MATCHING CROP REQUIREMENTS TO LAND CHARACTERISTICS IN A TROPEPTIC EUTRUSTOX IN HAWAII[1] /

*L. A. MANRIQUE**
*D. J. HARRIS**
*G. UEHARA**

Resumen

Los autores presentan el desarrollo de una secuencia de cultivos a base de maíz, soya y papa para un Tropeptic Eutrustox de Hawai. Se obtuvo rendimientos de 2.0 a 2.5 t ha^{-1} de grano de soya, 36.0 t ha^{-1} de tubérculos de papa y 10.0 t ha^{-1} al aprovechar el período cálido de abril a noviembre para cultivar el maíz (mayo-setiembre) y la soya (setiembre-diciembre), cultivando la papa en los meses más fríos (diciembre-marzo). Se concluye que se puede obtener aumentos en rendimientos haciendo coincidir los requerimientos de los cultivos con las variaciones estacionales del clima.

Introduction

Multiple cropping, the growing of two or more crops on the same land during one year, is a widespread method of agriculture in the tropics. There are obvious advantages of sustained year-round production; however, it is also known that seasonal temperature variation can markedly alter crop yields even in the tropics. This seasonal effect becomes greater as one moves away from the equator. Therefore, developing cropping systems capable of taking full advantage of the seasonal variation is important for improved efficiency of crop production in the tropics. This paper reports the results of a cropping pattern developed for a clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox from Hawaii.

Materials and methods

Maize experiments. Maize (*Zea mays* L.) experiments were conducted at different times of the year at Waipio, Island of Oahu, Hawaii, during 1978 through 1981. The soil at this experimental site belongs to the Wahiawa series and is classified as clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox. Soil properties of this soil family were reported by Ikawa (2). The mean annual rainfall at Waipio (1978-1981) was 921 mm (Table 1). The lowest rainfall period occurred in the summer months (June-August). The mean annual temperature was 25°C, with a difference of 3 to 4°C between summer and winter (January-March).

Plots, 8 by 3 meters, with rows spaced at 75 cm were planted with maize (hybrid X304C from Pioneer Hi-Bred International). Plants were 23 cm apart in the row, giving a population of 58.000 plants/ha. At planting nitrogen fertilizer was applied at 120 kg/ha and potassium at 100 kg/ha. Growing conditions were near-optimum because of control of water supply and pests. Field operations including harvest followed standard procedures and guidelines (1).

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* Research Associates, Benchmark Soils Project, and Professor, Department of Agronomy and Soil Science, University of Hawaii, Honolulu, Hawaii, 96822.

Table 1. Climatic data (1978-1871) at Waipio, Island of Oahu, Hawaii.

Month*	Rainfall (mm)	Solar Radiation 10^4 $Jm^{-2}d^{-1}$	Temperature °C
January	171.6	1 236	22.3
February	105.9	1 479	22.3
March	42.8	1 793	23.5
April	83.8	1 953	24.0
May	87.6	2 036	24.6
June	61.3	2 078	25.6
July	30.9	2 133	26.3
August	26.7	2 074	26.6
September	46.2	1 978	26.2
October	124.4	1 517	26.0
November	46.5	1 425	24.9
December	94.2	1 173	23.2

* Summer (June-August), Winter (January-March).

Potato experiments. Potatoes (*Solanum tuberosum*, var. Kennebec) were planted in the winter and summer of 1980. Plots 8 x 3 meters were seeded with potatoes spaced 35 cm apart in rows 75 cm apart to achieve a density of 36 666 plants/ha. Nitrogen fertilizer was applied at 160 kg/ha and potassium at 120 kg/ha. Half of the N fertilizer was applied at planting and half at 30 days after planting. Irrigated and nonirrigated plots were included in the summer of 1980. All plots were irrigated uniformly until 30 days after planting, thereafter water was applied only in irrigated plots when soil water tension reached 0.50 bars. Details of these potato experiments were reported elsewhere (4, 5)

Cropping sequence. A cropping sequence of potato-maize-soybean was grown during 1979 and 1980. Table 2 shows planting and harvest dates for the different crops. The maize and potato experiments in this sequence were similar to the experiments described above. Soybean (*Glycine max* L.) seeds were planted 5 cm apart with 75 cm between rows, giving a population of 266 666 plants/ha. Soybean seeds were inoculated with strains of *Rhizobium japonicum*. At planting nitrogen fertilizer was applied at the rate of 40 kg/ha and potassium at 100 kg/ha. Initially, the maize crop was planted on May 1, 1980; however, an accidental application of herbicide in an adjacent experimental plot severely affected germination and further emergence. The crop was replanted on May 20 and the harvest was delayed until September 30. This delay prevented planting the following soybean crop at the scheduled time on the same plots. To adhere to the planting schedule, soybeans were planted in adjacent plots on September 2, 1980

Table 2. Crop yields in the crop sequence potato-maize-soybean.

Crop	Year	Date of Planting	Date of Harvest	Yield t ha^{-1}
Soybean	1979	August 20	November 30	2.5
Potatoes	1980	December 20	March 30	34.0
Maize	1980	May 20	September 30	10.0
Soybean	1980	September 2	December 9	2.0
Potatoes	1981	January 19	April 22	38.6

Since maize and potatoes are the two main crops of this sequence, and soybean is simply a filler crop for the months of September to December, the results of the maize and potato experiments are emphasized here

Results

Maize yields. The effect of seasonal variation on the length of the growing period of several maize plantings is presented in Table 3. Maize growth in the cool winter months was slow. Maize planted in December and January did not reach maturity until summer and took almost 170 days. Maize planted in March also grew slowly and reached maturity in summer. Maize planted in June and July matured normally in 130-140 days. Similar results were reported by Jon *et al.* (3) in maize experiments conducted in a isohyperthermic (mean annual soil temperature > 22°C) Typic Haplustoll in Hawaii.

The number of days required to reach 50% tasseling was also dependent upon planting date. Summer plantings of maize reached 50% tasseling 20 days eralier than winter maize crops. In studies comparing days to tasseling and maturity in Tropeptic Eutrustox from Hawaii, Puerto Rico and Brazil, Manrique and Tsuji[1] found that X304C generally takes longer to tassel and mature in Hawaii and Brazil than X304C grown in a similar soil in Puerto Rico. Delayed tasseling and maturity was attributed to seasonal temperature variation in the Hawaii sites and also to relatively cool temperature in the Brazil site. From these studies, it is apparent that tasseling and maturity differences between members of this tropical soil family are temperature related even though they are located in a narrow climatic range.

Maize yields were less dependent on seasonal variation than tasseling and maturity (Table 3). Yields between 8.5 to 11.5 t ha^{-1} were obtained in most cases. Similar yields between winter and summer

1 1983, unpublished data.

Table 3. Number of days to tasseling and harvest and yields of maize as affected by seasonal temperature variation. Variety X304C.

Maize Experiment		Season[a]	Date of Planting	Air Temperature[b], °C		Days to		Grain Yield[c], t ha^{-1}	Yield Production Rate, t ha^{-1} day^{-1}
				Planting	Tasseling	Tasseling	Harvest		
WAI	A10	S	July 10, 1978	27.1	26.8	60	140	10.5	0.075
	B10	W	Jan. 03, 1979	21.7	23.0	86	170	11.5	0.068
	D10	S	June, 07, 1979	25.3	25.4	64	139	10.0	0.072
	A11	W	Dec. 13, 1979	22.7	23.4	79	167	8.5	0.051
	A12	S	July 22, 1980	25.2	23.1	57	134	10.7	0.080
	A13	W	Mar. 06, 1981	23.0	24.5	69	146	9.7	0.066

a S = summer, W = winter.
b Air temperature for the months of planting and tasseling.
c Yields correspond to the +0.85N, +0.85P (code level) treatment of transfer experiments

crops seem to be attributed to accumulated solar radiation that winter crops benefied due to extended maturity periods (3). However, grain yield per day was greatly diminished in the winter crops.

Potato yields. Potatoes grown under the short days of the winter season had a short growing season and tuber initiation began at 40 days after planting (Table 4). Soil temperatures, measured at 20 cm depth, ranged from 18 to 20°C (5). Potato grown during the relatively long summer days had a prolonged growing season, tuber initiation was delayed by 15 days and yields were reduced. Soil temperatures, measured at 20 cm depth, ranged from 24 to 26°C.

Cropping sequence. The cropping sequence developed in this soil family yielded 10.0 t ha^{-1} of maize in the summer followed by 2.0 to 2.5 t ha^{-1} of soybeans (Table 2). Potato yield in the winter of 1980 was 34.0 t ha^{-1}. A tuber yield of 38.6 t ha^{-1} was obtained in the winter of 1981, due mostly to better seed and also to improved crop management.

Discussion

The results of the maize experiments demonstrate that summer is the best season to attain high maize yields in short growing periods. The results stress the importance of time in the context of more efficient use of land and energy. Furthermore, the differential response of potatoes to seasonal temperature variation stress the importance of matching crops not only to the particular soil family but also to seasons. The results of this study pattern indicate that a summer planting of maize, followed by a crop of soybeans, and a final winter planting of potato appears to be one cropping sequence that makes efficient use of land area and solar energy. This cropping sequence takes advantage of the warm periods with high solar radiation, which fall between spring and autumn, to grow maize and soybeans and uses the winter months to meet cooler soil temperature requirements for potato production. By matching crops not only to a particular soil family but also to seasons within a family, crop production can be very much increased without increasing land area.

Table 4. Potato performance at Waipio, Island of Oahu, Hawaii[a].

Parameter	Winter 1980	Summer 1980
Air Temperature, °C	21.5 – 23.4	23.2 – 25.4
Tuber initiation, days	40	55
Growth period, days	100	120
Yield[b], t ha^{-1}	34.2	25.4

a Sources: Manrique (4) and Manrique *et al.* (5).
b Irrigated plots

Summary

A cropping sequence consisting of maize, soybean and potatoes has been developed for a clayey, kaolinitic, isohyperthermic soil family of Tropeptic Eutrostox in Hawaii. Each crop required a land preparation and growing period of 3 to 5 months. Supplemental irrigation was provided using a drip irrigation system. A soybean crop was grown between September and mid-December giving a grain yield of 2.0 to 2.5 t ha^{-1}. Between late December and early January, potato was planted. After 100 days, the average tuber yield was 36.0 t ha^{-1}. Maize was grown between May and September and yielded 10.0 t ha^{-1}. This cropping pattern was designed to take advantage of the warm, sunny period between April and

November to grow maize and soybean. Potato, which requires cool soil temperatures for tuber development, was grown in the winter months. Marked increases in yields can be obtained on this soil by matching crop requirements to seasonal variation.

Literature cited

1. HAWAII. UNIVERSITY OF HAWAII. BENCHMARK SOIL PROJECT. Procedures and guidelines for agrotechnology transfer experiments with maize in a network of Benchmark soils. University of Hawaii, Benckmark Soil Project, 1982. 64 p. (BSP Tecn. Rep. 3)

2. IKAWA, H. Laboratory data and description of soils of the Benchmark Soils Project. Vol. 1. Hawaii Agricultural Experiment Station. Miscellaneous Publication 165. 1979. 37 p.

3. JONG, S. K., BREWBAKER, J. L. and LEE, C. H. Effects of solar radiation on the performance of maize in 41 successive monthly plantings in Hawaii. Crop Science 22:13-18. 1982.

4. MANRIQUE, L. A. Performance of potatoes in three tropical soil families. **In** Symposium of the International Society of Tropical Root Crops, Lima, Peru, 1983. Proceedings. (In Press).

5. MANRIQUE, L. A., TSUJI, G. Y., UEHARA, G. and FOX, R. L. Winter and summer performance of potato (*Solanum tuberosum*) in isohyperthermic temperature regimes. American Potato Journal 61:41-54. 1984.