

Recovery pattern of cyclone-affected coconut palms in littoral sandy soils of Orissa-Part I

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Abstract

The experiment to study the recovery pattern of cyclone affected coconut palms cv. Sakhigopal Local was carried out in an ongoing fertilizer trial with three levels each of N (500, 1000 and 1500 g N/palm/year), P (250, 500 and 750 g P₂O₅/palm/year) and K (750, 1250 and 1750 g of K₂O/palm/year) at Coconut Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, India. The rate of leaf production and number of functional leaves on the crown increased appreciably with nitrogen fertilization at 1000 g per palm per year as compared to 500 g per palm during early years of damage in all the three categories. The different levels of phosphorus fertilization did not influence the recovery of growth characters favourably.

Keywords: Coconut, Sakhigopal Local, super-cyclone, littoral.

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Introduction

Coconut in India is grown in 17 States and 3 Union Territories in an approximate area of 1.89 million hectares with an estimated annual production of 12,822 million nuts. Orissa is one of the traditional coconut growing states with an estimated fruit bearing area of 29,000 hectares and annual production of 205 million nuts (Anonymous, 2004). The cultivation is concentrated in poor soils of coastal districts and even in coastal sandy soils stretching over 480 kms coast line. The productivity of coconut is low, not sustained owing to improper fertilizer management (based on blanket dose rather than on diagnostic leaf nutrient content) in coastal sandy soils littoral sandy soils. Moreover, the frequent cyclone damage arrests the production temporarily for 2-3 years. An analysis of the cyclone disturbances in the Bay of Bengal region reveals that in the past 100 years (1891-1990), Orissa had the highest number of storms (79), which is 30.62 per cent of the total. But, the cyclone that struck on 29th October 1999 was perhaps the worst of its kind in the living memory of the people of Orissa nay India. The cyclone referred to as "Super cyclone" (as per the India Meteorological Department Classification 200-250 kms wind speed/hr) had swept the entire Orissa coast destroying most of the plantations in 40,714 ha, spread over 13 districts, sparing only 17,235 ha. The ability of the cyclones to damage the ecosystems is obvious; however, the nature of recovery has not been subjected to a proper study for most components and subsystems. Till date, little or no attempt has been made to systematically study the effect of cyclones on the domesticated coconut subsystems, the nature of recovery by affected trees and plantations or the future threat of cyclones to the coconut industry. Unfortunately, almost all the existing knowledge regarding the recovery of the palms and plantations is anecdotal. Keeping the above facts in view, an experiment was designed to study the recovery pattern of coconut palms in three

different damage categories under different fertilizer combinations.

Materials and methods

The experiment to study the recovery pattern of cyclone-affected palms was conducted in the Coconut Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, India. Palms belonging to the "Sakhigopal Local", a tall cultivar, were in the age group of 27 years and planted at a spacing of 7.5 m x 7.5 m with a population density of 175 palms per hectare. The palms were drip irrigated uniformly @ 32 litres/palm/day through drippers from October onwards till the onset of monsoon in June. The experiment on the cyclone recovery study was carried out in an ongoing fertilizer trial with three levels each of N (500, 1000 and 1500 g N/palm/year), P (250, 500 and 750 g P₂O₅/palm/ year) and K (750, 1250 and 1750 g K₂O/palm/year). For the different levels of nitrogen, phosphorus and potassium included in this investigation (N₁, N₂ and N₃; P₁, P₂ and P₃; K₁, K₂ and K₃), the amount of the different fertilizers was worked out for each palm and was supplied through urea, single super phosphate and muriate of potash for nitrogen, phosphorus and potassium, respectively. One third of the total dose was applied during the month of May before the onset of Southwest monsoon and the remainder was given during September-October. The fertilizers were spread around the base of each palm after removing all the weeds, within a radius of 1.0-1.5 m, and incorporated to a depth of 5-8 cm with a suitable digging tool. This study was laid out following a 3³ Confounding Design with two replications and two palms per replication.

Types of damage studied:

Damage category	Nature of damage
Damage category I	Few leaves of lower whorl, majority of the leaves in the middle and top whorl were

	completely broken/ twisted, giving appearance of a beheaded palm, suspecting damage to the cabbage of the palm.
Damage category II	Majority of the leaves in the middle whorl and young leaves of top whorl were broken/ damaged/twisted giving an appearance of crown twisting.
Damage category III	Majority of the leaves were affected in the windward direction. Only the top young leaves were damaged/ broken.

Results

Recovery of the palms with respect to the rate of leaf production

Recovery of the palms under damage category I:

The statistical analysis of the data pertaining to the recovery in the rate of leaf production in the successive years in the palms under damage category I has been summarized in Table 3. Table 3 revealed that on an average, the rate of leaf production was 11.35 per palm per year before the cyclone, which then decreased by 83.5 per cent (1.87 per palm) during 1999-00 (November-June). Subsequently the rate of leaf production per palm per year increased to 5.49, 8.59, 10.66 and 10.31 during 2000-01, 2001-02, 2002-03 and 2003-04, respectively.

The rate of leaf production per palm during a normal year was maximum (11.44) in N_{1000} and this trend continued during successive years after cyclone except in the year just following the cyclone where N_{1500} produced

more number of leaves, though at par with N_{1000} . Significantly higher rate of leaf production was recorded in N_{1000} (1.94, 5.69, and 8.81 during 1999-00, 2000-01 and 2001-02, respectively) than in N_{500} and which was at par with the rate of leaf production in N_{1500} . Towards the later part of the study, the difference among the levels of nitrogen nutrition had not resulted in any significant effect.

Similarly, application of 500 g of P_2O_5 per palm per year resulted in higher rate of leaf production per palm (2.00) during 1999-2000, which was significantly superior to the rate of leaf production in P_{250} . No marked variation was observed in later part of the experiment. Application of different doses of potassium did not produce any significant results with respect to this character.

Recovery of the palms under damage category II:

The rate of leaf production per palm per year has reduced to 3.54 in the initial period of damage from 11.32 before the cyclone under this damage category. The palms then exhibited progressive improvement in the rate of leaf production per palm up to 2002-03 (3.54 during 1999-00 to 11.24 during 2002-03) but the percentage increase in between 1999-00 and 2000-01 was comparatively more (Table 4 and Figure 1).

The palms applied with 1000 g nitrogen was found to produce significantly more number of leaves per palm per year during 1999-00 and 2000-01 than the palms grown with 500 g nitrogen. The rate of leaf production per palm at N_{500} was 3.17 as against 3.75 at N_{1000} during 1999-00, whereas during 2000-01, the leaf production rate was 7.86 and 8.35 at N_{500} and N_{1000} , respectively. The benefits in the rate of leaf production accruing to increasing level of nitrogen fertilization (N_{1500}) over the preceding one, was, however,

Table 1. Mechanical analysis of the soil

Components	Soil depth (cm)	
	0-25	25-50
Sand (%)	89.4	89.3
Silt (%)	3.4	3.6
Clay (%)	7.2	7.1

International Pipette Method (Piper, 1950).

Table 2. Chemical analysis of the soil

Components	Soil depth (cm)		Methods
	0-25	25-50	
Available N (kg/ ha)	118.7	60.8	Alkaline Permanganate method (Subbiah and Asija, 1956).
Available P ₂ O ₅ (kg/ ha)	178.2	124.1	Bray's extractant spectrophotometric method (Jackson, 1973).
Available K ₂ O (kg/ ha)	145.4	186.2	Ammonium acetate extractant flame photometric method (Jackson, 1973).
Organic carbon (%)	0.19	0.08	Walkley and Black (Jackson, 1973).
p ^H (1: 2 soil to water ratio)	5.48	6.30	Potentiometric method (Jackson, 1973).
Electrical conductivity (dSm ⁻¹) (1: 2 soil to water ratio)	0.027	0.095	Conductometric method (Jackson, 1973).

Table 3. Rate of leaf production (nos.) in successive years for damage category I

Treatment	Pre-cyclonic period	Cyclonic period	Post-cyclonic period			
	1998-99 (Nov.-Oct.)	1999-00 (Nov.-June)	2000-01 (July-June)	2001-02 (July-June)	2002-03 (July-June)	2003-04 (July-June)
Nitrogen (g/ plant)						
N ₅₀₀	11.39	1.61	5.24	8.28	10.69	10.31
N ₁₀₀₀	11.44	1.94	5.69	8.81	10.72	10.33
N ₁₅₀₀	11.22	2.06	5.54	8.69	10.56	10.28
SEm (±)	0.090	0.068	0.095	0.079	0.087	0.128
C.D. (0.05)	NS	0.20	0.28	0.24	NS	NS
Phosphorus (g P₂O₅/ plant)						
P ₂₅₀	11.33	1.64	5.53	8.58	10.78	10.25
P ₅₀₀	11.47	2.00	5.56	8.67	10.64	10.33
P ₇₅₀	11.25	1.97	5.39	8.53	10.56	10.33
SEm (±)	0.090	0.068	0.095	0.079	0.087	0.128
C.D. (0.05)	NS	0.20	NS	NS	NS	NS
Potassium (g K₂O / plant)						
K ₇₅₀	11.39	1.94	5.53	8.67	10.78	10.36
K ₁₂₅₀	11.44	1.89	5.53	8.67	10.65	10.25
K ₁₇₅₀	11.22	1.78	5.42	8.44	10.54	10.31
SEm (±)	0.090	0.068	0.095	0.079	0.087	0.128
C.D. (0.05)	NS	NS	NS	NS	NS	NS
Mean	11.35	1.87	5.49	8.59	10.66	10.31

Table 4. Rate of leaf production (nos.) in successive years for damage category II

Treatment	Pre-cyclonic period	Cyclonic period	Post-cyclonic period			
	1998-99 (Nov.-Oct.)	1999-00 (Nov.-June)	2000-01 (July-June)	2001-02 (July-June)	2002-03 (July-June)	2003-04 (July-June)
<i>Nitrogen (g/plant)</i>						
N ₅₀₀	11.28	3.17	7.86	10.28	11.36	11.22
N ₁₀₀₀	11.39	3.75	8.35	10.50	11.22	11.30
N ₁₅₀₀	11.31	3.69	8.33	10.50	11.14	11.09
SEm (±)	0.113	0.078	0.097	0.106	0.083	0.078
C.D. (0.05)	NS	0.23	0.29	NS	NS	NS
<i>Phosphorus (g P₂O₅/plant)</i>						
P ₂₅₀	11.31	3.53	8.11	10.53	11.25	11.19
P ₅₀₀	11.50	3.61	8.29	10.50	11.34	11.31
P ₇₅₀	11.17	3.47	8.14	10.25	11.13	11.11
SEm (±)	0.113	0.078	0.097	0.106	0.083	0.078
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Potassium (g K₂O / plant)</i>						
K ₇₅₀	11.42	3.50	8.19	10.44	11.31	11.18
K ₁₂₅₀	11.31	3.56	8.25	10.42	11.31	11.31
K ₁₇₅₀	11.25	3.56	8.10	10.42	11.11	11.11
SEm (±)	0.113	0.078	0.097	0.106	0.083	0.078
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Mean</i>	11.32	3.54	8.18	10.43	11.24	11.20

Table 5. Rate of leaf production (nos.) in successive years for damage category III

Treatment	Pre-cyclonic period	Cyclonic period	Post-cyclonic period			
	1998-99 (Nov.-Oct.)	1999-00 (Nov.-June)	2000-01 (July-June)	2001-02 (July-June)	2002-03 (July-June)	2003-04 (July-June)
<i>Nitrogen (g/plant)</i>						
N ₅₀₀	11.44	4.08	10.42	11.31	11.29	11.25
N ₁₀₀₀	11.53	4.69	10.45	11.25	11.31	11.25
N ₁₅₀₀	11.42	4.50	10.10	11.11	11.09	11.28
SEm (±)	0.084	0.090	0.130	0.095	0.079	0.096
C.D. (0.05)	NS	0.27	NS	NS	NS	NS
<i>Phosphorus (g P₂O₅/plant)</i>						
P ₂₅₀	11.39	4.44	10.31	11.33	11.31	11.31
P ₅₀₀	11.56	4.47	10.50	11.28	11.28	11.22
P ₇₅₀	11.44	4.36	10.17	11.06	11.11	11.25
SEm (±)	0.084	0.090	0.130	0.095	0.079	0.096
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Potassium (g K₂O / plant)</i>						
K ₇₅₀	11.61	4.44	10.31	11.35	11.39	11.25
K ₁₂₅₀	11.38	4.42	10.44	11.24	11.19	11.33
K ₁₇₅₀	11.40	4.43	10.22	11.08	11.11	11.19
SEm (±)	0.084	0.090	0.130	0.095	0.079	0.096
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Mean</i>	11.46	4.43	10.32	11.22	11.23	11.26

non-significant during 1999-00 and 2000-01. In the later part of the experimental period (2001-02 to 2003-04), the differences between the levels of nitrogen were decreased and, as a result, showed only nominal differences in the rate of leaf production per palm.

The rate of leaf production per palm, recorded with the application of different doses of phosphorus, showed some response during the initial years of damage, up to P₅₀₀. Nevertheless, all the doses produced non-significant results during the whole study period. The same trend was noticed for different doses of potassium as well.

Recovery of the palms under damage category III:

The rate of leaf production per palm has decreased to 4.43 during 1999-00 from 11.46 produced in a normal year (before cyclone). After the cyclone damage, in the succeeding years, the leaf production per palm per year increased to 10.32, 11.22, 11.23, and 11.26 during 2000-01, 2001-02, 2002-03, and 2003-04, respectively (Table 5 and Figure 1).

Application of 1000 g nitrogen per palm per year exhibited remarkable and pronounced effect on the rate of leaf production per palm (4.69) as compared to application of 500 g nitrogen to the palm during 1999-00. A further increase in the level of nitrogen to 1500 g per palm resulted in the decrease in the rate of leaf production per palm (4.50), though the difference was found to be non-significant. Different levels of nitrogen did not produce any significant result in terms of this character in the post-cyclonic period.

Application of different doses of phosphorus and potassium had no significant bearing on the rate of leaf production per palm in either of the years after the cyclonic damage.

Recovery of the palms with respect to the number of functional leaves on the crown

Recovery of the palms under damage category I:

There was a marked reduction in the number of functional leaves on the crown due to the super cyclone. The data in Table 6 revealed that on an average the number of functional leaves was reduced by about 63 per cent due to the cyclone, i.e., from 23.56 recorded before cyclone to 8.78 recorded as on June 2000. During the successive years the number of functional leaves went on increasing and at the end of the experimental period 21.70 functional leaves were recorded on the crown of the palms affected under damage category I. The number of functional leaves was found to vary from 23.47 to 23.69 under different levels of nitrogen before the cyclone (Table 6). In successive years after the cyclonic damage the number of functional leaves increased at all stages with the increasing levels of nitrogen up to N₁₀₀₀. The increase in this character by the application of 1000 g nitrogen per palm per year was well marked up to June 2003, after which there seemed to be no noticeable variation in this character due to applied levels of nitrogen (Figure 2).

The effects of different doses of phosphorus applied were studied on the number of functional leaves on the crown at each year ending on June from 2000 to 2004. The analysis of variance showed a non-significant response for this character to the different levels of phosphorus fertilization. The results of the effect of phosphorus have been summarized in Table 6.

Different doses of potassium also, similarly did not exercise any significant influence on the number of functional leaves on the crown per plant in either of the experimental years. However, slightly more

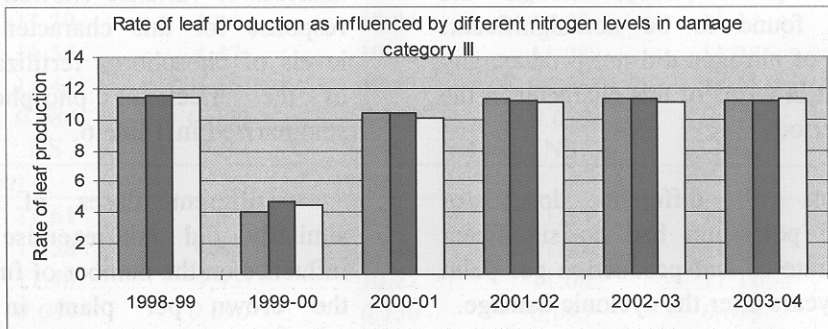
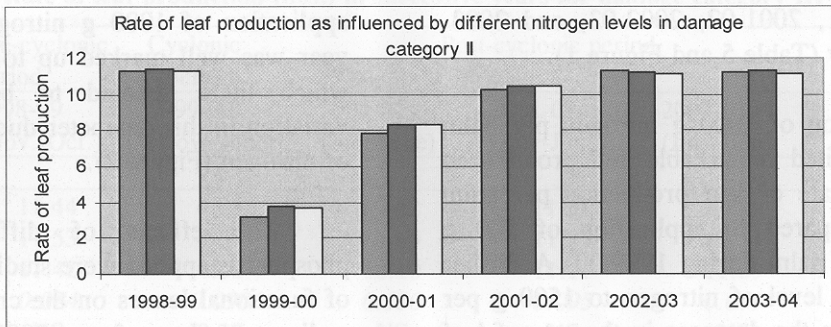
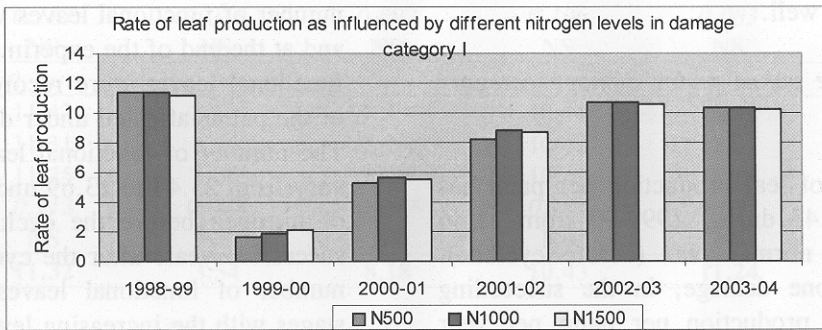
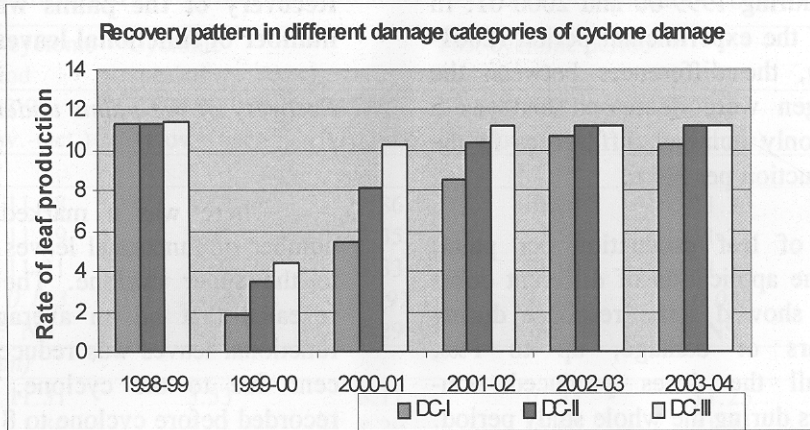


Fig. 1. Recovery pattern in case of rate of leaf production

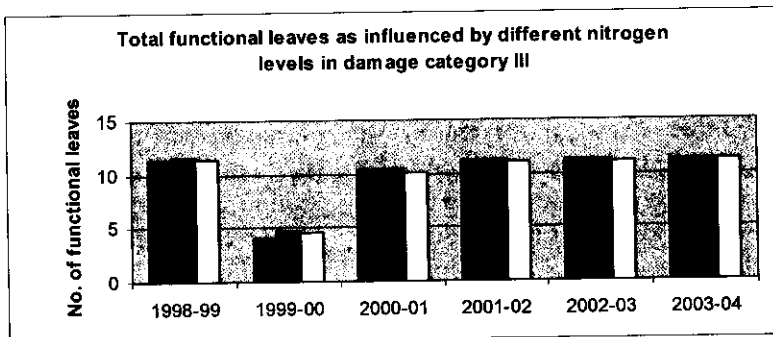
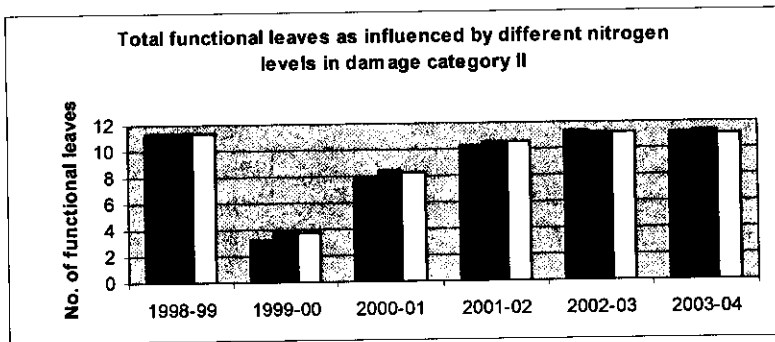
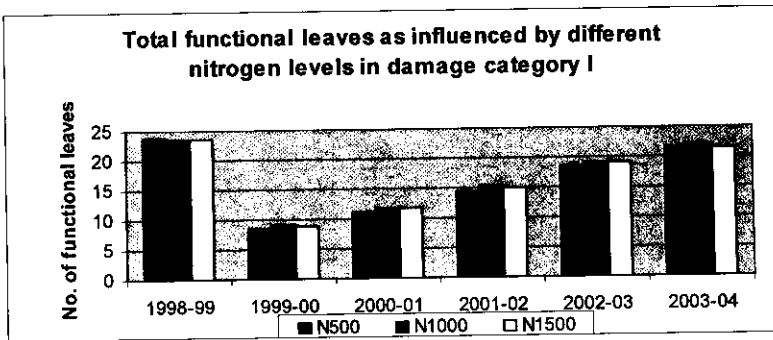
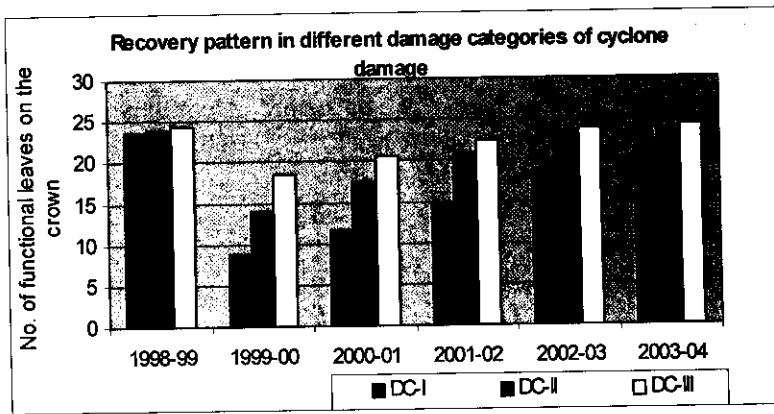


Fig. 2. Recovery pattern in case of number of functional leaves on the crown

Table 6. Number of functional leaves on the crown in successive years for damage category I

Treatment	Pre-Cyclonic period	Cyclonic period	Post-cyclonic period			
	As on Oct, 1999	As on June, 2000	As on June, 2001	As on June, 2002	As on June, 2003	As on June, 2004
<i>Nitrogen (g/plant)</i>						
N ₅₀₀	23.69	8.47	11.28	14.28	18.60	21.56
N ₁₀₀₀	23.47	9.00	11.81	15.19	19.25	22.03
N ₁₅₀₀	23.50	8.86	11.64	15.06	19.04	21.52
SEm (±)	0.142	0.114	0.110	0.143	0.142	0.182
C.D. (0.05)	NS	0.34	0.32	0.42	0.42	NS
<i>Phosphorus (g P₂O₅/plant)</i>						
P ₂₅₀	23.33	8.69	11.42	14.75	18.81	21.64
P ₅₀₀	23.72	8.94	11.67	14.92	19.17	21.89
P ₇₅₀	23.61	8.69	11.64	14.86	18.92	21.58
SEm (±)	0.142	0.114	0.110	0.143	0.142	0.182
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Potassium (g K₂O / plant)</i>						
K ₇₅₀	23.53	8.86	11.69	14.83	18.92	21.64
K ₁₂₅₀	23.64	8.78	11.58	15.03	19.00	21.94
K ₁₇₅₀	23.50	8.69	11.44	14.67	18.97	21.53
SEm (±)	0.142	0.114	0.110	0.143	0.142	0.182
C.D. (0.05)	NS	NS	NS	NS	NS	NS
Mean	23.56	8.78	11.57	14.84	18.96	21.70

number of leaves were recorded in plants provided with 1250 g of K₂O per palm per year from June 2002 to June 2004, the respective figures for this character under this treatment was 15.03, 19.00 and 21.94 (Table 6).

Recovery of the palms under damage category II:

The data recorded on number of leaves on the crown after each year of study was statistically analyzed and the analyzed data have been presented in Table 7 and illustrated in Figure 2. Table 7 revealed that the functional leaves on the crown per palm that recorded as high as 23.86 before cycloné (October ending 1999) was drastically reduced to 13.83 in June 2000. Thereafter, the functional leaves on the crown went on increasing in every year of the experimental period.

No significant variation was noted among the different doses of nitrogen on the number of functional leaves on the crown before the cyclonic event, which varied from 23.75 to 24.03 among the nitrogen levels. However, the plants receiving 1000 g nitrogen per palm per year resulted in maximum number of leaves on the crown in the subsequent years after the cyclone. The number of functional leaves recorded with the application of this dose was 14.11, 17.69, 21.06 on June 2000, 2001, and 2002, respectively. However, no marked variation was observed between this dose and the latter dose of nitrogen i.e., N₁₅₀₀. After this period, little variation was noticed among all the levels of nitrogen nutrition in terms of this character.

Phosphorus fertilization did not produce any significant difference during the period of investigation, except during 2001, where palms

Table 7. Number of functional leaves on the crown in successive years for damage category II

Treatment	Pre-Cyclonic period	Cyclonic period	Post-cyclonic period			
	As on Oct, 1999	As on June, 2000	As on June, 2001	As on June, 2002	As on June, 2003	As on June, 2004
<i>Nitrogen (g/plant)</i>						
N ₅₀₀	24.03	13.47	17.08	20.40	23.47	23.83
N ₁₀₀₀	23.75	14.11	17.69	21.06	23.50	23.64
N ₁₅₀₀	23.81	13.92	17.42	20.88	23.36	23.61
SEm (±)	0.151	0.136	0.110	0.154	0.138	0.133
C.D. (0.05)	NS	0.40	0.32	0.45	NS	NS
<i>Phosphorus (g P₂O₅/plant)</i>						
P ₂₅₀	23.64	13.64	17.08	20.67	23.39	23.61
P ₅₀₀	24.03	13.97	17.61	21.03	23.64	23.78
P ₇₅₀	23.92	13.89	17.50	20.64	23.31	23.69
SEm (±)	0.151	0.136	0.110	0.154	0.138	0.133
C.D. (0.05)	NS	NS	0.32	NS	NS	NS
<i>Potassium (g K₂O / plant)</i>						
K ₇₅₀	23.83	13.83	17.39	20.86	23.50	23.64
K ₁₂₅₀	23.94	13.92	17.56	20.94	23.44	23.89
K ₁₇₅₀	23.81	13.75	17.25	20.53	23.39	23.56
SEm (±)	0.151	0.136	0.110	0.154	0.138	0.133
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Mean</i>	23.86	13.83	17.40	20.78	23.44	23.69

Table 8. Number of functional leaves on the crown in successive years for damage category III

Treatment	Pre-Cyclonic period	Cyclonic period	Post-cyclonic period			
	As on Oct, 1999	As on June, 2000	As on June, 2001	As on June, 2002	As on June, 2003	As on June, 2004
<i>Nitrogen (g/plant)</i>						
N ₅₀₀	24.47	17.86	19.64	22.39	23.95	24.22
N ₁₀₀₀	24.67	18.86	21.00	22.47	23.72	24.69
N ₁₅₀₀	24.06	18.47	20.81	22.17	23.75	24.14
SEm (±)	0.213	0.176	0.139	0.164	0.172	0.185
C.D. (0.05)	NS	0.52	0.41	NS	NS	NS
<i>Phosphorus (g P₂O₅/plant)</i>						
P ₂₅₀	24.19	18.47	20.28	22.19	23.62	24.08
P ₅₀₀	24.64	18.19	20.67	22.42	23.97	24.61
P ₇₅₀	24.36	18.53	20.50	22.42	23.83	24.36
SEm (±)	0.213	0.176	0.139	0.164	0.172	0.185
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Potassium (g K₂O / plant)</i>						
K ₇₅₀	24.67	18.33	20.67	22.56	23.78	24.58
K ₁₂₅₀	24.47	18.42	20.47	22.36	23.86	24.31
K ₁₇₅₀	24.06	18.44	20.31	22.10	23.78	24.17
SEm (±)	0.213	0.176	0.139	0.164	0.172	0.185
C.D. (0.05)	NS	NS	NS	NS	NS	NS
<i>Mean</i>	24.40	18.40	20.48	22.34	23.81	24.35

fertilized with 500 g P₂O₅ had significantly more number of functional leaves (17.61) than P₂₅₀. Similarly, no significant changes have been observed in the number of functional leaves on the crown with the change of potassium doses from 750 g to 1750 g per palm per year in either of the experimental years.

Recovery of the palms under damage category III:

The reduction in the number of functional leaves on the crown subsequent to the super cyclone under this category of damage was comparatively less than other two damage categories. The total number of functional leaves was recorded as 18.40 on June 2000 as against 24.40 as observed on October 1999, just before cyclone (Table 8 and Figure 2).

The different doses of nitrogen fertilization brought significant differences in this character. Application of nitrogen at the rate of 1000 g per palm per year resulted in the maximum number of functional leaves on the crown in either of the years of the study (except 2003). However, the superiority of this dose of nitrogen over N₅₀₀ was statistically significant during the initial two years of damage, i.e., on 2000 and 2001 (18.86 and 21.00, respectively in N₁₀₀₀ as against 17.86 and 19.64 in N₅₀₀), whereas, N₁₅₀₀ has shown at par results with N₁₀₀₀. In rest of the years, different levels of nitrogen did not result in any significant variation in respect of number of leaves on the crown.

It was observed that the variation in doses of phosphorus and potassium did not produce any significant differences in terms of number of functional leaves on the crown during the period of investigation. However, in most of the periods second level of phosphorus and initial dose of potassium had better results when compared with their other levels.

Discussion

Rate of leaf production

The likely cause of the effect of cyclones to tree damage is reduced root growth following defoliation. Loss of foliage or any other occurrence that reduces carbon fixation might inhibit formation of feeder roots (Vogt and Bloomfield, 1991), and reduced root growth following cyclone damage was reported for a number of species (Parrotta and Lodge, 1991; Silver and Vogt, 1993 and Herbert *et al.*, 1999).

The results of this study revealed that there was marked effect of the levels of fertilizers on the recovery of growth characters of the affected coconut palm, irrespective of the types of damage. Undoubtedly, the most glaring responses were obtained to nitrogen in the initial years of damage. A significant increase in the rate of leaf production was recorded with the increase in the nitrogen level up to 1000 g per palm per year in the initial three years of damage in the damage category I and the addition was restricted to initial two years and one year of damage under damage category II and III, respectively (Fig. 1).

The rate of leaf production in N₁₀₀₀ was decreased from 11.44 to 1.94 after cyclone, which then increased to 5.69 and 8.81 during 2000-01 and 2001-02, respectively under damage category I. In the later stages, the effect of nitrogen was found to be non-significant with respect to this character. However, under damage category II, N₁₀₀₀ showed significant effect in 1999-00 and 2000-01 and under damage category III, N₁₀₀₀ showed significant effect only during 1999-2000. The rate of leaf production in N₁₀₀₀ was 3.75 and 8.35 in 1999-00 and 2000-01, respectively, under damage category II whereas, the palms under damage category III produced 4.69 leaves per palm during 1999-2000. Reports on the effect of higher dose of nitrogen on coconut growth were also

presented by several workers (Nethesinghe, 1963; Tan, 1973; Nelliath, 1974; Nelliath *et al.*, 1978; Louis and Chandrasekharan, 1983; Davis, 1989). Sumbak (1970) studied the effect of nitrogen and observed that heavier appliance of this element might be necessary for obtaining maximum growth in coconut. Fenwick and Maharaj (1967) also reported the positive effects of higher levels of nitrogen on the growth of the coconut palm.

The different levels of phosphorus and potassium did not generate any significant results except occasionally. The role of phosphorus and potassium for regaining growth in terms of the rate of leaf production was not important in the littoral sandy soils of the experimental site where phosphorus and potassium contents in the soil were reported to be high and medium, respectively. Menon and Pandalai (1958) also reported that the response to phosphorus was seen only in certain conditions. Halliday and Sylvester (1954) commenting upon the phosphorus manuring of coconuts in Ceylon, stated that while at Bandirippuwa, with adequate reserves of phosphorus, there was no response to phosphorus application; experiments in poor laterite soils of Veyanagoda with low phosphorus on the other hand, gave impressive responses. Lognathan and Balakrishna Murti (1980) found that application of nitrogen increased girth, height and leaf production during the pre-bearing period, but phosphorus and potassium had no effect on vegetative growth characters.

The interaction effects of different nutrient elements were observed to be non-significant in all the years under different categories of damage except in 1999-00 under damage category I, where maximum rate of leaf production (2.08) per palm was recorded in the combination of 1000 g nitrogen and 500 g phosphorus per plant. The highest level of nitrogen also produced more number of leaves per palm but found to be non-significant among different levels of phosphorus. The beneficial

effect of phosphorus was more pronounced only when used in combination with nitrogen. Thampan (1982) also made similar observations while studying response of palms to fertilizer applications.

The leaf production invariably started after 2-3 months of cyclonic depression in damage category II and III while, it took about 5-6 months in damage category I. Dash *et al.* (2002) while surveying the recovery pattern of the coconut palms in various places after cyclone also opined that the leaf production started after 4 months in palms with partial crown damage.

In all the categories of damage the rate of leaf production per palm per year has attained the normality except in the palms of damage category I. It was observed that the palms under damage category III has attained the normality during the third year of the damage while, damage category II palms took one year more to regain the original growth (Fig.1).

Number of functional leaves on the crown

Among the different fertilizer nutrients only the nitrogen had significant influence on the number of functional leaves on the crown. Application of nitrogen at the higher dose i.e., 1000 g per palm per year significantly affected the number of functional leaves over 500 g nitrogen under the damage category I (9.00, 11.81, 15.19 and 19.25 leaves in the crown in N₁₀₀₀ compared to 8.47, 11.28, 14.28, and 18.60 leaves in N₅₀₀ during 2000, 2001, 2002, and 2003, respectively). Increasing the nitrogen dose to one level up did not have any marked effect, which observed to be at par with the result obtained in N₁₀₀₀ (Fig.2). Similar trend in the increase in the number of functional leaves on the crown in the treatment with N₁₀₀₀ was observed in 2000, 2001 and 2002 under damage category II and in 2000 and 2001 under damage category III. After these periods the effect of different levels of nitrogen nutrition was found to be non-

significant. Davis (1989) highlighted the importance of nitrogen in coconut nutrition and reported that nitrogen accounts for over 1.6 per cent of the coconut leaf on dry matter basis; this is much greater than any other major and minor nutrient element in the palm. An increase in the nitrogen supply not only delays senescence and stimulates growth but also changes plant morphology in typical manner. Typical nitrogen induced changes in leaf morphology has been well documented (Marschner, 1995). The length, width and area of leaf blades increase in response to N fertilization. Nitrogenous compounds make up a significant part of the total weight of the plants (Olsthoorn *et al.*, 1991), which in the coconut, accounts for 10 per cent of the plant weight. This vital nutrient controls the growth and this element may be said to play an essential part in photosynthesis apart from its role in formation of proteins (Black, 1964). Tan (1973) while working on oil palm growth and productivity observed the beneficial effect of nitrogen on increasing the number of functional leaves in oil palm. Mathew and Ramadasan (1964) also reported the favorable effects of nitrogen on the functional leaves of juvenile coconut seedlings.

Different levels of phosphorus nutrition did not result any marked variation in respect of this character under all categories of the damage. The second dose of phosphorus i.e., 500 g per plant had little positive effect over other levels of phosphorus except in one case under damage category II in 2001, where 500 g phosphorus resulted in a significant effect on the number of functional leaves on the crown. The effect of potassium did not bear any significance in terms of the functional leaves on the crown. Louis and Chandrasekharan (1983) also reported increased number of leaves with regular manuring of the palms over the palms with no manuring.

To sum up the rate of leaf production and number of functional leaves on the crown increased appreciably with nitrogen fertilization

at 1000 g per palm per year over 500 g per palm during early years of damage in all the three categories. Further increase in nitrogen dose to 1500 g per palm per year did not show any striking effect and the improvement was at par to that of 1000 g nitrogen. The recovery of growth characters like rate of leaf production per palm and number of functional leaves on the crown was not influenced favourably by the different levels of phosphorus fertilization except where the second level of phosphorus (P₅₀₀) had a significant effect on the rate of leaf production under damage category I during 1999-00 and number of functional leaves on the crown under damage category II in 2001. The rate of leaf production per palm per year and number of functional leaves on the crown was not influenced significantly by potassium nutrition during the post-cyclonic period.

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