Water Use and Efficiency in Lowland Taro Production

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ABSTRACT

Experiments were conducted to determine the effects of different rates of water flow and depth of flooding on the yield and yield components of lowland taro.

Using rates of water flow of 280,470 l/ha/day to 981,640 l/ha/day (30,000 gal/A/day to 105,000 gal/A/day), no significant differences were obtained in total corm and cormel yields of lowland taro, variety Lehua Maoli. Corm, marketable cormel and total yields averaged 32.3, 31.7, and 64.0 tons/ha, respectively. Water use efficiency calculated on the basis of liters water needed to produce a kilogram of taro corms was 800 l/kg for the lowest rate of water flow and 2,790 l/kg for the highest.

Yields of lowland taro decreased as depth of flooding increased from 0 cm to 20 cm. Highest yields were obtained from plots where water depth was maintained at 0 cm. Flooding to a depth of 16 and 20 cm drastically reduced marketable cormel yields causing a severe drop in total yield. Optimum depth of flooding in lowland taro appear to be 4 to 8 cm as this is sufficient to keep weeds under control without causing severe yield losses. Total yield at 0 cm depth was 28.5 tons/ha compared to 16.9 tons/ha at 20 cm depth of flooding.

Taro, Colocasia esculenta (L.) Schott, is a crop grown throughout the tropics and sub-tropics under a wide range of environmental and edaphic conditions. It is grown under extremes of water regimes, i.e. dryland or unflooded culture to waterlogged or flooded culture. Although majority of the approximately 760,000 ha of land used for taro production is under dryland or upland growing conditions (FAO, 1975), almost all of the taro in Hawaii is grown under waterlogged or flooded culture (Plucknett and de la Peña, 1971). Under flooded growing conditions, taro is assumed to use excessive amounts of water during its cropping period. Water used to flood the taro fields is allowed to flow continuously assuring low water temperature which helps to prevent development of corm diseases and also enhances the growth of the taro plant. Estimates on the actual amount of water needed to grow lowland taro has varied from farmer to farmer. Even water measurements done in taro farms vary considerably depending on the season when measurements are taken. Watson (1970) estimated that the average water requirement of taro is 140,000 to 373,000 l/ha/day (15,000 to 40,000 gal/A/day) based on measurements made in taro fields of Oahu, Hawaii between 1962 and 1964.

In Hawaii, taro is a crop of major commercial importance. It was cultivated by the early Hawaiians who used taro as the source of "poi," the staple food which is prepared from boiled taro corms, mashed and pounded into a paste. Early records of Hawaiian agriculture report large acreages of taro in Hawaii, however, production over the last decade has declined considerably. In 1972, Hawaii produced about 4.1 million kg while in 1981, the production was only about 2.8 million kg, showing a decline of approximately 31% (Hawaii Agricultural Reporting Service, 1982). Much of the decline in Hawaiian taro production is attributed to the declining acreage used for taro. The decrease in acreage of taro is again attributed to the urban encroachment which is not only squeezing out the land used for taro but also drastically reducing the availability of water for lowland taro production.

Farmers in Hawaii, in their efforts to save the declining taro lands have gone to the extent of suing the government for water needed in taro production. To assess the water needs of taro growers, especially in Oahu, Hawaii where population is concentrated, experiments were conducted to determine the effects of different rates of water flow and depth of flooding on the growth and yields of lowland taro. The experiments on the rate of water flow were conducted in a commercial field in Hanapepe Valley, Kauai while the experiments on depth of flooding were conducted at the Kauai Branch Research Station, Kapaa, Kauai.

Materials and Methods

Experiment I - Water Flow Rate

This experiment was in Hanapepe Valley on the Island of Kauai in a commercial taro farmer's field. The soil is a typic Fluvaquents (U.S. Soil Taxonomy) or Eutric Gleysols (FAO/UNESCO) (Beinroth, Ikawa and Uehara, 1974) which is used for lowland taro production in Hawaii.

Using a replicated randomized complete block design, six rates of water flow were assigned in plots approximately 6x9 m in size. The rates of water flow used ranged from 280,470 l/ha/day (30,000 gal/A/day) to 981,640 l/ha/day (105,000 gal/A/day). Water flowing into each individually diked plot was provided through plastic pipes with individual control valves.

Taro, variety Lehua Maoli, the commercial lowland variety used in Hawaii, was planted with a 60x45 cm spacing, a recommended plant density for lowland taro (de la Pena, 1978). Except for different rates of water flow, all management practices including fertilization and weeding were uniformly applied. Fertilization and soil amendments consisted of a pre-plant application of hydrated lime (calcium hydroxide) at 500 kg/ha and urea, treble superphosphate and potassium chloride to provide rates equivalent to 100 kg/ha each of N, P_2O_5, and K_2O. A complete fertilizer mix (16-16-16) was applied 2 months after planting at 312.5 kg/ha. Urea was applied at 110 kg/ha 5 months after planting. Irrigation was stopped and the plots allowed to drain before each fertilizer application. Irrigation was resumed 5 to 7 days after application of fertilizers.

The crop was harvested 15 months after planting. Twenty hills were harvested from each plot for yield and yield component estimation.

Experiment 2 - Depth of Flooding

The depth of flooding experiment was performed in concrete tanks approximately 2 m wide, 3 m long and 1 m deep containing Kapaa Soil (Typic Gibbsiorthox). Six depths of flooding were assigned in a randomized complete block design replicated three times. Depths of flooding used ranged from 0 cm to 20 cm. Flooding was continuous except when fertilizers were applied during which time tanks were drained before the fertilizers were broadcast. Flooding was resumed 5 to 7 days after fertilizer applications. Basal fertilizer used was 16-16-16 at 110 kg/ha immediately before the last puddling operation. Three weeks after planting, the plots were inoculated with *Azolla filiculoides*, a floating fern capable of fixing atmospheric nitrogen, at 100 kg/ha fresh weight basis. At 3 and 6 months after planting, 50 kg/ha each of P and K were applied using treble superphosphate and muriate of potash.

Taro, variety Lehua Maoli was planted at 45x45 cm spacing. Water was applied to each tank via individual faucets and depths of flooding were controlled by varying the height of the outlet. The 0 cm depth of flooding received continuous water but it was allowed to drain without causing flooding above the soil surface making the soil completely saturated only. Amount of water going into each tank was approximately 280,000 l/ha/day.

The crop was harvested 14 months after planting. All of the plants were harvested from each tank and used for estimation of yield and yield components.

Results and Discussion

There is no significant effect of rate of water flow on growth and development of lowland taro. However, vegetative yield tended to increase with high water flow rates. Height of plants at harvest were highest at the highest rate of water flow with a difference of approximately 11% over the lowest rate used. Total leaf yield difference between the two rates was 16.9%. The total corm and cormel yields were not significantly affected (Table 1).

Based on water use efficiency or amount of water used calculated to produce 1 kg of taro corms, the value ranges from 800 l/kg to 2,790 l/kg for the lowest and highest water flow rates. Current use of water for lowland taro in some areas are almost unlimited. It is obvious from the results of the experiments that lowland taro can be produced with much less water. With judicious water control, there is great potential for expanded taro production, especially in Hawaii.

The depth of flooding in Kapaa Soil (Typic Gibbsiorthox) has a great effect on growth and consequently yield and maturity of lowland taro. Table 2 shows that shallow flooding or soil saturation enhances early growth and development and hastens maturity of Lehua Maoli. Deep flooding slowed growth and prevented early development of suckers. This resulted in greatly reduced cormel yields (Table 3). The significant yield difference between 0 cm flooding and 20 cm flooding is a result of the detrimental effect of deep flooding on cormel yields which are over 54% of total yields for 0 cm flooding and only 14% for the 20 cm flooding. The slight increase in corm yield of 14.5 t/ha compared to 13.0 t/ha did not compensate for the great difference in cormel yields between 20 cm and 0 cm flooding.

Table 1. Effects of water flow rates on yields of taro grown in Hanalei soil.

Water flow l/ha/day	(gal/A/day)	Corm yield mt/ha	Corm yield t/A	Marketable cormels mt/ha	Marketable cormels t/A	Total mt/ha	Total t/A
280,470	(30,000)	36.5	(16.3)	31.4	(13.9)	67.9	(30.2)
420,700	(45,000)	35.0	(15.6)	30.3	(13.5)	65.3	(29.1)
560,900	(60,000)	29.6	(13.2)	37.0	(16.5)	66.7	(29.7)
701,200	(75,000)	27.2	(12.1)	29.6	(13.2)	56.8	(25.3)
841,400	(90,000)	28.0	(12.5)	32.3	(14.4)	60.3	(26.9)
981,640	(105,000)	37.5	(16.7)	29.2	(13.0)	66.7	(29.7)
Ave.		32.3	(14.4)	31.7	(14.1)	64.0	(28.5)

Location: Hanapepe Valley, Kauai

Age at harvest: 15 months

Table 2. Effects of depth of flooding on vegetative growth of taro.

Water depth cm	(in)	Height (cm) 6 MAP*	14 MAP*	Leaf yields t/ha
0	(0)	56.7	56.5	8.3
4	(1.5)	40.9	70.5	15.6
8	(3.0)	46.2	72.5	16.7
12	(4.75)	45.8	74.1	13.1
16	(6.25)	45.2	76.3	11.2
20	(7.75)	45.7	73.3	7.6

*MAP = months after planting.

Table 3. Yield components of taro grown in a Kapaa Soil at different depths of flooding.

Water depth cm	(in)	Yield components (t/ha) Corms	Cormels*	Total
0	(0)	13.0	15.5	28.5
4	(1.5)	13.2	4.6	17.8
8	(3.0)	17.3	3.5	20.8
12	(4.75)	16.1	1.5	17.6
16	(6.25)	14.4	1.8	16.2
20	(7.75)	14.5	2.4	16.9

*Marketable cormels only.

In another experiment using Hanalei Soil, contrasting results were obtained (de la Peña and Melchor, 1982). Plants grown in Hanalei Soil performed better under flooded and highly reduced conditions. Continuously flooded taro in Hanalei Soil also grew better than plants which had been drained to a point where the soil started to crack. Addition of high rates of fertilizers, especially nitrogenous materials which is a customary practice among lowland taro farmers, proved detrimental. Excessive fertilizer in drained plants drastically reduced corm yields. There is also a strong relationship between over drying and application of high rates of lime and phosphorus with the occurrence of taro hard rot, a disease suspected to be physiological in nature.

The contrasting results obtained from drained and flooded soils of Hanalei and Kapaa Soils is speculated to be due to their contrasting chemical properties. Soil analysis data reveal that Kapaa Soil has extremely high free iron oxide and total iron contents compared to Hanalei Soil. Free iron oxide in Kapaa Soil is 33.9% compared to 8.9% for Hanalei Soil at 0 to 30 cm-depth (Soil Survey Staff, 1972).

In rice production, several researchers have shown that yields were better under soil moisture conditions of less than 100% saturation (Matsushima, 1976; Wang and Hagan, 1981). In a recent report from India, the beneficial effect of flooding was obtained from a Vertisol while soil saturation and soil water content below saturation gave better yields in an Alfisol (Dongale and Chavan, 1982). It is apparent from the present studies on water requirements of taro and rice that both crops' response to varying water regimes depend on the types of soils used.

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