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Nutrient budgeting and nutrient balance under high density planting system in cashew (*Anacardium occidentale*)

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ABSTRACT

The study on nutrient budgeting and nutrient balance was conducted to determine the optimal fertilizer requirement for cashew (*Anacardium occidentale* L.) under high-density planting system in relation to yield and net profit. The six-year old plantation of cashew Bhaskara variety under high-density planting system (625 trees/ha) was used. A negative N, P and K balance of 113, 22 and 45 kg/ha/year was found in the control plot where no fertilizers were applied. A strong positive N balance ranged from 137 to 251, P balance from 34 to 75 and K balance from 89 to 164 kg/ha/year were found in trees with two-thirds and full doses of fertilizer treatments. In treatments with one-third dose of fertilizers, a positive N, P and K balance of 40, 19 and 40 kg/ha/year were found. This indicates that in high-density planting system, existing fertilizer schedule, viz. recommended dose of fertilizers (RDF) is on higher side and optimal dose of fertilizer required is only one-third of the RDF. The yield and net profit in full dose and one-third dose of fertilizer treatments were on par. The higher yield of 1.47 and 1.41 tonnes/ha/year and a net profit of ₹ 40 030 and ₹ 41 274/ha/year were obtained in these two treatments. The application of one-third dose of fertilizer to soil instead of recommended dose of fertilizer not only helps to reduce the input required and cost of cultivation but also the ecological hazards arising from excess inorganic fertilizer application. Hence, one-third dose of fertilizer is optimal for cashew plantation under high-density planting system.

Key words: Cashew, Nutrient balance, Nutrient budgeting

It is estimated that about 28 Mt of primary plant nutrients are removed annually by crops in India, while only 18 Mt or even less are applied as fertilizer, leaving a net negative balance of about 10 Mt of primary plant nutrients (NPK) (NAAS 2006). The data available from some centres under the Project Directorate of Cropping Systems Research (PDCSR), Modipuram also indicate that inadequate and imbalanced fertilization is a major causative factor for low and declining crop response to fertilizers. In West Coast region of India, cashew (*Anacardium occidentale* L.), the perennial horticultural crop, is mainly grown as a rainfed crop along the steep slopes of barren hillocks where the fertile topsoil is eroded and the substratum is exposed. Here, the mean annual rainfall ranges from 3000 to 3500 mm with 80% of its contribution during monsoon season (June to October). With the high intensity rainfall distributed over a short duration, the runoff and soil erosion is quite high in steep slopes. Hence, the nutrient content of the soil and productivity of the cashew plantations are low in this region. The average productivity of cashew in India is 0.86 tonne/ha and in Karnataka it is 0.69 tonne/ha against the target of 1.0 tonne/ha (DCCD 2009). Though cashew is hardy and drought tolerant, it responds well to water and nutrients (Sawke 1979, Veeraraghavan 1985, Richards 1993, Kumar *et al.* 1993, Yadukumar and Mandal 1994, Kumar *et al*. 1995, Patrick *et al*. 2002, Yadukumar *et al*. 2001, Yadukumar and Rejani 2004, Yadukumar *et al.* 2009). The productivity of cashew can also be enhanced by adopting high density planting system of cashew (Yadukumar *et al.* 2003). Kumar *et al.* (1993) found the effect of nitrogen, phosphorus and potassium on growth and yield of cashew in coastal soils of Karnataka. Yadukumar (2007) conducted nutritional trials and found that the recommended dose of fertilizer (RDF) with 10 kg poultry manure per tree resulted in cashew nut production of 1.2 tonnes/ha compared to 0.56 tonne/ha in control without any manure.

The present system of cashew nutrition is based on general recommendation for a whole state, without considering the variation in the inherent soil fertility and the

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productivity of cashew. In high density planting system of cashew, the fertilizer recommended is reasonable up to 80-100% canopy coverage which is normally achieved during the initial 6-8 years after planting. After certain stage of the crop, reduction in recommended doses of fertilizers/plant may be necessary due to the nutrient build up in soil due to the deposit of cashew biomass fall out. It has been estimated that by systematically recycling all the waste biomass produced by coconut, it is possible to get back 20.7 kg N, 10.5 kg P_2O_5 and 30.8 kg K_2O/ha/year (Yadukumar *et al.* 2003). Yadukumar and Nandan (2005) determined the nutrient composition of organically recyclable biomass compost with 20% cowdung slurry as N as 0.91 to 1.5 %, available P as 0.34 to 0.6 %, K as 0.39 to 0.46%. Productivity linked prediction models have been developed by Salam *et al.* (2008) to determine the nutrient recommendation in cashew. In this model, the fertlizer N is depending on the soil N and nut yield; fertilizer P_2O_5 and fertilizer K_2O are depending on the nut yield. Nutrient removal by various crops from soils of different agroclimatic zones of Andhra Pradesh was computed on the basis of nutrient removal per specified economic yield by Singh *et al.* 2001. He determined the nutrient balance depending on total fertilizer nutrients used in the zone for all the crops, fertilizer use efficiency factor (N = 0.45, P = 0.25, K = 0.70), nutrient addition through organic manures and total nutrients removed by crops. In Rajasthan, Gupta (2001) calculated the nutrient balance with regard to nutrient status of soils, removal of nutrients by different crops/varieties, amount of N fixed by various legumes, and probable contribution of organic manures. In India, no study has been taken up to determine the optimal NPK requirement based on nutrient budgeting, nutrient balance and yield in cashew. Hence, the study was undertaken with the objective of quantifying the processes involved in nutrient enrichment and nutrient depletion in cashew and to develop a system model for determining the optimal nutrient requirement in cashew. The application of optimal manure to the soil will help to reduce the input required, cost of cultivation and finally the ecological hazards arising out of inorganic fertilizer application.

MATERIALS AND METHODS

The experiment was conducted at Directorate of Cashew Research, Puttur, Dakshina Kannada, Karnataka during 2000–2008 period and it was a part of the National Agricultural Technology Project (NATP) on developing integrated production packages for enhancing productivity of cashew. The study area is characterized by seasonally wet, hot humid with dry season (January to May) during the fruiting period of cashew. The average annual rainfall is 3500 mm and is distributed from May to November. The soil is lateritic, sandy clay loam. The soil moisture holding capacity at field capacity is 33 % by volume and available moisture ranges from 15 to 33% by volume.

The recommended doze of fertilizers varies with the age of plants, tree density and fertility of the soil. The recommended dose of fertilizer (RDF) for the normal density planting of cashew at a spacing of 10 m × 5 m (200 trees/ha) in Karnataka is 500 g N, 125 g P_2O_5, 125 g K_2O/plant. Similarly, for high density planting system at spacing of 4 m × 4 m, it is 250 g N, 62.5 g P_2O_5 and 62.5 g K_2O/plant. The six year old cashew plants of Bhaskara variety with spacing of 4 m × 4 m was used for the experiment. The recommended dose of fertilizer (RDF) during first year after planting (YAP) is 1/5th of the full dose, 2YAP is 2/5th, 3YAP is 3/5th, 4YAP is 4/5th and fifth year onwards is full dose of fertilizers. The present experiment was laid out in random block design with 4 nutrient schedules comprising three manure treatments and a control plot with five replications. The treatments were T1 with no fertilizer, T2 with 1/3rd of recommended dose, T3 with 2/3rd of recommended dose and T4 with full dose of fertilizers.

Estimation of total biomass

In each treatment plot, two trees were cut and different parts such as stem, branches, twigs and leaves were separated. In case of roots, samples were taken at 30 cm cut size laterally as well as vertically between two trees. The fresh and dry weight of roots excavated was converted to tree basis by calculating total root volume for such soils. The bark and wood portions in stem and branches were sampled and the ratio was worked out for each component.

Nutrient analysis of biomass

The nutrient analysis was done for leaf, bark, wood and root samples obtained from dry matter samples collected according to the methods explained above using mean ratio of wood to bark in the whole branch samples. Total wood and bark weight were calculated to determine the separate nutrient contributions to the total. Chemical analysis of the apples and nuts were done as per the standard procedures. All plant samples were washed in tap water and dried at 75 °C for 48 hours in a forced ventilation oven, then powdered and sieved using 1 mm mesh sieve. All samples were digested with H_2SO_4 /H_2O_2 at 360 °C. The extracts were analyzed for nutrients using Atomic Absorption Spectrophotometer (AAS) for K, Ca and Mg. Nitrogen was determined by using Kjeltech autoanalyser with Kjeldal digestion of plant samples and the phosphorus was determined by adopting Olson method.

Nutrient uptake

The nutrient uptake by whole tree basis was determined based on mean macronutrient concentrations present in each component. The total nutrient uptake is the sum of uptake by all the components.

Nutrient analysis of soil

Nutrient content of the soil before and after fertilizer application were determined. Soil samples at three different depths (0 to 90 cm) were oven dried at 70° C and powdered. Nitrogen was determined using Kjeltek Auto-Analyzer, phosphorus was estimated calorimetrically by Vanado Molybdo Phosphate method (Jackson 1958). K was estimated using flame photometer. Calcium, magnesium, ferrous, zinc, manganese and Cu were determined using AAS (by wet digest method).

Nutrient cycling and nutrient balance

Under two cashew plants in each treatment, a net was tied at 20 cm above the ground level to collect canopy fall out such as dried leaves, flowers, apples, nuts and immature nut fall. The canopy fallout was weighed once in a quarter and finally calculated for the whole year. The samples collected for individual components like leaves, flowers and apples were dried, weighed and analyzed for nutrients separately. The nuts were analyzed for kernel nutrient content and the shells were analyzed after separating kernels from the nuts. The immature nuts were included with mature nuts fraction for total nutrients removed by the nuts. After weighing and sampling the cashew canopy biomass fallout (CBF), the materials except nuts were applied back uniformly to the tree as a nutrient source. The soil samples were air dried and sieved using 2 mm sieve. For determining the N, Kjeldal digestion and titration was used. The P was determined by Olson extraction and spectrometer. Ca and Mg were determined by extraction in neutral ammonium acetate and analysis by atomic spectrometer.

NPK addition/deficit was estimated using the equation (Richard 1993)

$$N = N_i + N_{CB} + N_{AM} + N_{CW} - (N_P + N_{uptake}) \quad (1)$$

$$P = P_i + P_{CB} + P_{AM} + P_{CW} - (P_P + P_{uptake}) \quad (2)$$

$$K = K_i + K_{CB} + K_{AM} + K_{CW} - (K_P + K_{uptake}) \quad (3)$$

where N, P and K are the nitrogen, phosphorous and potassium (addition/deficit), N_i, P_i and K_i are the initial soil N, P and K, N_{CB}, P_{CB} and K_{CB} are the canopy biomass N, P and K, N_{AM} P_{AM} and K_{AM} are the applied manure N, P and K, N_{CW} P_{CW} K_{CW} are the canopy wash N, P and K, Np, Pp and Kp are the post soil N, P and K, N_{uptake}, P_{uptake} and K_{uptake} are the N, P and K uptake.

Nut yield and economics

Cashew nut yield was recorded annually from eight trees in each treatment for a period of seven years from 2000 to 2008. The collected nuts were counted and weighed. Fresh and dry weights of a sub sample of 100 nuts from each tree were determined. The dry weight was recorded after sun drying the nuts for six days. The weight per nut including shell was determined at 14 per cent moisture as per the Industrial standard (Kuppelwieser 1989). Then the nut yield/ tree was calculated. The data were subjected to statistical analysis using AGRISTAT package.

RESULTS AND DISCUSSION

Total tree biomass

The total tree biomass at the end of 6th year was high (34.3 kg) in the case of tree receiving full recommended dose of fertilizers. It was low (24.78 kg) in trees receiving no fertilizers (Fig 1). The biomass of each component is presented treatment wise in Fig 2. The biomass of stem, branches and leaves were more. Flower biomass was negligible and hence it was not included while calculating total biomass.

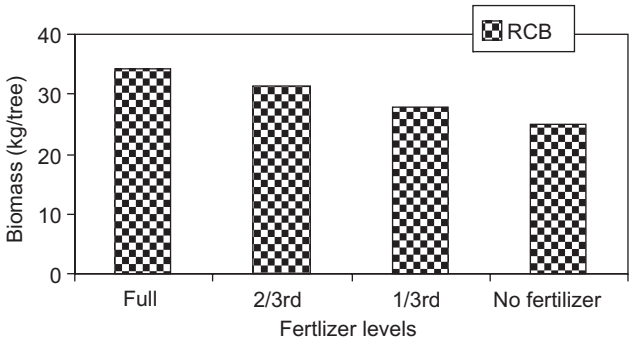

Fig 1 Recyclable cashew biomass available in different treatments

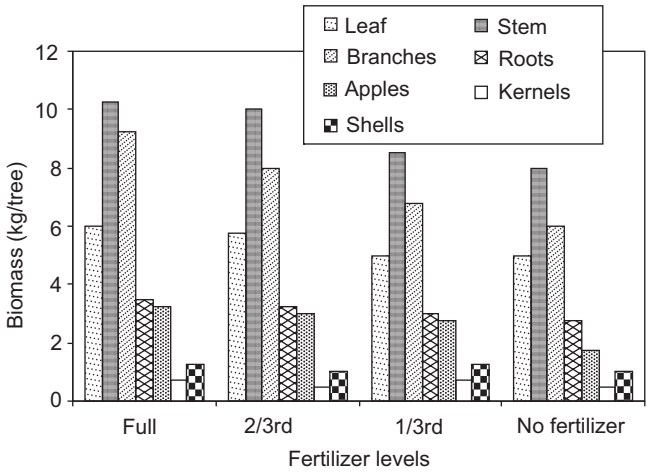

Fig 2 Biomass available from different parts of a 6-year-old cashew tree

Leaf and apple biomass

The total quantity of cashew leaf and apple biomass obtained quarterly is presented in Table 1. The highest leaf and apple biomass was recorded during first quarter (April to June 2001) and then in fourth quarter (January to March 2002). The lowest biomass was recorded during second quarter (July to September 2001). The leaf and apple biomass collected annually was highest in treatment with recommended dose of fertilizers and it was lowest in control plot with no fertilizer. It was observed that 30.5 to 33.5 kg N, 2.95 to 3.27 kg P, 5.17 to 5.73 kg K, 8.12 to 8.99 kg Ca and 7.01 to 7.78 kg Mg/ha year was available from leaf biomass

Table 1 Total leaf and apple biomass/tree/year

Treatment	Leaf biomass (tonnes/ha) Quarter				Total leaf biomass (tonnes/ha)	Apple biomass (tonnes/ha) Quarter				Total apple biomass (tonnes/ha)	Total biomass (tonnes/ha)
	1	2	3	4		1	2	3	4		
T1(No fertilizer)	1.87		0.31	0.94	3.12	1.00			0.087	1.087	4.19
T2 (1/3rd dose)	2.00		0.63	1.13	3.76	1.25			0.500	1.750	5.51
T3 (2/3rd dose)	2.00		0.50	1.19	3.69	1.31			0.543	1.850	5.54
T4 (Full dose)	2.15		0.69	1.25	4.09	1.56			0.475	2.030	6.12

Table 2 Total nutrient contents (kg/ha) in canopy biomass fallout (recyclable biomass)

Treatment	Nutrient contents (kg/ha)				
	N	P	K	Ca	Mg
T1(No fertilizer)	24.00	2.49	4.37	6.87	5.93
T2 (1/3rd dose)	30.60	3.01	5.26	8.27	7.14
T3 (2/3rd dose)	30.50	2.95	5.17	8.12	7.01
T4 (Full dose)	33.50	3.27	5.73	8.99	7.78

collected yearly in treatments receiving 2/3rd of the full dose of fertilizers (Table 2). In treatment with 1/3rd dose of fertilizer, it was 30.60 kg N, 3.01 kg P, 5.26 kg K, 8.27 kg Ca and 7.14 kg Mg/ha respectively. In plot receiving no fertilizer application (control), it was 24.00 kg N, 2.49 kg P, 4.37 kg K, 6.87 kg Ca and 5.93 kg Mg/ha per year respectively. Similar trend in nutrient contents in recyclable canopy biomass fallout was observed after the application of fertilizers also and are presented in Table 4, 5 and 6. The nutrient concentration in different plant parts of a six years old plant are presented in Fig. 3 to 6. The higher nutrient concentrations were observed in leaf and branches. Among the leaves, K concentration was higher in older leaves compared to immature leaves (Table 3).

Total nutrients uptake in six year old cashew trees

The nutrients uptakes in plant receiving different doses of fertilizers are shown in Fig 3 to 7. The nutrient uptake was

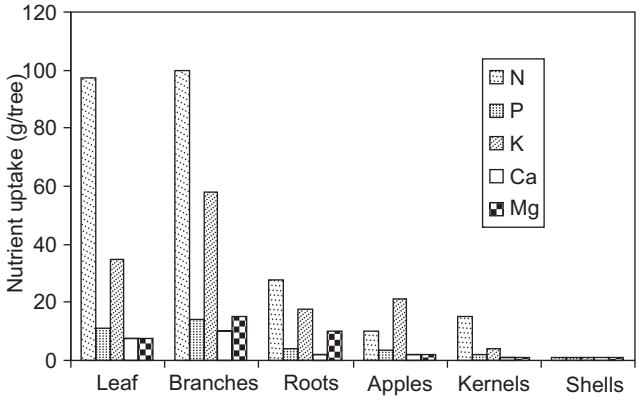

Fig 3 Nutrient distribution in different plant parts receiving control treatment

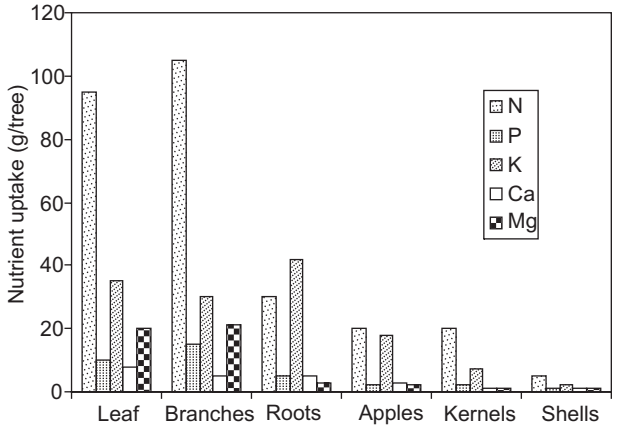

Fig 4 Nutrient distribution in different plant parts receiving 1/3rd RDF

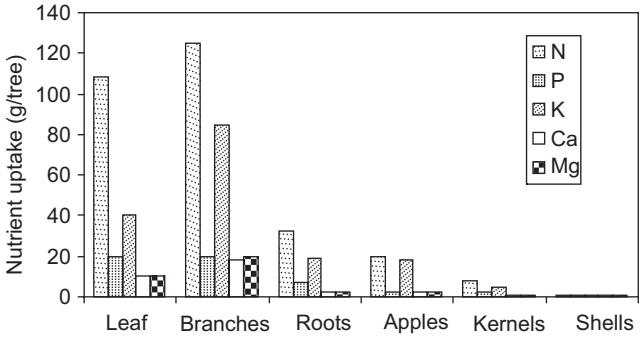

Fig 5 Nutrient distribution in different plant parts receiving 2/3rd RDF

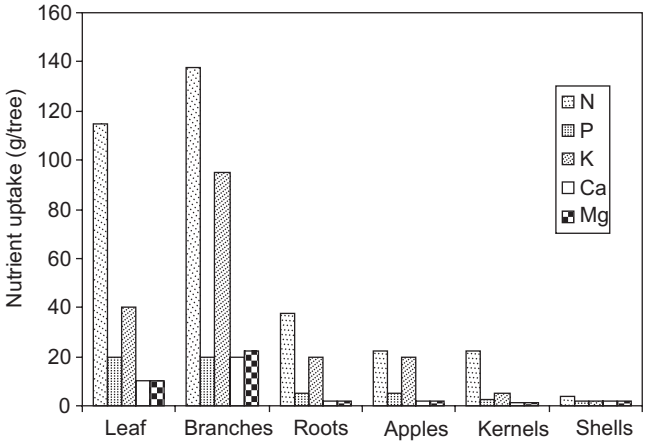

Fig 6 Nutrient distribution in different plant parts receiving RDF

Table 3 Concentration of nutrients in cashew leaves of 6 years old cashew tree

Samples	N(%)	P(%)	K(%)	Ca(%)	Mg(%)
Leaves					
Immature	2.15	0.25	0.68	ND	ND
Matures	2.10	0.29	0.72	0.16	0.16
Old	1.50	0.22	0.69	ND	ND
Mean	1.92	0.25	0.68	0.16	0.16

ND, Not determined

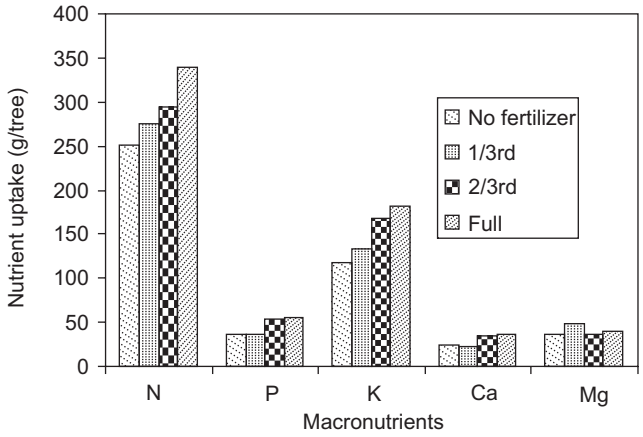

Fig 7 Total nutrients present in whole tree in relation to fertilizer levels

more in leaves and branches compared to roots, apples, kernels and shells. In cashew plants receiving different doses of fertilizers, the N content was in higher quantity followed by P, K, Mg and Ca (Fig 7). The nutrient uptake in plants treated with full dose of fertilizer was 339g N, 55g P and 182g K/tree/year, 2/3rd was 295g N, 55g P and 168g K/tree/year, 1/3rd was 275g N, 36g P and 134g K/tree/year and control treatment was 251g N, 36g P and 117g K/tree/year. It was found that the total nutrient uptake in plants increased with increased application of fertilizers (Fig 7). The N, P and K uptake in kg/ha with different fertilizer levels are presented in Table 4, 5 and 6. Grundon (2001) conducted studies to estimate fertilizer requirement of cashew in Northern Australia and found that an eight year old cashew tree removes 610g N, 58g P and 394g K/tree/year. Mohapatra *et al.* (1973) and Beena *et al.* (1992) also quantified the nutrient removal by cashew.

Soil nutrients

The nutrient content in soil increased significantly after the application of fertilizers. The general build up of nutrients in soil was mainly due to yearly application of fertilizers (Table 4, 5 and 6). It was found that even in control plot the general build up in nutrient contents in soil was found which is mainly due to yearly increasing leaf deposit in the plot which added additional nutrients to the soil resulting

Table 4 Nutrient balance studies on nitrogen

Treatment	Nutrient addition (kg/ha)					Nutrient removal (kg/ha)			N balance
	Initial soil N	Canopy biomas fallout	Fertilizer application	Canopy wash N	Total (A)	Post soil N	N uptake	Total (B)	(kg/ha) (A-B)
T1(No fertilizer)	160	24.00		25.00	209	165	157	322	–113
T2 (1/3rd dose)	165	30.60	156.25	30.00	382	170	172	342	+40
T3 (2/3rd dose)	158	30.50	312.15	35.00	536	215	184	399	+137
T4 (Full dose)	163	33.50	468.75	39.00	704	241	212	453	+251

Table 5 Nutrient balance studies on phosphorus

Treatment	Nutrient addition (kg/ha)					Nutrient removal (kg/ha)			P balance
	Initial soil P	Canopy biomas fallout	Fertilizer appllication	Canopy wash P	Total (A)	Post soil N	P uptake	Total (B)	(kg/ha) (A-B)
T1(No fertilizer)	7.5	2.49		2.5	12	10.5	23	33.5	–22
T2 (1/3rd dose)	9.0	3.01	41.7	3.0	57	15.0	23	38.0	+19
T3 (2/3rd dose)	8.2	2.95	83.3	3.0	97	59.5	34	63.5	+34
T4 (Full dose)	7.2	3.27	125.0	3.0	138	29.2	34	63.2	+75

Table 6 Nutrient balance studies on potassium

Treatment	Nutrient addition (kg/ha)					Nutrient removal (kg/ha)			K balance
	Initial soil K	Canopy biomas fallout	Fertilizer application	Canopy wash K	Total (A)	Post soil K	K uptake	Total (B)	(kg/ha) (A-B)
T1(No fertilizer)	140	4.37		4.5	149	121	73	194	–45
T2 (1/3rd dose)	149	5.26	83.3	5	243	119	84	203	40
T3 (2/3rd dose)	137	5.17	166.7	5	314	120	105	225	89
T4 (Full dose)	135	5.73	250.3	6	397	119	114	233	164

Table 7 Nut and apple yield in relation to fertilizer application (mean of 7 years)

Treatment	Nut yield (kg/ha/year)								Nut weight	Apple yield
	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07	2007–08	Mean	(g/nut)	(kg/ha/year)
T1(No fertilizer)	543.8	1 132	1 640	1 090	1 380	954	620	1 051	7.45	1 089
T2 (1/3rd dose)	912	1 398	2 080	1590	1879	1216	800	1 411	7.70	1 753
T3 (2/3rd dose)	1 017	1 131	1 820	1380	1875	1397	838	1 351	7.95	1 858
T4 (Full dose)	1 116	1 429	1 960	1610	1989	1308	830	1 470	8.12	2 035
	302	415	214.9	266.4	295.7	227.3	87.9	137.1	NS	564

enrichment of soil fertility. This indicates that in high density planting system application of full dose of fertilizers is not necessary for at least six years after planting. Also, no significant change in yield was found due to application of one third and full dose of recommended fertilizer nutrients. However application of one third to full doses of fertilizer nutrients resulted in significantly more yield than control treatment plot without fertilizer application (Table 7).

Nutrient cycling balance and nutrient requirement

The two years mean value for total dry weight of canopy biomass fall out was 55% as leaves, 27.3% as apples, 5.6% as kernels and 12.1 % as shells. The major portion of N, P, K, Ca, and Mg of canopy biomass came from leaves, branches, kernels and apples. Using the mean values for canopy biomass fallout, rainfall and soil nutrient contents developed in plant system, nutrient balance sheet was prepared (Table 4, 5 and 6). It was found that larger amount of nutrients are available for recycling into the system. The largest input of N, P and K were from leaves and apples. K was more from apples and Ca and Mg were more from leaves. A negative N, P and K balance of 113, 22 and 45 kg/ha/year was found in control plot where no fertilizers were applied. A strong positive N balance ranged from 137 to 251, P balance ranged from 34 to 75 and K balance ranged from 89 to 164 kg/ha were found in trees with two third and full doses of fertilizer treatments. In treatments with one-third dose of fertilizers, a positive N, P and K balance of 40, 19 and 40 kg/ha/year were found. This indicates that in high density planting system of cashew, the existing fertilizer schedule is on the higher side and the optimal dose of fertilizer required was only 1/3rd of the recommended doses of fertilizers.

Variation of cashew yield in response to fertilizer and manure application

The application of fertilizers at 1/3rd to full doses (T2 to T4) resulted in significantly more yield (nut and apple production) compared to control treatment (T1) where fertilizers were not applied (Table 7). Among those treatment plots receiving fertilizer doses, no significant difference in yield and net profit were found. This indicates that two third and above recommended doses of fertilizers is not necessary and the quantity of fertilizers to be applied can be curtailed to one third without causing any financial loss. The nut characteristics indicated that nut weight has improved substantially in treatment plots receiving fertilizers (T2 to T4) compared to treatment receiving no fertilizer. The dry weight of apple increased 75 to 100% in treatment plots receiving fertilizers (T2 to T4) compared to control (T1).

Increase in cashew yield due to N application was reported by Veeraraghavan *et al.* (1985) and Ghosh (1988). Positive effect of phosphorous on cashew yield was reported by and Sawke *et al.* (1985). Significant positive effect of potassium on yield of cashew tree was reported by Ghosh (1988) and Ghosh (1990). Increased nut weight and nut yield due to application of higher levels of NPK was reported by Ghosh and Bose (1986), Harishu Kumar and Sreedharan (1986), Ghosh (1990), and Kumar *et al.* (1995).

Economics of high density planting of cashew

Economics worked out indicated that the profit was ₹ 4 127/ha/year and 40 030/ha/year in treatments with 1/3rd and full dose of fertilizers and in control treatment it was only ₹ 32 325/ha/year. The net profit in plants with 1/3rd and full dose of fertilizers were on par. This indicates that 1/3rd dose is sufficient to meet nutrient requirement and to get almost same yield (Table 7). The cost benefit ratio was high in control treatment since no manure application costs were involved. Kumar *et al.* (1993) reported that the application of 500:125:125 g NPK/plant/year produced higher nut yield of 6.23 to 7.8 kg/tree, and a net return of ₹ 21 740/plant/year.

Conclusions

The application of optimal manure to the soil instead of recommended dose of fertilizer will help to reduce the input required, cost of cultivation and finally the ecological hazards arising in case of inorganic fertilizer application. For the judicious use of fertilizers, prior soil testing is required for getting the nutrient status in the soil from time to time. In this nutrient budgeting and nutrient balance study, optimal manure requirement for cashew under high density planting system was determined based on initial soil NPK, NPK uptake by trees, post soil NPK, yield and net profit. A negative N, P and K balance of 113, 22 and 45 kg/ha/year was found in control plot where no fertilizers were applied. A strong positive N balance ranged from 137 to 251, P balance ranged from 34 to 75 and K balance ranged from 89 to 164 kg/ha were found in trees with two third and full doses of fertilizer treatments.

In treatments with one-third dose of fertilizers, a positive N, P and K balance of 40, 19 and 40 kg/ha/year were found. This indicates that in high density planting system of cashew, the existing fertilizer schedule is on the higher side and the optimal dose of fertilizer required was only 1/3rd of the recommended doses of fertilizers. The cashew nut yield and net profit from full dose and 1/3rd dose treatments were on par. The cashew nut yield was 1.47 tonnes/ha/year in treatment with full dose of fertilizer and 1.41 tonnes/ha/year in 1/3rd dose treatment. Similarly, the net profits from these two treatments were ₹ 40 030/ha/year and ₹ 41 274/ha/year respectively. In control plot without any fertilizer application, the net profit was only ₹ 32 325/ha/year. From the point of view of sustainable agriculture, treatment with 1/3rd dose of fertilizer is optimal for cashew.

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