A STUDY OF THE PLANTING OF *ZOYSIA TENUIFOLIA* FOR UNIRRIGATED ORCHARD COVER

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ABSTRACT

A series of trials combining biological and mechanical approaches showed that a specially managed ground cover of the slow growing grass Zoysia tenuifolia has a potential for enabling substantial savings of labour for weeding while giving excellent erosion protection in tropical orchards on lands where the use of machines or herbicides would be unsafe or impractical. Spot planting of the Zoysia using ZT cells (plants grown in small containers) or plugs of mature sod was recommended.

The Zoysia planting method was tested at a site in Jamaica having 1900 mm average annual rainfall, but no irrigation. The planting method was found to be nearly 100% reliable. Early growth of the Zoysia was only slightly influenced by the time of planting in the cases of sod plugs and two- and three-month old ZT cells, but four-month cells were unaffected. The exact nature of the seasonal influences was not clear.

Three months appeared to be the desirable minimum age for the planting out of ZT cells prepared as in this study. In situations similar to those of the study, such ZT cells or suitable sod plugs may be planted out at any time convenient to a farmer.

1.0 INTRODUCTION

Population pressure in several West Indian islands and other tropical countries has forced the cultivation of steep, watershed lands, resulting in serious soil erosion often having severe and costly consequences with respect to water and other resources. Tree crop cultivation with a permanent, protective ground cover is one approach to the conservative cultivation of watershed areas. The land formation, tree stand, and cover crop constitute a system that the farmer, often a peasant small holder, must economically and safely manage with the limits of his or her real constraints. A satisfactory approach for lands sloping more than 20° has been wanting. Several years of trials (by the first-named author), examining and combining biological and mechanical factors, showed that a managed ground cover of *Zoysia tenuifolia* Willd. ex Trin. (Korean Velvet Grass, Mascarenegrass) offers the advantages of a substantial saving in labour as well as excellent soil erosion protection in situations where manual methods of weed control are likely to be considered.

Z. tenuifolia is notorious for being difficult to establish; and although much prized for lawns and slope protection in landscaping, no mention of its use as an orchard cover crop was found in the literature.

In a series of experiments reported in a dissertation by Hall [1], certain aspects of the development and management of a *Z. tenuifolia* orchard cover were tested. This paper reports the test of the reliability of planting *Z. tenuifolia* for cover in unirrigated hillside orchards.

2.0 BACKGROUND

Weed control is fundamental to the economy of tree crop cultivation. Weed control on lands sloping 20° or more (i.e., nearly 60% of the area of Jamaica [2], for instance) faces problems of:

(a) risk in the use of wheeled machines;
(b) high cost of handheld machines;
(c) risk of soil erosion with the use of herbicides;

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(d) high cost of terracing, and
(e) high cost of labour.

By trials extending over some 14 years, Hall sought to identify a "living mulch" solution to the said problems applicable on his test sites in Jamaica. Several plant species were tried, but grasses grew too tall, and broad-leaved creepers and vines lacked the necessary permanence. Slow-growing *Z. tenuifolia* was selected as the best compromise; and a system for its establishment and management by hand tools was worked out. With the Zoysia cover system, soil protection was good to excellent; and as the Zoysia turf developed, the labour required for good management declined to about one-half that required for other covers in common use. This system was dubbed the "Zoysia Cover Mulch Circle" or "ZCMC" system. These trials are described[(a)] in Hall [1].

The ZCMC system was devised to be a system of orchard management and not a system of lawn-making. Spot planting is employed; and with practical planting densities and the observed average advance rate of the turf-growing tips of about 750 mm per year, one to two years will normally be required for developing a full Zoysia cover. (*Cynodon dactylon*(L.) Pers. (Bermudagrasss) was observed to advance more than 10 m in a year under similar conditions).

The ZCMC system was contrived to be easily usable by West Indian small farmers. *Z. tenuifolia* is now in widespread use for lawns in the region; and after the planting of the Zoysia, the system may be managed entirely by machetes in common use and likely to be in the possession of the farmers. However, *Z. tenuifolia* is regarded as difficult to establish in lawns, therefore the feasibility of planting it in unirrigated orchards had to be conclusively demonstrated.

Planting in the ZCMC system may be done by means of plugs of mature sod or plants grown in small containers, dubbed "ZT cells". ZT cells would be grown in a nursery from sprigs when turf for supplying plugs is unavailable.

3.0 OBJECTIVE

The objective of this study was to determine the influence of planting time and ZT cell age on survival of planted *Z. tenuifolia* in unirrigated orchard environments.

4.0 LOCATION

The experimental site was in the St. Johns Red Hills district of St. Catherine parish on the south side of the island of Jamaica, at approximate latitude 18°02'N and longitude 77°02'W. Average elevation was 140 m above sea level; and the surface soil a non-saline, stony bauxite ("Tropeptic Euthorthox; clayey, gibbsitic, isohyperthermic" [2]) with limestone outcrops. Average annual rainfall was approximately 1900 mm, usually with bimodal peaks in May and October, and drought periods from June to July and December to March.

5.0 EXPERIMENTAL DESIGN

Plantings were made on the same day of each of the 12 months of a year, and assessment of survival and vigour was done three months later. Soil moisture at planting and rainfall throughout the period were measured.

Treatments to be compared were:

(a) three ages of ZT cells for planting (two, three and four months) and sod plugs as control, making four levels of the factor, planting material.

(b) two planting environments, viz. "sun" (representing a new orchard) and "shade" (representing a mature orchard).

Thus, there were eight treatment combinations per month per replication, the requisite minimum for a day's planting. Six plants per treatment per replication were employed.

Planted plots remained undisturbed for three months; then were cleared of weeds and evaluated. The three-month period was selected because:

(a) experience had shown such a period to be necessasry for confirming any well planted *Z. tenuifolia* as dead; and

(b) three months after planting is deemed a reasonable time for the first weeding in developing a *Z. tenuifolia* cover.

Response values were assigned as 1.0 for a vigorously growing plant, 0.5 for a lingering plant, and 0.0 for a dead plant. There was no interpolation. Conventional practice in biological survival experiments would suggest that all plants still living at the time of evaluation be assigned a value of 1.0 as they had the potential to grow and spread. However, experience with the ZCMC system had shown that relatively small, lingering Zoysia plants may be overlooked in weeding operations and be lost, therefore lingering plants had to be considered only "half good". At the end, there were so few deaths of plants in the experiment that the real result was to show the distribution of vigorous and lingering starts; actually an unexpected result.

Two replications of planting were the minimum for statistical validity. Experiment sensitivity was tested by variance theory with the conservative assumption of the three possible outcomes being equally probable. Two replications of six plants per treatment plot were found to offer acceptable sensitivity.

With two replications in 12 months of planting, if each of the eight treatment combinations was assigned a separate plot, there would have been 192 plots. Logical arrangement into four blocks of 48 plots would still have strained the available resources. A split plot arrangement with 48 plots in four blocks of 12 each denominated by month of planting was therefore chosen. Each plot was divided into four sub-plots for the four levels of planting material. As the chosen field sites had ground slopes of less than 5°, simple randomisation of the plot layout within each block was permissible. The sub-plot layout within each plot was also randomised. The result was a randomised complete block design with a split plot configuration.

6.0 ZT CELLS

ZT cells were grown in soil from the site area. Commercial 75 x 150 mm perforated black polyethylene planting bags were used as the containers. Zoysia material used for starting the cells was pieces (sprigs) of young stolon/rhizomes taken from beneath the edges of mulch circles to trees already under the ZCMC system. Sprigs were selectively cut with secateurs each two clear nodes long and bearing at least one root not less than 3 mm long, and one shoot not less than 10 mm long. Roots longer than about 25 mm and shoots longer than about 40 mm were trimmed. Prepared sprigs were carefully set one to a bag, with the roots and shoots upright, and the stems horizontal; then the bags were maintained in a nursery having direct sunlight for more than a half of each day.

ZT cells in the nursery were watered three times per week, a good rain being deemed equal to a watering. Once per month, each cell was given approximately 0.08 g of a proprietary 20:20:20 soluble fertiliser, the first dose being given at the first watering after the setting of the sprigs. Insect infestations were controlled by spraying with proprietary organophosphates.

Because of the previously observed wide variation in growth rates of young *Z. tenuifolia* plants, the nursery was arranged to start a 50% excess of cells for each age for each month of planting (36 started vs. 24 required), in order to allow the selection of those showing more vigorous growth as would be done in a commercial operation. On the afternoon before each planting session, the cells were selected, trimmed of projecting stolon/rhizomes and roots, watered, then packed for transportation. Rejects were discarded.

The ZT cell ages at planting must be interpreted strictly in conjunction with the forementioned method of production. In other words, ages here indicate states of development. With other methods of production, such states may occur at other ages. Three representative cells of each age were trimmed as for planting, washed, oven-dried and weighed. The mean dry weights and root/remainder (R/R) weight ratios were found to be:

AGE (MONTHS)	WEIGHT (g)	R/R RATIO
2	0.786	0.227
3	3.166	0.236
4	5.769	0.153

7.0 SOD PLUGS

Turgeon [3] describes turfgrass plugs as being square or circular with dimensions ranging from 12 to 200 mm; the most common dimensions being approximately 50 mm across and 50 mm deep. Turgeon also explains that plugs may be cut mechanically or by hand, using cup cutters or other devices. Cup cutters were not available in Jamaica and are not likely to be used by small farmers in the tropics. A simple and effective device for cutting the required quantitites of plugs was a sharpened, square-nosed spade. Cubes of 50 mm sides were desired; but the dimensions of the spade cut plugs varied from 37 mm to 100 mm. The dimension most difficult to control was the depth, and this tended more often to the higher value. An effort was made to ensure a similar size distribution in each set of plugs planted each day.

Near to the locations chosen for the experimental plots, there existed a patch of *Z. tenuifolia* turf established some four years previously. This turf was conditioned by cutting out weeds and cutting back "tall" growths approximately one week before each scheduled planting. Plugs were cut immediately before planting.

8.0 PLANTING AND EVALUATION

Planting plots were first cleared by the slash-and-burn method, and the dividing lines laid out. In the "shade" area, trees were sidestepped where necessary. Immediately before planting each plot, it was cleaned of all weeds, stumps and debris. The planting spots were marked; a pickaxe was used to loosen the soil at each spot, then the planting holes were completed with a garden trowel.

ZT cells and sod plugs were set into the holes with the tops of the soil balls about 25 mm below the ground surface in dry ground, or 10 mm in wet ground. The planting bags were slipped off the ZT cell immediately before placing them into their holes; however, in this, the two-month cells proved fragile because of their small amount of roots. Holes were backfilled and loose soil was infiltrated among the Zoysia shoots roughly to the ground surface level, leaving the shoot tips exposed. The planting was firmed by pressing with the feet.

Finally, soil samples for moisture determination (gravimetric) were taken from three corners of each planted plot; the sampling depths being 0-4 and 15 cm. Planted plots were left undisturbed until evaluation three months later. Rainfall was measured throughout the experiment.

Finished plots were cleared of weeds by careful uprooting in order to avoid damaging or obscuring the Zoysia plants. Weed measurements were made at the last three evaluations, i.e., six measurements each in the "shade" and "sun" areas. The weed count averages were 242 (c.v. 36%) and 150 (c.v. 34%) per m^2 in the shade and sun respectively.

As stated earlier, response values were assigned as 1.0 for a vigorously growing plant, 0.5 for a lingering plant and 0.0 for a dead plant. Some difficulty was met in deciding the upper limit of the 0.5 value. This was resolved by assigning the 0.5 value to all live plants doing less than half as well as the obviously thriving plants in the group of plots being evaluated. This comparative approach, as well as the irregular spreading of the Zoysia plants was considered more appropriate than trying to determine a set of maximum plant dimensions for the 0.5 value as the seasonal factors influencing Zoysia plant size would similarly influence weed plant size, making the spotting of lingering plants in the crucial first weeding in commercial operations to be mainly a matter of comparative size.

9.0 RESULTS

The mean outcomes of the study are shown in **Table 1**. Differences in planting material performances from month to month are small, with all materials doing well (actually, much better than was expected), especially the three- and four-month old ZT cells. This small variation in outcomes produced a high degree of statistical sensitivity in the experiment. There were only two deaths in the 1,140 items actually planted, both deaths being of two-month cells in the shade area. The two-month cells had a 99.3% absolute survival and the other materials 100%. The differences in outcomes are therefore indicative only of the vigour of early growth of the planted Zoysia, with actual survival being practically certain with planting by the methods used.

Overall mean outcomes for the shade and sun areas differed at the 2% level, that for the sun area being the higher (5.625 vs. 5.396; s.e.d. 0.0313). Outcomes for planting materials differed at less than 0.1%, the outcomes for materials in the separate areas differing at the 0.8% level. For the months of planting, outcomes differed at the 2.4% level, the month effect being similar in the separate areas ($p = 33.5\%$). Differences in outcomes for the various planting materials for the separate months of planting were not significant at the 5% level (actual $p = 14.6\%$).

MONTH OF PLANTING	MEAN OUTCOME FOR PLANTING MATERIAL				
	2-MONTH	3-MONTH	4-MONTH	PLUGS	ALL
(a) Sun					
March 1992	6.000	6.000	6.000	3.500	5.375
April	5.500	6.000	6.000	4.500	5.500
May	6.000	6.000	6.000	4.500	5.625
June	5.750	6.000	6.000	4.500	5.562
July	5.750	6.000	6.000	4.500	5.562
August	6.000	6.000	6.000	5.500	5.875
September	6.000	6.000	6.000	5.250	5.812
October	5.500	5.750	6.000	5.000	5.562
November	5.750	6.000	6.000	5.000	5.688
December	5.750	6.000	6.000	5.000	5.688
January 1993	5.250	6.000	6.000	4.500	5.438
February	5.750	6.000	6.000	5.500	5.812
Year	5.750	5.979	6.000	4.771	5.625
(b) Shade					
March 1992	5.500	5.250	5.750	5.000	5.375
April	4.500	5.250	5.750	4.250	4.938
May	4.750	6.000	6.000	4.250	5.250
June	5.250	6.000	6.000	4.500	5.438
July	5.000	5.250	6.000	4.750	5.250
August	5.250	6.000	6.000	4.750	5.500
September	6.000	6.000	6.000	4.750	5.688
October	4.750	5.750	6.000	5.500	5.500
November	4.750	5.500	6.000	5.000	5.312
December	4.750	6.000	6.000	4.250	5.250
January 1993	5.750	6.000	6.000	4.750	5.625
February	5.500	5.750	6.000	5.250	5.625
Year	5.146	5.729	5.958	4.750	5.396
(c) Combined					
March 1992	5.750	5.625	5.875	4.250	5.375
April	5.000	5.625	5.875	4.375	5.219
May	5.375	6.000	6.000	4.375	5.438
June	5.500	6.000	6.000	4.500	5.500
July	5.375	5.625	6.000	4.625	5.406
August	5.625	6.000	6.000	5.125	5.688
September	6.000	6.000	6.000	5.000	5.750
October	5.125	5.750	6.000	5.250	5.531
November	5.250	5.750	6.000	5.000	5.500
December	5.250	6.000	6.000	4.625	5.469
January 1993	5.500	6.000	6.000	4.625	5.531
February	5.625	5.875	6.000	5.375	5.719
Year	5.448		5.979	4.760	5.510

Standard errors of differences of means for the factors:

AREA	MATERIAL	MONTH	AREA/ MATERIAL	AREA/ MONTH	MATERIAL/ MONTH
0.0313	0.0611	0.1484	0.0812	0.2033	0.2906

Table 1: **Mean Outcomes**

A statistical difference of 5.625 - 5.396 = 0.229 in the overall mean outcomes for the separate areas is of no practical consequence to farmers. What are the consequential differences? This question may be answered by comparing the maximum and minimum monthly outcomes of **Table 1** irrespective of area. These are shown in **Table 2.** For the plugs and two-month cells, it may be worthwhile to avoid the conditions producing the minimum outcomes. For the two-month cells, this condition was planting in the shade area near the end of the long dry season. For the plugs, the condition was planting in the sun area at the peak of the long dry season. However, planting time of three- and four-month cells was of little or no consequence.

10.0 CORRELATIONS AND REGRESSIONS

Causes of the monthly differences in outcomes were investigated by linear correlations with the collected data on rainfall and soil moisture at planting. Rainfall was considered in two ways: the depth in the first month after planting, and the total depth from planting to evaluation. The results are summarised in **Table 3.** Soil moisture correlations with the combined area outcomes could not be made as the two areas could not be made as the two areas consistently manifested different soil moisture levels.

For rainfall, the correlation coefficients were generally higher for the combined outcomes than for those of the separate areas. Coefficients for the first month rainfall were erratic and low, ranging from -0.482 to +0.459, these for three-month cells in sun and shade respectively. Coefficients for the total rainfall were less scattered; but coefficients greater than 0.5 were shown for plugs only, +0.568 in the sun and +0.619 combined (for combined two-month cells, r was +0.489.

	OUTCOME FOR PLANTING MATERIAL			
	2-MONTH	3-MONTH	4-MONTH	PLUGS
Maximum	6.00	6.00	6.00	5.50
Minimum	4.50	5.25	5.75	3.50
Range	1.50	0.75	0.25	2.00

Table 2: **Maxima, Minima and Ranges of Mean Outcomes**

PARAMETER TESTED	AREA	r FOR PLANTING MATERIAL			
		2-MONTH	3-MONTH	4-MONTH	PLUGS
1st month rainfall	Sun	+0.178	-0.482	0.000	+0.138
	Shade	+0.228	+0.459	+0.366	+0.257
	Combined	+0.267	+0.357	+0.411	+0.240
Total rainfall	Sun	+0.246	+0.055	0.000	+0.568
	Shade	+0.458	+0.201	+0.387	+0.361
	Combined	+0.489	+0.212	+0.423	+0.619
0-4cm soil moisture	Sun	-0.025	-0.028	0.000	+0.477
	Shade	+0.299	+0.110	+0.180	+0.416
15cm soil moisture	Sun	-0.239	-0.144	0.000	+0.472
	Shade	+0.042	+0.105	+0.007	+0.291

Table 3: **Summary of Linear Correlation Coefficients, r**

For soil moisture at planting, only the outcomes for plugs showed a measure of meaningful correlation. At the 0-4cm depth, r for plugs was +0.477 in the sun area and +0.416 in the shade area; and for the various cells, r varied from -0.028 to +0.299. At the 15cm depth, r for plugs was +0.472 in the sun, but only +0.291 in the shade; and for the various cells, r varied from -0.239 to +0.105.

A multiple regression analysis of the outcomes vs. the total rainfall and the soil moisture percentages was carried out using the GENSTAT 5 computer programme [4]. As the linear correlations indicated that the rainfall had the stronger influence, the analysis was arranged to compute the influence of rain last. The results are summarised in **Table 4**. The year's mean outcomes for the planting materials and areas are included in **Table 4** for comparison.

Table 4 shows that:

(a) Two cases stand out, these being four-month cells and plugs in the sun area. For the four-

MATERIAL	AREA	CONSTANT/ STD. ERR./ t PROB.	COEFF./STD. ERR./t PROB. FOR: SOIL MOISTURE % @ 0-4cm	SOIL MOISTURE % @ 15cm	TOTAL RAIN	YEAR'S MEAN OUTCOME
2-month	Sun	7.407 0.833 <0.001	0.0536 0.0244 0.041	-0.1101 0.0466 0.023	0.00141 0.00408 0.734	5.750
	Shade	5.34 1.09 0.001	0.1074 0.0403 0.015	-0.1310 0.0628 0.051	0.00940 0.00611 0.141	5.146
3-month	Sun	6.282 0.267 0.001	0.00869 0.00782 0.281	-0.0182 0.0143 0.217	-0.00014 0.00131 0.918	5.979
	Shade	4.96 1.08 0.001	0.0009 0.0397 0.982	0.0160 0.0619 0.799	0.00480 0.00602 0.436	5.729
4-month	Sun	6.0000 0.0000 *	0.0 * *	0.0 * *	0.0 * *	6.000
	Shade	5.988 0.305 0.001	0.0171 0.0112 0.145	-0.0214 0.0175 0.236	0.00174 0.00171 0.319	5.958
Plugs	Sun	1.06 1.36 0.444	0.0028 0.0397 0.945	0.0871 0.0726 0.245	0.02000 0.00664 0.007	4.771
	Shade	3.52 1.22 0.009	0.0653 0.0449 0.162	-0.0345 0.0699 0.628	0.00747 0.00681 0.286	4.750

[Asterisks (*) as output by programme. Values not calculated.]

Table 4: **Summary of GENSTAT 5 Multiple Regression Equations compared with the Year's Mean Outcomes**

month cells, the outcomes were constant at the possible maximum of 6.0. For the plugs, the regression constant is relatively small and not significant, while rain is the significant regressor ($p = 0.007$).

(b) For all other cases: the regression constants are large, have large standard errors, and are highly significant, suggesting that they incorporate important variables not measured in the experiment; rain is not significant; and where soil moisture at planting is shown as significant, there is a regressor sign conflict between the depths of measurement with the larger regressor being negative.

(c) Rainfall after planting had an important influence on the early growth of plugs in the sun; and four-month cells are rather insensitive to the weather variations experienced in the experiment; but the monthly differences in outcomes in the other cases were determined more by factors not measured in the experiment.

(Later experience suggests that atmospheric humidity may be an important influence on the rate of growth of small *Z. tenuifolia* plants).

11.0 CONCLUSIONS

The following conclusions were drawn from this study:

(a) Adequately developed ZT cells and freshly cut plugs of mature *Z. tenuifolia* sod (cubes of at least 37 mm sides or equivalent) are unlikely to die of water deficiency if well planted in a soil and climate similar to those of this study regardless of the season of planting. Such ZT cells and sod plugs are suitable means for establishing Zoysia cover in tropical hillside orchards.

(b) For ZT cells produced in the manner employed in this study, the ability to survive was well developed at the age of two months. However, such two-month-old ZT cells lacked satisfactory resistance to handling. Satisfactory resistance to handling was present at the age of three months. ZT cells of 3 months age or more showed little or no sensitivity to the weather conditions at planting or to the variations experienced in the amount of rainfall in the three months following planting.

(c) Sod plugs showed some sensitivty to the weather conditions at and following planting, especially in the "sun" area simulating a new orchard. This sensitivity was manifested only in lesser amounts of growth in the three months following planting. Where suitable sod is available for supplying plugs, the ease of their use may outweigh any slower starting of growth after planting.

12.0 RECOMMENDATIONS

The following recommendations may be made on the basis of the experimental results:-

1. Planting materials for establishing a *Z tenuifolia* cover in an unirrigated orchard should be at least the equivalent of freshly cut cubes of mature sod of 37 mm side or 3-month-old ZT cells produced in the manner employed in this study.

2. In climates similar to that of the experimental site, farmers wishing to establish a *Z. tenuifolia* orchard cover may do the planting at any convenient time if the recommended materials are used.

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Note: (a) Improvements in the ZCMC technique have since been developed. These will be the subject of a future publication. (ABH). ■