INFLUENCE OF CLIMATE AND WEATHER ON THE NUT YIELD OF COCONUT (*Cocos nucifera*)

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Thesis

Submitted for the Degree

of

Doctor of Philosophy

in the

Faculty of Science

University of Colombo

Sri Lanka

1997

SUMMARY

Coconut is one of the most important and valuable tree crops in Sri Lanka as a part of diet and as a source of export earning. It is grown exclusively for nut production in Sri Lanka and the main kernel products of coconuts are copra, desiccated coconut, coconut oil and poonac. The coconut palm generally comes into flower in about the 5-6 th year, if water, light and nutrient conditions are favourable and it produces twelve bunches at the rate of one per month. Development from the flower primordium to the harvest of mature nuts (drupe) takes 44 months of which the primordium takes about 32 months to emerge ('non-visual cycle'), and the last 12 months represent the period taken from the opening of the spathe to harvest of mature nuts ('visual cycle').

Coconut in Sri Lanka is harvested during January/February, March/April, May/June, July/August, September/October, and November/December. Within a location of uniform soil and management, the nut yield of coconut has a large variation among picks and among years due to the climate variabilities. However, extensive attention has not been carried out to understand the effects of climate and weather on the nut yield of coconut and on the phenology of the crop development (Prasada Rao, 1991).

The importance of these studies is enormous. The knowledge gathered by the previous work on the effects of climate and weather on nut yield of coconut is not sufficient to determine the important climatic variables, to explain the yield variability within years, to quantify the effects of climatic variables etc. No studies have been carried out to find the effects of climatic variables simultaneously either on pick-wise yield or total annual yield. The studies in Sri Lanka were carried out to find the effects of rainfall on the total annual yield. Thus, in this study the effects of eight climatic variables simultaneously on both pick-wise and annual yield are studied to address some of the gaps mentioned above.

The yield data of the six picks and the monthly climatic data of rainfall (RF), pan evaporation (EV), sunshine duration (SS), wind velocity at 3 m (WV), minimum air temperature (TMIN), maximum air temperature (TMAX), relative humidity forenoon (RHAM), and relative humidity afternoon (RHPM) at the Coconut Research Institute (CRI) from 1976 to 1992 were used.

Based on the long-term average yield of picks one to six the ranking order of the picks was pick 3 > pick 4 > pick 2 > pick 5 > pick 1 > pick 6, but this order was significantly different among years. Of them pick 2 had the lowest coefficient of variation, whilst pick 4 had the highest coefficient of variation. Ignoring the interdependence among the climatic variables the best parametric models were developed via multiple regression techniques at monthly intervals, for the lags of 36 months prior to each harvest. The variables which were found most significantly influential during this period of 36 months were wind velocity (WV), maximum air temperature (TMAX), relative humidity in forenoon (RHPM), precipitation (RF), and sunshine duration (SS). The order of importance of significantly influential variables during this period was found as WV >> TMAX > RF > RHPM > SS > EV > RHAM > TMIN. This order varied from pick to pick, but WV and TMAX were the two most influential variables on the yield of each pick.

Irrespective of time and picks the most influential four climatic variables during the visual cycle were TMAX, SS, RHPM, and RF. The order of importance of all the variables during the visual cycle was TMAX >> SS > RHPM ≈ RF > EV > WV > TMIN > RHAM, but it varied from pick to pick. The importance of TMAX and SS during the visual cycle was thus established. A strong linear relationship ($n=17$; $R^2 = 0.90$; $p < 0.001$) was established between sunshine duration and solar radiation. This model can be used to estimate the solar radiation intercepted by the canopy of the palm. The mean daily solar radiation at the CRI was estimated to be 18.3 MJ $m^{-2}d^{-1}$ and the total annual solar radiation receipts per year is 6680 MJ m^{-2} (66.8 TJ ha-1). The importance of TMAX and SS can be hypothesized for the use of the energy requirement for the photosynthesis process to produce dry matter which determines the final nut yield of the palm.

Irrespective of picks, the order of importance of climatic variables prior to the visual cycle was WV > > TMAX > RF > RHPM > RHAM > SS > EV > TMIN. The wind velocity before the spathes open is useful to the growth of rachille of the inflorescence take place and to form primordium of male flowers. The study concluded that rainfall is not the most important climatic variable on the yield of coconut in respect to the climate variability at the CRI, when all the climatic variables were taken into consideration simultaneously as proxy variables such as RHPM implicitly take into account the effect of rainfall.

The most and the least influential picks in respect of climate and weather variability were pick 5 and pick 2 respectively and their order of impact was ranked as pick 5 > pick 3 > pick 4 > pick 2 > pick 6 > pick 2. The first most influential (FMI) periods of the picks 1 to 6 in respect of the impact of climate and weather during the visual cycle, were second, fourth, third, third, fourth, and fourth months after spathe opening of the respective bunches. These months correspond to February, June, July, September, December, and February. The crop-weather models developed at the FMI period of each pick represented the yield variabilities adequately. These models can be used to predict pick-wise yield separately using different climatic variables. It is concluded that yield fluctuations between picks were primarily determined by the climate and weather changes in these five months.

The significant variables in the models were different from pick to pick, but air temperature in the afternoons (TMAX) and relative humidity in the afternoons (RHPM) were the two main determinable variables in most of the models. Thus the role of TMAX and RHPM in respect of those months in controlling the yield at the CRI was well shown. Among the variables influencing the yield the rainfall of the post-south-west monsoon rains in July and pre-north-east monsoon rains in September were favourable to the yield in pick 3 and pick 4 respectively.

In order to identify 'factors' affecting yield the principal component analysis (PCA), and factor analysis (FA) with varimax transformation were used. It was found that the climate variability at the CRI can be represented by three factors namely SS+RHPM-SS-TMAX-TMIN ('warming' factor), WV+EV ('evaporation' factor), and TMIN+RHPM ('saturation' factor) irrespective of the months. The combined results of multivariate and univariate analyses, and the use of biological and practical considerations enabled the use of the variables EV, TMAX, and RHPM as most appropriate variables to represent the distributions in yields within-and-between years. Further, as only three variables were selected it was possible to explore the different interactions and transformations in developing most parsimonious parametric (MPP) crop-weather models.

The most parsimonious parametric (MPP) crop-weather models at the FMI period of each pick as against the best parametric (BP) crop-weather models, also explained a substantial amount of yield variabilities of the respective picks. Those models can be used to predict pick-wise yield separately using the same climatic variables at the corresponding FMI month. Most of the models used had two variable interaction terms. Based on the results of each model a crop-weather model ($n=84$; $R^2 = 0.60$; $p < 0.0001$) was developed for the combined data across picks. Thus yield of a given pick can also be estimated from a single model using EV at lag 10, TMAX at lag 9, and RHPM at lag 10 in respect of that pick. Based on the results of the model for combined data a model to explain the yield variability between years was also developed ($n=14$; $R^2 = 0.80$; $p < 0.002$). From this model annual yield in a given year can be predicted 18 months in advance using EV and RHPM in August and TMAX in July of the previous year. These models are of vital importance for policy makers, scientists, and growers.

High values for evaporation, air temperature in the afternoons, and relative air humidity in the afternoons in February reduce the yields in picks 1 and 6. Of these variables, maximum air temperature is the determinant variable which influences the low yield in these two picks. The output from pick six is lower than the output from pick 1 because the bunches in respect of pick 6 take three months (wettest, dry, and dry and hot months) to reach the FMI period as against one hot and dry month of the bunches in respect of pick 1. An appropriate mulch to cover around the palms during February can be recommended to reduce the maximum air temperature and enhance the yields in these two picks.

Higher air temperature (afternoons) in June leads to lowering of pick 2 yields. The yields of pick 2 can be increased by removing lower-position (unproductive) leaves of the crown during June because well arranged leaves minimize the radiation that passes through the canopy to the ground and consequently increase the air humidity (Foale, 1993).

As for the pick 2, it was found that the maximum air temperatures in December adversely affect the yield in pick 5, while evaporation in December is favourable to increase the yield. As the bunches in respect for pick 5 pass two wettest months during October and November the shedding of button nuts can be expected to be high. The evaporative demand for atmosphere in December can be increased by exposing more area around the bole of the palm. Therefore mulching is not recommended during December after heavy showers of north-east monsoon, though there may be practical difficulties in particular for large estates in removing the mulch placed in February.

The bunches in respect of pick 3 pass through two wet months (May and June) before they reach the FMI period (July). In contrast the bunches in respect of pick 4 also pass through two dry months (July and August) before they reach the FMI period (September). These four months have the lowest vapour pressure deficits ranging from 1.0 to 1.2 kPa. Thus it can be hypothesized that for the bunches opening during low vapour pressure deficit the incidence of shedding of button nuts is low, leading to higher yield. Increase of RHPM in June and September is beneficial to enhance the yields of picks 3 and 4 respectively. The study showed the rainfall in post-south-west monsoon during July, and pre-north-east monsoon during September is beneficial to increase RHPM in these two months respectively.

The information obtained from this study on the effects of climate variability on nut yield of coconut is of immense use to a crop physiologist to develop dynamic crop-weather models. The techniques used to fit most parsimonious models can be applied to find the effects of climate and weather for other perennial crops. Based on the results in this study some recommendations are given to increase yields of coconut. The important areas which require further research on agroclimatology aspects in coconut are also discussed. As coconut has adapted to the climate associated with a particular location it is recommended that such studies should be extended to different climate and weather situations.