 to 0.20 with average value of 0.17 in monsoon, 0.12 to 0.19 with average value of 0.16 in winter and 0.12 to 0.17 with average value 0.15 in summer.

**Non irrigated**

SAR of water samples from study area are presented in Table 53, 54, 55. It is observed from data that SAR of irrigation water sample were ranged from 0.18 to 0.22 with average value of 0.19 in monsoon, 0.15 to 0.21 with average value of 0.18 in winter and 0.13 to 0.22 with average value 0.18 in summer.

Singh and Bishnoi (2004) reported that SAR content of Malouit block of Mukstar district of Punjab varied from 0.55 to 24.00 values. Similar result also found by Shahid et al. (2008) and Khodapanah et al. (2009).

Categorizations of collected irrigation water samples from study area based on SAR are represented in following Table 5.1. Out of 60 water samples, all the water samples were categorized safe for irrigation while not a single water sample was found unsafe for irrigation.

**Table 5.1 Categorization of irrigation water sample based on SAR value**

<table>
<thead>
<tr>
<th>Water quality class</th>
<th>Range of SAR</th>
<th>Suitability for irrigation</th>
<th>Per cent of irrigation water sample</th>
<th>No. of irrigation water sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>&lt;10</td>
<td>Safe</td>
<td>100%</td>
<td>60</td>
</tr>
<tr>
<td>S2</td>
<td>10-18</td>
<td>Moderately safe</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>S3</td>
<td>18-26</td>
<td>Moderately unsafe</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>S4</td>
<td>&gt; 26</td>
<td>Unsafe</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>
2) Residual Sodium Carbonate (RSC)

**Irrigated**

Result regarding, RSC of irrigated water sample collected from study area are presented in Table No. 53, 54, 55. It is observed that irrigation water sample collected in monsoon season were ranged from -45.60 to -11.60 with average value -34.77 in winter season it was ranged from -52.20 to -30.20 with average value -38.81 and in summer season it ranged from -47.61 to -32.40 with average value -40.10.

**Non Irrigated**

Result regarding, RSC of irrigated water sample collected from study area are presented in Table No. 53, 54, 55. It is observed that irrigation water sample collected in monsoon season were ranged from -34.80 to -25.00 with average value -28.92 in winter season it was ranged from -35.20 to -22.60 with average value -27.60 and in summer season it ranged from -36.50 to -21.00 with average value -30.77.

Out of 60 water samples, all water samples were recorded negative RSC value (<1.25). More *et al.* (1998) recorded that RSC content in water sample in Purna command area were ranged from -2.31 to 2.98 me L$^{-1}$. Similar result was also reported by Mohandas Marimuthu (2002), Mahmud *et al.* (2007) and Shahid *et al.* (2008).

Carbonate is generally absent or seldom occurs in more than 0.1 me L$^{-1}$ concentration, but in that case magnesium ions are not precipitated. Therefore the concept of RSC as visualised involving CO$_3^{-}$ + HCO$_3^{-}$ and Ca$^{++}$ + Mg$^{++}$ became questionable although the RSC concept served useful purpose qualitatively but had limited value on quantitative basis for salinity appraisals (Gupta *et al.*2005). On an average Mg$^{++}$ and Ca$^{++}$ content high in irrigation water samples as compared to carbonate and bicarbonate as well as majority carbonate was generally absent in water due to no precipitation of Ca$^{++}$ and Mg$^{++}$ therefore all RSC value recorded the negative.

Categorization of collected irrigation water samples from study area based on RSC are represented in following table out of 60 water samples all 60 water samples were categorized in class I (< 1.25 me L$^{-1}$) suitable for irrigation. Not a single water sample were found marginal suitable Class II (1.25 to 2.50 me L$^{-1}$) and unsuitable class III (> 2.50 me L$^{-1}$).
Table 5.2 Categorization of irrigation water based on RSC value

<table>
<thead>
<tr>
<th>Water quality class</th>
<th>Range of RSC (me L(^{-1}))</th>
<th>Suitability for irrigation</th>
<th>Per cent of irrigation water sample</th>
<th>No. of irrigation water sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt; 1.25</td>
<td>Suitable</td>
<td>100%</td>
<td>60</td>
</tr>
<tr>
<td>II</td>
<td>1.25 to 2.50</td>
<td>Marginal suitable</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>III</td>
<td>&gt; 2.5</td>
<td>Unsuitable</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Correlation between water parameter and soil parameter (Irrigated)

pH of irrigation water showed negative significant correlation with soil pH (r=0.465*) and positive significant correlation with potassium (r=0.783**) EC of irrigation water showed positive correlation with DTPA Zn of soil and negative correlation with CaCO\(_3\) (r=-0.502**).

HCO\(_3^-\) (bicarbonate) of water showed significant positive correlation with soil CaCO\(_3\) (r=0.661**) and negative correlation with available S (r=-0.553**) and P (r=-0.560**) of soil.

Chloride of water showed positive relationship with S (r=0.472*) and N (r=0.405*) and negative relationship with DTPA Fe (r=-0.587**).

Sodium showed positive significant correlation with organic carbon (r=0.600**), nitrogen (r=0.630**) and DTPA Cu (r=0.386).

Potassium showed positive significantly relationship with EC (r=0.484*), CaCO\(_3\) (r=0.500**) and organic carbon (r=0.399**) where as negative relationship with DTPA Fe (r=-0.525) and DTPA Zn (r=-0.536**).

Calcium show positive correlation with soil EC (r=0.688**). Magnesium showed negative correlation with soil EC (r=-0.399*) and DTPA Mn (r=-0.689**).

Correlation between water parameter and soil parameter (non irrigated)

pH of water positively correlated with available N (r=0.380*), K (r=0.526**) and S (r=0.380*) and negatively correlated with DTPA Fe (r=-0.454*) and DTPA Zn (r=-0.459*).
EC of water positive correlated with soil pH ($r=0.585^{**}$), available N ($r=0.461^{*}$) and negatively correlated with DTPA Mn ($r=-0.779^{**}$) and DTPA Zn ($r=-0.438^{*}$).

Chlorides of water showed positive correlation with DTPA Cu and negative correlation with DTPA Mn.

Sulphate of water sample showed positive correlation with available Ca ($r=0.550^{*}$) and DTPA Fe ($r=0.503^{**}$) and negative correlation with K ($r=-0.455^{*}$).

Sodium showed negative correlation with calcium ($r=-0.785^{**}$).

Potassium water sample showed positive correlation with soil characteristics viz. CaCO$_3$ ($r=0.733^{**}$), organic carbon ($r=0.559^{**}$), Calcium ($r=0.492^{**}$) available S ($r=0.728^{**}$), available P ($r=0.637^{**}$).

Calcium showed negative correlation with mg ($r=-0.495^{**}$) and DTPA Mn ($r=-0.391^{*}$).

Magnesium showed positive correlation with CaCO$_3$ ($r=0.432^{*}$), organic carbon ($r=0.452^{*}$), available sulphur ($r=0.491^{**}$), available K ($r=0.613^{**}$) and negative correlation with DTPA Fe ($r=-0.590^{**}$).