International Journal of Agricultural Sciences
Volume **10** | Issue 1| January, 2014 | 36-41 ***RESEARCH PAPER***

Effect of nutrient management on leaf chlorophyll and productivity of yellowing affected arecanut (*Areca catechu* L.)

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Abstract : Among various factors associated with yellowing of arecanut, soil health and balanced nutrition are profoundly important. Field experiment was conducted in sixteen year old irrigated arecanut (*Areca catechu* L.) plantation in farmer's field during 2004-2006 to study the effect of application of sulphur, magnesium, silicon, zinc, boron and varying levels of calcium, potassium and organic manure on leaf chlorophyll and yield of yellowing affected arecanut. Prevailing farmer's practise and recommended practice were taken as controls. The experiment was laid out in randomized block design with five replications. Observations taken on leaf chlorophyll content, yellowing index, kernel weight and fruit number were analysed. Magnesium sulphate application significantly increased leaf chlorophyll-a by 221 per cent, chlorophyll-b by 200 per cent and total chlorophyll by 201 per cent than the pre-experiment contents and thus significantly lowered yellowing index by 77 per cent. Applications of sulphur together with potassium markedly increased fruit number resulting in 6 per cent increased kernel yield compared to treatments where higher than recommended rate of potassium alone was applied. The study indicated that application of 150 g lime, a minimum of 15 kg farm yard manure, fertilizer at 100 g N, 40 g P_2O_5 and 200 g K_2O/palm/year applied in two equal splits in February and September by way of including a sulphur containing fertilizer source to supply a minimum of 100 g sulphur, 60 g magnesium sulphate, 20 g zinc sulphate and borax at 20 g/palm/year may be adopted for managing yellowing affected arecanut palms cultivated in irrigated terraced upland toposequence of Western ghat.

Key Words : Arecanut, Boron, Chlorophyll, Magnesium, Yellowing, Zinc

View Point Article : Jacob, D., George , Mercy and John, P.S. (2014). Effect of nutrient management on leaf chlorophyll and productivity of yellowing affected arecanut (*Areca catechu* L.). *Internat. J. agric. Sci.*, **10** (1): 36-41.

Article History : Received : 22.07.2013**; Revised :** 08.09.2013**; Accepted :** 06.10.2013

INTRODUCTION

India is the largest producer of arecanut (*Areca catechu* L.) with annual production of 0.478 million tonnes and a total acreage under cultivation of 0.4 million hectares during 2009-10 (DASD, 2010). States of Karnataka and Kerala together account for 79 per cent of total production. Most of the arecanut growing tracts in Kerala and Karnataka are located in humid tropics of Western Ghat region with high rainfall and undulating topography. Arecanut palms in most of these areas suffer from a malady called 'yellowing in arecanut'. The first visible symptom in affected palms is yellowing starting from tips of leaflets in two or three leaves of the outermost whorl (Rawther, 1976). The yield of affected palm is reduced to the extent of 50 per cent over a short span of three years (Nair and Rawther, 2000). Among the various factors associated with yellowing in arecanut, soil health and balanced nutrition are profoundly important as they influence the incidence of yellowing (Ramanandan and Abraham, 2000). As yellowing in arecanut is not amenable to any chemical control methods, the only way out to get good yield is to resort to better management of the plantation (Saraswathy and Bhat, 2001).

Researchers had earlier believed that yellowing in arecanut palm is due to imbalanced nutrition. Deficiency of Zn and Mg (Velappan, 1969); increase in soil acidity and consequent increase in exchangeable Al (CPCRI, 1976); high Ca/Mg ratio and low N, P and Zn content of soil (Mathai, 1986); deficiencies of Mo (Gurumurthy, 1989), K (CPCRI,

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1990), Ca (CPCRI, 1991; Abraham *et al*., 1991), B and S (Guruswamy and Krishnamurthy, 1994) and Mg (Chowdappa *et al*., 2002) were reported to cause yellowing in arecanut palms. However, definite cause effect relationship could not be established. Given that nutrient imbalance predisposes the arecanut palm to yellowing, an experiment was conducted to examine the effect of proper soil amelioration and enrichment of soil with farmyard manure, macro and micronutrients on reduction in yellowing and restoration of productivity of affected arecanut palms.

MATERIAL AND METHODS

Field experiment was carried out for three consecutive years from 2004 to 2006 in a farmer's field. The site was located in terraced upland toposequence at Kannara, Thrissur, Kerala under hot humid tropical climate with average annual rainfall of 2971 mm and mean monthly maximum temperature of 22^{o}C and minimum temperature of 37^{o}C during experimental period. Soil of the experimental site was sandy loam (*Oxisol*) having pH 5.8, organic carbon 8.2 g/kg, available N 131 mg/kg, available P 7.7 mg/kg, available K 118 mg/kg, exchangeable Ca 424 mg/kg, exchangeable Mg 132 mg/kg, available S 5.0 mg/kg, available Fe 39 mg/kg, available Mn 17 mg/kg, available Zn 12 mg/kg, available Cu 8.0 mg/kg, available B 40 mg/kg and total Si 142 mg/kg.

Sixteen year old irrigated plantation with arecanut variety Mangala was used in this study. Traditional farmer's practice (FP) which included application of farmyard manure (FYM) 10 kg/palm (N 8.5 mg/g, P 1.0 mg/g and K 5.4 mg/g) and lime 100 g/palm as a single dose each year during June was the pre-treatment management given to all arecanut palms at the experimental site. Irrigation was also given during summer months with 100 litre water once in three days. Yellowing symptoms were noticed by 2002, two years before start of experiment. An index based on score values for the intensity of yellowing and necrosis observed in lower 50 per cent of leaves of the crown and the reduction in crown size (George *et al.*, 1980; Jacob, 2007) was worked out to characterize the yellowing of the palms. Based on index value, arecanut palms were categorised as 'healthy' with yellowing index 0, 'mildly affected' with yellowing index less than 20, 'moderately affected' with yellowing index 20 to 50 and 'severely affected' with yellowing index more than 50. In the present study, moderately affected palms having yellowing index between 45 and 55 were selected for superimposing nutrient management regimes.

The recommended practice (RP) by Kerala Agricultural University for fertilizing matured bearing arecanut palms under irrigated condition is to apply 12 kg FYM, 500g lime once in 3 years, 100:40:140 g N:P_2O_5:K_2O/palm in two equal split doses during February and September every year (KAU, 2002). The twelve treatments for the experiment were formulated considering the physiochemical properties of the soil and it included the FP; addition of 5 kg FYM to FP; RP and various combinations of FP with RP, FYM, lime, potassium, silicon, sulphur, magnesium and boron (Table 1). The experiment was laid out in randomized block design with five replications. In RP where lime at 500 g (once in three years) was to be applied, the application was done in the first year of experimentation before application of FYM. 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. NPK fertilizers were applied in two equal splits during February and September every year; other nutrients were applied along with the first split.

Soil samples taken at three random locations from the circular basin at 40-50 cm distance away from the bole at 0-25 cm depth using a tube auger were made into composite samples, air dried in shade, ground through 2mm sieve and analysed for soil nutrients. Leaf samples were collected early morning from the fourth leaf from top of crown which is considered as index leaf (Mohapatra and Bhat, 1985) by cutting 4-5 leaflets from the middle of the frond on both sides. The collected leaf samples were kept in black polythene covers and transported to laboratory for estimation of leaf chlorophyll (Shoaf and Livin, 1976). Nuts from freshly harvested bunches were sampled and weight of dry kernel and number of nuts/palm were recorded. Kernel yield/palm was computed by multiplying weight of dry kernel with number of nuts/palm. The data were subjected to analysis of variance for randomised 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 imposition of treatments implying pre-treatment comparability of the plots. The results are thus discussed based on post-treatment variations among the treatments and the percentage change over the pre-treatment values.

Chlorophyll content:

The mean contents of chlorophyll-a, chlorophyll-b and total chlorophyll in the index leaf prior to the experiment were 0.38, 0.34 and 0.85 mg/g of leaf tissue, respectively (Table 1). Addition of 5 kg FYM over farmer's practice (T_2) increased chlorophyll-a by 53 per cent, chlorophyll-b by 24 per cent and resulted in 36 per cent increased total chlorophyll. Significant increases in chlorophyll-a, chlorophyll-b and total chlorophyll were observed by way of imposing inorganic treatments (T_3 to T_{12}) where percentage increase in chlorophyll-a varied from 95 to 221 per cent, chlorophyll-b varied from 103 to 200 per cent and resulted in 79 to 201 per cent in increased total chlorophyll. Magnesium sulphate application recorded highest chlorophyll-a 1.22 mg/g, chlorophyll-b 1.02 mg/g and total chlorophyll 2.47 mg/g contents after third year of experiment resulting in 221, 200 and 201 per cent increased contents of chlorophyll-a, chlorophyll-b and total chlorophyll, respectively than the pre-experiment contents. Application of zinc and boron had resulted in 110 and 134 per cent increase in total chlorophyll content.

Under the lowest potassium level (T_4 and T_5), application of sulphur had brought about 5 per cent increase in chlorophyll-a and 7 per cent decrease in chlorophyll-b whereas at higher level of potassium (T_8 and T_9) the effect due to sulphur application was reverse with a 1 per cent decrease in chlorophyll-a and 5 per cent increase in chlorophyll-b. Thus at higher potassium level, applied sulphur facilitates development of chlorophyll-b which is a precursor of chlorophyll-a. The relative proportion of chlorophyll-a and chlorophyll-b was also found to vary depending on treatments. Ratio of percentage increase in chlorophyll-a to percentage increase in chlorophyll-b for organic treatments (T_1 and T_2) was high at 1.4 to 2.2 whereas inorganic treatments (T_3 to T_{12}) recorded a lower ratio of 0.9 to 1.1. At suboptimal nutrient concentrations particularly nitrogen, chlorophyll-a alone will develop and chlorophyll-b, believed to be developed from chlorophyll-a, fail to develop because of inhibition in the concerned reaction mechanism (Bridgit and Potty, 1992). This incidentally will explain the reason for low productivity under low nutrient concentrations. Mayers and French (1960) reported that photosynthetic efficiency will be maximum only in the two pigment system process. A deficiency in one will bring about more than proportionate reduction in assimilation rate.

Chlorophyll being a proteinaceous product and seat of photosynthesis, its content in plant is very much indicative of physiological and growth processes taking place in plant. The stress developed due to climate, and soil characteristics particularly imbalance of nutrient elements largely affect the biosynthetic pathway of chlorophyll development. Dhananjaya *et al.* (2009) had reported deficiency of nitrogen and magnesium in leaves of yellowing affected arecanut palms. Nitrogen and magnesium being essential for chlorophyll synthesis their supply along with other nutrient elements as enzyme activators were proved to be highly essential to increase chlorophyll-a, chlorophyll-b and thereby total chlorophyll.

Yellowing index:

The treatment palms selected were having yellowing index in the range of 45-55 with minimum variation in the incidence of yellowing as evidenced by statistical non significance at pre-treatment stage (Table 1). Farmer's practice of applying FYM and lime (T_1) had reduced yellowing

Table 1 : Effect of nutrient management on leaf chlorophyll and yellowing index of yellowing affected arecanut palms

	Treatments	Chlorophyll-a (mg/g)				Chlorophyll-b (mg/g)				Total chlorophyll (mg/g)				Yellowing index			
		2004	2005	2006	Per cent change	2004	2005	2006	Per cent change	2004	2005	2006	Per cent change	2004	2005	2006	Per cent change
T_1	FP (10 kg FYM + 100 g L)	0.38	0.37	0.48	26	0.34	0.30	0.4	18	0.85	0.81	1.02	20	55	44	39	29
T_2	FP + 5 kg FYM	0.36	0.44	0.55	53	0.34	0.35	0.42	24	0.81	0.94	1.1	36	49	39	35	29
T_3	RP (12 kg FYM + 500 g L + 100:40:140 g N:P_2O_5:K_2O)	0.4	0.75	0.78	95	0.34	0.60	0.69	103	0.82	1.49	1.47	79	54	23	26	52
T_4	T_2 + 200 g SS + 50 g L + 100:40:140 g N:P_2O_5:K_2O	0.4	0.74	0.92	130	0.32	0.59	0.73	128	0.85	1.47	1.78	109	45	22	19	58
T_5	T_4 + 97 g S	0.4	0.75	0.94	135	0.34	0.62	0.75	121	0.85	1.52	1.82	114	52	24	22	58
T_6	T_4 + 60 g K_2O	0.4	0.77	0.95	138	0.34	0.59	0.76	124	0.86	1.49	1.85	115	51	22	14	73
T_7	T_5 + 60 g K_2O	0.4	0.76	0.86	115	0.34	0.59	0.78	129	0.84	1.49	1.79	113	53	19	16	70
T_8	T_4 + 110 g K_2O	0.38	0.75	0.91	139	0.34	0.60	0.77	126	0.83	1.48	1.81	118	53	25	11	79
T_9	T_5 + 110 g K_2O	0.4	0.74	0.95	138	0.32	0.62	0.74	131	0.83	1.49	1.85	123	53	21	13	75
T_{10}	T_9 + 60 g MS	0.38	0.75	1.22	221	0.34	0.72	1.02	200	0.82	1.60	2.47	201	48	18	11	77
T_{11}	T_9 + 20 g ZS	0.42	0.74	0.97	131	0.36	0.60	0.81	125	0.91	1.47	1.91	110	52	18	14	73
T_{12}	T_9 + 20 g B	0.4	0.77	1.03	158	0.34	0.65	0.83	144	0.85	1.56	1.99	134	47	21	14	70
	S.E.±	0.03	0.04	0.05		0.03	0.03	0.04		0.06	0.07	0.11		1.2	0.7	0.5	
	CD (P=0.05)	NS	0.105	0.147		NS	0.086	0.122		NS	0.212	0.307		NS	2.02	1.39	

B- borax, FP- farmer's practice, FYM- farm yard manure, L- lime, MS- magnesium sulphate, RP- recommended practice, S- sulphur, SS- sodium silicate, ZS- zinc sulphate NS=Non-significant index from pre-treatment value of 55 to 39 after three years probably due to the better management practices such as regular weeding and intercultivation during experimentation. Application of additional FYM over and above FP had further reduced yellowing index significantly to 35 over the years. The recommended fertilizer dose of 100g N, 40g P_2O_5 and 140g K_2O/palm/year (T_3 and T_4) reduced yellowing index to 26-19 range. Imposition of fertilizer treatments with higher dose of potassium together with nitrogen as ammonium sulphate (T_9 to T_{12}) had further reduced yellowing index to 11-14 range. Yellowing index was as low as 11 in treatment where magnesium sulphate was applied (T_{10}) resulting in 77 per cent reduction in index after third year of experiment. Menon and Kalyanikutty (1961) have reported successive increase in the number of non chlorotic leaves of yellowing affected arecanut palms due to foliar application of magnesium sulphate. Variation from green to yellow colour of the leaf is indicative of the leaf chlorophyll status. Both the defective chlorophyll formation process and disintegration of chlorophyll can lead to yellowing. Being a highly mobile element even nitrogen in chlorophyll can be mobilized to younger leaves in a nitrogen deficient situation in the plant and yellowing can result in older leaves.

Yield components and yield:

During first year of experiment, kernel yield was not significantly influenced by any treatment and ranged from 2.76 to 3.06 kg/palm (Table 2). Farmer's practice (FP) of applying farmyard manure and lime (T_1) showed a 20 per cent decrease in kernel yield of 0.56 kg/palm by third year from pre-treatment level. Enhancing the quantity of organic manure in FP (T_2) also failed to increase the kernel yield. Application of fertilizers together with FYM (T_3 to T_{12}) had resulted in 16 to 31 per cent increased kernel yield ranging from 0.46 to 0.90 kg/palm after the third year of experiment. Annual application of lime at 150 g/palm (T_4) brought about 22 per cent increase in yield compared to application of 500g lime once in three years (T_3) which could increase the kernel yield only by 16 per cent. Enhancement of potassium to 200 g and 250 g K_2O/palm without sulphur application (T_6 and T_8) resulted in 19 and 25 per cent increased yield. However together with sulphur application (T_7 and T_9) the yield increase was 32 and 25 per cent at 200 and 250 g K_2O/palm, respectively. A comparison of treatments which received sulphur (T_5, T_7 and T_9) and which did not receive sulphur (T_4, T_6 and T_8) showed an average of 5.7 per cent increase in kernel yield due to sulphur application through ammonium sulphate. Imposition of fertilizer treatment with 250 g K_2O and nitrogen as ammonium sulphate (T_9) resulted in 25 per cent increase in kernel yield by third year. Supplementing the above treatment with application of magnesium sulphate (T_{10}), zinc sulphate (T_{11}) and borax (T_{12}) could increase kernel yield by 31, 27 and 29 per cent, respectively after third year

Table 2 : Effect of nutrient management on yield attributes and yield of yellowing affected arecanut palms

	Treatments	Dry kernal weight (g)				Fruits per palm (Nos.)				Kernel yield (kg/palm)			
		2004	2005	2006	Per cent change	2004	2005	2006	Per cent change	2004	2005	2006	Per cent change
T_1	FP (10 kg FYM + 100 g L)	5.78	6.02	6.27	8	478	367	350	-27	2.76	2.21	2.20	-20
T_2	FP + 5 kg FYM	5.96	6.22	6.43	8	465	375	354	-24	2.77	2.33	2.28	-18
T_3	RP (12 kg FYM + 500 g L + 100:40:140 g N:P_2O_5:K_2O)	6.11	6.86	7.35	20	471	409	454	3	2.88	2.80	3.34	16
T_4	T_2 + 200 g SS + 50g L+ 100:40:140 g N:P_2O_5:K_2O	6.30	6.88	7.57	20	476	419	483	2	3.00	2.88	3.66	22
T_5	T_4 + 97 g S	6.87	7.47	7.99	16	437	414	474	8	3.00	3.09	3.78	26
T_6	T_4 + 60 g K_2O	6.06	6.85	7.30	20	472	408	467	-1	2.86	2.79	3.41	19
T_7	T_5 + 60 g K_2O	6.90	7.70	8.19	19	418	423	463	11	2.88	3.26	3.79	32
T_8	T_4 + 110 g K_2O	6.08	6.86	7.27	20	461	408	482	5	2.80	2.80	3.50	25
T_9	T_5 + 110 g K_2O	6.85	7.46	8.15	19	434	419	455	5	2.97	3.12	3.71	25
T_{10}	T_9 + 60 g MS	7.01	7.66	8.04	15	418	414	477	14	2.93	3.17	3.83	31
T_{11}	T_9 + 20 g ZS	6.91	7.47	8.07	17	441	432	481	9	3.05	3.23	3.88	27
T_{12}	T_9 + 20 g B	7.01	7.60	8.19	17	437	434	484	11	3.06	3.30	3.96	29
	SEm±	0.14	0.11	0.14		29	31	25		0.09	0.08	0.09	
	CD (P=0.05)	NS	0.322	0.387		NS	NS	71		NS	0.226	0.245	

B- borax, FP- farmer's practice, FYM- farm yard manure, L- lime, MS- magnesium sulphate, RP- recommended practice, S- sulphur, SS- sodium silicate, ZS- zinc sulphate NS=Non-significant of experiment.

The increase in kernel yield due to various treatments during the third year was due to increase in fruit number and/ or the dry kernel weight. In all the fertilizer applied treatments, the increase in dry kernel weight was in the range of 16 to 20 per cent whereas it was only 8 per cent in treatments which did not receive fertilizers (T_1 and T_2). During the third year, there was marked decrease in fruit number to the extent of 24 to 27 per cent in T_1 and T_2 where fertilizers were not applied. In the fertilizer applied treatments, the percentage increase in fruit number varied from -1 to 14 per cent. The lowest increase in fruit number was registered in treatments which did not receive sulphur (T_4 and T_6) and lime applied at higher quantity of 500g/palm once in three years (T_3). The highest increase in fruits number was observed in sulphur, magnesium, boron and zinc applied treatments (T_7, T_{10}, T_{12} and T_{11}). It is reiterated that these treatments which had resulted in high yield components and yield were also having high chlorophyll contents and reduced yellowing index.

An increasing trend in chlorophyll components and total chlorophyll were observed in treatments where nitrogen was applied through ammonium sulphate than urea indicating the role of sulphur in enhancing chlorophyll content. Such increasing trend was also noted in treatments where a higher dose of potassium had been applied. Thus variation in development of chlorophyll throws light into the management practices adopted. Srinivasan (1982) recorded association of a deranged chlorophyllase-chlorophyll system with yellow leaf affected arecanut palms. In the affected palms, activity of chlorophyllase was enhanced and concomitantly the pigment chlorophyll declined. Chlorophyll destruction had primary relation with the degree of expression of yellow leaf syndromes. Consequently, pigment changes were apparently related to the diagnostic symptoms of yellowing in arecanut.

Boron is involved in cell wall metabolism along with calcium (Srivastava, 1999). Boron also plays an important role in stimulating growth of pollen tubes which might have influenced the percentage of fruit set and thus the fruit number. Ramanandan and Abraham (2000) had reported that application of NPK+lime+boron and NPK+lime+zinc increased the arecanut yield by 20 per cent in a comprehensive package trial in farmers' field in Karnataka. In the present study application of silicon through sodium silicate did not significantly influence leaf chlorophyll, yellowing index and kernel yield.

The results of the present investigation indicated that application of 150 g lime, a minimum of 15 kg farm yard manure, split application of fertilizer at 100g N, 40g P_2O_5 and 200g K_2O/palm/year in February and September by way of including any sulphur containing fertilizer source to supply a minimum of 100 g sulphur, 60 g magnesium sulphate, 20g zinc sulphate and borax at 20 g/palm may be adopted for managing yellowing affected arecanut palms cultivated in irrigated terraced upland toposequence of Western ghat.

Acknowledgement:

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

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