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EFFECTS OF PIGEONPEA HEDGEROWS ON SOIL WATER AND YIELD OF INTERCROPPED PEPPER UNDER DRIP IRRIGATION

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ABSTRACT

An alley cropping experiment was conducted to determine the effects of pigeonpea [*Cajanus cajan* (L.) *Millsp.*] hedgerows on soil water and yield of intercropped pepper (*Capsicum annuum* L.). Results showed that soil water content in hedgerow intercropping was generally higher than the control (no hedgerows) which was attributed to the combined effects of low evapotranspiration, reduced wind speed and green manure mulch. In spite of high soil water content and low evapotranspiration, total water use in hedgerow intercropping was slightly higher than the control. Low pepper plant population due to intercropping and the combined effects of partial shading by hedgerows and competition for soil water resulted in significant ($P<.01$) yield reduction of intercropped peppers ranging from 48 to 58%. These results indicate that alley cropping pigeonpea with vegetable crops has some limitations even with irrigation in the semi-arid tropics. However, its positive effect on microclimate and soil may lead to long term benefits for vegetable crop production in the semi-arid tropics.

Key Words: agroforestry, alley cropping, drip irrigation, intercropping, *Cajanus cajan, Capsicum annuum.*

INTRODUCTION

Hedgerow intercropping, popularly known as alley cropping was developed as an alternative to the traditional bush-fallow farming system in the humid tropics. Basically, it is a form of agroforestry wherein food crops are grown in alleys formed by hedgerows of trees and shrubs. The hedgerows are pruned periodically to reduce competition with crops and prunings are applied as mulch and green manures (Kang et al., 1984).

Hedgerow intercropping has been proven to benefit continuous crop production in the humid tropics by reducing soil erosion and improving soil fertility (Young, 1989). In semiarid tropics where water is a major limiting factor in crop production, the application of hedgerow intercropping has some limitations (Kessler and Breman, 1991). Studies conducted in semi-arid regions indicated that hedgerows of trees and shrubs compete for soil moisture with food crops resulting in considerable yield reduction (Singh et al., 1989; Rao et al., 1990; Ong et al., 1991). However, with proper selection of tree species and cultural management, particularly plant and hedgerow spacing, hedgerow intercropping can be beneficial to crop production in drier regions. For example, micro-climate modifications such as shading and reduced wind speed due to hedgerow may increase the efficiency with which the crop is able to convert water or light into dry matter and economic yield (Kessler and Breman, 1991; Ong et al., 1991). In areas were irrigation water is available, competition for soil moisture may also be reduced if water is applied directly to the root zone of the intercrop through drip irrigation.

The use of tree species with extensive root systems is less desirable for hedgerow intercropping in semi-arid regions. Trees with such characteristics are aggressive and capable of depleting soil moisture otherwise available for crops. Therefore, in drier areas where annual rainfall is less than 1000 mm, the use of tree or shrub species which are drought tolerant, less aggressive and less competitive would be ideal for hedgerow intercropping.

A potential leguminous shrub for alley cropping in drier areas is pigeonpea [*Cajanus cajan* (L.) *Millsp.*]. The plant is a short-lived perennial with deep tap root and a woody stem which can grow over 3 m in height (Nene et al., 1990). The deep tap root allows the plant to survive the long dry season. In the Caribbean, pigeonpea is grown as a full season crop by small-scale farmers or in mechanized large-scale production systems (Ariyanayagam, 1981). In the former system, tall, indeterminate and long duration genotypes are grown at low plant population and usually intercropped with maize (*Zea mays*), whereas in the latter system, early grain types are grown at high plant population (Ariyanayagam, 1975). Pigeonpea is also grown in small backyard gardens usually as boundary plants or in mixed cropping with vegetables.

In spite of its popularity and wide use in the Caribbean, little research has been conducted on pigeonpea intercropping and alley cropping. Intercropping studies in India-have indicated that perennial pigeonpea behaves like medium-duration types in the first year and is less competitive than leucaena (*Leucaena leucocephala*) to annual crops in the system (Troedson et al., 1990). Multiple prunings for fodder harvest or as a green manure crop are possible, and studies on different cutting intervals and pruning heights have been conducted (Salih, 1981; Tayo, 1985; Venkataratnam and Sheldrake, 1985). Pruning experiments in Trinidad showed good survival rates and regrowth of pigeonpea (Mohoyodeen et al., 1989). In many African countries, pigeonpea is alley cropped with maize, sorghum (*Sorghum bicolor*), cowpea (*Vigna unguiculata*) and cassava (*Manihot esculenta*) (Rachie, 1983; Ali, 1990; Kang et al., 1991). In Zambia, perennial pigeonpea produced almost 5.0 $t.ha^{-1}$ of dry matter after 7 months of growth, and farmers are considering pigeonpea a good potential agroforestry component (Boehringer and Caldwell, 1989).

Studies on hedgerow intercropping with pigeonpea and vegetables are few. Alley cropping studies with leucaena and vegetable crops in the humid tropics indicated yield improvement and maintenance without fertilizer application (Chen et al., 1989; Palada et al., 1992). Similar research has not been conducted in the semi-arid tropics where hedgerows might play an important role in efficient use and conservation of soil water for crop production. This investigation was carried out to determine the potential of pigeonpea for alley cropping with vegetable crops and to study the influence of pigeonpea on soil water, evapotranspiration, water use and yield of intercropped pepper under drip irrigation.

MATERIALS AND METHODS

The experiment was established at the Agricultural Experiment Station, University of the Virgin Islands in St. Croix (lat. 17°42'N and long. 64°48'W). The soil is Fredensborg loamy, fine carbonatic, isohyperthermic, shallow, typic Calciustolls (Lugo-Lopez and Rivera, 1980). The average annual rainfall is 1016 mm, but evapotranspiration exceeds rainfall 10 months of the year resulting in a negative water balance.

The experiment used a split plot in randomized block design with four replications. The mainplots were hedgerow and no hedgerow (control). The subplots were three drip irrigation levels corresponding to irrigation regimes of 20, 40, and 60 kPa. Pigeonpea hedgerows were established using 2 month old seedlings transplanted on August 8, 1991. Hedgerows were spaced 4 m apart with a plant spacing of 25 cm within the hedgerow. Three hedgerows were planted forming two 4-m wide alley mainplots. The hedgerows were allowed to grow for four months before intercropping with peppers.

Hedgerows were pruned to 50-cm stubble height using a brush cutter. Pigeonpea hedgerows were pruned on January 15 and May 17, 1992, approximately 5 and 7 months after planting. The prunings were then applied as green manure mulch in the alleys.

Forty five-day old pepper seedlings of the cultivar "Calwonder" were transplanted on January 24, 1992, at a row spacing of 100 cm and a plant spacing of 61 cm. This spacing resulted in plant population equivalent to 12,500/ha for alley crop and 18,750/ha for monoculture. The area occupied by pigeonpea hedgerows reduced pepper plant population by 33 percent. Peppers were fertilized with 200N-100P-50K $kg.ha^{-1}$. Nitrogen was applied in two splits, 1/3 at 17 days after transplanting and 2/3 at 52 days after the first application. All of the phosphorus and potassium was applied together with the first nitrogen application.

Drip irrigation was applied at various regimes corresponding to soil water tensions of 20, 40 and 60 kPa. The mainlines and submains consisted of 15-mm polyethelene tubes. The laterals were made of

15-mm bi-wall drip strip tube (Hardie Irrigation, California) with laser drilled orifices of 61 cm apart.One week after transplanting, tensiometers (Irrometer Co. Riverside, CA) were installed in two replications per treatment. Tensiometers were placed 10 cm from the plant and at a depth of 15 cm- Tensiometers were checked and read daily and irrigation water was applied to subplots when soil moisture tension reading exceeded the prescribed tensions of 20, 40 and 60 kPa. Water use by treatments was measured weekly through water meter readings.

Soil samples from 0-15 cm depth were taken each week except when soil was too wet after a heavy rainfall. From these samples, soil water content was determined by gravimetric (oven-drying) method. Separate samples were taken from pepper rows adjacent to hedgerows and from the middle rows of peppers. Evapotranspiration (ET) by pepper plants was estimated using the pan evaporation method integrated with crop coefficient values (Doorenbos and Pruitt, 1977). Crop coefficient values for pepper at different stages of growth were obtained from Doorenbos and Kassam (1979) as cited by Stanley and Maynard (1990). Crop coefficient was adjusted using a formula based on the fraction of the ground covered by the plants as reported by Hoare et al (1974). Ground cover was determined from weekly measurements of plant canopy width and ET was estimated weekly from February 27 to April 10, 1992. To obtain a rough estimate of wind velocity in hedgerow and control plots, wind speed was measured using a hand-held wind speed indicator (Wind Wizard, Davis Inst., Hayward, CA). The indicator was held 50 and 100 cm above ground level and measurements were made only during days when there were strong gusty winds.

For each harvest, pepper yield samples were taken from four middle rows in the hedgerow plot and five middle rows in the control plots. The sample size (9 m^2) in the hedgerow plot included an area occupied by the middle pigeonpea hedgerow. Total and marketable pepper yields were determined from ten harvests over a period of eight weeks. Fruits were graded according to marketable and non-marketable size.

Pigeonpea biomass production was determined from dry weights of two prunings. Biomass included woody stem and leaves. Statistical significance of treatment effects was determined using the analysis of variance (ANOVA) of data collected and differences among treatment means were compared using the least significant difference (LSD). Statistical analysis of data was performed using the MSTAT-C Microcomputer Program (Michigan State University, East Lansing).

RESULTS AND DISCUSSION

Pigeonpea Biomass Yield

Pigeonpea hedgerows reached a height of 1.95 m at the first pruning. Total dry matter produced from first pruning was 2.06 $t.ha^{-1}$. The second pruning produced 1.71 $t.ha^{-1}$ dry matter giving a total of 3.77 $t.ha^{-1}$ for the two prunings. This value is one ton less than that reported by Boehringer and Caldwell (1989) in Zambia. Varietal characteristics and frequency of pruning may account for the difference in dry matter production. Fresh biomass produced from the two prun ings provided a thin layer of mulch for the alley plots.

Effect of Hedgerows on Plant Growth

Pigeonpea hedgerows suppressed growth of peppers resulting in shorter and smaller plants relative to the control (Fig. 1). The effect was pronounced in plant rows adjacent to pigeonpea hedgerows due to partial shading. Plants in the middle row were less affected and grew almost as high as the controls. During the early stage of growth, plants adjacent to the hedgerows were shaded in early morning and late afternoon resulting in slower growth rate.

The plants slowly recovered during the latter stage. Irrigation regime did not affect plant height. The data would suggest that hedgerow pruning height lower than 50 cm and more frequent harvest may be needed to minimize the competitive effect of pigeonpea and provide optimum growth for pepper.

Soil Water Content

Soil water content in hedgerow plots was generally higher than the control (Fig. 2). It was observed that soil water content (data not shown) between pepper row and hedgerow and between pepper rows in the control (no hedgerows) was lower than in the middle rows where drip irrigation was applied. Comparing soil water content in samples taken between pepper row and hedgerow with those taken between pepper rows in control plot, it was found that soil water in hedgerow intercropping was higher than the control. This could be explained by the effect of mulch and shading. Irrigation water regime had no effect on soil water content. Mulch from prunings may have reduced soil water loss in the alleys resulting in higher values for hedgerow plots. This result is consistent with the findings of Lal (1989) who reported a higher soil moisture content in the top 0-15 cm layer in agroforestry system than in the control. Furthermore, hedgerows essentially serve as windbreaks which prevent rapid soil moisture evaporation. In this experiment wind speed (data not shown) in hedgerow plots was lower than the control.

Evapotranspiration

Hedgerow intercropping significantly reduced evapotranspiration (ET) of pepper plants (Fig. 3). There were no significant differences in ET among irrigation regimes. Since ET is directly associated with the size of plant canopy, the high ET of plants in the control can be explained by larger plant canopy and taller plants as compared to plants in the hedgerow. This resulted in higher leaf area with greater evaporative potential. Low ET in the hedgerow plots may be considered an indirect effect of hedgerow. By reducing plant growth and canopy size due to competition, hedgerow intercropping indirectly decreased the rate of ET. Low ET in hedgerow intercropping may also be the effect of lower wind speed and turbulence as previously mentioned. Thus, the combined effects of reduced wind speed and low ET may have led to higher soil water retention in hedgerow intercropping.

The result presented here supports the report of Houerou (1980) as cited by Kessler and Breman (1992) where potential ET under a tree canopy is considerably reduced as compared to the unprotected open field. The hedgerows provide shelter for the associated crops, thereby reducing wind speed and sunshine intensity. Connor (1983) also reported that windbreaks increase soil moisture availability due to lower evapotranspiration and improved infiltration.

Water Use

As expected, irrigation water use varied with irrigation regime (Table 1). Water use was almost similar between hedgerow and control plots from February to April, except for the 60 kPa treatment. Water use by plants during May was the highest for the 20 and and 40 kPa treatments. During this period plants were at their active reproductive stage and therefore, had a higher demand for water. Total water use for the 4-month period was highest with treatment under 20 kPa in both hedgerow and control plots. Total water use by hedgerow plots for the 40 and 60 kPa treatments were slightly higher than the control. Low ET in hedgerow intercropping should have reduced water use. It was possible that maintenance of high soil water content would require increased water use in hedgerow intercropping. Also, the roots of pigeonpea may have utilized some of the water applied through the drip system, although water was directly applied to peppers. The low soil water content in rows adjacent to the hedgerows may explain for this difference.

The above results seem to be consistent to the reports by Ong et al (1990) who studied water use by trees and crops in an agroforestry system in semi-arid region of India.. In a hedgerow experiment involving pigeonpea and groundnut, they reported that total water use as measured by transpiration in the intercropping system was higher than that in pure stands of either crop. They postulated that hedgerow intercropping uses more water than monoculture which should result in higher biomass production although not necessarily in higher crop yields.

Total and Marketable Yield of Pepper

Hedgerow intercropping significantly reduced pepper yield. As shown in Table 2, total and marketable yields of pepper in hedgerows were lower than the control. Pepper yield in hedgerow intercropping was only 47 % of the control. Irrigation water regime did not influence pepper yield, but the lowest yields were obtained from treatment with the lowest rate of irrigation (60 kPa). The low yield in hedgerow intercropping can be attributed to the combined effects of two major factors: lower plant population density and crop/hedgerow competition. As mentioned earlier, under similar row spacing hedgerows replaced 25 % of the plot area which reduced pepper plant population by 33 %. Partial shading of plants in adjacent rows and competition for soil water depressed plant growth by reducing photosynthesis. Yields of pepper rows adjacent to hedgerows (data not shown) was only 43 % of yield of the middle row and 34 % of the control.

Reduced crop yields in hedgerow intercropping in the semi-arid tropics have been reported by several researchers. Rao et al (1990) reported 50 to 80 % reduction in sorghum yield when alley cropped with leucaena. They attributed the yield decline to severe competition for soil moisture between hedgerows and intercrops. In hedgerow intercropping involving pigeonpea and groundnut, Ong et al (1991) reported that groundnut yields were 90 % lower than in pure stands in the second year. Yield reduction was mainly due to narrow alley width (1.2 m) and low plant population. They suggested that competition for water in agroforestry systems can be reduced by modifying the spatial arrangement of trees.

Yield reduction in the experiment reported here is not primarily due to competition for soil water since irrigation water was directly applied to pepper plants and was not a major limiting factor. Reduced yield is mainly due to shading by pigeonpea resulting in suppressed growth.

CONCLUSIONS

This study has shown some positive effects of pigeonpea hedgerows on soil water and evapotranspiration, but these effects were not reflected in increased yield of intercropped peppers under drip irrigation. Hedgerow intercropping conserved soil water through the effects of green manure mulch applied on surface soil, reduced wind speed and low evapotranspiration. These beneficial effects, however, were outweighed by the negative effect of hedgerows on yield. The reducing effect on yield was mainly attributed to the low plant population inherent to intercropping and partial shading in hedgerow intercropping.

The results of this experiment suggest that under drip irrigation, competition for soil water is minimized in hedgerow intercropping. Although total water use in hedgerow intercropping was slightly higher than sole cropping, water loss through evapotranspiration was reduced suggesting that in the long term, high soil water retention in hedgerow intercropping may eventually decrease water requirement and benefit the associated crops. The results also show that pigeonpea produced a fair amount of biomass and survived after two prunings. This indicates that it has potential as a leguminous shrub for alley cropping in a dry climate of the Virgin Islands. However, to take advantage of its potential, modification in alley arrangement, such as increasing alley width and plant population will reduce crop competition and increase benefits from this system. Additional research is needed to study the interface between crops and hedgerows in a modified system.

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Table 1. Total monthly irrigation water use (liters/plant) of peppers in hedgerow intercropping and monoculture plots, 1992.

Treatment	Irrigation regime (kPa)		Feb	Mar	Apr	May	Total
Hedgerow	20		5.99	6.31	5.99	16.72	35.01
	40		5.36	6.31	5.99	11.36	29.02
	60		5.04	5.36	1.89	4.42	16.71
		Mean	5.46	5.99	4.62	10.83	30.25
No Hedgerow	20		7.57	5.47	6.73	17.03	36.80
	40		5.46	4.84	5.26	10.09	26.46
	60		4.84	3.79	1.26	4.00	13.89
		Mean	5.96	4.70	4.42	10.37	25.71

Table 2. Total and marketable yield ($t.ha^{-1}$) of peppers in hedgerow intercropping and monoculture, 1992.

Treatment	Irrigation regime (kPa)		Total yield	Marketable yield	Water Use efficiency*
Hedgerow	20		12.2	10.0	27.9
	40		12.4	10.2	34.2
	60		9.7	7.9	46.4
		Mean	11.4	9.4	36.2
No Hedgerow	20		25.7	22.5	37.2
	40		23.5	19.8	47.4
	60		23.5	18.7	90.2
		Mean	24.2	20.3	58.3

*Kilograms fruits per cu.m. irrigation water applied based on total yield.
LSD ($P=0.05$) for comparing means (total yield) = 4.29
LSD ($P=0.05$) for comparing means (marketable yield) = 4.76

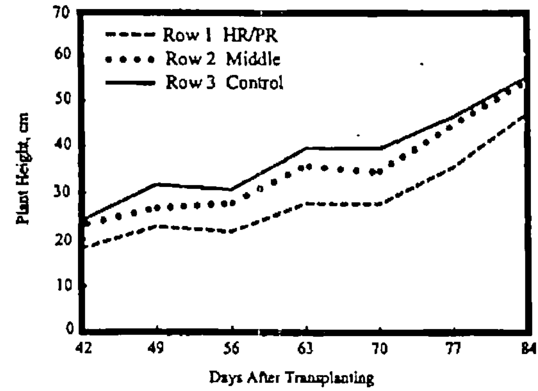

Fig. 1. Height of pepper plants as affected by hedgerow intercropping.
Row 1 = adjacent to hedgerow; Row 2 = middle row;
Row 3 = control (no hedgerow).

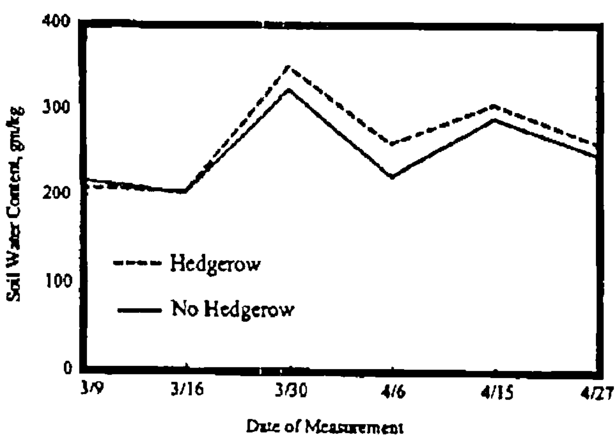

Fig. 2. Soil water content as affected by hedgerow intercropping.

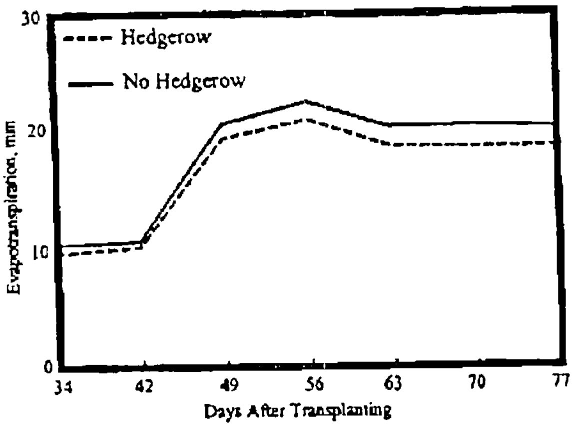

Fig. 3. Estimated evapotranspiration of pepper plants in hedgerow intercropping and monoculture plots.