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# Crop Simulation Growth Model in Cassava

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**Abstract:** Field experiment was conducted at Veterinary College and Research Institute Farm, Namakkal during 2002 to find out the effect of forage intercropping and organic manures on the growth and growth rate of cassava. The popular hybrid of cassava H 226 was tried as test crop. Three intercropping systems viz., Sole cassava, Cassava + maize (var. African tall) and Cassava + cowpea (var. CO 5) and six organic manurial treatments viz., FYM (25 t $ha^{-1}$), Poultry manure (10 t $ha^{-1}$), Composted poultry manure (10 t $ha^{-1}$), FYM (12.5 t $ha^{-1}$) + poultry manure (5 t $ha^{-1}$), FYM (12.5 t $ha^{-1}$) + composted poultry manure (5 t $ha^{-1}$) along with Control (no organic manure) were tested. The treatments were replicated thrice. Several growth models were tried for estimating the cassava growth and growth rate. The study revealed that based on the $r^2$ value and predicting ability, Richards' growth model was found to be the best. For all the estimated values, the correlation co-efficient was around 0.99 (99%). This indicated the correct fitness and the suitability of the model for the present study. Maximum growth was associated with application of composted poultry manure irrespective of the intercropping systems. Even though the treatment combinations involving sole cassava recorded higher initial growth rate, cassava + cowpea combinations recorded the highest growth rate than sole cassava.

**Key words:** Cassava, intercropping, organic manures, Richards' growth model, growth rate

## INTRODUCTION

Intercropping in cassava is a widely followed practice in the humid and sub-humid tropics. Cassava, a long season, wide spaced crop is slow in its initial growth and development and therefore, intercropping a short duration crop may increase the biological efficiency as a whole. Normally, green covers are planted with cassava for a variety of purposes such as cultural weed control, fertility and moisture conservation and forage production [5].

Intercropping in cassava helps to reduce soil erosion, leaching nutrient, depletion of fertility and check the growth of weeds than pure crop of cassava. The use of legumes as ground cover with cassava besides providing protection against runoff and erosion, also enhance grain yields in succeeding crops due to nutritional contributions from their residues.

Application of organic manures has various advantages like increasing soil physical properties, water holding capacity, organic carbon content apart from supplying good quality of nutrients. Poultry manure is rich organic manure since solid and liquid excreta are excreted together resulting in no urine loss. In fresh poultry excreta uric acid or urate is the most abundant nitrogen compound (40-70 per cent of total N) while urea and ammonium are present in small amounts[4].

Crop yield is mainly dependent on growth and its rate, which occurs at different stages and is influenced by various factors like intercropping, manures, fertilizers apart from irrigation, weeding etc. The precise effect of these factors can be effectively determined through growth models. Hence, in the present study, various growth models were considered to find out the effect of intercropping and organic manures on the growth and growth rate of cassava at different stages.

## MATERIALS AND METHODS

Field experiment was conducted at Veterinary College and Research Institute Farm, Namakkal during 2002 to find out the effect of forage intercropping and organic manures on the growth and growth rate of cassava intercropping systems. The popular hybrid of

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cassava, H 226 was tried as test crop. Three intercropping systems viz., Sole cassava, Cassava + maize (var. African tall) and Cassava + cowpea (var. CO 5) and six organic manurial treatments viz., FYM (25 t $ha^{-1}$), Poultry manure (10 t $ha^{-1}$), Composted poultry manure (10 t $ha^{-1}$), FYM (12.5 t $ha^{-1}$) + poultry manure (5 t $ha^{-1}$), FYM (12.5 t $ha^{-1}$) + composted poultry manure (5 t $ha^{-1}$) along with control (no organic manure) were tested. The treatments were replicated thrice.

Two rows of intercrops were sown in between the rows of main crop as additive intercropping series. Nutrients were applied only to the main crop. Disease free sets of 20 cm length were prepared and planted at a spacing of 90x90 cm. Seeds of fodder maize and cowpea were dibbled in lines at a spacing of 30x20 cm accommodating two rows of intercrops between the rows of cassava. Manures were applied as per treatments and thoroughly incorporated at the time of forming beds and channels.

A fertilizer dose of 60:60:150 NPK Kg $ha^{-1}$ was uniformly applied to all the plots. The entire dose of phosphorus, 50 per cent of recommended dose of nitrogen and 50 per cent of potassium were applied basally at the time of planting and the remaining 50 per cent of the recommended dose of nitrogen and potassium were top dressed in two equal splits at third and fifth month, respectively. Fertilizers were applied only to the main crop. After initial and life irrigation on third day, subsequent irrigations were given to the experimental field at an interval of ten days. Three hand weeding on 30th, 60th and 90th day after planting and an earthing up at 120 DAP was given commonly for all the plots irrespective of the treatments.

Composting of poultry manure was initiated using poultry manure and chopped sorghum straw. The bits of sorghum straw were mixed with poultry manure at the rate of 1:10 and packed in dug pits and closed with mud plaster. To maintain optimum moisture, water was sprinkled before it is being packed and left under anaerobic conditions for 75 days as suggested by Sims *et al.*[11] for composting poultry manure and poultry carcasses. The chemical analysis of the manures is furnished in Table 1.

Several growth models were tried for estimating the cassava growth rate, in the present investigation as detailed below:

**Table 1:** Chemical analysis of FYM and poultry manure

| Particulars | FYM | Poultry manure | Composted poultry manure |
|---|---|---|---|
| N content (%) | 0.55 | 2.20 | 1.92 |
| P content (%) | 0.48 | 1.41 | 1.35 |
| K content (%) | 0.90 | 1.52 | 1.55 |
| p H | 7.60 | 6.40 | 7.10 |
| C: N ratio | 20.8 | 11.8 | 16.9 |

$$\text{Richards } W = Wm\,[1 + e\beta\text{-}kt]^{-1}/n \qquad \text{(1) Richards' [9]}$$

$$\text{Logistic } W = \frac{Wm}{1 + ce\text{-}bt} \qquad \text{(2) Meek } et\ al.\ [6]$$

$$\text{Gompertz's } W = Wm / \exp(\exp(\beta + ct)) \qquad \text{(3) Meek } et\ al.\ [6]$$

$$\text{Hill } W = Wmtc / \exp(\beta) + tc \qquad \text{(4) Meek } et\ al.\ [6]$$

$$\text{Gauss } W = W\,(1\text{-}eb + ct^2) \qquad \text{(5) Meek } et\ al.\ [6]$$

where,

Wm= Maximum growth
t = Time in days
b,c,ß, k are the constants (parameters to be estimated)

Out of these five models, based on the $r^2$ value and predicting ability, Richards' growth model was found to be the best. The Richards' function, first introduced in 1959 was considerably improved later and proved to be a reasonable model for crop growth estimation by Causton and Venus, [2] and Kailasam *et al.* [3].

The Richards' growth model was estimated by the method of least squares. The data on total dry matter production of cassava at different stages of growth was used for the estimation. The average growth rate was arrived at by using the formula

$$R = \frac{k}{n + 1.}$$

## RESULTS AND DISCUSSIONS

**Crop Simulation Model:**

**Estimated Richard's Total Crop growth Model:** The estimated Richard's growth model values as influenced by intercropping systems and organic manures are given in Table 2. As per the model, the maximum cassava growth ranged from 16.71 to 26.05 t $ha^{-1}$ between the treatments studied. The maximum growth was found to be in sole cassava applied with composted poultry manure ($I_1M_4$) (26.05 t $ha^{-1}$) followed by cassava + cowpea applied with composted poultry manure ($I_3$ $M_4$) (24.88 t $ha^{-1}$) and $I_3M_6$ (24.84 t $ha^{-1}$) and the minimum growth was with $I_2M_1$ (16.71 t $ha^{-1}$). For all the estimated values, the correlation co-efficient was around 0.99 (99%). This indicated the correct fitness and the suitability of the model for the present study.

**Table 2:** Estimated Richards crop growth model as influenced by intercropping systems and organic manures (t ha$^{-1}$) n=2.5

| Treatment | Wm (t ha$^{-1}$) | β | k | r | R (t ha$^{-1}$) |
|---|---|---|---|---|---|
| $I_1 M_1$ | 18.50 | 10.7182 | 0.04289 | 0.996 | 0.01226 |
| $I_1 M_2$ | 23.40 | 11.0060 | 0.04465 | 0.998 | 0.01276 |
| $I_1 M_3$ | 23.80 | 11.0455 | 0.04489 | 0.997 | 0.01284 |
| $I_1 M_4$ | 26.05 | 11.1534 | 0.04532 | 0.998 | 0.01295 |
| $I_1 M_5$ | 23.91 | 10.9766 | 0.04479 | 0.997 | 0.01280 |
| $I_1 M_6$ | 24.01 | 10.9556 | 0.04497 | 0.997 | 0.01285 |
| $I_2 M_1$ | 17.25 | 10.6563 | 0.04260 | 0.994 | 0.01217 |
| $I_2 M_2$ | 22.53 | 10.9743 | 0.04442 | 0.997 | 0.01269 |
| $I_2 M_3$ | 22.07 | 10.8943 | 0.04426 | 0.996 | 0.01265 |
| $I_2 M_4$ | 24.75 | 11.0906 | 0.04491 | 0.998 | 0.01283 |
| $I_2 M_5$ | 23.00 | 10.9564 | 0.04470 | 0.997 | 0.01277 |
| $I_2 M_6$ | 23.63 | 11.0137 | 0.04485 | 0.997 | 0.01281 |
| $I_3 M_1$ | 18.02 | 10.9206 | 0.04353 | 0.993 | 0.01243 |
| $I_3 M_2$ | 23.56 | 11.3878 | 0.04790 | 0.993 | 0.01308 |
| $I_3 M_3$ | 22.71 | 11.2903 | 0.04580 | 0.993 | 0.01309 |
| $I_3 M_4$ | 24.88 | 11.4593 | 0.04640 | 0.994 | 0.01326 |
| $I_3 M_5$ | 23.36 | 11.3102 | 0.04600 | 0.993 | 0.01314 |
| $I_3 M_6$ | 24.84 | 11.4702 | 0.04624 | 0.993 | 0.01321 |

$W_m$ - Maximum growth R - Correlation co-efficient
ß, k - Estimated parameters (constant) R - Average growth rate

**Intercropping systems**
$I_1$ Sole cassava
$I_2$ Cassava + maize
$I_3$ cassava + cowpea

**Organic manures**
$M_1$ Control (no organic manure)
$M_2$ FYM (25 t ha$^{-1}$)
$M_3$ Poultry manure (10 t ha$^{-1}$)
$M_4$ Composted poultry manure (10 t ha$^{-1}$)
$M_5$ FYM (12.5 t ha$^{-1}$) + poultry manure (5 t ha$^{-1}$)
$M_6$ FYM (12.5 t ha$^{-1}$) + composted poultry manure (5 t ha$^{-1}$)

The average growth rate ranged from 0.01216 to 0.01326 t ha$^{-1}$. The treatment combinations $I_3M_4$ had the highest average growth rate (0.01326 t ha$^{-1}$). Even though $I_1M_4$ had shown the maximum total cassava growth, it was not reflected in the growth rate of the concerned treatment.

The predicted total growth was higher for the treatment combination $I_1M_4$. As indicated elsewhere due to the fitness of this Richard crop growth model, in reality (in the present investigation) the maximum total dry matter production was recorded in the treatment combination $I_1M_4$. This might be due to full recommended application supplemented with nutrients from CPM. With the application of the nutrients from two sources might have influenced availability of soil nutrients and led to higher uptake resulting in better growth. Positive influence of this treatment might be due to slow and steady availability of nutrients throughout the crop growth period from CPM. Increased drymatter production in castor due to the application of 10 t ha$^{-1}$ of poultry manure was reported by Ugbaja [12]. Ponsica *et al* [8] observed a higher efficiency of poultry manure than cattle manure in increasing the dry matter and yield of maize.

Since the treatment combination $I_1M_4$ did involve sole cassava (without any intercrop), intercrop competition was absent. This might have favoured the treatment $I_1M_4$ for obtaining maximum possible growth. The higher growth under $I_3M_4$ next to $I_1M_4$ might be due to the utilisation of N fixed by the component intercrop cowpea both during and harvest of the intercrop in addition to the nutrients availability from CPM, even though it had experienced a set back in the initial stage as a result of luxuriant vegetative growth of the intercrop cowpea. Savithri and Alexander [10] reported that there was no significant difference in growth and yield of cassava when intercropped with cowpea and this lend support to this present finding.

**Table 3:** Estimated growth of cassava at different stages as influenced by intercropping systems and organic manures (t ha$^{-1}$)

| Treatments | 60DAP | 120DAP | 180DAP | 240DAP | 300DAP (Harvest) |
|---|---|---|---|---|---|
| $I_1 M_1$ | 0.711 | 1.99 | 5.47 | 12.76 | 17.70 |
| $I_1 M_2$ | 0.837 | 2.44 | 6.20 | 16.66 | 22.09 |
| $I_1 M_3$ | 0.843 | 2.47 | 7.12 | 17.02 | 23.00 |
| $I_1 M_4$ | 0.892 | 2.65 | 7.71 | 18.61 | 25.20 |
| $I_1 M_5$ | 0.868 | 2.54 | 7.30 | 17.29 | 23.14 |
| $I_1 M_6$ | 0.883 | 2.59 | 7.48 | 17.59 | 23.29 |
| $I_2 M_1$ | 0.675 | 1.88 | 5.12 | 11.88 | 16.49 |
| $I_2 M_2$ | 0.811 | 2.35 | 6.71 | 15.96 | 21.73 |
| $I_2 M_3$ | 0.818 | 2.36 | 6.70 | 15.78 | 21.31 |
| $I_2 M_4$ | 0.861 | 2.53 | 7.29 | 17.51 | 23.89 |
| $I_2 M_5$ | 0.840 | 2.45 | 7.03 | 16.61 | 22.25 |
| $I_2 M_6$ | 0.846 | 2.48 | 7.14 | 16.98 | 22.85 |
| $I_3 M_1$ | 0.649 | 1.84 | 5.15 | 12.29 | 17.24 |
| $I_3 M_2$ | 0.782 | 2.27 | 6.60 | 16.16 | 21.96 |
| $I_3 M_3$ | 0.745 | 2.24 | 6.59 | 16.14 | 21.97 |
| $I_3 M_4$ | 0.760 | 2.44 | 7.69 | 19.00 | 24.38 |
| $I_3 M_5$ | 0.764 | 2.30 | 6.82 | 16.71 | 22.63 |
| $I_3 M_6$ | 0.766 | 2.32 | 6.94 | 17.35 | 23.99 |

The least growth and growth rate was associated with treatment combinations involving cassava intercropped with fodder maize and this might be due to the depression of early growth in cassava by vigorous maize growth as evidenced in reduction in plant height and LAI. Similar result was reported by Olasantan *et al* [7] in cassava-maize intercropping.

**Predicted Growth of Cassava at Different Stages:** The model predicted that the growth of cassava had increased progressively from 60 DAP and reached the maximum at 300 DAP (harvest) (Table 3). Among the treatment combinations, $I_1M_4$ had the highest growth at all the stages, followed by $I_1M_6$ as per the prediction as well as in reality (in the present investigation). This is quite natural that the same treatment had exhibited overall higher total growth. This treatment was followed by $I_1M_6$. In the case of $I_1M_6$ the variable introduced was CPM + FYM as compared to CPM of $I_1M_4$ combination.

**Growth Rate of Cassava at Different Stages:** The growth rate of cassava as predicted by the model also increased progressively from 60 DAP and was the

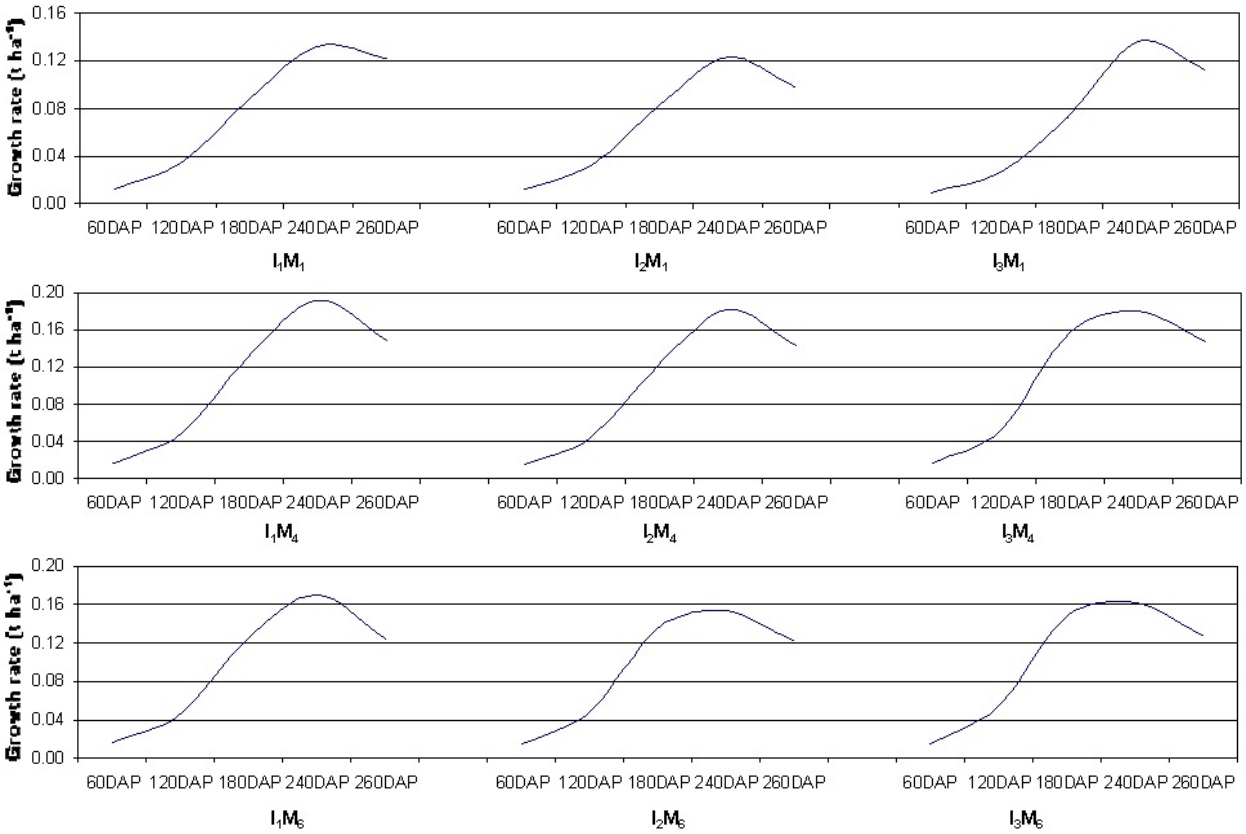


**Fig. 1:** Growth rate of cassava at different stages

**Table 4:** Growth rate of cassava at different stages as influenced by intercropping systems and organic manures (t $ha^{-1}$)

| Treatment | 60 DAP | 120 DAP | 180 DAP | 240 DAP | 260 DAP |
|---|---|---|---|---|---|
| $I_1 M_1$ | 0.0122 | 0.0340 | 0.089 | 0.132 | 0.122 |
| $I_1 M_2$ | 0.0149 | 0.0430 | 0.119 | 0.170 | 0.125 |
| $I_1 M_3$ | 0.0150 | 0.0440 | 0.122 | 0.173 | 0.126 |
| $I_1 M_4$ | 0.0160 | 0.0478 | 0.133 | 0.192 | 0.148 |
| $I_1 M_5$ | 0.0160 | 0.0453 | 0.124 | 0.172 | 0.133 |
| $I_1 M_6$ | 0.0159 | 0.0464 | 0.127 | 0.171 | 0.125 |
| $I_2 M_1$ | 0.0115 | 0.0318 | 0.083 | 0.123 | 0.098 |
| $I_2 M_2$ | 0.0144 | 0.0417 | 0.113 | 0.164 | 0.122 |
| $I_2 M_3$ | 0.0148 | 0.0417 | 0.113 | 0.159 | 0.119 |
| $I_2 M_4$ | 0.0155 | 0.0452 | 0.125 | 0.182 | 0.143 |
| $I_2 M_5$ | 0.0147 | 0.0427 | 0.117 | 0.167 | 0.128 |
| $I_2 M_6$ | 0.0152 | 0.0473 | 0.136 | 0.154 | 0.123 |
| $I_3 M_1$ | 0.0094 | 0.0266 | 0.073 | 0.136 | 0.112 |
| $I_3 M_2$ | 0.0136 | 0.0489 | 0.141 | 0.160 | 0.113 |
| $I_3 M_3$ | 0.0119 | 0.0355 | 0.122 | 0.178 | 0.132 |
| $I_3 M_4$ | 0.0159 | 0.0540 | 0.157 | 0.180 | 0.147 |
| $I_3 M_5$ | 0.0132 | 0.0396 | 0.128 | 0.179 | 0.145 |
| $I_3 M_6$ | 0.0149 | 0.0538 | 0.148 | 0.163 | 0.128 |

highest at 240 DAP (Table 4). The growth rate was very slow in the initial stage (60 DAP). A sharp increase in the growth was deducted between 60 and 180 DAP. The increase in the growth between 180 and 240 DAP was at a diminishing rate. Among the treatment combinations, highest predicted growth rate was associated with $I_1M_4$ and $I_1M_6$ at 60 DAP, I3M4 and $I_3M_6$ at 120 and 180 DAP respectively and in $I_1M_4$ at 240 DAP.

At 60 DAP, $I_1M_4$, $I_1M_5$ and $I_1M_6$ had higher growth rate over other combinations evaluated. This might be due to the sole cassava crop environment associated with application of recommended nutrients in addition to application of organic manures like CPM, PM + FYM and CPM + FYM. The superiority of these three organic manures (CPM, PM + FYM, CPM + FYM) might be due to the nitrogen supplying ability of these manures.

This trend was reverse at 120 and 180 DAP where in $I_3M_4$ and $I_3M_6$ stood first in registering higher growth rate. This is possible in biological science where in after the release of physical, chemical and environmental stresses from the intercrop the tendency of the cassava was to exhibit a spurt in growth. Anilkumar and Sasidhar [1] observed lower growth of cassava when intercropped with cowpea in the earlier stages and after fourth month such difference was not observed by them.

But, such spectacular growth rate was not observed in respect of the treatment $I_1M_4$, $I_1M_5$ and $I_1M_6$ at 120 and 180 DAP, since these combinations were without intercrop. This indirectly indicated a sustainable growth

rate existing in these three treatments. Because of the steady and sustainable growth rate, the treatment combination $I_1M_4$ had shown increased growth rate at 240 DAP. The influence of the treatment combinations ($I_3M_4$, $I_3M_6$) that was observed at 120 and 180 DAP was absent at 240 DAP probably due to a lag period after a heavy spurt in growth.

**Conclusion:** The study revealed that based on the r2 value and predicting ability, Richards' growth model was found to be the best. For all the estimated values, the correlation co-efficient was around 0.99 (99%). This indicated the correct fitness and the suitability of the model for the present study. Maximum growth was associated with application of composted poultry manure irrespective of the intercropping systems. Even though the treatment combinations involving sole cassava recorded higher initial growth rate, cassava + cowpea combinations recorded the highest growth rate than sole cassava.

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