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The Impact of Farmer's Participatory Interventions in Improving the Productivity and Income from Cashew in the Indian West Coast

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Abstract: The participatory extension approaches in the dissemination of agro-techniques serve as an important strategy in reaching the technologies to the clients. Farmer's participatory extension was carried out in cashew plantations in coastal India to demonstrate the usefulness of scientific management practices of nutrient management. The preliminary survey showed that 65% of the farmers did not apply manure and chemical fertilizers. The rest of the selected farmers applied only less than half of the recommended fertilizers, mainly nitrogenous fertilizers or NPK mixture. Only 23% of fields received a minimal quantity of manures. About 12% of fields received the integrated application of manures and fertilizers. Organic carbon status was low to medium in the selected fields and among major nutrients, nitrogen was the most limiting nutrient, followed by potassium. Micronutrient deficiencies of zinc, boron and molybdenum were also observed. The adoption of scientific nutrient management practices along with other agro-techniques for two years found to increase the soil pH. The organic carbon content was improved by 7% and available nitrogen by 9.7%, soil phosphorus and potassium by 6.6 and 15.8% respectively by the adoption of scientific management practices. Among the micronutrients in soil, the copper content was increased by 19%. The adoption of scientific nutrient management practices as per the soil test and leaf nutrient status was beneficial to improve the nutrient uptake by the plants as observed from the increased leaf nutrient status of all essential nutrients. The beneficial effects of the technologies on improving the yield, net returns and the benefit-cost ratio were experienced by the growers.

Key words: Cashew, degraded soils, improved nutrient management, soil carbon, raw cashewnut yield, participatory research.

Cashew is an important economic crop in several tropical countries, supporting the livelihood of millions of people. The tree has its origin on the northeast coast of Brazil and has been spread throughout the tropics during the initial colonization period (Alencar *et al.*, 2018). Among the 36 major tropical countries producing cashew as on 2018, the largest reported area under cashew was with Côte d'Ivoire (1.65 m ha), followed by India (1.00 m ha), Benin (0.62 m ha) and Tanzania (0.57 m ha) (FAOSTAT, 2018). The introduction of this crop to India occurred during the 1600s through Portuguese travelers. Based on the climatic suitability, it is cultivated along the West and East coast in India. During the initial periods, the cashew predominantly found its place in landscapes that are less fertile, without any source of irrigation and not suitable or not profitable for many other crops (Mog *et al.*, 2019). Cashew is regarded as a climate resilient crop requiring fewer inputs compared to other commercial crops. Nevertheless, planting of cashew along the hillocks was also beneficial to prevent soil erosion and runoff helping to arrest further degradation of such fragile landscapes (Rejani and Yadukumar, 2010). As per the FAO statistics, India's position in terms of raw cashewnut productivity was 21 with 762 kg ha^{-1} of raw cashewnuts compared to other producer countries such as Vietnam, Philippines, Peru and Mali. While, the targeted yield is 2 tonnes ha^{-1} under wider spacing (7.5 × 7.5 m) with improved cultivation practices. During the year 2017-18, India produced 0.82 million tons of raw cashewnuts from an area of 1.06 million hectares (Anonymous, 2019). The country imported 0.84 million tonnes of raw cashewnuts from other countries to meet the demand from processing industries. The deficit in production is due to low productivity levels and Nayak *et al.* (2019) attributed the

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low productivity in India to the existence of non-uniform seedling progenies, cultivation in wastelands and non-adoption of modern agro techniques. The continuous cropping in degraded land without the addition of nutrients can lead to reduced land and crop productivity. The nutrient management and other agro techniques were not adequately taken care of by the growers and was one of the reasons for the low productivity in India (Mangalassery *et al.*, 2019b). Similarly, limited attention was paid on soil and water conservation activities and pest management. Supplementing the nutrients removed by the tree from the soil for its growth and development is important to maintain the ecological balance and to harness potential yield (Mangalassery *et al.*, 2019a). Declining soil fertility due to inadequate attention to soil nutrient management is an issue of concern in developing world (Lal, 2015) and is mainly attributed to land degradation caused by excessive nutrient mining (Esilaba *et al.*, 2005).

Technologies developed at research institutes show that 50 to 100% yield increase is possible in cashew by providing timely nutrition (Rupa, 2017). The economic threshold yield (2.8 t ha^{-1}) from mature trees of cashew in Australia was achieved with the application of higher N rates (O'Farrell *et al.*, 2010). The dissemination of agro techniques related to the crop management and plant protection was slow in cashew due to non-involvement of farmers in the technology dissemination programs. The limitation of the top-down approach of technology transfer paved ways for increased involvement of farmers in technology testing and validation, and it helps the farmers appreciate the effect of technology available to them (Richelle *et al.*, 2018). Several researchers addressed the issue of low adoption of technologies developed by scientists and suggested to adopt farmer participatory learning and action research for development and transfer of technologies (Hauser *et al.*, 2016).

Under this background a farmer participatory research cum demonstration was undertaken in the major cashew growing areas in coastal India with the objectives of, i) demonstrating the scientific crop management practices in cashew in the farmer's field to let farmers experience the importance of technology and ii) to assess the impact of such practices on soil fertility, plant nutrient status, yield and economics in cashew.

Materials and Methods

Experimental sites

On-farm trials for the participatory learning and action research were organized across 59 farmer's fields located in three coastal districts of Karnataka, namely Uttara Kannada, Dakshina Kannada and Udupi during 2018-19 and 2019-20 under rainfed conditions (Fig. 1). The farmers were selected based on reconnaissance visits and in consultation with field level extension workers, people's representatives, group discussion and participatory rural appraisal exercises with farmers. The selected farmers possess cashew plantations in the age group of 5 to 10 years under normal planting density (8 m x 8 m). The information such as the age of the plantation, variety of cashew grown, and current fertilizer application rate if any and previous year yield data were collected along with other baseline data. The details of varieties of cashew and age of the plantation of the selected fields are provided in Table 1.

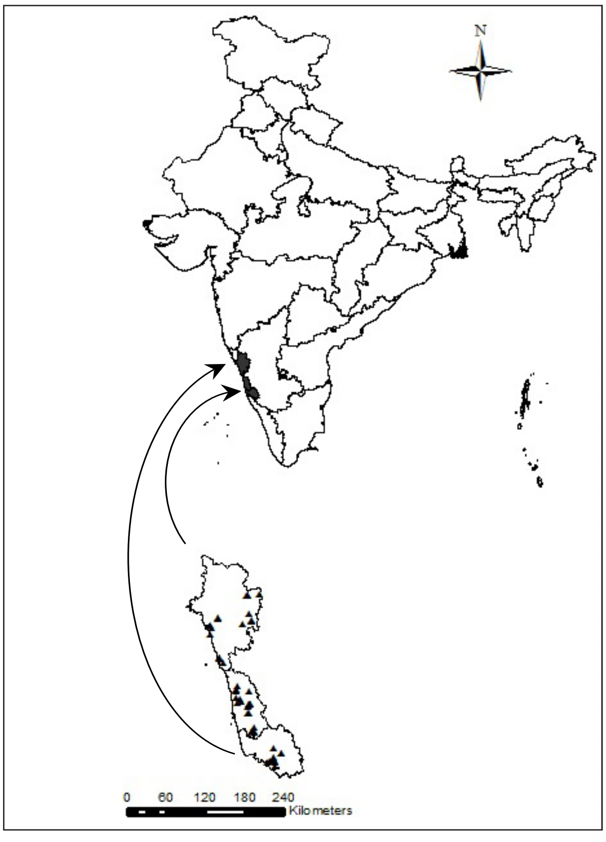

Fig. 1. Location map of the study area.

Table 1. Details of variety of cashew grown, age of the plantation and baseline raw cashewnut yield and benefit-cost ratio

Variety of cashew	Age of the plantation	No. of farmers	Range (kg ha^{-1})	Mean	BCR*
Bhaskara	5	2	35.61-48.56	42.09	1.2±0.1
	6	5	32.70-71.22	51.96	1.3±0.1
	7	2	25.90-100.36	63.13	1.8±0.6
	8	5	38.85-142.45	90.65	2.1±0.3
Ullal-1	5	4	21.04-74.46	47.75	1.3±0.2
	6	3	32.37-42.09	37.23	1.1±0.02
	8	4	25.90-80.94	53.42	1.4±0.21
Ullal-2	8	2	38.85-71.22	55.04	1.5±0.22
Ullal-3	5	4	21.04-80.94	50.99	1.4±0.17
	6	4	32.37-80.94	56.66	1.4±0.2
	8	2	67.99-97.12	82.56	2.2±0.09
Vengurla-4	5	3	27.52-48.56	38.04	1.2±0.07
Vengurla-7	5	6	22.66-64.75	43.71	1.3±0.12
	6	4	25.90-64.75	45.32	1.5±0.08
	8	4	48.56-71.22	59.89	1.6±0.12
	10	2	106.84-145.69	126.26	3.1±0.07
VRI-3	5	3	27.52-64.75	46.13	1.3±0.19

BCR = Benefit-Cost Ratio; *Mean±SEm.

The farmers were instructed to follow the recommended soil fertilizer application based on soil test data for a patch of 1 acre consisting of 80 trees. In the rest of the area, they shall continue to do farming as was followed by them earlier. They also need to record the data on raw cashewnut yield. They were given financial support for all the inputs as well as other crop management practices required for cashew such as weeding, training and pruning, plant protection and soil and water conservation activities.

Soil and leaf sampling and analysis

During the initial traverse during the month of September 2018, soil and leaf samples were collected from each of the 59 selected fields. Soil samples were drawn from the top 15 cm layer after removing the dried leaves and gravels. The samples were dried in the laboratory and sieved through 200 mm sieve. Soil pH was measured in 1:2.5 soil-water suspension using a pH meter and electrical conductivity was measured on the supernatant of 1:2.5 soil-water suspension using a conductivity meter (Jackson, 1973). The available nitrogen content in soil was estimated by following Subbiah and Asija method (Subbiah and Asija, 1956). The available phosphorus (P) was extracted using Bray's reagent (Bray and Kurtz, 1945) and estimated by ascorbic acid reduction method using a UV-Visible spectrophotometer (Shimadzu UV-1900) (Watanabe and Olsen, 1965). The available potassium (K), calcium (Ca) and magnesium (Mg) in soil were extracted with neutral normal ammonium acetate solution (Page *et al.*, 1982). Micronutrients such as iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) in soil was extracted using diethylene triamine penta acetic acid (DTPA) extractant consisting of 0.005M DTPA, 0.01M $CaCl_2.2H_2O$ and 0.1M triethanolamine adjusted to pH 7.3 (Lindsay and Norvell, 1978). The extracted micronutrients, K, Ca and Mg were estimated using a Microwave Plasma Atomic Emission Spectrometer (MP-AES) (AGILENT 4210 MP-AES). The available boron (B) content in soil was extracted using hot water and B in the extract was estimated by measuring the intensity of the color of complex developed by reaction of boric acid with azomethine-H reagent, at 420 nm using a spectrophotometer (Gupta, 1967). The available molybdenum in soil was extracted using ammonium oxalate reagent and was estimated using spectrophotometer, by measuring the absorbance at 680 nm.

In cashew, the index leaf for sampling is 4th leaf with petiole, from the tip of matured branches. The leaf samples were collected from the selected cashew orchards during September 2018 and later after the two year period. About 10 leaves were collected from different branches from all four sides. The leaves were transported to the laboratory and washed using tap water, followed by 0.2% detergent solution, 0.1N hydrochloric acid and double-distilled water. After washing, the leaves were allowed to dry under room temperature, followed by drying in hot air oven at 60°C for 48 hours. The dried leaves were then powdered to pass through 0.5 mm sieve and stored in paper bags for analysis. For nitrogen estimation, the ground plant samples were digested using a mixture of concentrated sulphuric acid and concentrated perchloric acid in 10:4 ratio for 2 hours on sand bath. Total nitrogen in plant sample was determined by distillation to ammonia form using 40% sodium hydroxide using a nitrogen analyser (Pelican – Kelpus Classic DX VATS), followed by titration with 0.02 N sulphuric acid. For all other elements, the plant samples were digested using a mixture of concentrated nitric acid and concentrated perchloric acid in 9:4 ratio. Phosphorus content in the plant digest was estimated by measuring the intensity of yellow color of the vanadomolybdophosphoric complex using a spectrophotometer at 420 nm. The contents of K, Ca, Mg, Fe, Mn, Zn and Cu in the plant digest were measured using Microwave Plasma Atomic Emission Spectrometer. The boron and molybdenum contents in the plant extract were determined using spectrophotometer similar to soil described previously.

Statistical analysis

The statistical software package SAS was used for data analysis. The data on plant nutrient contents were subjected to two-way analysis of variance at $P < 0.01$ level with variety and age of the cashew tree. Standard errors of means were calculated and provided as required. Descriptive statistics of soil nutrient content was derived and provided.

Results and Discussion

Nutrient management practices followed

Out of 59 selected farmers, 38 (64.4%) did not follow any kind of nutrient management program in their cashew plantations. About 35.6% of the selected farmers followed some kind of fertilizer and/or manure application. However, the doses were about 50% lower than the requirement or recommendation. Among the selected farmers 22.0% of them (i.e. 61.9% of the adopters) applied some form of manure in their field once in a few years. Overall, 13.6% (38.1% of the adopters) of the selected farmers applied both fertilizers and manure once in a while. None of the farmers tested their soil before and they believed that soil nutrient may be adequate. The farmers did not apply soil ameliorants such as lime during the past 5 years. The production technologies with respect to nutrient management in cashew for various cashew growing regions has been standardized through research efforts of different workers as summarized by Mangalassery *et al*. (2019b). However, adoption by farmers was largely limited. The decline in soil fertility and land degradation is the consequence of mismanagement of land resources and will have alarming consequences by facilitating soil erosion and runoff (Wiśniewski and Märker, 2019). The levels of utilisation of scientific technologies by cashew farmers of the region were reported to be low and 43% farmers recorded very poor overall adoption of cashew production technologies (Sajeev *et al*., 2015). More than 50% of farmers apply little or no manures and fertilizers to the cashew (Nirban and Sawant, 2000). In the present study, 64.4% farmers did not apply manure and fertilizers to cashew. Poor adoption of modern technologies in cashew by farmers is mainly due to the notion that cashew is a wasteland crop and does not require fertilisation. The other factors being lack of convincing extension approaches (Sajeev *et al*., 2015), non-suitability with regard to the local farming conditions (Wennink *et al*., 2000), availability and accessibility of the inputs and/ or socio-economic conditions of farmers (Sajeev and Manjusha, 2016). The non-application or excess application of essential nutrient elements disturb uptake of nutrients by plants thereby affecting the yield and quality of the produce (Li *et al*., 2019). Corales *et al*. (2019) observed on-farm participatory technology demonstration as the most preferred extension approach among small-holder farmers over farmer field schools and the farmer-to-farmer extension. This increases their confidence in experimentation and risk perception (Kraaijvanger *et al*., 2016). The farmers readily adopt the technologies that are cost-effective and participatory research

Table 2. Soil fertility status of cashew plantations

Parameter	2017-18			2019-20		
	Range	Mean	SD	Range	Mean	SD
pH	4.98- 6.05	5.43	0.23	5.07-6.22	5.53	0.26
EC (dS m^{-1})	0.01-0.07	0.03	0.01	0.01-0.07	0.03	0.01
OC (%)	0.06-1.27	0.57	0.24	0.06-1.36	0.61	0.26
N (kg ha^{-1})	124.79-396.33	253.57	49.16	141.41-453.84	282.77	53.98
P (kg ha^{-1})	7.68-27.10	17.18	5.74	8.15-28.61	18.31	6.10
K (kg ha^{-1})	75.33-292.13	186.91	65.80	84.24-345.57	216.48	76.34
Ca (mg kg^{-1})	73.59-495.37	287.67	111.48	78.53-516.92	303.82	117.53
Mg (mg kg^{-1})	12.26-298.25	110.16	78.04	13.41-323.77	119.79	85.01
Fe (mg kg^{-1})	6.35-86.04	53.51	21.57	6.42-87.62	54.60	21.98
Mn (mg kg^{-1})	0.88-57.94	24.09	19.14	0.90-58.64	24.62	19.58
Zn (mg kg^{-1})	0.20-3.12	0.79	0.54	0.18-2.88	0.74	0.50
Cu (mg kg^{-1})	0.02-9.93	2.05	2.07	0.02- 12.0	2.44	2.48
B (mg kg^{-1})	0.04-0.74	0.44	0.20	0.04-0.70	0.40	0.19
Mo (mg kg^{-1})	0.05-0.49	0.27	0.14	0.04-0.41	0.22	0.11

SD: Standard deviation.

convince them the value for the investment (Jagtap and Abamu, 2003).

Fertility characteristics of soil

The descriptive statistics of the initial soil fertility status is given in Table 2. Wide variability in soil fertility characteristics was observed among the cashew plantations studied. The soil pH ranged from 4.98 to 6.05 with an average value of 5.43 and electrical conductivity from 0.01 to 0.07 dS m^{-1}. The soils were non-saline (0.03 dS m^{-1}). After two years of adoption of the improved crop management practices, no change in electrical conductivity occurred. However, the soil pH increased slightly (5.53). The initial organic carbon status was 0.57% and ranged from 0.06 to 1.27% which was increased by 7% over the initial value with the scientific interventions for 2 years. A similar effect on available nitrogen content in soil was also observed. The farmer participatory interventions led to a 9.7% increase in available soil nitrogen content. The soil P and K content varied from 7.7 to 27.1 kg ha^{-1} and 75.3 to 292.1 kg ha^{-1} respectively at the beginning of the participatory research. The average initial P and K content were 17.2 and 186.9 kg ha^{-1} respectively. The adoption of improved production technologies led to an improvement of soil P and K by 6.6 and 15.8% respectively compared to the initial status. The secondary nutrients such as Ca and Mg showed an increase of 5.6 and 8.7% respectively over the initial status due to the adoption of site-specific nutrient management practices. There was not much change in the content of micronutrients such as Fe and Mn in soil. The Zn content was slightly decreased. The average Cu content was increased from 2.05 to 2.44 mg kg^{-1} (19%), whereas the B and Mo contents were decreased by 9 and 19% respectively. The rating of soil fertility parameters with respect to the soil test rating chart recommended for the region is presented in Table 3. The adoption of scientific practices such as liming of soil led to an increase in soil pH. After two years of interventions, the soils in the strongly acid category decreased to 40.7% from the initial 61.0%. The strongly acid category soil moved to moderately acid and slightly acid category. The electrical conductivity of studied soils remains unchanged. The adoption of the improved management practices for cashew was beneficial to increase the soil organic carbon status. The percentage of soils high in organic carbon was increased from 15.3 to 23.7%. In the case of nitrogen, the number of cashew plantations in different areas under low category was decreased to 28, compared to 48 in the initial period and that under medium category was increased. The soil P and K status also showed improvement due to the adoption of scientific management practices. However, the Ca and Mg content did not change.

Table 3. Frequency distribution of soil fertility parameters as per soil test rating (% distribution under each class in parenthesis)

Parameter	Rating	Class	No. of farms under each class	
			2017-18	2019-20
pH	4.50-5.00	Very strongly acid	1 (1.7)	0 (0.0)
	5.01-5.50	Strongly acid	36 (61.0)	24 (40.7)
	5.51-6.00	Moderately acid	20 (33.9)	28 (47.5)
	6.01-6.50	Slightly acid	2 (3.4)	7 (11.9)
EC (dS m^{-1})	<1	Normal	59 (100.0)	59 (100.0)
OC (%)	<0.50	Low	18 (30.5)	17 (28.8)
	0.51-0.75	Medium	32 (54.2)	28 (47.5)
	>0.75	High	9 (15.3)	14 (23.7)
N (kg ha^{-1})	<280	Low	48 (81.4)	28 (47.5)
	281-560	Medium	11 (18.6)	31 (52.5)
	>560	High	0 (0.0)	0 (0.0)
P (kg ha^{-1})	<9	Low	5 (8.5)	3 (5.1)
	9-22	Medium	40 (67.8)	36 (61.0)
	>22	High	14 (23.7)	20 (33.9)
K (kg ha^{-1})	<120	Low	13 (22.0)	8 (13.6)
	120-280	Medium	40 (67.8)	39 (66.1)
	>280	High	6 (10.2)	12 (20.3)
Ca (mg kg^{-1})	<300	Deficient	27 (45.8)	25 (42.4)
	>301	Sufficient	32 (54.2)	33 (55.9)
Mg (mg kg^{-1})	<120 ppm	Deficient	43 (72.9)	41 (69.5)
	>121 ppm	Sufficient	16 (27.1)	18 (30.5)
Fe (mg kg^{-1})	<4.5	Deficient	0 (0.0)	0 (0.0)
	>4.6	Sufficient	59 (100.0)	59 (100.0)
Mn (mg kg^{-1})	<2.00	Deficient	2 (3.4)	2 (3.4)
	>2.10	Sufficient	57 (96.6)	57 (96.6)
Zn (mg kg^{-1})	<0.60	Deficient	26 (44.1)	26 (44.1)
	>0.61	Sufficient	33 (55.9)	33 (55.9)
Cu (mg kg^{-1})	<0.20	Deficient	2 (3.4)	2 (3.4)
	>0.21	Sufficient	57 (96.6)	57 (96.6)
B (mg kg^{-1})	<0.50	Deficient	35 (59.3)	37 (62.7)
	>0.51	Sufficient	24 (40.7)	22 (37.3)
Mo (mg kg^{-1})	<0.20	Deficient	18 (30.5)	27 (45.8)
	>0.21	Sufficient	41 (69.5)	32 (54.2)

The soil test rating of different plantations remained unaffected for micronutrients such as Fe, Mn, Zn and Copper. The number of deficient category soils with respect to B and Mo was increased from 35 to 37 and 18 to 27 respectively, after the interventions. The positive influence of soil application of manures and fertilizers and foliar application of major and micronutrients to supply different nutrients to cashew was reported by several authors (Kesavan, 1996; O'Farrell *et al*., 2010; Robinson *et al*., 1993; Yadukumar *et al*., 2013). Application of nutrients in a balanced form as per the plant requirement is important to attain the potential yield of crop (O'Farrell *et al*., 2010). Ipinmoroti and Ogeh (2015) while studying the nutrient dynamics under plantation crops including cashew stressed the need for site-specific plantation management for optimal production.

Table 4. The initial leaf nutrient status in cashew in farmer's fields in coastal India during 2017-18

Variety	Age	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mo (mg kg^{-1})	B (mg kg^{-1})
Bhaskara	5	0.78	0.14	0.59	0.46	0.39	252.68	164.36	29.24	27.19	2.36	8.77
	6	1.01	0.08	0.49	0.45	0.30	201.31	280.08	23.58	26.22	2.25	14.95
	7	0.90	0.14	0.50	0.62	0.38	274.99	134.35	26.88	22.47	2.20	9.33
	8	0.85	0.11	0.43	0.71	0.40	299.28	212.33	26.56	18.03	2.24	12.31
Ullal-1	5	1.08	0.09	0.59	0.69	0.41	231.57	249.72	18.52	19.66	2.27	13.02
	6	0.86	0.09	0.57	0.54	0.41	305.90	322.13	18.76	20.73	2.31	8.91
	8	1.09	0.07	0.48	0.77	0.41	277.19	288.96	18.71	21.02	2.16	14.60
Ullal-2	8	0.56	0.11	0.48	0.79	0.41	223.33	200.06	23.64	28.28	2.11	15.52
Ullal-3	5	0.78	0.09	0.54	0.83	0.40	288.13	370.44	26.99	22.38	1.99	11.31
	6	0.88	0.08	0.48	0.74	0.42	269.17	234.06	25.57	26.68	2.26	10.95
	8	0.85	0.11	0.37	0.73	0.37	251.87	223.27	15.15	24.18	2.05	18.48
Vengurla-4	5	0.76	0.11	0.56	0.52	0.41	270.10	209.52	26.80	17.38	2.87	11.22
Vengurla-7	5	0.87	0.10	0.43	0.67	0.41	340.83	273.73	23.18	19.94	1.95	12.45
	6	0.91	0.10	0.49	0.78	0.35	264.19	198.58	22.57	16.65	2.03	11.15
	8	0.79	0.10	0.36	0.71	0.41	243.87	266.77	29.30	17.09	2.21	12.60
	10	0.38	0.07	0.38	0.68	0.41	162.56	135.55	30.14	16.22	2.86	17.36
VRI-3	5	1.01	0.10	0.57	0.63	0.40	214.33	224.86	25.37	22.14	2.29	15.30
$F_{6,12}$ (Variety)		161**	71**	290**	1062**	1587**	383**	360**	234**	284**	529**	479**
$F_{3,42}$ (Age)		163**	30**	374**	1712**	998**	397**	689**	380**	1094**	790**	363**
$F_{18,83}$ (VxA)		60**	13**	99**	622**	334**	135**	231**	147**	413**	275**	109**

Mean values are given, $^{**}p < 0.01$.

Leaf nutrient status

The leaf nutrient status in cashew plantations under study during the year 2017-18 is given in Table 4. The leaf nitrogen content ranged from 0.38 to 1.09% in different cashew plantations. The ranges in leaf P and K status at the beginning of nutrient management interventions were 0.07 to 0.14% and 0.36 to 0.59% respectively. The initial Ca and Mg content in leaves ranged from 0.45 to 0.83% and 0.30 to 0.42% respectively. The lowest Ca content (0.45%) and Mg content (0.30%) in index leaf was observed in 6 year old cashew variety Bhaskara and the highest content of leaf Ca (0.83%) was recorded in 5 year old cashew variety Ullal-3 and Mg (0.42%) in 6 year old Ullal-3. The initial micronutrient status for Fe, Mn, Zn, Cu, B and Mo ranged from 162.6 to 340.8, 134.4 to 370.4, 15.2 to 30.1, 16.2 to 28.3, 8.8 to 18.5 and 2.0 to 2.9 mg kg^{-1} respectively.

The data on leaf nutrient status in the cashew plantations 2 years after following the scientific interventions by growers is presented in Table 5. The leaf N, P and K status in different cashew plantations ranged from 0.47 to 1.49%, 0.08 to 0.15% and 0.42 to 0.73% respectively. The Ca and Mg content in leaf, 2 years after the implementation of scientific crop management ranged from 0.50 to 0.90 and 0.33 to 0.46% respectively. The ranges in micronutrients such as Fe, Mn, Zn, Cu, B and Mo in the leaf during 2019-20 was 221.2 to 376.8, 139.9 to 385.2, 18.0 to 35.0, 17.6 to 29.7, 9.5 to 20.1 and 2.0 to 2.9 mg kg^{-1} respectively.

Unlike soil, the leaf status of all the nutrient elements studied, showed increased contents, 2 years after following the scientific crop management technologies. The increase was prominent for N (18.1 to 45.5% higher in the year 2019-20 compared to status in the year 2017-18) and K (9.2 to 33.8%). After the adoption of the scientific interventions for two years, the P status in the index leaves of the cashew plantations was increased by 6.1 to 12.9%, Ca by 4.1 to 15.8% and Mg by 6.0 to 10.9%. The lowest incremental leaf nutrient content post scientific interventions was observed for Mo (0.53 to 1.98%), preceded by Mn (2.2 to 6.8%) and B (5.1 to 11.8%). The per cent increase in leaf content for micronutrients such as Fe, Zn

Table 5. The leaf nutrient status during 2019-20 in cashew in farmer's fields in coastal India, post interventions

Variety	Age	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Mo (mg kg^{-1})	B (mg kg^{-1})
Bhaskara	5	1.03	0.15	0.73	0.53	0.42	273.04	171.07	35.00	28.36	2.40	9.51
	6	1.33	0.09	0.59	0.50	0.33	221.16	290.80	26.74	27.95	2.28	16.03
	7	1.17	0.15	0.63	0.66	0.41	300.06	139.86	31.62	24.05	2.23	10.39
	8	1.10	0.12	0.53	0.80	0.43	327.63	221.98	31.16	19.01	2.27	13.29
Ullal-1	5	1.45	0.10	0.72	0.76	0.44	254.98	263.37	20.97	20.45	2.29	14.08
	6	1.07	0.10	0.71	0.59	0.44	340.04	336.49	21.63	22.34	2.34	9.51
	8	1.49	0.08	0.56	0.83	0.44	306.21	300.52	21.49	22.24	2.19	15.54
Ullal-2	8	0.74	0.12	0.61	0.90	0.44	245.58	212.59	26.93	29.68	2.14	16.91
Ullal-3	5	1.02	0.10	0.66	0.89	0.44	314.06	385.22	30.45	23.55	2.01	12.47
	6	1.11	0.09	0.56	0.82	0.46	294.34	244.27	29.51	28.49	2.28	12.08
	8	1.09	0.12	0.43	0.80	0.40	276.98	236.04	18.00	25.25	2.07	20.10
Vengurla-4	5	0.98	0.12	0.71	0.56	0.44	293.46	221.50	31.37	18.48	2.90	12.19
Vengurla-7	5	1.16	0.11	0.53	0.75	0.44	376.77	286.58	26.01	21.16	1.97	13.68
	6	1.22	0.11	0.60	0.83	0.38	292.23	208.77	26.18	17.61	2.06	12.11
	8	1.06	0.11	0.42	0.78	0.45	267.96	282.05	34.07	18.00	2.24	13.73
	10	0.47	0.10	0.44	0.77	0.45	238.25	235.55	34.57	17.77	2.45	15.37
VRI-3	5	1.37	0.11	0.68	0.70	0.44	236.88	238.29	29.92	23.49	2.31	16.72
$F_{6,12}$ (variety)		264**	451**	137**	58**	1039**	727**	837**	2306**	730**	1602**	292**
$F_{3,42}$ (Age)		347**	269**	204**	56**	905**	719**	898**	334**	838**	1572**	289**
$F_{18,83}$ (VxA)		127**	107**	54**	19**	300**	227**	274**	132**	321**	557**	94**

Mean values are given, $^{**}p < 0.01$.

and Cu consequent to the adoption of scientific crop management for 2 years ranged from 8.0 to 12.0, 8.2 to 22.0 and 3.1 to 9.0% respectively. In the present study, the improved nutrient management increased N and K content in leaves in cashew trees by 18.1 to 45.5% and 9.2 to 33.8% respectively. Similar kind of increased uptake was observed for other nutrients also. The leaf and soil test based nutrient application ensures the balanced application of required nutrients based on soil fertility status and crop demand, which in turn ensures positive nutrient interactions in soil and balanced nutrient ratios in plants as has been observed by Li *et al*. (2019). They suggested that for the optimum yield and quality of Satsuma (*Citrus unshiu* Marc) fertilizer application should be based on environmental indicators. The increased nutrient status in both soil and plant 2 years after interventions showed efficient utilisation of applied nutrients by the plant and improvement in soil fertility status. Some of the nutrients such as Zn, B and Mo exhibited decreased content in soil post interventions compared to initial soil content. This may be due to the inherent deficiency of these nutrients in tropical acid soils (Bhat *et al*., 2012) and increased uptake of these nutrients and its utilisation in the growth and metabolism in the plant.

Cashewnut yield

The baseline yield data on raw cashewnut before the start of the experiment is given in Table 1. The raw cashewnut yield in cashew plantations ranged from 21.04 to 145.7 kg ha^{-1}. Among different varieties and age of the plantations, the highest raw cashewnut yield was recorded by the 10 year old variety Vengurla-7 and the lowest by 5 year old variety Ullal-1. The raw cashewnut yield from the cashew plantation after 2 years of adoption of scientific crop management practices ranged from 67.14 to 394.04 kg ha^{-1} (Table 6). During the post-implementation period, the highest average yield of 331.86 kg ha^{-1} was recorded by 10 year old cashew variety Vengurla-7 and the lowest (97.55 kg ha^{-1}) by 6 year old variety Ullal-1. The per cent increase in yield due to the adoption of improved technologies was

Table 6. Raw cashewnut yield and benefit-cost ratio after the adoption of scientific management practices in cashew

Variety	Age of the plantation	Raw cashewnut yield (kg ha^{-1}) (2019-20)	Mean	BCR
Bhaskara	5	89.56-130.07	109.81	1.7±0.3
	6	83.24-177.0	130.11	1.8±0.2
	7	67.14-250.58	158.86	2.2±1.1
	8	88.10-394.04	241.07	2.9±0.5
Ullal-1	5	70.82-169.40	120.11	1.6±0.3
	6	75.31-119.77	97.55	1.5±0.18
	8	76.53-225.17	150.85	1.8±0.40
Ullal-2	8	98.66-165.07	131.87	2.0±0.41
Ullal-3	5	67.38-219.95	143.66	1.8±0.30
	6	84.05-216.18	150.12	2.0±0.34
	8	160.78-246.94	203.86	2.8±0.44
Vengurla-4	5	73.21-137.19	105.20	1.5±0.27
Vengurla-7	5	72.76-186.12	129.44	1.6±0.22
	6	68.07-182.7	125.43	1.8±0.30
	8	135.61-192.19	163.90	2.4±0.14
	10	264.14-399.59	331.86	3.9±0.52
VRI-3	5	74.66-154.91	114.79	1.6±0.34

SD: Standard deviation, BCR: Benefit-cost ratio.

in the range of 55.8 to 72.0%. The 5 year old variety Ullal-1 responded well to the improved management practices and recorded an average increased yield of 66.1% compared to baseline yield. The lowest increment in yield (58.7%) was exhibited by 8 year old variety Ullal-2.

Effect of improved crop management technologies on economics

The baseline benefit-cost ratio (BCR) is provided in Table 1. The average baseline BCR was highest for 10 year old variety Vengurla-7 and the lowest for 6 year old Ullal-1. The gross returns and net returns were improved by the adoption of scientific technologies, and it ranged from INR 18249 to 108611 and INR 1890 to 84037 per acre respectively. The average BCR post-intervention period ranged from 1.5 to 3.9. The adoption of scientific crop management was found to be useful to increase the BCR by 13.3 to 43.1% in two years. The response of cashew to nutrient management has been reported by several workers (O'Farrell *et al.*, 2010; Yadukumar *et al.*, 2013; Yadukumar *et al.*, 2011). The application of balanced fertilizers in right quantity lead to improved crop productivity and soil fertility (Mahajan and Gupta, 2009). The increase in raw cashewnut yield due to the adoption of improved management practices by the farmers in this participatory research was in the range of 55.8 to 72.0%. This is in accordance with those reported in experimental fields of research institutions where 50 to 100% increase in yield of cashew is reported in response to nutrient management (Babu *et al.*, 2015). The per cent increase in benefit-cost ratio varied from 13.3 to 43.1%.

Conclusions

Increased yields and income in farmer's fields can be realized in cashew by following improved management practices based on site-specific fertilizer recommendations and other management practices. The improvement in yield due to the scientific management in the farmer's field was in the range of 55.8 to 72.0%. The net income and benefit-cost ratio was also improved indicating the income advantage to the growers, by following the advanced technologies. The non-adoption of scientific technologies can adversely affect the ecosystem, considering the fact that cashew is grown in most neglected and low fertile landscapes in India. The soil acidity and associated land degradation was found to be reduced in cashew plantations managed in a sustainable manner. The soils under cashew showed improvement in soil organic carbon, nitrogen, phosphorus and potassium by the adoption of scientific management practices. The farmer participatory extension approaches are useful for effective dissemination of agricultural technologies and scientific management practices among the growers.

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