Journal of Tropical Agriculture 50 (1-2) : 37-44, 2012

Nutritional management of yellowing affected areca palms (*Areca catechu* L.) in the Oxisols of central Kerala, India

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Received 24 July 2012; received in revised form 17 September 2012; accepted 18 September 2012.

Abstract

Arecanut (*Areca catechu* L.) plantations in Kerala and the neighbouring states are affected by yellowing caused by soil ill-health and malnutrition. An experiment was conducted in the irrigated garden lands (farmer's fields) at Kannara, Thrissur, Kerala from 2004 to 2006 to study the impact of applying S, Mg, Si, Zn, B, and varying levels of Ca, K, and organic manure on soil and plant nutrient status, yellowing index, and yield of yellowing affected areca palms. Prevailing farmers' practices and recommended practices were taken as controls. The experiment was laid out in randomized block design with five replications. Yield variations manifested either as differences in dry kernel weight of individual nuts or number of nuts palm^{-1}, or both. Higher rates of K improved yield and yield attributes in the presence of S. Application of 150 g lime, 10 kg farm yard manure, chemical fertilizers at 100-40-250 g N, P_2O_5, K_2O, and 60 g magnesium sulphate palm^{-1} year^{-1} (to supply at least 100 g S) resulted in significantly high foliar Mg and chlorophyll contents, kernel yield (3.99 kg palm^{-1}), and lowest yellowing index (84% reduction in yellowing index), implying that it is the best method for managing yellowing affected areca palms in the irrigated garden lands of central Kerala.

Keywords: Kernel yield, Organic manure, Chlorophyll content, Yellowing index.

Introduction

Arecanut (*Areca catechu* L.), popularly known as 'betelnut' or 'supari', is the most popular masticatory stimulant in India. India is also the largest producer of arecanut with a production of 0.478 Tg (10^{12} g) from an area of 0.4 million ha in 2009–'10 (DASD 2010). The states of Kerala and Karnataka together accounts for 79% of the production. Much of the arecanut growing tracts in Kerala and Karnataka are located in the humid tropics of Western Ghats with high rainfall and undulating topography. Palms in most of these areas also suffer from a malady called 'yellowing in arecanut'. The first visible symptom of which is yellowing at the tips of leaflets in two or three leaves of the outermost whorl. Reduction in yield up to 50% and a leaf fall up to 40% are noticed in the affected palms over a span of about three years (Saraswathy and Bhat, 2001). Suspecting the association of plant pathogens, Rawther (1976) and Gurumurthy (1989) called it 'yellow leaf disease'. However, since no definitive information on the causative factors could be elucidated, the nomenclature of 'yellow leaf syndrome' was adopted subsequently (Krishnamurthy and Vajranabhaiah, 2000).

Many previous researchers thought that yellowing of areca palms is due to inadequate and imbalanced nutrition. For example, Mathai (1986) reported high Ca-Mg ratio, and low N, P, and Zn content of the soil as the main cause of yellowing. Deficiency of Zn and Mg (Velappan, 1969), increase in soil acidity and consequent increase in exchangeable Al (CPCRI

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1976) and deficiencies of Mo (Gurumurthy, 1989), K (CPCRI, 1990), Mg (Chowdappa et al., 2002), Ca (CPCRI, 1991; Abraham et al., 1991), B, and S (Guruswamy and Krishnamurthy, 1994) also caused yellowing in areca palms. However, no firm cause-effect relationships could be established. Given that nutrient imbalance and malnutrition are predisposing factors that cause yellowing in areca palms, we hypothesised that addition of soil amendments may restore productivity of the affected palms. We specifically studied the effects of enriching the soil with farmyard manure, macro and micronutrients on elemental composition, chlorophyll content, yellowing index, and yield and yield attributes of yellowing affected areca palms.

Materials and Methods

The field experiment was conducted for three years from 2004 to 2006 in a farmer's field (garden land) at Kannara, Thrissur, Kerala, India (10°32'N, 76°19' E, 35m altitude). The site experienced a hot humid tropical climate with average annual rainfall of 2971 mm and mean monthly temperature from 22 to 37°C during the experimental period. The soil of the experimental site is sandy loam (Oxisol) having acidic pH (5.3), 7.3 g kg^{-1} organic C, 105 mg kg^{-1} available N, 21 mg kg^{-1} available P_2O_5, 129 mg kg^{-1} available K_2O, 712 mg kg^{-1} exchangeable Ca, 88 mg kg^{-1} exchangeable Mg, 6 mg kg^{-1} available S, 57 mg kg^{-1} available Fe, 33 mg kg^{-1} available Mn, 12.5 mg kg^{-1} available Zn, 8 mg kg^{-1} available Cu, 4.3 mg kg^{-1} available B, and 174 mg kg^{-1} total Si.

A garden, planted with variety 'Mangala', and affected by moderate intensities of yellowing was selected after a reconnaissance survey. To characterize yellowing of the palms, an index based on the intensity of yellowing and necrosis in the lower 50% of leaves of the crown and reduction in crown size was worked out (George et al., 1980; Jacob, 2007). Moderately affected palms having an yellowing index between 40 and 50 were selected for superimposing the nutrient management regimes, as part of this study. The palms were 13 year-old and its pre-treatment management included application of 5 kg farmyard manure (FYM) $palm^{-1}$ (8.5 mg N g^{-1}, 2.5 mg P_2O_5 g^{-1}, and 6.5 mg K_2O g^{-1}), 100 g lime $palm^{-1}$, 100 g bone meal $palm^{-1}$ (20.5 % non-water soluble P_2O_5), and irrigation during summer months with 100 L of water once in three days. Yellowing symptoms were noticed from 2002, two years prior to the start of this study.

The treatments were formulated considering the physiochemical properties of the soil and it included the farmers practice (FP) of giving 5 kg FYM, 100 g lime, and 100 g bone meal $palm^{-1}$ as a single dose every year during June; FP+5 kg FYM; recommended practices (RP; 12 kg FYM + 500g lime once in three years + 100-40-140 g N-P2O5-K2O $palm^{-1}$; KAU, 2002); and various combinations of FP with RP, FYM, lime, K_2O, sodium silicate, sulphur, $MgSO_4$, and borax (for details see Table 1). Urea, ammonium sulphate, diammonium phosphate, muriate of potash, sodium silicate, magnesium sulphate, zinc sulphate, and borax were used to supply the required quantities of nutrient elements. The experiment was laid out in randomized block design using single tree plots with five replications. NPK fertilizers were applied in two equal splits during February and September every year; other nutrients were applied along with the first split. Lime at 500 g (once in three years) was applied in the first year of experimentation before the application of FYM. After super-imposing the treatments, weeding and intercultural operations were carried out as per recommendations (KAU, 2002).

Soil and plant samples were collected at pre- and post- treatment stages (i.e., after three years). Soil cores (0 to 25 cm depth at 40 to 50 cm distance from the palm) at three random locations were taken and made into composite samples, dried, sieved through 2 mm sieve, and analysed for pH, organic carbon (Jackson, 1969), available N (Subbiah and Asija, 1956), available P_2O_5, K_2O, and exchangeable Ca and Mg (Jackson, 1969), available S (Hesse, 1971), available B (Wolf, 1974), and total Si (Kolthoff and Sandell, 1952). Foliage samples were

Table 1. Soil physical properties, major nutrient concentration and % change over pre-treatment values (after three years) of an yellowing affected arecanut garden in Thrissur, Kerala, India following adoption of varying nutrient management practices.

Treatments	Organic Carbon (g/kg)	pH	% change	Available N (mg kg^{-1})	% change	Available P (mg kg^{-1})	% change	Available K (mg kg^{-1})	% change
T_1 FP (5 kg FYM + 100g L[1] + 100g BM)	7.9^{a}	4.6^{b}	–16	88^{e}	–16	5.0^{c}	–50	67^{d}	–37
T_2 FP + 5 kg FYM	7.1^{a}	4.5^{b}	–17	94^{e}	–6	5.5^{c}	–39	77^{d}	–25
T_3 RP (12 kg FYM + 500g L + 100-40-140g N-P_2O_5-K_2O)	7.4^{a}	5.9^{a}	+7	132^{cd}	+23	8.5^{ab}	–6	182^{abc}	+65
T_4 FP + 5 kg FYM + 200 g SS + 50g L+ 100-40-140g N- P_2O_5-K_2O	8.4^{a}	5.8^{a}	+9	138^{bcd}	+30	7.5^{b}	–17	167^{bc}	+54
T_5 T_4 + 97 g S	6.8^{a}	6.0^{a}	+17	150^{abc}	+45	9.0^{a}	0	193^{a}	+82
T_6 T_4 + 60 g K_2O	7.5^{a}	5.9^{a}	+16	128^{d}	+24	7.5^{b}	–6	177^{abc}	+69
T_7 T_5 + 60 g K_2O	7.8^{a}	5.9^{a}	+11	133^{cd}	+29	8.0^{ab}	0	188^{ab}	+79
T_8 T_4 + 110 g K_2O	8.1^{a}	6.2^{a}	+22	126^{d}	+21	8.0^{ab}	–16	158^{c}	+49
T_9 T_5 + 110 g K_2O	7.2^{a}	6.1^{a}	+12	135^{cd}	+26	8.0^{ab}	–6	193^{a}	+75
T_{10} T_9 + 60 g $MgSO_4$	6.9^{a}	6.3^{a}	+20	147^{abcd}	+33	9.0^{a}	–5	176^{abc}	+57
T_{11} T_9 + 20 g $ZnSO_4$	7.7^{a}	6.2^{a}	+15	163^{a}	+57	8.5^{ab}	+6	197^{a}	+86
T_{12} F T_9 + 20 g Borax	7.1^{a}	5.8^{a}	+10	157^{ab}	+44	8.0^{ab}	–11	199^{a}	+79

BM= bone meal, FP= farmers' practice, FYM= farm yard manure, L= lime, RP=recommended practices, SS= sodium silicate; Values followed by the same superscript are statistically similar; [1]once in three years

collected from the fourth leaf from the apex (index leaf: Mohapatra and Bhat, 1985) to estimate N, P, K, Ca, Mg (Jackson, 1969), S (Hart, 1961), Zn (Lindsay and Norvell, 1978), B (Wolf, 1974), and Si (Nayar et al., 1975) and leaf chlorophyll content (Shoaf and Livm, 1976). Nuts from freshly harvested bunches were sampled and the weight of dry kernel and number of nuts per palm recorded. Kernel yield palm^{-1} was computed by multiplying weight of dry kernel with number of nuts per palm. The data were subjected to analysis of variance for randomized block design, and the means were compared by Duncan's Multiple Range Test (Duncan, 1955).

Results and Discussion

The characters studied were not statistically significant prior to the imposition of the treatments, implying pre-treatment comparability of the plots. The results are thus discussed based on post-treatment variations among the treatments and the % change over the pre-treatment values.

Rhizosphere nutrient content

Addition of organic manures either at 5 or 10 kg palm^{-1} for three years did not significantly alter the soil organic carbon content (Table 1). This may be because of the relatively high pre-treatment levels (6.7 to 7.8 g organic C kg^{-1}). The high soil organic matter content also did not reflect in terms of available N, which varied from 100 to 110 mg kg^{-1}. Application of 100 g lime palm^{-1} year^{-1} reduced soil pH by 16 to 17 % (Table 1) and exchangeable Ca levels by 31 to 41% (Table 2), implying the inadequacy of this treatment to correct soil pH. Higher dose (e.g., 500 g lime palm^{-1} once in three years) although increased pH moderately, there was a reduction in exchangeable Ca by 4%. Application of 150 g lime palm^{-1} year^{-1}, however, increased pH by 9 to 22 % and exchangeable Ca by 3 to 36%. All

Table 2. Secondary and micro nutrient concentrations in soil and % change over pre-treatment values (after three years) of an yellowing affected arecanut garden in Thrissur, Kerala, India following adoption of varying nutrient management practices.

Treatments	Exchangeable Ca ($mg\ kg^{-1}$)	% change	Exchangeable Mg ($mg\ kg^{-1}$)	% increase	Available S ($mg\ kg^{-1}$)	% increase	Available Zn ($mg\ kg^{-1}$)	% change	Available B ($mg\ kg^{-1}$)	% change
T_1	448^{f}	–41	195^{bcd}	113	9.0^{c}	29	10.8^{bc}	–15	3.9^{bcde}	–5
T_2	494^{f}	–31	207^{b}	152	8.5^{c}	31	10.7^{bc}	–11	4.1^{bcde}	–2
T_3	668^{de}	–4	176^{cde}	106	15.5^{b}	138	10.2^{c}	–21	3.8^{bcde}	–14
T_4	919^{a}	+36	163^{e}	82	16.5^{b}	175	11.5^{bc}	–9	3.7^{bcde}	–15
T_5	941^{a}	+26	199^{bc}	137	22.0^{a}	214	11.3^{bc}	–10	4.3^{bc}	–8
T_6	691^{cde}	+3	185^{bcde}	117	16.0^{b}	167	11.0^{bc}	–11	4.2^{bcd}	–7
T_7	784^{bcd}	+7	193^{bcde}	148	24.0^{a}	269	10.9^{bc}	–12	4.0^{bcde}	–6
T_8	807^{bc}	+12	178^{bcde}	105	15.5^{b}	138	11.7^{bc}	–6	3.6^{de}	–7
T_9	762^{bcde}	+4	191^{bcde}	98	23.5^{a}	262	12.3^{b}	–5	4.3^{b}	+9
T_{10}	717^{cde}	0	241^{a}	162	22.5^{a}	246	11.1^{bc}	–16	3.5^{e}	–15
T_{11}	874^{ab}	+35	189^{bcde}	105	23.0^{a}	283	16.9^{a}	+36	3.6^{cde}	–7
T_{12}	650^{e}	–13	168^{d}	84	21.5^{a}	207	10.4^{bc}	–20	5.3^{a}	+13

Treatment details (T1 to T12) as in Table 1.; Values with the same superscript do not differ significantly.

nutrients applied through inorganic fertilizers except Si and P increased N, K, Ca, Mg, S, Zn, and B contents of the rhizosphere significantly. However, there was considerable reduction in available P and exchangeable Ca in treatments where lime was applied at 100 g per palm and P applied through bone meal, which is intriguing. Nonetheless, a similar decrease in available Zn except in the Zn applied treatment suggested the possibility of insoluble zinc phosphate formation (Debnath and Hajra, 1972). As expected, lower rhizospheric B concentration was noted except in the borax applied treatments. Boron is liable to leaching losses due to its anionic nature under the high rainfall conditions prevailing at the experimental site. Annual addition of borax, however, could maintain its availability within the optimal range. Application of K through inorganic fertilizers increased soil K (49 to 86%). Likewise, soil Mg increased by 241% in $MgSO_4$ treatments. Application of K conjunctively with Mg increased soil K (57%) and Mg (162%) availability. Being a divalent cation, Mg is held more tightly in the soil than monovalent K due to complementary ion effects. Application of magnesium sulphate, therefore, ensured better availability of Mg and available K status of soil. Available S increased noticeably in all fertilizer treatments, regardless of whether the material contained S or not. It was further augmented by the application of S containing fertilizers (Table 2).

Leaf elemental composition

Average plant nutrient status of index leaf prior to application of treatments were 18.6 $mg\ g^{-1}$ N, 2.3 mg P g^{-1}, 8.2 mg K g^{-1}, 4.5 mg Ca g^{-1}, 2.0 mg Mg g^{-1}, 2.4 mg S g^{-1}, 24 mg Zn kg^{-1}, 84 mg B kg^{-1}, and 5.4 mg Si g^{-1} (Table 3). Application of organic manures (T_1 and T_2) reduced N (30 and 21%), P (33 and 30%), K (41 and 33%), and S (15 and 8%) concentrations of the index leaf, implying the need for additional doses of nutrients for yellowing affected palms, which the inorganic fertilizers provided (Table 3). Compared to farmer's practice (T_1) application of additional dose of FYM (T_2) increased Ca content from 2 to 11% and Mg content from 35 to 56% in the index leaf. Likewise, increasing the dose of lime from 100 to 150 g $palm^{-1}$ increased Ca from 36 to 74%. Significant increases in all the leaf nutrients except Si, Zn, and B were observed in the inorganic fertilizer treatments. Increase in leaf N over pre-treatment content ranged from 1.74

Table 3. Nutrient contents in leaf and % change over pre-treatment values (after three years) of an yellowing affected garden in Thrissur, Kerala, India following adoption of varying nutrient management regimes.

Treatments	N (mg g^{-1})	% change	P (mg g^{-1})	% change	K (mg g^{-1})	% change	Ca (mg g^{-1})	% increase	Mg (mg g^{-1})	% increase	S (mg g^{-1})	% change
T_1	13.9^{b}	–30	1.57^{cd}	–33	5.00^{h}	–41	4.88^{b}	2	2.72^{e}	35	2.16^{b}	–15
T_2	14.0^{b}	–21	1.56^{cd}	–30	5.10^{gh}	–33	5.02^{b}	11	2.76^{de}	56	2.23^{b}	–8
T_3	19.6^{a}	+5	2.13^{a}	–9	6.20^{cefg}	–22	6.37^{a}	43	3.69^{ab}	95	3.26^{a}	+38
T_4	18.3^{a}	–6	2.10^{a}	–5	6.30^{c}	–24	6.87^{a}	60	3.73^{ab}	85	3.41^{a}	+48
T_5	17.4^{a}	–5	2.07^{ab}	–17	6.80^{bcdef}	–13	6.43^{a}	36	3.13^{bcde}	63	3.62^{a}	+44
T_6	18.1^{a}	–2	1.90^{abc}	–14	7.05^{bcde}	–11	7.33^{a}	74	3.51^{bc}	84	2.36^{b}	+4
T_7	18.6^{a}	+10	2.14^{a}	–13	7.10^{bcd}	–1	7.26^{a}	57	2.95^{cde}	71	3.41^{a}	+36
T_8	17.6^{a}	–7	2.07^{ab}	–13	6.74^{bcdef}	–16	7.12^{a}	54	3.25^{bcde}	68	2.36^{b}	–4
T_9	19.5^{a}	+9	2.14^{a}	–13	7.18^{bcd}	–21	6.43^{a}	39	3.36^{bcd}	55	3.68^{a}	+44
T_{10}	18.7^{a}	+3	1.91^{abc}	–17	9.30^{a}	+8	7.33^{a}	62	4.34^{a}	105	3.54^{a}	+46
T_{11}	18.9^{a}	+2	2.05^{a}	0	7.50^{bc}	–13	6.46^{a}	59	3.25^{bcde}	57	3.83^{a}	+73
T_{12}	19.1^{a}	–4	2.03^{ab}	–17	7.60^{b}	–11	6.44^{a}	36	2.95^{cde}	50	3.64^{a}	+48

Treatment details (T1 to T12) as in Table 1. Values with the same superscript do not differ significantly.

to 1.96% compared to 1.39 to 1.40% in unfertilized treatments. Foliar P (pre-treatment value 0.16%) increased to 0.19 –0.21% in the inorganic fertilizer applied treatments. Lime applied at 500 g once in three years along with inorganic P fertilizer (T_3) did not significantly increase leaf P content compared to lime applied at 150 g annually (T_4 to T_{12}). This might be due to reduced uptake of P in an excess Ca situation in the soil. Deepa (2001) also reported reduced uptake of P in presence of high Ca content due to formation of insoluble calcium phosphate. Application of K increased the content to 0.62 to 0.93% from the pre-treatment level of 0.5%; the increase was noticeably higher with higher K rates. Application of Mg through inorganic fertilizers resulted in 105% increase in Mg content of the index leaf. However, Zn, B and Si additions did not show variations in their concentrations in the index leaf.

Leaf chlorophyll content and yellowing index

Foliar chlorophyll content varied from a pre-treatment range of 1.06 to 1.19 mg kg^{-1} to 1.20 to 2.03 mg kg^{-1} (Table 4). It was significantly lower in the organic manure alone treatments. Fertilizer application significantly increased chlorophyll content with the highest being in the magnesium sulphate treatment. This is consistent with the findings of Bridgit and Potty (1992). N and Mg being essential for chlorophyll synthesis, their supply along with other elements are essential to increase chlorophyll content. Srinivasan (1982) recorded association of a deranged chlorophyllase-chlorophyll system with yellow leaf affected areca palms. In the affected palms, activity of chlorophyllase was enhanced and concomitantly the chlorophyll content declined.

Application of FYM over and above FP reduced yellowing index significantly to 36 as against the pre-treatment yellowing indices of 40 to 50, through modifying leaf composition of N, S, and Mg. Fertilizer treatments brought about notable reduction in the index values (range of 9 to 18). Application of S and higher rates of K further reduced the yellowing index. In magnesium sulphate treatment it was as low as 7 (i.e., 84% reduction in yellowing index over three years). Menon and Kalyanikutty (1961) also reported successive increase in the number of non-chlorotic leaves of yellowing affected areca palms due to foliar application of magnesium sulphate.

Table 4. Leaf chlorophyll content, yellowing index, yield attributes and yield, and % change over pretreatment values (after three years) of an yellowing affected arecanut garden in Thrissur, Kerala, India following adoption of varying nutrient management regimes.

Treatments	Chlorophyll (mg kg^{-1})	% increase	Yellowing index	% change	Dry kernel weight (g)	% increase	nuts palm^{-1} (number)	% change	Kernel yield (kg palm^{-1})	% change
T_1	1.20^{c}	11	38^{a}	–5	5.98^{c}	2	372^{b}	–12	2.22^{c}	–10
T_2	1.28^{c}	15	36^{b}	–10	6.18^{c}	6	364^{b}	–17	2.25^{c}	–11
T_3	1.7^{7b}	64	16^{d}	–60	7.06^{b}	16	482^{a}	+12	3.40^{b}	+30
T_4	1.76^{b}	59	16^{d}	–60	7.06^{b}	12	510^{a}	+22	3.60^{b}	+36
T_5	1.77^{b}	61	18^{c}	–57	7.59^{a}	10	491^{a}	+25	3.73^{ab}	+38
T_6	1.75^{b}	65	9^{e}	–82	6.88^{b}	14	527^{a}	+14	3.62^{b}	+29
T_7	1.74^{b}	58	9^{e}	–78	7.63^{a}	11	480^{a}	+22	3.66^{ab}	+35
T_8	1.69^{b}	58	10^{e}	–79	6.94^{b}	14	506^{a}	+12	3.51^{b}	+28
T_9	1.75^{b}	58	9^{e}	–82	7.57^{a}	11	501^{a}	+24	3.79^{ab}	+37
T_{10}	2.03^{a}	71	7^{f}	–84	7.73^{a}	10	516^{a}	+28	3.99^{a}	+41
T_{11}	1.67^{b}	46	9^{e}	–80	7.67^{a}	11	488^{a}	+15	3.74^{ab}	+28
T_{12}	1.76^{b}	60	10^{e}	–78	7.60^{a}	8	505^{a}	+23	3.84^{ab}	+34

Treatment details (T1 to T12) as in Table 1.; Values with the same superscript do not differ significantly.

Yield and yield attributes

Significant variations in the yield attributes and yield of areca palm were noticed (Table 4). Both variations in dry kernel weight of individual nuts or number of nuts per palm were noted. The pre-treatment yield (2.48 to 2.92 kg palm^{-1}) changed to 2.22 to 3.99 kg palm^{-1} during a period of three years following the imposition of treatments. Favourable rhizosphere environment, leaf nutrient contents, and chlorophyll development are plausible explanations in this regard. Likewise, annual addition of lime at 150 g palm^{-1} (T_4) increased the number of nuts per palm by 10% over that of 500 g once in three years (T_3). Liming, in particular, improved soil pH and rhizosphere nutrient levels (Tables 1 and 2) and S content of the index leaf (Table 3).

Dry kernel weight was significantly influenced by the application of S, Mg, and the high K dose. Number of nuts per palm increased following inorganic fertilization compared to organic manures. However, the major improvement was due to the application of Mg, highest rate of K, and S application. It is well known that the number of nuts is decided at the time of spikelet differentiation, which happens approximately 18 months before harvest. Any stress either in the form of nutrient or water at that stage may reduce the number of nuts (Ananda, 1999). S application in conjunction with high rates of K resulted in greater increase in nuts and yield than S +low K dose. In the absence of S, higher rate of K, however, did not increase yield ($T_{4,}$ $T_{6,}$ and T_8: Table 3). The yield increase of 36% at lower level of 140 g K_2O was reduced to 29 and 28% at higher levels of 200 and 250 g K_2O palm^{-1} respectively, particularly due to reduction in the number of nuts palm^{-1}. Application of sodium silicate did not show any significant influence as shown by the total Si content in the rhizhosphere or Si content in the index leaf. Application of Zn or B although increased the available contents of nutrients in the rhizosphere, did not ameliorate the leaf elemental composition and consequently the yield attributes or yield were not affected.

On a final note, the present study reveals that application of 150 g lime, a minimum of 10 kg farm yard manure, 60 g magnesium sulphate palm^{-1} year^{-1}, fertilizers at 100-40-250g N, P_2O_5, K_2O palm^{-1} year^{-1}

in two splits in February and September in conjunction with any S containing fertilizer source to supply at least 100 g S may be adopted for managing the yellowing affected areca palms in the irrigated garden lands of central Kerala.

Acknowledgements

The senior fellowship awarded to the first author and project funding to the second author by the Kerala State Council for Science Technology and Environment are gratefully acknowledged.

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