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Soil Quality Assessment using Deviation method under Different Soil and Nutrient Management Practices in Rainfed Vertisol

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ABSTRACT: To evaluate the long term influence of existing soil and nutrient management practices on soil quality using Relative Soil Quality Index (RSQI) approach, two ongoing long term integrated nutrient management experiments in medium black soil (Typic Chromustert) of Bijapur centre were adopted for the study. First experiment was initiated in 1984-85 under rabi sorghum-safflower crop rotation with T1: control, T2: Sorghum- 50 kg N: 25 kg P_2O_5: 0 kg K_2O ha^{-1} recommended dose of fertilizer (RDF), Safflower- 37.5 kg N: 50 kg P_2O_5 :15 kg K_2O ha^{-1} (RDF), T3: 50% N (FYM), T4: 50 % N sunhemp and T5: 50% RDF + 15 kg ha^{-1} $ZnSO_4$ as soil-nutrient management treatments. Second experiment was initiated in 1998-99 under rabi sorghum with T1: Control, T2: 100% N urea; T3: 25 kg N (compost); T4: 15 kg N (compost) + 20 kg N (inorganic), T5: 15 kg N (sunhemp) + 20 kg N (inorganic) and T6: 15 kg N (compost) + 10 kg N (sunhemp) as management treatments. Soil samples collected from these two experiments during 2005 were processed and analyzed for 16 soil quality indicators and Relative Soil Quality Index (RSQI) was computed. In the first set, the order of treatments from the view point of RSQI was 50% RDF + 15 kg ha^{-1} $ZnSO_4$ (1.00) > 50% N (FYM) (0.97) > 50 kg N: 25 kg P_2O_5: 0 kg K_2O ha^{-1} (RDF for Sorghum) - 37.5 kg N: 50 kg P_2O_5 :15 kg K_2O ha^{-1} (RDF for Safflower) (0.84) > 50 % N sunhemp (0.76). Application of 50% RDF + 15 kg ha^{-1} $ZnSO_4$ to sorghum and safflower was found superior most. In the second set, application of 15 kg N (compost) + 10 kg N (sunhemp) (RSQI 1.00) was found most promising. Based on the RSQI, the general ranking was 15 kg N (compost) + 10 kg N (sunhemp) (1.00) > 15 kg N (compost) + 20 kg N (inorganic) (0.86) > 100% N urea (0.78) > 25 kg N compost (0.64) > 15 kg N (sunhemp) + 20 kg N (inorganic) (0.62). The full paper deals with the method of soil quality assessment and computation in detail.

Key words : Soil quality, deviation method, soil quality indicators, relative soil quality index, long-term, sorghum.

In rainfed agro-ecosystem diversity of management practices such as different kinds of tillage, varying levels of fertilizers, conjunctive use of organics and inorganic sources of nutrients, application of herbicides, different crop rotations, mono-crops, intercropping with legumes etc., are being followed on long-term basis in experimental stations. At the same time, farmers are also following variety of management practices. Some of these practices may be quite beneficial for improving soil quality, whereas, others may not prove beneficial. Because of degrading nature of some of the practices, soil quality has deteriorated considerably and response to the inputs such as fertilizer, water and other management levels has gone down. Poor soil quality associated with moisture scarcity results in stagnated low yields in drylands. If suitable soil health restoration management practices are not identified and adopted, there will be further decline in soil quality and productivity. Therefore, it was felt essential to evaluate the changes caused by predominant soil management practices being followed at different rainfed locations for their aggradative and degradative nature using appropriate method, and to work out research strategies for restoration of soil health and its functional capacity for getting optimum returns for every input used.

Soil quality has been defined as the "capacity of the soil to function" (Doran and Parkin 1994; Karlen 1997). Seybold *et al.,* (1998) defined the soil quality as 'The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation.' Soil quality has a profound effect on the health and productivity of a given ecosystem and the environments related to it. Soil quality is often thought of as an abstract characteristic of soils which cannot be defined because it depends on external factors such as land use and soil management practices, ecosystem and environmental interaction, socioeconomic and political priorities and so on (Doran *et al.*, 1996).

The best means to improve or maintain soil quality are, alternative agricultural practices such as crop rotations, recycling of crop residues and animal manures, reduced input of chemical fertilizers and pesticides, and increased use of cover crops and green manure crops, including nitrogen-fixing legumes. These help to maintain a high level of soil organic matter that enhances soil tilth, fertility and productivity while protecting the soil from erosion and nutrient runoff. Effective implementation of these alternative agricultural practices using a holistic or systems approach requires skilled management and innovativeness by the farmers (Parr *et al,* 1992). In other words, soil quality is a net result of degradative and aggradative practices and processes.

Soil quality cannot be measured directly, but must be inferred from measuring changes in its attributes or attributes of the ecosystem, referred to as indicators. Indicators are measurable properties of soil or plants that provide clues about how well the soil can function. Indicators provide signal about desirable or undesirable changes in land and vegetation management that have occurred or may occur in the future. By measuring key attributes of a system, indicators show the condition and trend of the resource being used (Dalal *et al.* 1999). Indicators can be physical, chemical, and biological characteristics and assessed by qualitative or quantitative techniques. After measurements are made, they can be evaluated by looking for patterns and comparing results to measurements taken at a different time or field. Principal soil properties most affected by soil degradation processes could form key attributes for soil quality evaluation. Quantitatively, soil quality can be assessed by developing an integrated or relative soil quality index. A valid soil quality index would help to interpret data from soil measurements and show whether management and land use are having the desired results for productivity, environmental protection and health (Granatstein and Bezdicek, 1992).

Keeping in view the above, study was conducted on existing long-term soil and nutrient management systems being practiced at Bijapur (Karnataka) centre of AICRPDA representing semi arid tropical Vertisols. The prime objective of the study was to evaluate the long term influence of existing soil and nutrient management practices on soil quality using Relative Soil Quality Index (RSQI) approach.

Materials and Methods

Experiment 1 : An ongoing long term permanent manurial trial on integrated nutrient management under sorghum-safflower cropping system representing medium black soil (Vertisols) at Bijapur centre situated at 16° 49’ N and 75° 42’E was adopted for assessment of soil quality as influenced by the management treatments. The experimental site represented Typic Chromustert, clayey soil texture having a soil depth of 60 cm and land slope of < 1%. The soils are deep loamy and clayey mixed red and black. The experiment has been initiated in 1984-85 under rabi sorghum (June - September) - safflower crop rotation (October-February) in a randomized block design with T1: control, T2: Sorghum-50 kg N: 25 kg P_2O_5: 0 kg K_2O ha^{-1} recommended dose of fertilizer (RDF), Safflower- 37.5 kg N: 50 kg P_2O_5 :15 kg K_2O ha^{-1} (RDF), T3: 50% N (FYM), T4: 50 % N sunhemp and T5: 50% RDF + 15 kg ha^{-1} $ZnSO_4$ as soil-nutrient management treatments.

Experiment 2 : Another on-going long-term experiment in Vertisols of Bijapur on integrated nutrient supply system for rainfed semiarid tropics was initiated from 1998-99 with T1: Control, T2: 100% N urea; T3: 25 kg N (through compost having concentration 5 g kg^{1}); T4: 15 kg N (through compost) + 20 kg N (inorganic), T5: 15 kg N (through sunhemp having N concentration 20 g kg^{-1}) + 20 kg N (inorganic) and T6: 15 kg N (compost) + 10 kg N (sunhemp) as management treatments applied to rabi sorghum with three replications with randomized block design was adopted for evaluation and assessment of soil quality. Soil samples collected from these two experiments during 2005 were processed and analyzed for 16 soil quality indicators. The data were subjected to statistical analysis for testing the statistical significance.

Analyses for assessment of soil quality indicators

Soil samples from 0-20 cm depth were collected from the experimental sites during 2005 were passed through 2 mm sieve and were used for chemical analysis for pH, EC, available N, available P, available K, exchangeable Ca and Mg, available S, and micronutrients such as Zn, Fe, Cu, Mn and B. A portion of 2 mm sieved sample was further grinded and passed through 0.2 mm sieve for organic carbon estimation. For biological properties like dehydrogenase assay the 2mm sieve processed samples were stored in a refrigerator for further analysis.

The pH in soil samples was measured in 1: 2.5 soil water suspension and electrical conductivity was also measured in 1:2.5 soil water suspension (Rhoades, 1982). Organic carbon was estimated by wet oxidation method (Walkley and Black, 1934), Available N was estimated using alkaline- $KMnO_4$ oxidizable N method (Subbaiah and Asija, 1956), available P using 0.5M $NaHCO_3$ method (Olsen et al., 1954), available K by neutral normal ammonium acetate extraction method (Hanway and Heidel, 1952), exchangeable Ca, Mg were also analyzed in neutral normal ammonium acetate extract. Exchangeable micronutrients viz., Zn, Fe, Cu, Mn were estimated by DTPA-$CaCl_2$-TEA (Lindsay and Norvell, 1978) using inductively coupled plasma spectrophotometer (ICP-OES, GBC model) while extractable boron was estimated by DTPA-Sorbitol extraction (Lindsay and Norvell, 1978). Bulk density was measured by Keen Raczowski (KR) box method. Dehydrogenase activity of the soils was measured by Triphenyl tetrazolium chloride (TTC) method (Lenhard, 1956).

Methodology for computation of Relative Soil Quality Index (RSQI):

In the present study, different soil-nutrient management treatments have been compared with the control. Hence, a deviation method has been used to see the positive and negative influences on soil chemical health with reference to control plot (Jaladhi Chaudhury et al, 2005). Data from the control plot was considered as reference. In other words, the basic focus was to judge if there was any soil aggradation or degradation due to different management practices being followed in experimental station. The data set generated for 16 soil parameters (physical, chemical and biological) has been considered for computation of relative soil quality indices as influenced by the management treatments. In the first step, the percent deviations of each parameter over the control plot were estimated. The computation was done as follows:

Per cent deviations over control (PD) = $X_i - X / X * 100$

where, X_i is the mean value of soil chemical quality parameter under different treatments and

X is mean value of soil chemical quality parameter under control

The positive (+) and negative (-) signs were assigned to the percent deviations based on the assumptions of the degradative or aggradative nature of the parameters. Positive sign was assigned for all the parameters when there was an increase of values over control and vice versa. The parameters were scored from 1 to 10 depending on their importance and responsiveness towards aggradation or degradation. Then the percent deviations were multiplied by the respective scores as suggested earlier by Dalal and Moloney (2000). The weighted mean was calculated by dividing the summation with the sum total of the ranks, and the weighted mean value was considered as Relative Soil Quality Index (RSQI). The relationship followed is given below:

$$RSQI = {}^{i}\Sigma_n PD_i \times S_i / \Sigma S_i$$

where PD_i is the percent deviation in soil quality parameter over control, S_i is the average score for soil quality parameter, i is the soil quality parameters and n is the number of soil quality parameters.

The RSQI values were then reduced to 0-1 scale. To do this, all the RSQI values were arranged in an ascending order. All the values so arranged were divided by the highest RSQI value so that the highest RSQI value should get the maximum score of 1.

Results and Discussion

Experiment 1 : Across the management treatments, the soil pH varied from 8.71 to 8.86 and EC from 0.23 to 0.26 dS m^{-1} (Tables 1 & 2). Organic carbon varied from 3.37 to 4.15 g kg^{-1}. Application of 50% N (FYM) and 50% RDF + 15 kg ha^{-1} $ZnSO_4$ recorded the highest organic carbon content of 4.15 g kg^{-1}. Suresh et al (1999) reported that the application of $ZnSO_4$ at 25 kg/ha as well as the recommended dose of N and P is required for sustaining the yield of sorghum and cumbu crop and the inclusion of organics in the treatment schedule maintained a higher organic carbon status and the highest available N, P and K. Available nitrogen in the experimental plots ranged from 50.77 to 74.09 which were considerably very low. Application of 50% nitrogen through sunhemp recorded the highest nitrogen content (74.09 kg ha^{-1}) followed by 50% of N through FYM (63.73 kg ha^{-1}). But Bellakki et al (1999) reported that combined application of organic matter and fertilizers

Table 1. Effect of different permanent manurial treatments on soil quality indicators under sorghum-safflower system in Vertisols of Bijapur.

Treatments	pH	EC dSm^{-1}	OC (g kg^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca cmol kg^{-1}	Mg cmol kg^{-1}	S µg g^{-1}
T1: control	8.83	0.23	3.37	50.77	8.26	498.40	10.85	7.58	12.59
T2: Sorghum-50: 25:0 kg ha^{-1} RDF, Safflower- 37.5:50:15 kg ha^{-1} (RDF)	8.71	0.25	3.65	59.04	13.95	541.7	10.85	7.61	16.46
T3: 50% N (FYM)	8.86	0.24	4.15	63.73	13.33	543.7	10.46	7.72	13.43
T4: 50 % N sunhemp	8.73	0.24	3.83	74.09	8.77	503.6	10.75	7.78	12.91
T5: 50% RDF + 15 kg ha^{-1} $ZnSO_4$.	8.83	0.26	4.15	58.24	11.61	526.9	10.69	7.87	25.95
CD @ 0.05	*NS*	*NS*	*0.18*	*6.95*	*1.46*	*22.57*	*NS*	*NS*	*2.02*

Table 2. Effect of different permanent manurial treatments on soil quality indicators under sorghum-safflower system in Vertisols of Bijapur.

Treatments	Zn (µg g^{-1})	Fe (µg g^{-1})	Cu (µg g^{-1})	Mn (µg g^{-1})	B (µg g^{-1})	Dehydrogenase assay (µg TPF hr^{-1}g^{-1})	Bulk density (Mg m^{-3})
T1: control	0.53	9.28	1.70	5.07	0.54	0.74	1.22
T2: Sorghum-50: 25:0 kg ha^{-1} RDF, Safflower- 37.5:50:15 kg ha^{-1} (RDF)	0.56	9.54	1.83	5.63	0.66	0.85	1.18
T3: 50% N (FYM)	0.61	9.66	1.84	6.17	0.75	0.93	1.16
T4: 50 % N sunhemp	0.56	10.64	2.03	6.51	0.65	0.94	1.16
T5: 50% RDF + 15 kg ha^{-1} $ZnSO_4$	2.45	11.00	2.05	6.62	0.62	0.84	1.19
CD @ 0.05	0.14	NS	0.24	NS	0.09	NS	0.04

markedly increased the removal of N by sorghum and safflower than their individual applications. Available phosphorus in the soil ranged from 8.26 to 13.95 kg ha^{-1} and was highest with the application of fertilizer doses @ 50: 25: 0 (N: P_2O_5: K_2O) for sorghum crop and 37.5:50:15 (N: P_2O_5: K_2O) kg ha^{-1} for safflower crop. Zhang and Fang (2007) also reported that available P concentrations in soils were generally higher in the treatments with chemical fertilizer application than with organic manure application. Available potassium in the soils was recorded in the range of 498.4 to 543.7 kg ha^{-1}. Application of 50% N through FYM recorded the highest available potassium content in the soils followed by application of recommended dose of fertilizer (50:25:0 for sorghum and 37.5:50:15 for safflower). There have been several reports of increase in the K content of the soil due to application of crop residues, green leaf manures, and other organic materials (Sharma et al 2005, Badanur et al 1990; Dhillon and Dhillon, 1991). Exchangeable calcium and magnesium in the soil were in the range of 10.46 to 10.85 and 7.58 to 7.87 cmol kg^{-1} respectively. Application of 50% RDF + 15 kg ha^{-1} of $ZnSO_4$ recorded the highest available sulphur (25.95 mg g^{-1}) and zinc (2.45 mg g^{-1}). The other treatments recorded available sulphur within the range of 12.59 to 16.46 mg g^{-1} of soil and available zinc from 0.53 to 0.61 mg g^{-1}.

Available iron and manganese ranged from 9.28 to 11.00 and 5.07 to 6.62 mg g^{-1} respectively and were not significantly influenced by the treatments. Application of 50% N through sunhemp and 50% RDF + 15 kg ha^{-1} of $ZnSO_4$ recorded the highest copper content of 2.03 and 2.05 mg g^{-1} respectively. Application of 50% N thorough FYM recorded the highest boron content of 0.75 mg g^{-1}. The soil dehydrogenase activity is an indicator of the oxidative metabolism in soils and thus of the microbiological activity (Skujins, 1973). Dehydrogenase assay in the soils was in the range of 0.74 to 0.94 mg TPF hr^{-1} g^{-1} and was higher with the application of 50% N through sunhemp (0.94 mg TPF hr^{-1} g^{-1}). Manna et al. (2005) reported that dehydrogenase assay improved significantly with the application of NPK and NPK + FYM. Bulk density of the soil varied from 1.16 to 1.22 Mg m^{-3}. Application of 50% N (FYM) and 50% N (sunhemp) recorded the lowest bulk density of 1.16 Mg m^{-3}.

Relative Soil Quality Index

Prior to computation of soil quality, the data on soil variables were tested for level of significance (P=0.05). Some of the variables such as pH, EC, Ca, Mg, Fe, Mn and dehydrogenase assay were not significantly influenced by the treatments. However, by considering the importance of these variables in black soils, they were included in the main data set while computation of relative soil quality index. It was interesting to note that because of one of the management treatments, the contents of DTPA extractable zinc as well as available sulphur estimated by turbidity method exceeded the higher critical limits. In order to avoid excessive and undue weightage to these two variables, because of their 'high' status, while computation of relative soil quality index, the maximum value considered were 15 mg g^{-1} for sulphur and 0.70 mg g^{-1} for zinc. Related soil quality index was computed using the percent deviation method. Relative soil quality index in these soils ranged form 0.76 to 1.00. Application of 50% RDF + 15 kg ha^{-1} $ZnSO_4$ recorded the highest RSQI of 1.00 followed by 50% N through FYM (0.97) (Fig 1). The order of aggradation of treatments from the viewpoint of soil quality were: 50% RDF + 15 kg ha^{-1} $ZnSO_4$ (1.00) > 50% N (FYM) (0.97) > Sorghum-50: 25:0 kg ha^{-1} RDF, Safflower-37.5:50:15 kg ha^{-1} (RDF) (0.84) > 50 % N sunhemp (0.76).

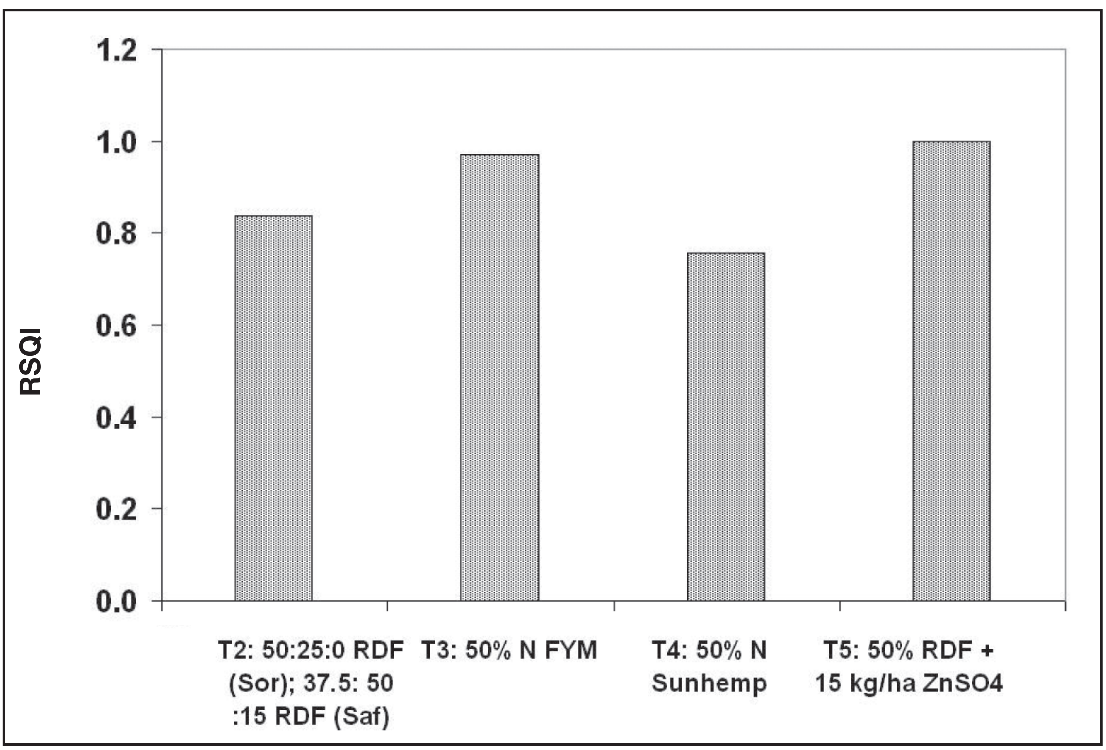

Fig 1. Relative Soil Quality index (RSQI) as influenced by permanent manurial treatments applied to sorghum safflower crops in Vertisols of Bijapur

Experiment 2 : Experimental soils recorded pH in the range of 8.82 to 9.11 and EC 0.25 to 0.31 dSm^{-1} across the treatments (Tables 3 & 4). Organic carbon was highest (6.00 g kg^{-1}) in the soils receiving 15 kg N (compost) + 10 kg N (sunhemp), followed by application of 15 kg N (compost) + 20 kg N (inorganic). Available nitrogen in these soils also was very low, the range being 66.31 to 95.71 kg ha^{-1}. Application of 15 kg N (compost) + 10 kg N (sunhemp) recorded the highest available phosphorus of 12.77 kg ha^{-1} followed by 15 kg N (compost) + 20 kg N (inorganic). Sharma *et al.* (2004) and Mohammad and Mohammad (1999) reported an increase in available P content by the conjunctive use of gliricidia, farmyard manure and inorganic fertilizers. Available potassium in the soils was in the range of 374.9 to 417.3 kg ha^{-1}. Sinha *et al.* (1997) reported that the continuous use of organic manures, either alone or in conjunction with inorganic fertilizers, improved the availability of N, P, and K in the soil. Exchangeable calcium and magnesium varied from 9.97 to 10.39 and 7.84 to 8.93 c mol kg^{-1}. Highest amount of available sulphur (24.23 mg g^{-1}) was recorded with the application

Table 3. Effect of different INM treatments on soil quality indicators under rabi sorghum in Vertisols of Bijapur.

Treatments	pH	EC dSm^{-1}	OC ($g\ kg^{-1}$)	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	Ca cmol kg^{-1}	Mg cmol kg^{-1}	S $\mu g\ g^{-1}$
T1: Control	8.94	0.27	4.95	66.31	6.33	374.9	10.39	8.55	16.47
T2: 100% N urea	8.82	0.31	5.22	95.71	8.54	391.4	9.97	7.84	24.23
T3: 25 kg N compost	9.07	0.25	5.38	85.37	8.21	410.9	10.07	8.55	19.66
T4: 15 kg N (compost) + 20 kg N (inorg)	9.11	0.28	5.51	71.10	11.21	417.3	10.30	8.93	19.30
T5: 15 kg N (sunhemp)+ 20 kg N (inorg)	8.90	0.29	5.03	87.42	9.90	378.9	10.17	8.64	19.41
T6: 15 kg N (compost) + 10 kg N (sunhemp)	8.57	0.27	6.00	93.71	12.77	408.5	10.30	8.25	19.79
CD @ 0.05	*0.31*	*NS*	*0.61*	*8.96*	*2.38*	*NS*	*NS*	*NS*	*3.90*

Table 4. Effect of different INM treatments on soil quality indicators under rabi sorghum in Vertisols of Bijapur.

Treatments	Zn ($\mu g\ g^{-1}$)	Fe ($\mu g\ g^{-1}$)	Cu ($\mu g\ g^{-1}$)	Mn ($\mu g\ g^{-1}$)	B ($\mu g\ g^{-1}$)	Dehydrogenase assay (μg TPF $hr^{-1}g^{-1}$)	Bulk density ($Mg\ m^{-3}$)
T1: Control	0.42	9.51	1.64	6.08	0.55	0.67	1.19
T2: 100% N urea	0.50	9.83	1.67	6.44	0.62	1.15	1.18
T3: 25 kg N compost	0.51	11.17	1.75	6.53	0.78	0.78	1.18
T4: 15 kg N (compost) + 20 kg N (inorg)	0.52	12.06	1.73	6.92	0.74	0.88	1.18
T5: 15 kg N (sunhemp) + 20 kg N (inorg)	0.44	9.53	1.70	6.18	0.82	0.87	1.17
T6: 15 kg N (compost) + 10 kg N (sunhemp)	0.56	9.75	1.91	6.32	0.71	0.89	1.18
CD @ 0.05	*NS*	*NS*	*NS*	*NS*	*0.09*	*0.16*	*NS*

of 100% N through urea. The INM treatments tested under this experiment did not have any significant effect on the availability of micronutrients such as Zn, Fe, Cu and Mn. However, their corresponding contents varied from 0.42 to 0.56, 9.51 to 12.06, 1.64 to 1.91 and 6.08 to 6.92 respectively. Available boron in the soil ranged from 0.55 to 0.82 and was highest with the application of 15 kg N (compost) + 20 kg N (sunhemp) (0.82 mg g^{-1}). Dehydrogenase assay in the soils was recorded to an extent of 0.67 to 1.15 mg TPF hr^{-1} g^{-1} (100% N through urea). The soils had bulk density in the range of 1.17 to 1.19 mg kg^{-1} (Tables 3 & 4).

Relative Soil Quality Indices

The data on all the 16 soil variables was statistically analyzed for testing their significance prior to computation of soil quality. Some of the soil variables viz., EC, K, Ca, S, Zn, Fe, Cu, Mn and bulk density were not significantly influenced by the soil-nutrient management treatments tested over a period of time. But keeping in view the importance of variables in Vertisols, whole data set was allowed for computation of soil quality index. The relative soil quality indices varied from 0.64 to 1.00. Application of 15 kg N (compost) + 10 kg N (sunhemp) recorded the highest RQSI (1.00) followed by 15 kg N (compost) + 20 kg N (inorganic) (0.861) followed by application of 100% N through urea (0.778). From the viewpoint of aggradation, the management treatments were in the order of 15 kg N (compost) + 10 kg N (sunhemp) (1.00) > 15 kg N (compost) + 20 kg N (inorganic) (0.86) > 100% N urea (0.78) > 25 kg N compost (0.64) > 15 kg N (sunhemp) + 20 kg N (inorganic) (0.62) (Fig 2).

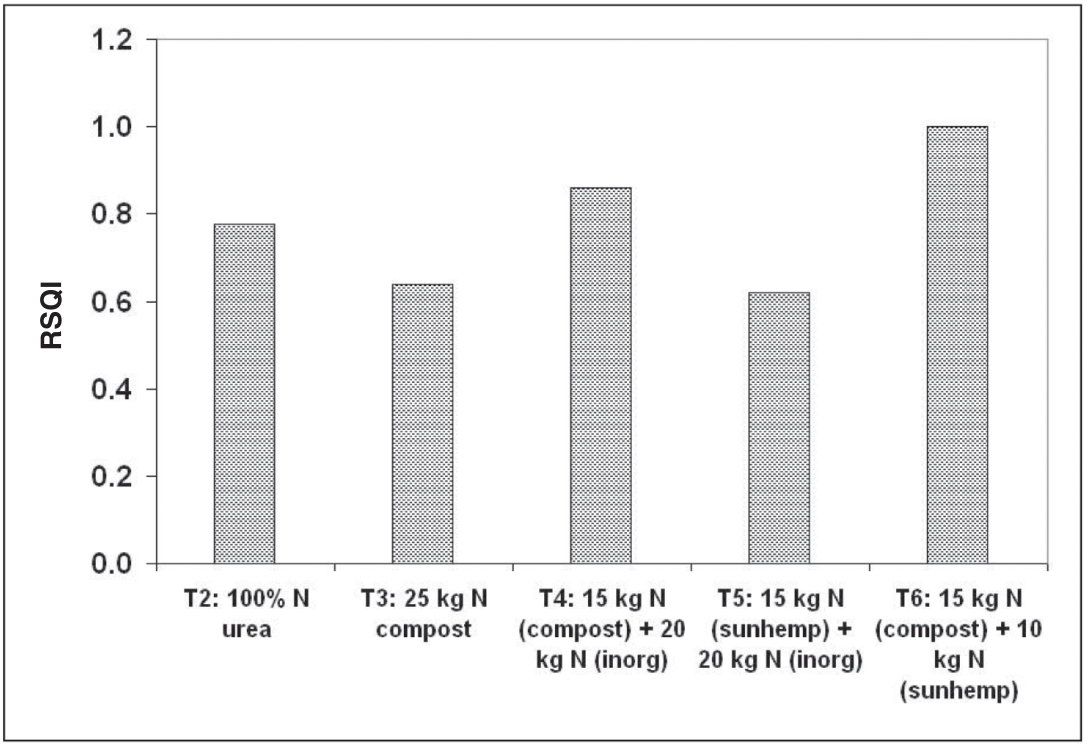

Fig 2. Effect of different INM treatments on relative soil quality index (RSQI) in Vertisols of Bijapur

Conclusions

The results of the present study made for Bijapur on evaluation and assessment of soil quality as influenced by soil nutrient management treatments has great practical significance in selecting the management treatments for future experimentation, as well as for transfer of technology in farmer's fields. The management treatments which reflected higher RSQI values can be advocated in future for field application in their respective identical type of environment (location). At Bijapur centre, two sets of treatments have been evaluated for soil quality and their aggrading and degrading behaviour. In the first set, the order of aggradation was 50% RDF + 15 kg ha^{-1} $ZnSO_4$ (1.00) > 50% N (FYM) (0.97) > 50: 25:0 kg ha^{-1} RDF (Sorghum) - 37.5:50:15 kg ha^{-1} RDF (Safflower) (0.84) > 50 % N sunhemp (0.76). Application of 50% RDF + 15 kg ha^{-1} $ZnSO_4$ to sorghum and safflower was found superior most. This probably is attributed to supplementation of sulphur and zinc to the soil. In another set of treatments applied to rabi sorghum, application of 15 kg N (compost) + 10 kg N (sunhemp) (RSQI 1.00) was found most promising. The second best option could be 15 kg N (compost) + 20 kg N (inorganic) (0.861) followed by application of 100% N through urea (0.778). Based on the relative soil quality index, the general ranking was 15 kg N (compost) + 10 kg N (sunhemp) (1.00) > 15 kg N (compost) + 20 kg N (inorganic) (0.86) > 100% N urea (0.78) > 25 kg N compost (0.64) > 15 kg N (sunhemp) + 20 kg N (inorganic) (0.62).

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