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Yield parameters of cassava *(Manihot esculenta)* as affected by method of addition of organic matter in two consecutive minor seasons of Sri Lanka

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ABSTRACT

A study was carried out at the experimental farm, University of Peradeniya, Sri Lanka, to evaluate the influence of 2 organic materials [rice *(Oryza sativa* L.) straw and *Gliricidia* leaves, applied as a surface mulch or incorporated at planting on soil moisture, growth and yields of cassava [*Manihot esculenta* (L.) Crantz] planted in 2 dry seasons (2002 and 2003) and the rainfall-utilization efficiency by this crop. Application of straw or *Gliricidia* leaves as a mulch increased the soil-moisture contents and enhanced vegetative growth, yield components, yields, harvest indices of cassava and rainfall-use efficiency in both seasons compared to incorporation of organic matter. The mean yield increment owing to the straw mulch were 46% and 54% in the 2 seasons and 25% due to *Gliricidia* in both seasons respectively. Incorporation of straw and *Gliricidia* reduced yields by 14-16% and 8%, respectively, compared with surface application. The benefit of rice straw was greater owing to its ability to maintain greater soil-moisture content in the minor dry season.

Key words : Cassava, Minor (dry) seasons, Rainfall utilization, Growth, Yields

The yield potential of cassava cultivars planted in the developing countries is not generally achieved due to environmental factors. Amongst these, soil moisture could be identified as one of the primary limiting causes affecting production (Conner *et al.,* 1981). Sangakkara (1994) reported the importance of the time of planting in enhancing yields of cassava and attributed the differences observed to rainfall variations over the growing season. Conservation of available moisture could be a profitable venture especially in dry seasons. This would enable the procurement of high returns, due to the low levels of management required for this crop, as the yield of cassava is susceptible to moisture stress at early stages of growth.

Farmers often cultivate cassava at different times, exposing the crop to moisture stress. However, information is lacking on the influence organic matter and its impact on the growth and yields of cassava. Hence a study was conducted to determine the effects of application of organic materials as surface mulch or incorporated into soil on soil-moisture status and on the growth and yield of cassava.

MATERIALS AND METHODS

The experiment was conducted in the research field of the University of Peradeniya, Sri Lanka (7 °N, 81 °E, 415 m above sea-level). The soil of the site was an Ultisol (Rhododult), loamy sand, having pH (1:2.5 H_2O) 6.08 ± 0.13, organic matter 1.02% ± 0.04%, total N 0.24% ± 0.03%, CEC 6.99 meq/100 g soil and water-holding capacity of 21.58 ± 0.14%. The climate of the site is characterized by a prominent major wet season receiving approximately 65% of the annual rainfall, corresponding to the North-east monsoon beginning in October, and the minor dry season beginning in late April. The minor seasons of 2002 and 2003 (late April–late September) received 456 and 397 mm rainfall, respectively, while the mean daily evaporation was 3.12 mm day. The mean temperature was 31.5 °C and 32.7 °C in the minor seasons of 2002 and 2003 respectively. Hence moisture loss through evaporation exceeded rainfall and the ambient temperature was higher in both seasons (Domroes and was Ranatunga, 1992), and crops generally experienced drought stress under rainfed conditions in the minor seasons. Thus the cassava crop was subjected to moisture stress over the first 5 months, until the major season corresponding to the North east monsoon began in late September.

The experiment was planted with the onset of rains in the minor (dry-late April 2002 and 2003) seasons respectively. In each season, uniform vegetative propagules of cassava ('CARI 555') having a mean length of 30 cm ± 2.5 cm) were established in well-prepared plots of dimension 5 m × 4 m at a spacing of 80 cm × 70 cm. At planting, all plots received a uniform basal application of fertilizer, equivalent to 80 kg N, 60 kg P_2O_5 and 80 kg K_2O.

This was followed by top-dressing of 40 kg N, and 50 kg K_2O at 100 days. Weeding was carried out on 3 occasions.

The treatments imposed in each season were the addition of the selected organic materials, rice straw (C:N ratio 46.5) and leaves of *Gliricidia sepium* (C:N ratio 19.6) as a surface mulch on the entire plot or incorpopraed into the soil of the plot soon after planting. The rate of application of both materials was 600 g/m^2 (i.e. 6 tonnes fresh material/ha). A control plot was maintained without organic matter as per normal farmer practice. These plots were not irrigated. The 5 treatments were replicated 4 times within a randomised block design in each season. The data were obtained in each season on leaf number and leaf-area indices of plants at 100 days (which corresponded to the end of the minor season by sampling 5 plants/plot), weeds at 100 days after planting. Tubers/plant, percentage marketable tubers (greater than 5 cm in diameter), tuber yield/plant and harvest indices were recorded by sampling 8 plants/plot at 12 months (which corresponds to the time of harvesting).

The soil was sampled at 5 random places/plot at 4-week intervals throughout both minor seasons (late April-late September) to a depth of 60 cm using a soil augur, and moisture content was determined gravimetrically.

The important climatic parameters over the seasons were obtained from the University field station. As the crop was planted in the minor season and as vegetative growth is adversely affected by rainfall in this season, the rainfall-utilization efficiency of the crop was calculated for the period where crop could be subjected to water stress. The rainfall of the wet season, which provides adequate soil moisture was not considered in this calculation. The rainfall utilization efficiency (RUE) calculated as : yield (q)/ mm rainfall of the minor season. The data of the 2 seasons were statistically analysed using a general linear model to determine significance of treatment differences in each season.

RESULTS AND DISCUSSION

Soil moisture

Organic matter conserved soil moisture over the dry seasons and the use of rice straw helped retain a greater quantity of soil moisture than *Gliricidia* leaves, irrespective of the method of addition (Table 1). The slower rate of microbial decomposition of straw due to its greater C:N ratio (46) could be considered the causal factor for this phenomenon. Incorporation of both materials reduced soil-moisture retention, as this process reduces particle size which facilitates faster breakdown. Hence incorporation of rice straw and *Gliricidia* leaves increased soil-moisture contents by 40% and 10% in season 1, and 57% and 14% in season 2, respectively, when compared to the plots without organic matter.

Surface application of both materials preserved soil moisture to a greater extent (i.e. 80% and 50% in season 1 and 100% and 71% in season 2 by rice straw and *Gliricidia* respectively). Again rice straw helped retain a greater quantum of soil moisture, which is attributed to slower breakdown, when compared to *Gliricidia* leaves, which have higher nitrogen content (2.25%). The faster breakdown facilitates quicker exposure of the soil surface, thus enhancing evaporation losses. In contrast rice straw remains on the soil surface for approximately 4 months, thus retaining a greater quantity of soil moisture in the minor season to facilitate better growth of cassava in the early stages.

An important phenomenon observed was the greater retention of soil moisture by both organic maerials in season 2, which received a lower quantum of rainfall. This implied that using organic matter, preferably as mulch, helps reduce moisture loss from soils to a greater extent under drier conditions.

Weed growth

The weeds/plot were found significantly greater in the plots without any organic mater, indicating the importance of this agronomic practice in suppressing weeds. Further, the presence of greater number of weeds, which are generally more aggressive than the slower growing cassava would extract soil moisture, thus, depleting this parameter in the dry minor season. As expected, the application of organic matter as a mulch reduced weed populations, while the incorporation enhanced weed populations compared to surface application (Table 1). The use of straw which has a lower higher C:N ratio suppressed weeds to a greater extent than the easily decomposable *Gliricidia* leaves.

Vegetative growth

Vegetative growth of cassava, as measured by leaf number and leaf-area index at 100 days (Table 1), was significantly improved by the organic matter. This increment in vegetative growth was owing to the availability of a greater amount of soil moisture for establishment and development, which is a pre-requisite for good growth of this species (Ezedinma *et al.,* 1980). Hence the lowest values of both parameters were in the control plots without organic matter. The incorporation of *Gliricidia* leaves marginally enhanced both parameters in the 2 seasons. Surface application of rice straw enhanced leaf number and leaf area compared to those of plants in plots where this material was incorporated. The beneficial effect of incorporating *Gliricidia* could be attributed to the greater nitrogen content of this material and also the faster microbial breakdown, which would provide some nitrogen to the growing cassava, which in turn increases vegetative growth, as reported for green manuring with this species (Zahara and Bah, 1999). In contrast, incorporation of rice straw with its higher C:N ratio could bind some soil nitrogen during decomposition (Takahashi *et al.*, 2003) which could affect the growth of cassava. Hence the enhanced vegetative growth of cassava when straw was applied as surface mulch could be attributed to the greater retention of soil moisture by this slower decomposing material.

The data also indicate that the magnitude of change in leaf number due to the different methods of applying organic matter was greater than that of leaf area. As cassava responds to moisture stress by shedding older leaves (El Sharkawy, 2004), the impact of stress over time is best observed in this parameter, rather than in leaf area, a phenomenon that warrants further study.

Yield components and yields

Cassava planted under normal farmer conditions is subjected to moisture stress in the early growth phase, which is most vulnerable to stress (El Sharkawy, 2004). This phenomenon was clearly observed under field conditions of this study and the yields of the plots without organic matter had the lowest yield components and hence the lowest yields and harvest indices (Table 2). Further, the measured yield components and yield were lower in the second season which received a lower quantum of rainfall. This clearly implies the benefits of organic matter on cassava growth and yields, when the crop is grown at the inception of the minor dry season, which brings a dry period of about 5 months, where moisture loss is greater than rainfall.

Application of organic matter enhanced yield components and yields significantly and hence the harvest indices (Table 2). The trend during the 2 seasons was similar, although measured parameters were lower in the second season due to the lower rainfall during the early growth phase, which is an important period of the life-cycle of this crop that determines the yields of tubercrops

Table 1. Leaf number, leaf-area indices of cassava and number of weeds as affected by the method of addition of organic matter over minor (dry) seasons and mean soil moisture contents over the 2 seasons in the 0–60 cm soil profile

Organic matter	Method of addition	Leaves/plant		Leaf-area index		Weeds/m²		Soil moisture (%)**	
		S1	S2	S1	S2	S1	S2	S1	S2
Rice straw	Surface	23	26	3.71	3.10	42	38	18.1	14.2
	Incorporation	18	20	3.47	2.91	58	55	14.1	11.6
	Mean	20.5	23	3.59	3.01	50	47	16.1	12.9
Gliricidia	Surface	20	22	3.32	2.90	56	61	15.3	12.4
	Incorporation	17	19	3.43	3.04	64	65	11.3	8.2
	Mean	18.5	20.5	3.37	2.97	60	63	13.3	10.3
No organic matter		16	15	2.59	2.31	74	81	10.2	7.1
	CD (P=0.05)								
	Organic matter	0.85	1.04	4.11	5.04	4.11	5.04	1.51	0.58
	Method of addition	0.24	0.19	0.08	0.05	2.97	3.10	0.48	0.29
	Interaction	0.31	0.13	0.04	0.06	0.99	1.48	1.93	0.92

**The mean soil-moisture content over the season in the 0–60 cm soil layer (soil moisture contents at field capacity and permanent wilting point were 25.4 ± 1.43% and 13.8 ± 0.99% respectively)

Table 2. Impact of organic matter and method of addition on yield components, yields and rainfall utilization efficiency (RUE) of cassava planted in 2 minor seasons

Organic matter	Methods of addition	Tubers/ plant		Marketable yield (%)		Tuber yield (q/ha)		Harvest index		RUE (q/mm rainfall of the minor season)	
		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
Rice straw	Surface	8.8	6.9	85	78	385	362	0.68	0.64	0.844	0.911
	Incorporation	7.5	6.1	74	68	331	304	0.64	0.59	0.725	0.766
Gliricidia	Surface	7.6	6.4	78	71	328	294	0.61	0.57	0.719	0.740
	Incorporation	7.1	5.8	71	65	285	247	0.58	0.55	0.625	0.619
No organic matter		5.8	5.1	58	53	245	216	0.54	0.51	0.537	0.038
	(P=0.05)										
	Organic matter	0.54	0.08	3.51	1.93	20.7	35.9	0.012	0.007	0.031	0.007
	Method of addition	0.22	0.04	2.16	0.84	14.6	18.1	0.004	0.006	0.025	0.003
	Interaction	0.08	0.01	1.94	0.53	6.48	8.41	0.001	0.004	0.008	0.002

S1 and S2, Minor (dry) seasons of 2002 and 2003 respectively

(Ekanayake *et al.,* 1990).

The beneficial impact of *Gliricidia* was lower than that of straw in both yield components, irrespective of the method of application. The mean increments in tuber numbers with the application of *Gliricidia* over that of the control plots were 26% and 21% in the first and second season respectively, compared to the increments with rice straw (40% and 27% in the 2 seasons). A similar trend was also observed in the percentage marketable tubers, indicating a significant positive correlation (r = 0.81*) between these 2 parameters. The greater beneficial impact of straw over *Gliricidia* is attributed to the better soil moisture-retention capacity (Table 1) of this organic material, which produces a more conducive environment during initial growth. Although *Gliricidia* promotes better vegetative growth (leaf-area index in season 2) due to the possible supply of mineralized nitrogen, yield components are enhanced to a greater extent by rice straw. A comparison of the 2 methods of application clearly highlights the benefits of surface mulching of both materials, which increased yield components significantly. This was again owing to better moisture retention during the dry season.

Application of rice straw increased the tuber yield of cassava by 46% and 54% in season 1 and 2 respectively. The impact of *Gliricidia* was lower (25% in both seasons). This also implied that the beneficial impact of straw was greater in the drier season which received a lower quantum of rainfall. Harvest indices also showed similar increments due to the 2 materials, although the magnitude of impact was lower. This clearly implied the benefits of using rice straw to increase yields of cassava in the dry seasons, especially when fertilizer is applied. Non-application of chemical fertilizers may provide different results as *Gliricidia* could contribute to the nitrogen nutrition of the crop.

Incorporation of both materials reduced yields and harvest indices, and the decline was greater with rice straw in both seasons (14-16%) compared to *Gliricida* (8%). Hence surface application of both materials, and especially rice straw as mulch, which does not require tillage for incorporation, has a greater impact on cassava tuber yields and harvest indices owing to the greater moisture-retention capacity by this cultural practice when the crop is planted in the minor dry season.

Rainfall-utilization efficiency (RUE)

The results (Table 2) highlight that RUE of cassava in terms of tuber yields grown without organic matter in this seasons is low. Organic matter, especially rice straw enhances this parameter significantly (46% and 54% in seasons 1 and 2 due to rice straw and 25% due to *Gliricidia* in both seasons). This again indicates the benefits of organic matter with a high C:N ratio for increasing yields of cassava, which is owing to its greater soil-moisture preservation properties. A faster decaying organic matter, which has a lower C:N ratio and could be of benefit in plant nutrition, has a lower impact in using the received rainfall with greater efficiency, especially when the crop is fertilized. Further, the beneficial impact of straw is greater in terms of RUE in the drier (second) season, which further enhances its value. Again, the benefits are greater when both materials are applied as a surface mulch rather than incorporation, which also has other benefits in terms of lower soil disturbance and labour use.

Soil-moisture conservation using organic matter as mulch or its incorporation shows increase in yield indices of cassava and RUE, when planted in a dry season under rainfed conditions. However, surface application of an organic matter with a high C:N ratio, such as rice straw has greater benefits in achieving high yields and better soil-moisture conservation.

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