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Effect of integrated nutrient management on soil properties in pigeon pea (*Cajanus cajan* L.) based intercropping system

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Abstract
A field experiment entitled "Effect of integrated nutrient management in pigeon pea (*Cajanus cajan* L.) based intercropping system" was conducted during the *Kharif* season of 2019-20 and 2020-21 at Agronomy Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.), India to evaluate the effect of three intercropping systems (Pigeon pea sole, Pigeon pea+ sesamum and Pigeon pea+ sorghum) with five integrated nutrient management practices((N_1-RDF alone, N_2- RDF + FYM @5t ha^{-1}, N_3- RDF+FYM@5t ha^{-1} + sulphur@40 kg ha^{-1}, N_4- RDF + FYM @ 5t ha^{-1}+ sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1} and N_5- RDF+FYM @ 5t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$@ 25 kg ha^{-1} + B@1.5 kg ha^{-1}). On the basis of two year results, maximum reduction of bulk density (1.43 and 1.42 Mg m^{-3}), soil pH (7.81 and 7.79), EC (0.33 and 0.31 dSm^{-1}), was recorded in pigeon pea + sesamum intercropping as well as pigeon pea + sesamum intercropping system recorded maximum particle density (2.65 and 2.64 Mg m^{-3}), organic carbon (0.34 and 0.36%). Pigeon pea sole was recorded maximum availability of Nitrogen (162.15 and 164.39 kg ha^{-1}), available Phosphorus (16.45 and 17.62 kg ha^{-1}), available Potash (242.27 and 244.51 kg ha^{-1}), available sulphur (11.68 and 12.80 ppm) and DTPA extracted zinc (0.48 and 0.52 ppm) and boron (0.47 and 0.48 ppm) in respective years of 2019-20 and 2020-21. Among the integrated nutrient management practices, application of N_5 (75% RDF + FYM@ 5t ha^{-1} + Sulphur@ 40 kg ha^{-1} + $ZnSO_4$@ 25 kg ha^{-1} + Boron @ 1.5 kg ha^{-1}) recorded maximum particle density (2.65 and 2.64 Mg m^{-3}) and organic carbon (0.35 and 0.36%), available Nitrogen (162.82 and 165.06 kg ha^{-1}), available Phosphorus (16.77 and 17.93 kg ha^{-1}), available Potash (241.63 and 243.87 kg ha^{-1}), available sulphur (12.78 and 13.90 ppm) and DTPA extractable zinc (0.52 and 0.54 ppm) and boron (0.54 and 0.56 ppm) and also recoded maximum reduction of bulk density (1.38 and 1.36 Mg m^{-3}), soil pH (7.71 and 7.70), EC (0.29 and 0.28 dSm^{-1}), respectively over RDF.

Keywords: Pigeon pea, sorghum, sesamum, integrated nutrient management, intercropping

1. Introduction

Pulse (Legume) crops are members of the family Leguminosae (Fabaceae). The term "pulse crops" generally refers to those plant species harvested primarily for a dry seed that is used as both human food and animal feed. Pulse crops are considered environmentally friendly due to their ability to form symbiotic associations with nitrogen-fixing *Rhizobium* bacteria in their tap root systems. Consumption of pulses as part of a regular diet may offer numerous health benefits including reduced risk of diabetes and heart diseases. Pigeon pea (*Cajanus cajan* L.) is an important perennial legume crop of the leguminous family. Among the pulses, pigeon pea is the second most important *Kharif* grain legume after chickpea in India and is grown predominantly under rainfed conditions. Since its domestication in the Indian subcontinent at least 3,500 years ago, its seeds have become a common food in Asia, Africa, and Latin America. Today, pigeon pea is widely cultivated in all tropical and semitropical regions of both the old and new worlds. Pigeon pea is very drought-resistant and can be grown in areas with less than 650 mm annual rainfall (Kumar *et al.*, 2017). The world area of pigeon pea is (69.93 Lakh ha) and the production of (59.61 Lakh Tonnes). Major Pigeon pea producing countries are India (42.90 Lakh tonnes), Myanmar (6.76 Lakh tonnes), Malawi (4.35 Lakh tonnes), Tanzania (3.16 Lakh tonnes), Haiti (0.88 Lakh tonnes), Kenya (0.86 Lakh tonnes), Dom. Republic (0.25 Lakh tonnes). The productivity of the pigeon pea, Philippines ranked first with 1857 kg ha^{-1} followed by Malawi (1743 kg ha^{-1}) and the productivity of India was 768 kg ha^{-1} (FAO Stat. 2018) [8]. India ranked first in area and production in the world with 80% and 72% of the world's acreage and production respectively. The country's total coverage area and production of tur (Arhar) were 54.40 lakh hectares and 38.30 lakh tonnes respectively. More than 83% of tur production comes from 6 states, Maharashtra, Karnataka, Uttar Pradesh, Telangana, Jharkhand, and Gujarat. The state-wise trend shows that Maharashtra ranked Ist both in area and production (34.01% and 28.59%). Karnataka stands second both in the area (26.32%) and production (27.72%). Uttar Pradesh third in the area (6.27) and production (7.30%). The highest productivity has been recorded by Bihar (1945 kg ha^{-1}) followed by Kerala (1668 kg ha^{-1}). The lowest productivity has been observed in the state of Andhra Pradesh (482 kg ha^{-1} followed by Himachal Pradesh (510 kg ha^{-1}) (Anonymous 2020) [1].

2. Materials and Methods

2.1 Experimental design and treatment details

The treatments were comprised as three inter cropping systems (Pigeon pea sole, Pigeon pea+ sesamum and Pigeon pea+ sorghum) and five integrated nutrient management system (N_1-RDF alone, N_2- RDF + FYM @5t ha^{-1}, N_3-RDF+FYM@5t ha^{-1} + sulphur@40 kg ha^{-1}, N_4- RDF + FYM @ 5t ha^{-1}+ sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1} and N_5- RDF+FYM @ 5t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$@ 25 kg ha^{-1} + B@ 1.5kg ha^{-1}. The experiment was laid out in factorial randomized block design (Two Factors) with three replications. The varieties namely pigeon pea (Narendra Arhar-1), Sesamum (T-12), and Sorghum (PKV-400) were sown in 4th and 12th July during 2019-20 and 2020-21 respectively. A basal dose of 20 kg N, 40 kg P_2O_5 and 0 kg K_2O for pigeon pea, sesamum and sorghum for 60 kg N, 30 kg P_2O_5 and 30 kg K_2O kg ha^{-1}.

2.2 Observations

After selection of the experimental site, ploughing, a composite soil sample from a depth of 0-15 cm was taken and analyzed for important physicochemical and biological properties of the soil. The chemical analysis of soil revealed that it was neutral in reaction, medium in organic carbon, available nitrogen and available phosphorus and potassium. Soil physical analysis (bulk density and particle density) measured by hydrometric method and Soil chemical analysis (pH) was determined with the help of a glass electrode pH meter using 1:2.5 soil water suspension as described by Jackson (1973) [10], EC was determined by conductivity bridge meter using 1:2.5 soil water suspension, Organic carbon was determined by Walkely and Black (1934) [31], Available nitrogen content in soil sample was estimated by the alkaline permanganates method as described by (Subbiah and Asija, 1956) [25], Available phosphorus was extracted by 0.5 M Na HCO3 as per the procedure of Olsen and determined calorimetrically by the molybdophosphoric blue color method as described by (Olsen *et al.*, 1954) [18], Available potassium in soil samples was determined by using neutral normal ammonium acetate solution as described by (Jackson, 1973) [10], The available (Zn) was determined in DTPA extract solution given by Lindsay and Norvell (1978) [13] using Atomic Absorption Spectrophotometer (SAI-304), Available B is extracted by hot water Berger and Troug (1939) [2].

2.3 Statistical analysis

The various data recorded in the experiment were analyzed statistically with the help of an electronic calculator following the procedure for factorial randomized block design (RBD) given by Cochrane and Cox (1970). The standard errors of mean were calculated in each item of investigation and critical differences (CD) at 5% level were worked out for comparing the treatment means wherever 'F' test was found significant.

3. Results and Discussion

3.1 Physical properties soil

Intercropping system could not being significant variation in bulk density and particle density during both the year of experimentation. Maximum bulk density was found under the pigeon pea sole (1.43 Mg m^{-3}, 2019-20 and 1.42 Mg m^{-3}, 2020-21) and minimum bulk density was found under the pigeon pea + sesamum intercropping system (1.40 Mg m^{-3}, 2019-20 and 1.39 Mg m^{-3}, 2020-21) during both years respectively. Maximum particle density was found under the pigeon pea + sesamum intercropping system (2.65 Mg m^{-3}, 2019-20 and 2.64 Mg m^{-3} 2020-21) and minimum particle density was found under the pigeon pea sole (2.62 Mg m^{-3}, 2019-20 and 2.61 Mg m^{-3} 2020-21). Pigeon pea + sesamum intercropping system reduced bulk density and increase particle density of the soil during both the years. This might be due to pulse crop roots (1-2 cm diameter) penetrated deep into the soil there by encouraging microbial and earth worm activities. The addition of sufficient quantity of plant leaf and stubble and their decomposition, make the soil more porous and productive and less utilization of these nutrients from the soil by leguminous crop. Similar results have also been reported by Singh *et al.* (2012) [24], Vyas (2010) [30]. Integrated nutrients management system could not being significant variation in bulk density and particle density during both the years of experimentation. Application of N_5-75% RDF + FYM@ 5t ha^{-1} + Sulphur@ 40kg ha^{-1} +$ZnSO_4$@ 25 kg ha^{-1} + Boron @ 1.5 kg ha^{-1} reduced the maximum bulk density (1.38 Mg m^{-3} and 1.36 Mg m^{-3}) comparison than RDF alone (1.40 Mg m^{-3} and 1.39 Mg m^{-3}) during both years. Maximum particle density was recorded under the application of N_5-75% RDF + FYM@ 5t ha^{-1} + Sulphur@ 40kg ha^{-1} + $ZnSO_4$@ 25 kg ha^{-1} + Boron @ 1.5 kg ha^{-1} (2.65 Mg m^{-3} and 2.64 Mg m^{-3}) and minimum particle density (2.61 Mg m^{-3} and 2.60 Mg m^{-3}) recorded under the RDF alone during both years analysis. FYM in combination with N, P and K chemical fertilizers resulted in higher soil organic carbon concentration, enhanced crop growth along with higher root biomass production. Bulk density and particle density of soil very slightly decreased under organic sources of nutrient used with inorganic fertilizer as compared to RDF alone supply through inorganic fertilizers alone. Similar results have also been reported by Prakash *et al.* (2002) [21], Piechota *et al.* (2007) [20] and Nagar, *et al*. (2016) [15].

Table 1: Bulk density and Particle density as influenced by integrated nutrient management practices under pigeon pea based intercropping system

Treatments	Bulk density (Mg m-3)		Particle density (Mg m-3)	
	2019-20	2020-21	2019-20	2020-21
Intercropping System				
C_1-Pigeon pea Sole	1.43	1.42	2.62	2.61
C_2-Pigeon pea+ Sesamum(1:1)	1.40	1.39	2.65	2.64
C_3-Pigeon pea+ Sorghum (1:1)	1.42	1.41	2.63	2.62
S.Em±	0.02	0.03	0.03	0.02
C.D.at 5%	NS	NS	NS	NS
Nutrient Management System:				
N_1- RDF	1.42	1.41	2.61	2.60
N_2-75%RDF + FYM@ 5t/ha.	1.41	1.40	2.62	2.61
N_3-75%RDF+FYM@5t/ha+ Sulphur @ 40 Kg/ha.	1.40	1.39	2.63	2.62
N_4-75%RDF+FYM@5t/ha+ Sulphur @ 40 Kg/ha + $ZnSO_4$ @ 25 Kg/ha.	1.39	1.38	2.64	2.63
N_5-75% RDF + FYM@ 5t/ha + Sulphur@40Kg/ha+$ZnSO_4$@ 25Kg/ha + Boron @ 1.5Kg/ha.	1.38	1.36	2.65	2.64
S.Em±	0.02	0.03	0.04	0.06
C.D.at 5%	NS	NS	NS	NS

3.2 Physico-chemical properties

Data on soil pH, EC (dSm^{-1}) and OC (%) as affected by different treatments are presented in Table. (2). Different treatments intercropping did not affect significantly the pH and EC (dSm^{-1}) of soil during both the years. Maximum pH observed in pigeon pea sole (7.81 and 7.79) and minimum in Pigeon pea + sesamum (7.79 and 7.78) and also maximum EC observed in Pigeon pea sole (0.33 and 0.31 dSm^{-1}) over slightly decreased with pigeon pea + sesamum (0.31 and 0.29 dSm^{-1}) intercropping system during both year of experiment. Maximum reduction in soil pH and EC were observed in pigeon pea + sesamum intercropping system during both the years. This might be due to addition of easily decomposable organic materials after which acquired might have greater part of nitrogen requirement from the air as diatomic nitrogen rather than from the soil as NO_3^- their net effect is to lower the pH of soil. Maximum organic carbon (0.34% and 0.36%) of soil was recorded under the pigeon pea + sesamum while, minimum in pigeon pea sole (0.30% and 0.32%) during both the years of study. After harvesting of crop, OC of soil recorded in pigeon pea + sesamum intercropping system was not significantly higher than pigeon pea sole but it was at par with sole pigeon pea + sorghum during both year experimentation. Pigeon pea being legume crops are likely to make liberal to used of atmospheric nitrogen by symbiosis process and thus may added in the fertility status of soil resulting improvement microbial population such as bacteria, actinomycetes, fungi and physical condition of soil. Maximum buildup of organic carbon was observed under pigeon pea + sesamum intercropping system as compared to pigeon sole. Similar results have also been reported by Nagar, *et al*. (2016) [15]. Maximum reduction of pH (7.71 and 7.70) and EC (0.30 and 0.29) recorded under the application of N_5 (75% RDF + FYM@ 5t ha^{-1} + Sulphur@40kg ha^{-1} + $ZnSO_4$@ 25kg ha^{-1} + Boron @ 1.5kg ha^{-1}) while, minimum reduction of pH (7.82 and 7.80) and EC (0.34 and 0.33) recorded under the application of N_1- (RDF alone) and at par with the treatment N_4 (75% RDF + FYM@ 5t ha^{-1} + Sulphur@40kg ha^{-1} + $ZnSO_4$@ 25kg ha^{-1}). Data revealed that amongst integrated nutrient systems, application of N_5 (75% RDF + FYM@ 5t ha^{-1} + Sulphur@40 kg ha^{-1} + $ZnSO_4$@ 25 kg ha^{-1} + Boron @ 1.5kg ha^{-1}) recorded maximum organic carbon in soil which was statistically at par with N_4 (75% RDF + FYM@ 5t ha^{-1} + Sulphur@40kg ha^{-1} + $ZnSO_4$@ 25kg ha^{-1}) during 2019-20 and 2020-21 respectively. Similar results have also been reported by Goud and Andhalkar (2012) [9] and Kumar *et al.* (2014) [12] and Nagar, *et al*. (2016) [15].

Table 2: Soil pH, EC and OC as influenced by integrated nutrient management practices under pigeon pea based intercropping system.

Treatments	pH		EC (dSm^{-1})		OC (%)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Intercropping System						
C_1-Pigeon pea Sole	7.81	7.79	0.33	0.31	0.30	0.32
C_2-Pigeon pea+ Sesamum(1:1)	7.78	7.76	0.31	0.29	0.34	0.36
C_3-Pigeon pea+ Sorghum (1:1)	7.79	7.78	0.32	0.30	0.32	0.34
S.Em±	0.11	0.17	0.02	0.01	0.01	0.01
C.D.at 5%	NS	NS	NS	NS	0.03	0.03
Nutrient Management System						
N_1- RDF	7.82	7.80	0.34	0.33	0.30	0.31
N_2-75%RDF + FYM@ 5t ha^{-1}.	7.75	7.74	0.32	0.31	0.32	0.33
N_3-75%RDF + FYM@5t ha^{-1} + Sulphur@40kg ha^{-1}.	7.74	7.73	0.31	0.30	0.33	0.34
N_4-75%RDF + FYM@5t ha^{-1} + Sulphur @ 40 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}.	7.73	7.71	0.30	0.29	0.34	0.35
N_5-75% RDF + FYM@5t ha^{-1} + Sulphur@40kg ha^{-1} + $ZnSO_4$@25kg ha^{-1} + Boron@1.5kg ha^{-1}.	7.71	7.70	0.29	0.28	0.35	0.36
S.Em±	0.13	0.14	0.02	0.03	0.01	0.02
C.D.at 5%	NS	NS	NS	NS	0.03	0.06

3.3 Chemical properties

3.3.1 Available Nitrogen, Phosphorus, Potassium (kg ha^{-1}) and Available Sulphur (ppm): Data pertaining to Available (N, P, K and S (kg ha^{-1}**)** I soil as influence by intercropping system and integrated nutrient managements system are presented in Table (3). Available nitrogen content in soil was influenced significantly due to pigeon pea sole during both the years of experimentation. Maximum available nitrogen (162.15 and 164.39 kg ha^{-1}) in soil was recorded under the C_1 (Pigeon pea sole) which was significant higher over C_2 (pigeon pea + sesamum) while, at par with C_3 (pigeon pea + sorghum) intercropping system during both the years. However, minimum nitrogen content (157.12 and 159.36 kg ha^{-1}) was recorded in pigeon pea + sesamum intercropping system during both the years. Available phosphorus content in soil was influenced in a pigeon pea sole during both the years. Maximum available phosphorus was observed under pigeon pea sole (16.45 and 17.62 kg ha^{-1}) which was significant higher over C_2 (pigeon pea + sesamum) while, at par with C_3 (pigeon pea + sorghum) intercropping system during both the years. However, minimum phosphorus content (16.24 and 17.40 kg ha^{-1}) was recorded in pigeon pea + sesamum intercropping system during both the yeas. Available potassium content in soil was influenced by pigeon pea sole during both years of experimentation. Maximum available potassium (242.27 and 244.51 kg ha^{-1}) in soil was recorded under the C_1 (pigeon pea sole) which was significant by higher over C_2 (pigeon pea + sesamum) while, at par with C_3 (pigeon pea + sorghum) intercropping system during both the years, respectively. However, minimum potassium content (236.38 and 238.62 kg ha^{-1}) was recorded in pigeon pea + sesamum intercropping system during both the years. Maximum available Sulphur (11.68 and 12.80 ppm) in soil was recorded under the C_1 (Pigeon pea ole) which was significant higher over C_2 (pigeon pea + sesamum) while, at par with C_3 (pigeon pea + sorghum) intercropping system during both the years. However, minimum Sulphur content (11.22 and 12.35 ppm) was recorded in pigeon pea + sesamum intercropping system during both the years. Similar results have also been reported by Kantwa *et al.* (2006) [11], Varalakshmi *et al.* (2005) [28] reported that the legume inter cropping helped to increase the available N, P_2O_5 and K_2O content of the soil. The benefits of including legumes in inter cropping system which improves soil fertility status was reported by Ramesh *et al*. (2008) and Das *et al*. (2010). Increasing levels of available nitrogen and phosphorus in soil has also been reported due to intercropping by Shivran and Ahlawat (2000) [23], Nagar, *et al.* (2016) [15]. The data provided in Table (3). revealed that available nitrogen content in soil differed significantly due to integrated nutrient management system during both the years of study. The available nitrogen in soil was increased under those treatments where organic and inorganic sources were used. Maximum available nitrogen (162.82 and 165.06 kg ha^{-1}) was obtained with N_5 (75% RDF + FYM@ 5t ha^{-1} + Sulphur @ 40kg ha^{-1}+ $ZnSO_4$ @ 25kg ha^{-1} + Boron @ 1.5kg ha^{-1}) while, minimum in N_1- RDF alone (156.55 and 158.79 kg ha^{-1}). With the treatments N_2 (75% RDF + FYM@ 5t ha^{-1}), N_3 (75% RDF + FYM@ 5t ha^{-1}+ Sulphur@40kg ha^{-1}) and N_4 (75% RDF + FYM @ 5t ha^{-1}+ Sulphur @ 40kg ha^{-1}+ $ZnSO_4$@ 25kg ha^{-1}), the available nitrogen content in soil was maximum than (RDF alone). Available phosphorus content in soil differed significantly due to integrated nutrient management system during both the years of study. The available phosphorus in soil was increased under those treatments where organic sources (FYM) of nutrients were used. Maximum available phosphorus (16.77 and 17.93 kg ha^{-1}) was obtained with N_5 (75% RDF + FYM@ 5t ha^{-1}+ Sulphur @ 40kg ha^{-1}+ $ZnSO_4$@ 25kg ha^{-1}+ Boron @ 1.5kg ha^{-1}) while, minimum available phosphorus (15.58 and 16.74 kg ha^{-1}) recorded in N_1 (RDF alone) while, at par with N_4 -75% RDF + FYM @ 5t ha^{-1}+ Sulphur @ 40kg ha^{-1}+ $ZnSO_4$@ 25kg ha^{-1} (16.65 and 17.81 kg ha^{-1}). During decomposition of organic manure, various organic acids will be produced which solubilize phosphates' and other phosphate bearing mineral and thereby lowers the phosphate bearing mineral and thereby lowers the phosphate fixation and increase its availability. Available potassium content in soil differed significantly due to integrated nutrient management system during both the years of study. The available potassium in soil was increased under those treatments where an organic and inorganic source of nutrients was used. Maximum available potassium (241.63 and 243.87 kg ha^{-1}) was obtained with N_5 (75%RDF + FYM@5 ha^{-1} + Sulphur @ 40 kg ha^{-1} + $ZnSO_4$@ 25 kg ha^{-1} + Boron@1.5kg ha^{-1}) while, minimum available potassium (236.46 and 238.70 kg ha^{-1}) was recorded by N_1 (RDF alone) in 2019-20 and 2020-21 respectively. Maximum available Sulphur (12.78 and 13.90 ppm) was obtained with N_5 (75% RDF + FYM@ 5t ha^{-1} + Sulphur @ 40kg ha^{-1}+ $ZnSO_4$ @ 25kg ha^{-1} + Boron @ 1.5kg ha^{-1}) while, minimum in N_1- RDF alone (156.55 and 158.79 kg ha^{-1}). With the treatments N_2 (75% RDF + FYM@ 5t ha^{-1}), N_3 (75% RDF + FYM@ 5t ha^{-1}+ Sulphur@40kg ha^{-1}) and N_4 (75% RDF + FYM @ 5t ha^{-1}+ Sulphur @ 40kg ha^{-1}+ $ZnSO_4$@ 25kg ha^{-1}), the available Sulphur content in soil was maximum than (RDF alone). Soil organic matter affects soil fertility and C and N mineralization capacities of the soil, which determine the availability of plant nutrient. A significantly increase in the available nitrogen, available phosphorus and available potassium content in soil observed with the application of different levels integrated nutrient management system. Similar results have also been reported by Varalakshmi *et al.* (2005) [28], Ullasa *et al*. (2017) [27], Nagar, *et al.* (2016) [15] reported that the legume inter cropping helped to increase the available N, P_2O_5 and K_2O content of the soil.

Table 3: Available N, P, K and S as influenced by integrated nutrient management practices under pigeon pea based intercropping system

Treatments	Available nutrient (kg ha^{-1})							
	N		P		K		S(ppm)	
	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21	2019-20	2020-21
Intercropping System								
C_1-Pigeon pea Sole	162.15	164.39	16.45	17.62	242.27	244.51	11.68	12.80
C_2-Pigeon pea+ Sesamum(1:1)	157.12	159.36	16.24	17.40	236.38	238.62	11.22	12.35
C_3-Pigeon pea+ Sorghum (1:1)	161.26	163.50	16.42	17.58	239.60	241.84	11.47	12.59
S.Em±	1.57	1.45	0.05	0.06	1.71	1.76	0.12	0.13

C.D.at 5%	4.71	4.35	0.15	0.18	5.13	5.28	0.36	0.41
Nutrient Management System								
N_1- RDF	156.55	158.79	15.58	16.74	236.46	238.70	9.30	10.42
N_2-75%RDF + FYM@ 5t ha^{-1}.	159.26	161.50	16.35	17.51	238.58	240.82	10.38	11.50
N_3-75%RDF + FYM@5t ha^{-1} + Sulphur@40kg ha^{-1}.	160.42	162.66	16.52	17.68	239.60	241.83	12.24	13.36
N_4-75%RDF + FYM@5t ha^{-1} + Sulphur @ 40 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}.	161.82	164.06	16.65	17.81	240.82	243.06	12.58	13.70
N_5-75% RDF + FYM@5t ha^{-1} + Sulphur@40kg ha^{-1} + $ZnSO_4$@25kg ha^{-1} + Boron@1.5kg ha^{-1}.	162.82	165.06	16.77	17.93	241.63	243.87	12.78	13.90
S.Em±	0.65	0.29	0.06	0.07	0.65	0.67	0.077	0.099
C.D.at 5%	1.65	0.85	0.19	0.21	1.95	2.01	0.23	0.29

3.3.2 DTPA extractable zinc and boron (ppm)

The data pertaining to DTPA extractable, zinc and boron content in soil as influenced by different intercropping systems and integrated nutrient management system during both the years of study are presented in Table 4. Data clearly revealed that DTPA extractable zinc and boron content in soil were influenced significantly in intercropping system during both the years of study. The maximum DTPA extractable zinc (0.48 and 0.52ppm) and boron (0.47 and 0.48ppm) was found under pigeon pea sole significantly over than pigeon pea + sesamum intercropping system while, at par with pigeon pea + sorghum intercropping system during both the years of experimentation. The minimum DTPA extractable zinc (0.45 and 0.48 ppm) and boron (0.42 and 0.45 ppm) was found under pigeon pea + sesamum intercropping system. Boron plays a key role in the transfer of water and nutrients from the roots to the shoots. The results of the present investigation are in close conformity with the findings of Vidyavathi, *et al.* (2012) [29]. It is clear from the data provided in Table No (4) that DTPA extractable zinc and boron differed significantly due to integrated nutrient management system during both year of experimentation. Significantly higher content of DTPA extractable zinc (0.52 and 0.54 ppm) and boron (0.54 and 0.56 ppm) in N_5 (75%RDF + FYM@5t ha^{-1}+ Sulphur@ 40kg ha^{-1}+ $ZnSO_4$@25kg ha^{-1}+ Boron @1.5kg ha^{-1}) and DTPA extractable of zinc (0.43 and 0.44ppm) and boron (0.40 and 0.41ppm) recorded under the RDF alone during both year of experimentation while, statistically at par with N_4 (75%RDF + FYM@5t ha^{-1}+ Sulphur @ 40 kg ha^{-1}+ $ZnSO_4$@25 kg ha^{-1}) during both the years of experimentation. It was probably due to the fact that application of FYM increased apparent availability of native and added B from soil to crops and higher biomass production. The lowest values of these parameters were under control. This might be due to increased supply of nutrient sources to the crop, as well as due to the indirect effect resulting from reduced loss of nutrients from organic sources. The higher availability of micronutrients in soil on application of manures could be as cribbed to mineralization of these nutrients from added manures. Chelating action of FYM during decomposition of organic manures increases the availability of micronutrient cations and also protected these cations from fixations. Continuous cropping devoid of balanced fertilizers for long time may decrease the available zinc content in soil. Similar results have also been reported by Nooli, Wali, and Bevinakatti. (2020) [16].

Table 4: DTPA extracted Zn and B (ppm) as influenced by integrated nutrient management practices under pigeon pea based intercropping system

Treatments	DTPA extracted of micronutrient(ppm)			
	Zn		B	
	2019-20	2020-21	2019-20	2020-21
Intercropping System				
C_1-Pigeon pea Sole	0.48	0.52	0.47	0.48
C_2-Pigeon pea+ Sesamum(1:1)	0.45	0.48	0.42	0.45
C_3-Pigeon pea+ Sorghum (1:1)	0.46	0.49	0.45	0.47
S.Em±	0.006	0.006	0.013	0.006
C.D.at 5%	0.018	0.018	0.039	0.020
Nutrient Management System				
N_1- RDF	0.43	0.44	0.40	0.41
N_2-75%RDF + FYM@ 5t ha^{-1}.	0.44	0.46	0.45	0.46
N_3-75%RDF + FYM@5t ha^{-1} + Sulphur@40kg ha^{-1}.	0.46	0.47	0.46	0.48
N_4-75%RDF + FYM@5t ha^{-1} + Sulphur @ 40 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}.	0.50	0.52	0.48	0.50
N_5-75% RDF + FYM@5t ha^{-1} + Sulphur@40kg ha^{-1} + $ZnSO_4$@25kg ha^{-1} + Boron@1.5kg ha^{-1}.	0.52	0.54	0.54	0.56
S.Em±	0.01	0.02	0.02	0.02
C.D.at 5%	0.04	0.06	0.06	0.06

4. Conclusion

Intercropping system and integrated nutrients system could not be significant variation in bulk density and particle density during both the years. Maximum reduction in soil pH and EC were observed in the pigeon pea+ sesamum intercropping system during both years. Maximum organic carbon of soil was recorded with pigeon pea+ sesamum while, minimum in pigeon pea sole during both the years. Maximum available macro and micronutrient content in soil was recorded under the C_1 (Pigeon pea sole) which was significantly superior to C_2 (pigeon pea+ sesamum) While, at par with C_3 (pigeon pea+ sorghum) intercropping system during both the years. Maximum bulk density and particle density reduced with the application of 75% RDF + FYM@ 5t ha^{-1} + Sulphur @ 40Kg ha^{-1} + $ZnSO_4$ @ 25 Kg ha^{-1} + Boron @ 1.5Kg ha^{-1} while, minimum in N_1 RDF alone. Maximum reduction of pH, EC and increase organic carbon under application of nutrient system 75% RDF + FYM@ 5t ha^{-1} + Sulphur@ 40 kg ha^{-1} + $ZnSO_4$@ 25 kg ha^{-1} + Boron @ 1.5 kg ha^{-1} over the RDF alone and at par with the treatment 75% RDF + FYM@ 5t ha^{-1} + Sulphur@ 40 kg ha^{-1} + $ZnSO_4$@ 25 kg ha^{-1}. Maximum available macro and micronutrient content was obtained with N_5 (75% RDF + FYM@ 5t ha^{-1} + Sulphur@ 40 kg ha^{-1} + $ZnSO_4$@ 25 kg ha^{-1} + Boron @ 1.5 kg ha^{-1}) while, minimum in N_1 RDF alone.

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