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Effect of Spacing and Nitrogen on Growth and Yield of Manioc, *Manihot esculenta* Crantz Grown as an Intercrop under Coconut

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Abstract : An experiment was conducted at the Coconut Research Institute of Sri Lanka, Lunuwila, to study the effect of spacing and nitrogen application on the growth and yield of manioc when grown as an intercrop under coconut. Level of nitrogen had no effect on tuber fresh weight yield or dry matter accumulation. Spacing had a marked effect on tuber fresh weight yield and 0.91 × 0.61 m spacing was significantly superior to the wider spacings tested. The reduction in leaf, stem and tuber dry matter yields and leaf area index (L) after 8 months of planting indicated that variety MU 72 reaches maturity and is ready for harvesting at this stage. Total and tuber dry matter yields were linearly correlated with leaf area duration (D) showing that leaf area is the major determinant of crop yield.

1. Introduction

Owing to the wide range of economic and agronomic advantages of intercropping coconut lands, it is being increasingly recognized in almost all the coconut growing countries as against the outmoded practices of monoculture. Of the many crops that could be cultivated as intercrops under coconut, manioc appears to be one of the most promising crops. It is a popular root crop among many farmers. This popularity is on account of its tuber yield which could be obtained with comparatively low capital expenditure, minimum possible management practices needed by the crops, the longer period for which the crops could be left in the soil with little or no loss of weight, etc. The crop is also remarkable in its adaptation and when established could withstand periods of severe drought which would have adverse effects on most of the crops. It is able to make use of the carbohydrates in the roots and make a rapid start when the moisture is available. It could also be grown on a wide range of soil types and could be filled into poor soils which gives it a comparative advantage over most of the other food crops. There are no serious problems in its culture and it is relatively free of pest and disease incidences. The demand for manioc is predominant as a food crop and most of the manioc produced locally is utilized for human consumption. Manioc could be used as a raw material for a variety of products such as animal feed, starch for laundry work, paper and textile sizing and painting, production of power alcohol, adhesives, beer and liquid glucose. Thus, it could form the basis for a number of agro-based industries and these could create new avenues of employment particularly in the villages where unemployment is a serious problem.

Although intercropping coconut with manioc has been an age old practice, it had been done without any scientific foundation particularly with reference to agronomic practices when this crop is grown in association with coconut. Due to poor culture, the yield of manioc has been very low. The trial reported in this paper is a preliminary attempt to investigate into the effect of plant spacing and nitrogen application on the growth and yield of manioc, and these cultural practices are regarded as being the most important in increasing the yield of manioc when grown under coconut.

2. Materials and Methods

The experiment was carried out during May, 1973 to March, 1974 under a mature stand of coconut of about 60 years planted on the square system at a spacing of 7.92 × 7.92 m at Bandirippuwa Estate of the Coconut Research Institute of Sri Lanka, Lunuwila.

The soil was a deep, well drained, brownish to yellow, to yellowish sandy clay loam, with lateritic gravel occurring at an average depth of 50.8 cm. Soil is classified under the great soil group of Red Yellow Podsolic soils.

Climatic data is given in Table 1. In general, weather conditions were satisfactory for plant growth until end of December, 1973. Thereafter, from beginning of January to mid February the crop experienced a period of severe drought during which the rainfall receipts amounted to only 0.05 cm.

TABLE 1. Climatic data, May 1973 — March 1974.

Period		Rainfall, cm	Temperature, °C.	
			Maximum	Minimum
01 — 15		8.2	31.8	25.6
16 — 31	May	8.7	31.0	25.2
01 — 15		18.6	30.2	25.2
16 — 30	June	5.6	30.5	25.6
01 — 15		9.7	30.2	24.4
16 — 31	July	2.1	30.9	25.1
01 — 15		0.8	29.6	24.7
16 — 31	August	5.8	30.0	25.1
01 — 15		0.5	30.6	23.7
16 — 30	September	1.6	30.8	25.1
01 — 15		3.8	31.0	24.4
16 — 31	October	20.8	30.2	23.3
01 — 15		38.4	29.9	22.3
16 — 30	November	9.1	31.1	22.2
01 — 15		6.9	30.7	21.9
16 — 31	December	13.6	28.8	21.2
01 — 15		—	30.8	19.8
16 — 31	January	—	31.7	20.0
01 — 15		0.05	33.2	20.4
16 — 28	February	1.9	32.9	21.4
01 — 15		1.5	32.6	21.8
16 — 31	March	6.3	32.3	23.2

The treatments consisted of 4 plant spacings (0.91 × 0.61 m, 0.91 × 0.91 m, 0.91 × 1.21 m and 0.91 × 1.52 m) and 3 levels of nitrogen application (44.8, 67.2 and 89.6 kg N/ha). All treatment combinations were arranged in randomized blocks replicated three times. Each plot measured an area of 15.8 × 15.8 m, which is equivalent to 4 coconut squares. Half of the total dressing of N as urea (46% N) was applied at the time of planting while the remainder was top dressed 60 days after planting. All plots received a basal application of 44.8 kg P_2O_5/ha as concentrated super phosphate (42% P_2O_5) and 112 kg K_2O/ha as muriate of potash (60% K_2O). 15 cm long cuttings of variety MU 72 containing 3 to 5 buds were planted at 2 cuttings per hill on 7th May, 1973.

The plants were sequentially sampled at monthly intervals, commencing 2 months after planting. At each sampling, a hill selected at random from each plot was sampled, except at the final harvest when 4 hills were sampled per plot. For each sample, tuber fresh weight and the dry weights of tubers, stems and leaves were determined. The leaf area was estimated by the disk method.[6]

3. Results and Discussion

Tuber Data. The main effects of treatments on tuber fresh weight yield are given in Table 2. Although the differences were non-significant throughout the entire period of growth there was a marked response to levels of applied nitrogen. The lower level of nitrogen reached maximum tuber fresh weight yield 6 months after planting while the intermediate and the higher levels of nitrogen recorded maximum tuber fresh weight yields 7 and 8 months after planting, respectively. Each increment of nitrogen increased tuber fresh weight yield ; the higher level of nitrogen recorded the highest yield of tubers which was an increase of 14% and 27% respectively, compared with the intermediate and lower levels of nitrogen.

TABLE 2. Main effect of treatments on tuber fresh weight yield kg/ha.

Level of N	Months after planting								
Level of N	2	3	4	5	6	7	8	9	10
44.8 kgN/ha	209	4223	7658	16992	30332	28722	32112	27958	24896
67.2 kgN/ha	487	5038	9711	19057	30589	33994	32339	28389	25594
89.6 kgN/ha	329	4179	11698	16489	26823	37316	38586	28905	24791
LSD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Spacing									
0.91 × 0.61 m	323	7656	17761	23504	47847	46191	44709	36891	40264
0.91 × 0.91 m	385	4370	9611	20981	34375	38845	45937	33541	25123
0.91 × 1.21 m	382	4009	7000	16456	23635	32470	28239	29830	23789
0.91 × 1.52 m	272	1851	4304	9109	11137	15871	18495	13405	11197
LSD (P = 0.05)	n.s	2726.5	7537	5821	11302	11780	11897	12950	12357

Significant differences in tuber fresh weight yields between spacing treatments were recorded throughout the entire growth except at 2 months after planting. An increase in spacing decreased tuber fresh weight yield and the highest tuber yield (47,847 kg/ha or 19 tons/acre) was recorded* for the closer spacing (0.91 × 0.61 m). The increase in tuber fresh weight between the closest and the widest spacing (0.91 × 1.52 m) was as high as 150% (P = 0.01) while the increase over the recommended spacing of 0.91 × 0.91 m for crops grown in monoculture was 4% (P = 0.05). The data clearly indicated that a higher yield of tubers could be obtained by growing manioc at a closer spacing of 0.91 × 0.61 m when grown as an intercrop under coconut.

The tuber fresh weight yield decreased after 8 months of planting for all treatments. At this stage of growth leaf area index (Table 8) also decreased indicating that the variety MU 72 could be harvested around 8 months after planting.** The reduction in tuber bulking and in tuber yield after the maximum has been reached may be associated with dry matter losses in respiration.

The mean tuber bulking rates were calculated over a period of 6 months from the commencement of the tuber growth by using a linear regression equation $Y = a + bx$, where Y = yield of tubers, a = a constant, b = slope of the regression and x = time. The lowest bulking rate was recorded for 0.91 × 1.52 m, followed by 0.91 × 0.61 m spacing, while the highest bulking rate was recorded for 0.91 × 1.21 m spacing. (Appendix, Table 3). The tuber bulking rates were linear (R^2 = 67.5%) however, unlike in the potato tuber, bulking rates were not correlated with the final tuber yield.[2,3] This may be due to the relatively long period of tuber bulking in manioc when compared with potato where the period of tuber bulking is comparatively short. However, Enyi[1] reported a close relationship between tuber bulking rate and tuber yield in coco yams.

TABLE 3. Main effect of treatments on tuber bulking rate.

a. Nitrogen	kg/ha/week	R^2 (%)
44.8 kgN/ha	956.0	73.0
67.2 kgN/ha	662.4	70.0
89.6 kgN/ha	917.3	67.5
b. Spacing		
0.91 × 0.61 m	485.3	69.5
0.91 × 0.91 m	1003.2	68.1
0.91 × 1.21 m	1133.7	76.6
0.91 × 1.52 m	458.7	68.6
LSD (P = 0.05)	N.S	

*Such a high yield estimate perhaps is due to the small sample size.

**Whether different times of planting would give similar observations as recorded here need to be investigated.

Dry matter accumulation

Main effect of treatments on total dry matter yield is given in Table 4. There were no interactions between treatments. Nitrogen increased total dry matter yield upto 8 months after planting and then declined. Each increment of nitrogen increased total dry matter yield but the difference between levels of nitrogen were not significant. Higher level of nitrogen recorded the highest dry matter yield which was 8% and 9% more than the intermediate and lower levels of nitrogen, respectively.

TABLE 4. Main effect of treatments on total dry matter yield kg/ha.

a. Nitrogen	Months after planting								
Levels of N	2	3	4	5	6	7	8	9	10
44.8 kgN/ha	982	2279	4926	8416	14343	13256	15765	12177	11774
67.2 kgN/ha	847	2671	5185	8355	13825	14559	15862	12888	12791
89.6 kgN/ha	952	2572	4752	8290	13184	15983	17134	13754	13206
LSD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
b. Spacing									
0.91 × 0.61 m	1352	3854	7338	12057	22656	20621	21534	18334	19643
0.91 × 0.91 m	1052	2693	5618	9699	15324	16853	13559	14352	13432
0.91 × 1.21 m	728	2125	3907	6985	11165	13318	13560	12575	11730
0.91 × 1.52 m	604	1358	2955	4675	5992	6565	9114	6493	5557
LSD (P = 0.05)	452	1025	1919	2659	5946	4350	5127	4036	5663

Significant differences in total dry matter yield between spacing treatments were recorded at all sample harvests and an increase in spacing decreased total dry matter yield. 0.91 × 0.61 m spacing reached the highest dry matter yield 6 months after planting while other spacings recorded highest total dry matter yields in the 7th and 8th months after planting. The difference in total dry matter yield between the closest and the widest spacing was 148%.

Leaf dry matter yield increased upto 6 months after planting and declined for all nitrogen treatments (Table 5). Each increment of nitrogen increased leaf dry matter yield but the differences between treatments were not significant at any stage of growth. The higher level of nitrogen increased leaf dry matter yield by 10% and 12% respectively, when compared with the intermediate and the lower levels of nitrogen at 6 months after planting.

TABLE 5. Main effect of treatments on leaf dry matter yield, kg/ha.

a. Nitrogen	Months after planting.								
Level of N	2	3	4	5	6	7	8	9	10
44.8 kgN/ha	226	504	703	635	1730	1354	1452	603	390
67.2 kgN/ha	245	545	726	664	1697	1467	1660	545	363
89.6 kgN/ha	235	558	665	678	1838	1543	1296	587	389
LSD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
b. Spacing									
0.91 × 0.61 m	346	827	1054	984	2834	1905	2040	807	563
0.91 × 0.91 m	242	562	804	675	1882	1923	1992	631	506
0.91 × 1.21 m	203	444	527	609	1527	1306	1056	575	298
0.91 × 1.52 m	151	310	402	367	776	684	689	300	157
LSD (P = 0.05)	104	187	N.S	208	792	529	496	283	184

Maximum leaf dry matter for spacing treatments was recorded at 6 months after planting except for the 0.91 × 0.91 m spacing which recorded maximum leaf dry matter two months later. The maximum leaf dry matter recorded for the closest spacing (0.91 × 0.61 m) was 2834 kg/ha, which was an increase of 42%, 86% and 265% respectively when compared with the wider spacings in an increasing order. This was due to the direct effect of plant population, more plants per unit area progressively increasing the leaf dry matter yield. The decrease in leaf dry matter yield 6 months after planting was due to rapid defoliation.

Nitrogen increased stem dry matter yield upto 9 months from planting and then declined (Table 6). Significant differences between treatments were recorded at the 9th harvest taken 10 months after planting when the intermediate and the higher levels of nitrogen were significantly superior to the lower level of nitrogen (P = 0.05). The reduction in stem dry matter yield after 9 months could be regarded as an index of crop maturity as the fresh weight yield of tubers also have declined after this stage of growth.

A decrease in spacing increased stem dry matter yield due to the production of more stems per unit area. Similar to that of the level of nitrogen, the maximum stem dry matter yield for all spacings were recorded at 9 months after planting. The highest stem dry matter yield recorded for the closest spacing (0.91 × 0.61 m) was 6280 kg/ha, this being an increase of 147% compared with the widest spacing (0.91 × 1.52 m).

TABLE 6. Main effect of treatments on stem dry matter yield, kg/ha.

a. Nitrogen	Months after planting								
Level of N	2	3	4	5	6	7	8	9	10
44.8 kgN/ha	718	1067	2356	2944	4928	2965	3355	4002	2966
67.2 kgN/ha	533	1271	1987	3218	5176	2903	3553	4036	4296
89.6 kgN/ha	667	1275	2019	3024	4872	2844	3602	4166	4054
LSD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	744
b. Spacing									
0.91 × 0.61 m	953	1895	3094	4329	8332	4522	5536	6280	5576
0.91 × 0.91 m	720	1267	2375	3933	5594	3037	3571	4290	4508
0.91 × 1.21 m	471	904	1571	2332	3742	2246	2758	3159	2920
0.91 × 1.52 m	414	754	1442	1623	2300	1812	2149	3543	2078
LSD (P = 0.05)	355	509	737	1190	815	230	374	905	859

Nitrogen had no significant effect on tuber dry matter yield (Table 7). Highest tuber dry matter yield for all nitrogen levels were recorded at 8 months after planting. The maximum tuber dry matter yield was recorded for the highest level of nitrogen (12,592 kg/ha) was only 2% more when compared with other levels of nitrogen.

TABLE 7. Main effect of treatments on tuber dry weight, kg/ha.

a. Nitrogen	Months after planting								
Level of N	2	3	4	5	6	7	8	9	10
44.8 kgN/ha	38	706	1868	4838	7680	8905	11048	7542	8418
67.2 kgN/ha	69	855	2471	4474	6952	10189	9947	9307	8135
89.6 kgN/ha	50	679	2068	4574	6474	11595	12252	9002	8768
LSD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
b. Spacing									
0.91 × 0.61 m	54	1050	3190	6743	11490	14494	13958	11208	13504
0.91 × 0.91 m	62	864	2434	5061	7487	11932	14434	9433	8417
0.91 × 1.21 m	54	777	1809	4023	5896	9724	9768	8845	8513
0.91 × 1.52 m	39	294	1110	2686	2909	5069	6171	3650	3329
LSD (P = 0.05)	N.S	503	1156	1745	3713	4266	1572	3841	5492

The tuber dry matter yield increased progressively and reached a peak value between the 7th and 8th months after planting and then declined. An increase in spacing decreased tuber dry matter yield. The highest tuber dry matter yield was recorded for 0.91 × 0.61 m at 7 months after planting. There was no significant difference in highest tuber dry matter yield between 0.91 × 0.61 m and 0.91 × 0.91 m, but both these treatments were superior to the other wider spacings. The closest spacing increased tuber dry matter yield by 135% when compared with the widest spacing (0.91 × 1.52 m).

Leaf area index, L.

Leaf area per unit area of land, the leaf area index was increased by nitrogen application (Table 8). The highest level of nitrogen had a maximum L value of 6.57, this being an increase of 18% and 21% when compared with the intermediate and lower levels of nitrogen.

TABLE 8. Main effect of treatments on leaf area index, L.

a. Nitrogen	Months after planting								
Level of N	2	3	4	5	6	7	8	9	10
44.8 kgN/ha	0.78	1.91	2.29	2.04	4.68	5.17	5.42	1.98	1.00
67.2 kgN/ha	0.90	2.22	2.26	2.27	4.75	5.52	5.56	2.04	1.02
89.6 kgN/ha	0.89	2.38	2.30	2.24	5.01	6.57	5.03	2.00	1.15
LSD (P = 0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
b. Spacing									
0.91 × 0.61 m	1.28	3.54	3.38	2.96	7.96	8.30	7.67	2.56	1.47
0.91 × 0.91 m	0.79	2.19	2.72	2.45	5.00	7.49	6.42	2.35	1.28
0.91 × 1.21 m	0.74	1.56	1.64	1.98	3.85	4.96	4.19	1.90	0.84
0.91 × 1.52 m	0.62	1.38	1.48	1.33	2.44	3.26	3.07	1.22	0.64
LSD (P = 0.05)	0.40	1.00	0.89	0.69	2.26	2.25	1.72	N.S	0.54

The closest spacing (0.91 × 0.61 m) had the highest L and this value was reached a month in advance of the other spacings. This could be attributed to the increase in shoot number resulting from the higher plant population. The maximum L recorded for the closest spacing (0.91 × 0.61 m) was 7.96 followed immediately by 7.49, 4.96 and 3.26 for the other wider spacings in an increasing order. After the 8th month of planting, defoliation was rapid and L declined quickly, but the population effects persisted until the final harvest was made 12 months after planting. This would mean that the tuber bulking will be reduced after 8 months of growth due to the reduction in L, leaf being the most important organ in manioc.

Leaf area duration (D), the integral of leaf area index with time was calculated from the first sample harvest taken 2 months after planting to the final sample harvest made 12 months after planting (Table 9). Each increment of nitrogen increased D. The closest spacing (0.91 × 0.61 m) recorded the highest D, followed by a progressive reduction in D as the spacing increased. The total and tuber dry matter yields were linearly correlated with D, and these relationships could be represented by the equations $Y = -15743.0 + 93.47\ D$ ($P = 0.01$) and $Y = -12746 + 56.73\ D$, ($P = 0.01$), D accounting for 97% and 86% of the variation in total and tuber dry matter yields respectively. Similar relationships between D and total and tuber dry matter yields have been reported for other root crops such as the potato[3] and Coco yams.[1] The results reported supports Watson's[5] contention that leaf area is the chief determinant of crop yield.

TABLE 9. Main effect of treatments on leaf area duration, D.

a. Nitrogen	D, weeks	% increase/decrease with increasing level of nitrogen or spacing
44.8 kgN/ha	97.52	—
67.2 kgN/ha	106.28	9.6
89.6 kgN/ha	108.00	10.7
b. Spacing		
0.91 × 0.61 m	146.66	—
0.91 × 0.91 m	118.42	19.3
0.91 × 1.21 m	83.48	43.1
0.91 × 1.52 m	59.24	59.6

The tubers of a single replicate harvested 8 months after planting were analysed for hydrocyanic acid content. The values ranged between 0.050% to 0.053% in fresh peeled tubers which according to Singha and Nair [4] is innocuous.

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