**Assessment of Soil Fertility Status of Available Nutrients in Red Soils of Jhansi Bundelkhand region in Uttar Pradesh under Cabbage Cultivation**

**ABSTRACT**

Assessment of the soil fertility status of red soils under cabbage cultivation was carried out during 2019-20 at Karguaji organic farm of Institute of Agricultural Sciences, Bundelkhand University, Jhansi district is located at Uttar Pradesh lying between 25̊ 44’ N latitude and 70̊ 25’ E longitude with 280 feet mean see level and normal annual rainfall is 550-750 mm. for evaluation of the soil fertility status of Karguaji organic farm. The pre planting and post harvesting soil sample were collected from 0-20 cm soil depth with auger in grid fation, total 27 plots under cabbage cultivation. The available nitrogen (N) was found mostly in low category, available phosphorus (P) was low to medium, available potassium (K) in medium range, and available sulphur (S) in low category, Regarding DTPA-extractable micronutrients, boron (B) and zinc (Zn), were in low category and level of copper (Cu), iron (Fe), manganese (Mn), and molybdenum (Mo), were in sufficient range Constraints in Karguaji organic farm of Bundelkhand University Jhansi. The balanced use of chemical fertilizers and micronutrients (B, Fe and Mn) based on the soil testing results along with the combination of bio-fertilizers and organic manures as an Integrated Nutrient management (INM) approach could greatly help in maintaining the soil fertility and Sustainable production in Bundelkhand region.

**Keywords:** *Cabbage, Soil fertility, available macro & micronutrients, red soil and INM.*

**INTRODUCTION**

In most places around the world, cabbage (*Brassica oleracea* L.), a member of the Cole crop family, is a significant crop for both fresh and processed vegetables. Although they are biennials, cole crops are typically planted as annuals (Hasan and Solaiman, 2012). As a heavy feeder crop, cabbage depletes the soil of several vital nutrients. Continuous and indiscriminate use of chemical fertilisers degrades soil quality and lowers crop output. The crop's cost-benefit ratio has decreased as a result of the farmers being burdened with additional expenses for chemical fertilisers. However, incorporating organic manures and biofertilizers not only enhances the soil's physical and chemical characteristics but also sustains the ecosystem and plant life (Maheshwarappa *et al*., 1999).

One of the most vital natural resources, soil is necessary for the production of food, fodder, and fibre as well as for ensuring the sustainability of the local, regional, and global environments (Pathak, 2010). A major challenge in India is the sustainability of crop production systems in order to meet the country's growing population's demand for food. Various forms of land degradation issues affect roughly 57% of India's total land area. (Sehgal and Abrol, 1994). Soil fertility is the innate capacity of a soil to provide plants with the essential nutrients in sufficient quantities, in the proper amounts, and at the right times for the best attainable growth.

The country's current and future food needs can only be satisfied by better managing land, water, nutrients, and other natural resources in order to fully utilise the enormous untapped potential of semi-arid/rainfed agriculture (Rockstrom *et al.*, 2010 and Wani *et al*., 2009). In order to produce more food on less land in the future, we must use natural resources sustainably. The central region of the country, Bundelkhand, is well known for its undiscovered, low-fertilized, and poorly developed soils because of its low soil depth, excessive drainage, extremely low water retention capacity, low organic matter content, and crust development on the soil surface (Srinivasan *et al*., 2016). The region encountered recurrent droughts from 2004 to 2007 as a result of insufficient and irregular rainfall, which caused variances in agricultural planning, policymaking, and the creation of intervention programs (Patel and Yadav, 2015). Thus, the assessing nutrient supply capacity of soils in this region is essential to ensure and enhance the agriculture sustainability. Therefore, an observational study fertility was undertaken to characterization of the soils on the basis of soil attributes districts i.e. of Jhansi of Bundelkhand region of central India.

**MATERIALS AND METHODS**

The current study, "Red Soils under Cabbage (*Brassica oleracea* var. capitata) Cultivation in Jhansi District of Uttar Pradesh," was carried out accurately enough to be taken into statistical consideration in 2019–20. The present experiment was carried out at Organic Research Farm, Karguanji, Department of Soil Science & Agricultural Chemistry, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.) which is located at 27˚ 15' N latitude and 77˚ 30' E longitude at a height of 228m above the mean sea level in the Bundelkhand Agro-climatic region of Uttar Pradesh. The available nitrogen content in soil samples was determined by alkaline permanganate method as described by Subbiah and Asija (1956). The available phosphorus in soil determined by Olsen’s method as per procedure described by Olsen’s *et al*. (1954). The available potassium in soil determined by Flame Photometer (Mahur *et al.,* 1965). The available sulphur in soil determined by 0.15% CaCl2 extractant and turbidimetric determination (Chesnin and Yien, 1950). The available boron in soil determined by Azomethine H Method (John *et al.*, 1975). The available zinc, manganese, iron and molybdenum in soil determined Atomic Absorption Spectrophotometer by Elwell and Gridley (1967).

Descriptive analysis (mean, range, standard error, standard deviation and coefficient of variation) of soil attributes were computed using the R software. Soil fertility rating (low, medium, and high) were determined based on the criteria (Lungmuana and Colney, 2016).

**RESULT AND DISCUSSION**

**Initial and post-harvest availability of primary nutrients in red soils under cabbage cultivation**

**Available nitrogen (kg ha-1)**

The data presented in Table 1 revealed that the available nitrogen in red soil was slightly decreased under cabbage cultivation. The available nitrogen in red soils at initial stage ranged from 83.25 to 135.00 kg ha-1 with a mean value of 108.46 kg ha-1 however, it was decreased after harvest of the cabbage and ranged from 67.50 to 127.23 kg ha-1 with a mean value of 100.43 kg ha-1. On the basis of criteria, suggested by Subbiah and Asija (1956) all the soils samples of both the stages (Initial and post-harvest) were found deficient (Low) to available nitrogen in the soil. The decrease in available nitrogen content in soil under cabbage cultivation might be due to heavy feeding of nitrogen by hybrid cabbage, leaching of nitrogen by frequent and more number of irrigations applied to cabbage and application of nutrients through organic manures which released nitrogen slowly to soil. Similar results were also reported by Kothyari *et al.* (2017) and Kumar *et al.* (2017).

**Available phosphorus (kg ha-1)**

Phosphorus content in red soils was moderately increased under cabbage cultivation (Table 1). The available phosphorus in red soils at initial stage varied from 10.22 to 13.50 kg P2O5 ha-1 with a mean value of 11.96 kg P2O5 ha-1 however, it was increased after harvest of cabbage and ranged between 12.52 to 18.50 kg P2O5 ha-1 with a mean value of 15.37 kg P2O5 ha-1. Considering the available phosphorus rating values suggested by Olsen’s *et al*. (1954), all the samples of both the stages were found under medium category. Application of organic manures only for cabbage cultivation may supply the phosphorus and increase microbial activity in the soil which leads to solubilisation of fix phosphorus in the soil results an increase in phosphorus content after cabbage cultivation reported by Singh *et al.* (2018) and Patel *et al.* (2018).

**Available potassium (kg ha-1)**

It is evident from data presented in Table 1 that the available potassium was minutely increased with cabbage cultivation. The available potassium at initial soil samples ranged between 125.00 to 172.10 kg K2O ha-1 with a mean value of 148.31 kg K2O ha-1 while, the available potassium ranged from 128.10 to 195.50 kg K2O ha-1 with a mean value of 162.01 kg K2O ha-1. On the basis of limits, all the soil samples of both the stages were found under medium category in respect to available potassium content. The organic manures like FYM and vermicompost applied to cabbage have sufficient content of potassium as well as cabbage is required minimum quantity of potassium as compare to nitrogen and phosphorus. The satisfactory conditions of extractable potassium in the farm might be due to the optimum application of potash as well as less loss of potassium ion from the soil. Similar results were also reported by Deshmukh (2012), Khadka *et al.,* 2017 and Kothyari *et al.* (2017).

**Table 1. Initial and post-harvest availability of primary nutrients in red soils under cabbage cultivation**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample No.** | **Nitrogen (kg ha-1)** | | **Phosphorus (kg ha-1)** | | **Potassium (kg ha-1)** | |
| **Initial** | **Post** | **Initial** | **Post** | **Initial** | **Post** |
| S1 | 83.25 | 67.50 | 11.00 | 13.70 | 125.00 | 128.10 |
| S2 | 94.12 | 87.53 | 12.10 | 15.00 | 132.12 | 136.00 |
| S3 | 97.84 | 88.13 | 11.50 | 12.52 | 128.42 | 131.22 |
| S4 | 84.50 | 78.92 | 11.87 | 13.93 | 137.51 | 141.00 |
| S5 | 87.60 | 85.12 | 12.33 | 14.70 | 127.24 | 134.52 |
| S6 | 92.10 | 87.30 | 12.66 | 15.12 | 131.22 | 142.12 |
| S7 | 96.52 | 90.00 | 11.00 | 13.23 | 135.25 | 140.54 |
| S8 | 101.22 | 97.12 | 11.09 | 14.86 | 141.21 | 154.13 |
| S9 | 97.42 | 92.66 | 12.11 | 16.00 | 138.52 | 146.45 |
| S10 | 92.54 | 88.80 | 11.23 | 14.74 | 131.54 | 142.12 |
| S11 | 101.30 | 97.13 | 11.90 | 15.90 | 136.41 | 145.00 |
| S12 | 109.21 | 99.20 | 12.22 | 17.00 | 165.72 | 178.11 |
| S13 | 111.88 | 107.40 | 11.10 | 15.78 | 138.66 | 152.44 |
| S14 | 122.12 | 116.44 | 12.88 | 17.35 | 147.36 | 163.88 |
| S15 | 131.25 | 127.23 | 11.23 | 14.88 | 151.12 | 167.16 |
| S16 | 127.54 | 118.32 | 12.09 | 16.77 | 141.23 | 162.00 |
| S17 | 98.74 | 95.44 | 13.00 | 17.23 | 164.55 | 176.23 |
| S18 | 110.54 | 107.30 | 12.23 | 15.05 | 139.00 | 157.44 |
| S19 | 127.54 | 122.71 | 11.94 | 14.71 | 152.11 | 170.11 |
| S20 | 135.00 | 117.00 | 12.52 | 16.12 | 163.72 | 185.32 |
| S21 | 117.20 | 102.32 | 13.23 | 16.82 | 171.17 | 191.16 |
| S22 | 101.00 | 91.22 | 11.21 | 13.52 | 166.23 | 188.66 |
| S23 | 97.52 | 87.44 | 10.22 | 14.10 | 170.37 | 193.31 |
| S24 | 122.90 | 108.65 | 13.15 | 17.52 | 168.52 | 186.99 |
| S25 | 131.02 | 124.52 | 13.50 | 18.50 | 172.10 | 195.50 |
| S26 | 129.13 | 117.41 | 12.20 | 15.36 | 164.27 | 185.00 |
| S27 | 127.31 | 108.71 | 11.54 | 14.70 | 163.88 | 179.87 |
| **Mean** | **108.46** | **100.43** | **11.96** | **15.37** | **148.31** | **162.01** |
| **Maximum** | **135.00** | **127.23** | **13.50** | **18.50** | **172.10** | **195.50** |
| **Minimum** | **83.25** | **67.50** | **10.22** | **12.52** | **125.00** | **128.10** |
| **SD** | **16.24** | **15.25** | **0.81** | **1.46** | **16.00** | **21.63** |
| **CV (%)** | **14.97** | **15.19** | **6.74** | **9.47** | **10.79** | **13.35** |

**Initial and post-harvest availability of secondary and micro nutrients in red soils under cabbage cultivation**

**Available sulphur (mg kg-1)**

The data presented in Table 2 revealed that the available sulphur (S) in red soils was minutely decreased under cabbage cultivation. The available sulphur in red soils at initial stage ranged from 11.13 to 14.50 mg kg-1 with a mean value of 12.67 mg kg-1 however, it was minutely decreased after harvest of the cabbage and ranged from 10.21 to 13.87 mg kg-1 soil with a mean value of 11.86 mg kg-1. On the basis of criteria, suggested by Chesnin and Yien (1950), all the soils samples of both the stages (Initial and post-harvest) were found high to available sulphur.

**Available boron (mg kg-1)**

The boron (B) content in red soils was minutely decreased under cabbage cultivation (Table 2). The available boron in red soils at initial stage varied from 0.53 to 0.64 mg kg-1 with a mean value of 0.57 mg kg-1 ,however, it was minutely decreased after harvest of cabbage and ranged between 0.51 to 0.63 mg kg-1 with a mean value of 0.56 mg kg-1. Considering the available boron rating values suggested by John *et al.* (1975), all the samples of both the stages were found under medium category. Our findings are partially accordance with Khadka *et al.* (2017) and Choudhari *et al.* (2018).

**Available molybdenum (mg kg-1)**

The data depicted in Table 2 clearly indicated that the available molybdenum (Mo) content in the red soils was minutely decreased by cabbage cultivation. The molybdenum content in initial soil samples was ranged from 0.036 to 0.046 mg kg-1 with a mean value of 0.041 mg kg-1 whereas, the available boron content in post-harvest soil samples was ranged between 0.032 to 0.046 mg kg-1 with a mean value of 0.039 mg kg-1. On the basis of limits suggested by Elwell and Gridley (1967) in respect to available molybdenum content indicates that 11 samples had low molybdenum content while, 16 samples had medium molybdenum content at initial stage whereas, 22 samples had low molybdenum content and rest 5 samples had medium molybdenum content after harvest of the cabbage. Similar findings reported by Velmurugan *et al.* (2013).

**Table 2. Initial and post-harvest availability of secondary and micro nutrients in red soils under cabbage cultivation**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample No.** | **Sulphur (mg kg-1)** | | **Boron (mg kg-1)** | | **Molybdenum (mg kg-1)** | |
| **Initial** | **Post** | **Initial** | **Post** | **Initial** | **Post** |
| S1 | 11.51 | 10.82 | 0.56 | 0.52 | 0.037 | 0.036 |
| S2 | 11.27 | 10.92 | 0.58 | 0.56 | 0.038 | 0.035 |
| S3 | 11.13 | 10.73 | 0.57 | 0.55 | 0.037 | 0.032 |
| S4 | 12.32 | 12.00 | 0.56 | 0.55 | 0.039 | 0.036 |
| S5 | 11.21 | 10.21 | 0.53 | 0.52 | 0.036 | 0.034 |
| S6 | 12.07 | 11.23 | 0.54 | 0.53 | 0.040 | 0.038 |
| S7 | 12.52 | 11.52 | 0.56 | 0.55 | 0.039 | 0.035 |
| S8 | 12.82 | 12.12 | 0.57 | 0.54 | 0.038 | 0.034 |
| S9 | 11.57 | 11.45 | 0.54 | 0.52 | 0.037 | 0.035 |
| S10 | 12.22 | 11.05 | 0.56 | 0.53 | 0.039 | 0.036 |
| S11 | 12.12 | 10.88 | 0.53 | 0.52 | 0.040 | 0.036 |
| S12 | 11.88 | 10.21 | 0.54 | 0.54 | 0.041 | 0.038 |
| S13 | 12.11 | 11.57 | 0.57 | 0.56 | 0.040 | 0.039 |
| S14 | 12.43 | 11.27 | 0.54 | 0.55 | 0.042 | 0.040 |
| S15 | 12.47 | 11.74 | 0.56 | 0.54 | 0.044 | 0.043 |
| S16 | 12.52 | 11.45 | 0.56 | 0.56 | 0.043 | 0.043 |
| S17 | 12.33 | 11.27 | 0.54 | 0.51 | 0.045 | 0.045 |
| S18 | 13.23 | 12.22 | 0.55 | 0.53 | 0.046 | 0.043 |
| S19 | 12.75 | 12.00 | 0.57 | 0.54 | 0.045 | 0.043 |
| S20 | 13.45 | 12.52 | 0.60 | 0.58 | 0.044 | 0.041 |
| S21 | 13.51 | 12.67 | 0.59 | 0.60 | 0.046 | 0.045 |
| S22 | 13.65 | 12.76 | 0.61 | 0.60 | 0.044 | 0.044 |
| S23 | 14.12 | 13.83 | 0.64 | 0.62 | 0.046 | 0.046 |
| S24 | 13.82 | 13.11 | 0.62 | 0.61 | 0.037 | 0.035 |
| S25 | 14.33 | 13.87 | 0.64 | 0.63 | 0.045 | 0.043 |
| S26 | 14.50 | 13.46 | 0.64 | 0.63 | 0.046 | 0.042 |
| S27 | 14.13 | 13.23 | 0.62 | 0.61 | 0.045 | 0.045 |
| **Mean** | **12.67** | **11.86** | **0.57** | **0.56** | **0.041** | **0.039** |
| **Maximum** | **14.50** | **13.87** | **0.64** | **0.63** | **0.046** | **0.046** |
| **Minimum** | **11.13** | **10.21** | **0.53** | **0.51** | **0.036** | **0.032** |
| **SD** | **0.99** | **1.04** | **0.03** | **0.04** | **0.003** | **0.004** |
| **CV (%)** | **7.82** | **8.75** | **6.02** | **6.62** | **8.367** | **10.855** |

**Available zinc (mg kg-1)**

The data presented in Table 3 revealed that the available zinc (Zn) in red soils was minutely decreased under cabbage cultivation. The available zinc in red soils at initial stage ranged from 0.81 to 1.31 mg kg-1 with a mean value of 0.99 mg kg-1 however, it was slightly decreased after harvest of the cabbage and ranged from 0.78 to 1.27 mg kg-1 with a mean value of 0.96 mg kg- 1. On the basis of criteria, suggested by Elwell and Gridley (1967), all the soils samples of both the stages (Initial and post-harvest) were found medium in available zinc. Partial immobilization and release from organic compounds might enhance the availability in the surface soils (Chitdeshwari *et al.*, 2019). Madhu and David (2017) reported that application of organic manures like FYM and vermicompost is sufficient for maintaining available zinc content in the soil.

**Available iron (mg kg-1)**

It is evident from the data presented in Table 3 clearly indicated that the available iron (Fe) content in the red soils was minutely decreased by cabbage cultivation. The iron content in initial soil samples was ranged from 0.24 to 0.29 mg kg-1 with a mean value of 0.26 mg kg-1 whereas, the available iron content in post-harvest soil samples was ranged between 0.22 to 0.28 mg kg-1 with a mean value of 0.25 mg kg-1. On the basis of limits suggested by Elwell and Gridley (1967) in respect to available iron content indicates that all the soils samples of both the stages (Initial and post-harvest) were found highly deficit (Very low) to available iron in the soil. The very low availability of iron might be due to low possibility of primary and secondary iron minerals like hematite, olivine, siderite, goethite, magnetite etc. application of 0.5 – 1.0 kg ha-1 ferrous sulphate regularly for reducing iron deficiency in the soil reported by Jagtap *et al.* (2016).

**Available manganese (mg kg-1)**

The manganese (Mn) content in red soils was minutely decreased under cabbage cultivation (Table 3). The available manganese in red soils at initial stage varied from 6.48 to 7.12 mg kg-1 with a mean value of 6.82 mg kg-1 however, it was minutely decreased after harvest of cabbage and ranged between 5.80 to 7.10 mg kg-1 with a mean value of 6.71 mg kg-1. Considering the available manganese rating values suggested by Elwell and Gridley (1967) in respect to available manganese content indicates that 20 samples had medium manganese content while, 7 samples had high manganese content at initial stage whereas, 24 samples had medium manganese content and rest 3 samples had high manganese content after harvest of the cabbage. The soils having more percent of finer fraction was found because increase in finer proportion in soils offered greater exchange sites for holding Mn2++ on it reported by Kumar *et al.* (2017) and Chitdeshwari *et al.* (2019).

**Table 3. Initial and post-harvest availability of micro nutrients in red soils under cabbage cultivation**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sample No.** | **Zinc (mg kg-1)** | | **Iron (mg kg-1)** | | **Manganese (mg kg-1)** | |
| **Initial** | **Post** | **Initial** | **Post** | **Initial** | **Post** |
| S1 | 0.81 | 0.78 | 0.26 | 0.22 | 6.48 | 5.80 |
| S2 | 0.87 | 0.85 | 0.25 | 0.24 | 6.52 | 6.41 |
| S3 | 0.84 | 0.82 | 0.26 | 0.25 | 6.51 | 6.42 |
| S4 | 0.81 | 0.78 | 0.24 | 0.23 | 6.50 | 6.38 |
| S5 | 0.87 | 0.85 | 0.27 | 0.27 | 6.55 | 6.52 |
| S6 | 0.88 | 0.87 | 0.25 | 0.25 | 6.52 | 6.41 |
| S7 | 0.85 | 0.85 | 0.26 | 0.26 | 6.54 | 6.52 |
| S8 | 0.84 | 0.83 | 0.24 | 0.23 | 6.56 | 6.53 |
| S9 | 0.86 | 0.84 | 0.26 | 0.24 | 6.58 | 6.57 |
| S10 | 0.87 | 0.83 | 0.25 | 0.25 | 6.53 | 6.48 |
| S11 | 0.89 | 0.87 | 0.24 | 0.23 | 6.59 | 6.57 |
| S12 | 0.86 | 0.84 | 0.26 | 0.25 | 7.00 | 6.89 |
| S13 | 0.92 | 0.91 | 0.26 | 0.24 | 6.88 | 6.85 |
| S14 | 0.91 | 0.90 | 0.27 | 0.26 | 6.92 | 6.92 |
| S15 | 0.83 | 0.80 | 0.27 | 0.26 | 6.97 | 6.85 |
| S16 | 0.95 | 0.91 | 0.26 | 0.25 | 7.05 | 6.99 |
| S17 | 0.96 | 0.95 | 0.28 | 0.27 | 7.10 | 7.00 |
| S18 | 0.94 | 0.92 | 0.27 | 0.26 | 7.00 | 6.91 |
| S19 | 0.97 | 0.95 | 0.26 | 0.25 | 7.11 | 7.02 |
| S20 | 1.10 | 1.04 | 0.28 | 0.25 | 7.02 | 6.79 |
| S21 | 1.31 | 1.17 | 0.28 | 0.27 | 6.88 | 6.66 |
| S22 | 1.21 | 1.19 | 0.26 | 0.25 | 6.97 | 6.74 |
| S23 | 1.25 | 1.24 | 0.27 | 0.25 | 7.12 | 6.92 |
| S24 | 1.27 | 1.23 | 0.26 | 0.26 | 7.09 | 7.00 |
| S25 | 1.24 | 1.22 | 0.27 | 0.24 | 7.00 | 6.99 |
| S26 | 1.22 | 1.21 | 0.29 | 0.28 | 7.12 | 7.10 |
| S27 | 1.29 | 1.27 | 0.28 | 0.27 | 7.00 | 7.05 |
| **Mean** | **0.99** | **0.96** | **0.26** | **0.25** | **6.82** | **6.71** |
| **Maximum** | **1.31** | **1.27** | **0.29** | **0.28** | **7.12** | **7.10** |
| **Minimum** | **0.81** | **0.78** | **0.24** | **0.22** | **6.48** | **5.80** |
| **SD** | **0.17** | **0.17** | **0.013** | **0.015** | **0.25** | **0.30** |
| **CV (%)** | **17.62** | **17.29** | **4.93** | **5.77** | **3.65** | **4.43** |

**CONCLUSION**

Based on the above study it is concluded that soil fertility status of Organic Research Farm, Karguanji considering the concept of nutrient index value of the soil of investigated area were found in 'medium fertility status' for available phosphorus, potassium, boron, zinc and manganese; low with respect of available organic carbon, nitrogen, molybdenum and iron; and high to availability of sulphur. Hence it is suggested that regular application of organic manures, inoculation of bio-fertilizers and growing of green manures may help to maintaining the soil fertility by increasing availability of deficit nutrients under cabbage cultivation.

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**REFERENCES**

Chesnin, L., & Yien, C. H. (1951). Turbidimetric determination of available sulfates. Soil Science Society of America Proceedings **15**:149-151.

Chitdeshwari, T., Jegadeeswari, D., & Shukla, A. K. (2019). Available sulphur and micronutrients status in the soils of the Nilgiris district, Tamil Nadu, India. *Int J Chem Stud*, *7*(1), 1297-1300.

Choudhari, B.; Basumatary, A.; Kandali, G. G.; Das, K. and Singh. C. (2018). Critical limit of boron for cauliflower (*Brassica oleracea* var Girija) in soils of Assam. *International Journal of Chemical Studies* **6**(5): 1819-1823.

Deshmukh, K. K. (2012). Evaluation of soil fertility status from Sangamner area, Ahmednagar district, Maharashtra, India. *Rasayan journal of Chemistry*, *5*(3), 398-406.

Elwell, W. T., & Gridley, J. A. F. (1967). Atomic absorption spectrophotometer ypergamon press Ltd. *London, W-1*.

Hasan, M. R., & Solaiman, A. H. M. (2012). Efficacy of organic and organic fertilizer on the growth of *Brassica oleracea* L.(Cabbage). *International Journal of Agriculture and Crop Sciences*, *4*(3), 128-138.

Jagtap, P. B., Kadam, M. B., & Chalak, S. U. (2016). Response of cabbage to foliar and soil application of iron and zinc in inceptisol. *Advances in Life Sciences*, *5*(17), 6823-6827.

John, M. K., Chuah, H. H., & Neufeld, J. H. (1975). Application of improved azomethine-H method to the determination of boron in soils and plants. *Analytical letters*, *8*(8), 559-568.

Khadka, D., Lamichhane, S., Shrestha, S. R., & Pant, B. B. (2017). Evaluation of soil fertility status of regional agricultural research station, Tarahara, Sunsari, Nepal. *Eurasian Journal of Soil Science*, *6*(4), 295-306.

Kothyari, H. S., Meena, K. C., Meena, B. L., & Meena, R. (2018). Soil fertility status in Sawai Madhopur district of Rajasthan. *Int. J Pure App. Biosci*, *6*(4), 587-591.

Kumar, M., Yadav, S. R., & Gulati, I. J. (2017). Evaluation of soil fertility status in Sriganganagar district of Rajasthan. *International Journal of Chemical Studies*, *5*(4), 776-780.

Lungmuana, Colney L. Soil testing - an important tool for assessing soil health and quality. Science Vision. 2011; 11(4):214 217.

Madhu, B. M., & David, A. A. (2017). Soil Fertility Status of Jamuna Paar region of Allahabad District, Uttar Pradesh, India. *Int. J. Curr. Microbiol. App. Sci*, *6*(12), 3069-3076.

Mahur, R.N.; Datta, N.P.; Subramoney Sankar, H.; Leley, V.K. and Donaline, L. V. (1965). Soil testing in India. U.S. Agency for International Development Mission to India pp: 39- 45.

Olsen, S.R.; Cole, C.V.; Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA. Cric., No.939, Washington. 1:19.

Patel, N. R., & Yadav, K. (2015). Monitoring spatio-temporal pattern of drought stress using integrated drought index over Bundelkhand region, India. *Natural Hazards*, *77*, 663-677.

Patel, S. J., Desai, L. J., SJ, K., & Patel, C. K. (2018). Cabbage (Brassica oleracea var. capitata L.) Yield, nutrients uptake and soil available nutrients as influenced by nitrogen and foliar nutrients application under South Gujarat condition. *Inter. Jour. Pure App. Biosci*, *6*, 1222-1225.

Pathak, H. (2010). Trend of fertility status of Indian soils. *Current Advances in Agricultural Sciences (An International Journal)*, *2*(1), 10-12.

Rockström, J., Karlberg, L., Wani, S. P., Barron, J., Hatibu, N., Oweis, T., ... & Qiang, Z. (2010). Managing water in rainfed agriculture—The need for a paradigm shift. *Agricultural Water Management*, *97*(4), 543-550.

Sehgal, J. L., & Abrol, I. P. (1994). *Soil degradation in India: status and impact*, Oxford & IBH Publishing Company Pvt. Ltd, New Delhi; 1994; 10-80.

Singh, S. P., Singh, S., Kumar, A., & Kumar, R. (2018). Soil fertility evaluation for macronutrients using parkers nutrient index approach in some soils of Varanasi district of eastern Utter Pradesh, India. *International Journal of Pure and Applied Bioscience*, *6*(5), 542-548.

Srinivasan, R., Tripathi, S. B., Rai, A. K., Das, S. K., Rao, D. V. K. N., & Ghosh, P. K. (2016). Strides in soil research: Soil health management and fodder production. *ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284*, *3*, 1-91.

Subbiah, B. V. and Asija,G. L. (1956). A rapid procedure for estimation of available nitrogen in soils. *Current Sciences* **25**: 259-260.

Velmurugan, R., Mahendran, P. P., Wani, S. P., Uttam, K., & Prabhavathi, M. (2013). Molybdenum status and critical limit in the soil for green gram (*Vigna radiata*) growing in Madurai and Sivagangai districts of Tamil Nadu, India. *Soil Science and Plant Nutrition*, *59*(2), 229-236.

Wani, S. P., Sreedevi, T. K., Rockström, J., & Ramakrishna, Y. S. (2009). Rainfed agriculture-past trends and future prospects. In *Rainfed agriculture: Unlocking the potential* (pp. 1-35). Wallingford UK: CABI.