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# Growth and Productivity of *Eucalyptus tereticornis* clones Under Agroforestry System

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**Key words:**

Eucalyptus clone, intercrops, Agro forestry, growth and productivity

## ABSTRACT

Field experiment was conducted at Tamil Nadu Newsprint and Papers Limited, Kagithapuram, Karur District, Tamil Nadu to screen suitable intercrops under Clonal Eucalyptus . This experiment was laid out in a randomized block design with three replications. *Eucalyptus* clone ITC 3 *was* planted in November 2005 at a spacing of 3 m x 1.5 m. Trees were coppiced in June, 2010. Different agricultural and horticulture crops belonging to millets, pulses, oilseed and vegetable were raised as intercrops under *Eucalyptus* clone when the trees were eight months old.. Separate plots were maintained for *Eucalyptus clone* as well as the intercrops for comparison. The biometric parameters were observed at 30DAS and 60DAS intervals for both intercrops and Eucalyptus clone.

## INTRODUCTION

*Eucalyptus* is the second dominant hardwood species planted after Pines in an area of 10 to 15 million ha throughout the world (Neilson 2000). It is native of Australia, which was introduced in India during early 19$^{th}$ century. *Eucalyptus* has emerged as one of the most favoured fast growing tree species for its unique adaptability to wide range of sites and suitability to varied environmental conditions. Silvicultural properties including straightness, narrow crown, self-pruning ability, high growth rate and adaptability to a wide range of soil and climate, coppicing ability and a tendency not to spread as a weed are some of the main features of *Eucalyptus* clones which are considered for plantation. The wide utility of wood makes it popular among the farmers for rising as block plantations. However, *Eucalyptus* clones have revolutionized the productivity and profitability of the plantations in many states of our country (Lal 2005). The productivity of clonal plantations raised under rainfed conditions varies from 20 to 44 $m^3 ha^{-1} yr^{-1}$ compared to 6 to 10 $m^3 ha^{-1} yr^{-1}$ of seed route plantations (Lal and Kulkarni 1992). The Current production of raw materials for pulp and paper is 2.76 million tonnes against the demand of 5.04 million tones, which shows a shortfall of 45 per cent. The projected demand by 2020 is 13.2 million tonnes, which is still more staggering (Palsaniya et al. 2009). Currently, there are about 594 paper mills in India (Srivastava 2005), with 34 considered as large companies. In Tamil Nadu, there are 39 paper mills, including Tamil Nadu Newsprint and Papers Ltd. (TNPL) and Seshasayee Paper and Boards Ltd. (SPB). The demand for wood based products in Tamil Nadu is 8 to 10 lakh tonnes of wood pulp per year, which is greater than the 4 lakh tonnes that are currently available (Parthiban and Rao 2008). *Eucalyptus* is the most popular choice to be planted along the edges or bunds of agricultural fields, and appears to be well

incorporated and accepted in agroforestry in India (Tejwani, 1994).There are very few studies carried out with respect to intercropping in intensively managed clonal plantations of *Eucalyptus*. Prasad et al. (2009) reported a successful case of intercropping in the clonal *Eucalyptus* plantations raised for pulpwood in Andhra Pradesh. They are generally harvested at 4 years interval and large numbers of crops are grown with Eucalyptus during the first year of planting. Annual crops not only provide early returns but also employment potential to the villagers as envisaged in poplar (Prasad et al. 2010).

**MATERIALS AND METHOD**

The study was conducted at Tamil Nadu Newsprint and Papers Limited, Kagithapuram, Karur District, located at latitude 11°02' N and longitude of 77°59' E at altitude of 125 m above the mean sea level. The climate of the study area is average annual rainfall is about 725 mm. It gets most of its seasonal rainfall from the north-east monsoon winds, from late September to mid November. The highest temperature is obtained in early May to early June usually about 34 °C, though it usually exceeds 38 °C for a few days most years. Average daily temperature during January is around 23 °C, though the temperature rarely falls below 17 °C. The soils are red sandy loam.

Eucalyptus trees (clone ITC 3) was planted in the year November 2005 at the spacing of 1.5 m. Plantation was done on TNPL, Karur area. Agricultural crops and horticulture crop belonging to millets, pulses, oilseed and vegetable were raised as intercrops under *Eucalyptus* clone when the trees were eight months old. The details of different intercrops raised during the study period are given in Table 1.

Biometric observations were recorded for Eucalyptus trees and agriculture crops. The tree height was measured before sowing and after harvesting of intercrops using a graduated bamboo pole. Height increment was calculated after deducting the height of the tree before sowing the intercrop from the height of the same tree after harvesting the intercrops. The basal diameter of the tree was measured before sowing and after harvesting of intercrops by using digital vernier caliper. For calculating the basal diameter increment, basal diameter of the tree before sowing the intercrops was deducted from the basal diameter of the same tree after harvesting the intercrops. It is expressed in centimeter**.** All the experimental trees were marked at 1.37 m from ground level with a band of 1 centimeter (cm) around the stem using orange paint. Then the DBH was taken by using digital vernier caliper. For calculating the basal diameter increment, basal diameter of the tree before sowing the intercrops was deducted from the basal diameter of the same tree after harvesting the intercrops. The volume of standing trees were estimated by using the following formula (Chaturvedi and Khanna, 1982) and expressed in cubic meter ($m^3$)

$$V = r^2h$$

Where,

V= Volume of standing trees

r = Radius at breast height

h = Total height of the tree

In case of intercrops, five plants were taken randomly for measurement plant height and collar diameter (except onion) by using scale at 30 DAS, 60 DAS and at harvest were measured. Seed/pod/bulb yields of all the intercrops were recorded after harvesting from each plot and expressed in terms of kg $ha^{-1}$.Representative plant samples from each treatment were pulled out carefully, washed, cleaned and their fresh weight was recorded. Dry weight was recorded after air drying the samples and expressed in kg $ha^{-1}$. The crop equivalent yield was calculated in terms of red gram. Crop equivalent yield was calculated and expressed as Rs $ha^{-1}$.

Light intensity was recorded under the *Eucalyptus* clone intercropping plots by using a Digital Lux meter for three stages *viz*., 30 DAS, 60 DAS and at harvest. Light availability in the morning was recorded at between 8 am and 9 am and mid day light intensity was measured between 12.00 to 13.00 hours. The lux meter readings were taken just over the crop, but under the canopy (between planting lines) and also over the crop

without tree cover.

The light transmission ratio was calculated by using the following formula and expressed as per cent of light transmitted.

$$LTR(\%) = \frac{\text{Light intensity under the tree canopy}}{\text{Light intensity in the absence of canopy}} \times 100$$

**RESULT**

***Effect of trees on growth and yield of intercrops***

The data with respect to plant height of intercrops at 30 DAS, 60 DAS and at harvest is presented in table 2. The results showed that among the seven intercrops tried, the highest reduction in plant height of intercrops at 30 DAS was observed in maize and sorghum with the reduction of 13 per cent for both the crops and the lowest reduction was observed in small onion with the reduction of 7 per cent. At 60 days after sowing, the highest reduction in plant height was observed in maize (16 %) and the lowest reduction of 7 per cent was observed in small onion. At harvest stage highest reduction in plant height was observed in maize with the reduction of 18 per cent and the lowest reduction was observed in small onion with the reduction of 8 per cent.

The data pertaining to collar diameter of intercrops at 30 DAS, 60 DAS and at harvest is presented in table 3.The results revealed that the reduction in collar diameter at 30 DAS was maximum in sesame with a reduction of 15 per cent and minimum of 7 % was noticed in sorghum. At 60 DAS, the maximum reduction in collar diameter was observed in sesame with a reduction of 18 per cent and the minimum reduction was noticed in maize and sorghum with a reduction of 12 per cent each. At harvest, the highest reduction in collar diameter was observed in sesame (21 %) and the lowest in sorghum (16 %). The magnitude of reduction in collar diameter at 30 DAS for the remaining crops were 9 %, 8 %, 11 % and 13 % in pearl millet, maize, green gram and red gram respectively. At 60 DAS, the magnitude of reduction in collar diameter was 13 %, 14 % and 15 % in pearl millet, green gram and red gram respectively. At harvest, the extent of reduction was 17 %, 19 %, 18 % and 19 % in pearl millet, maize, green gram and red gram respectively.

***Dry matter production (DMP)***

The data pertaining to the dry matter production of intercrops along with their percentage reduction as compared to their respective sole crop at harvest are furnished in table 4. The results showed that there was a marked difference in DMP between pure crop and intercrop. The results revealed that among seven intercrops, the highest DMP in the intercrops was recorded in red gram (2995 kg $ha^{-1}$) and the lowest in small onion (1225kg $ha^{-1}$). With respect to the per cent reduction in dry matter production of intercrops, the highest reduction was recorded in sesame and small onion (30 % each) and lowest reduction was noticed in sorghum with a reduction of 19 % over pure crop. Per cent reduction of DMP under intercropping for the remaining crops are 20 %, 27 %, 22 % and 25 % for pearl millet, sorghum, green gram and red gram respectively.

***Yield***

The data with respect to the yield of intercrops along with their percentage reduction as compared to their respective sole crop are furnished in table 4. The result revealed that there was a significant reduction in the yield of the intercrops when compared to pure crops. Among the millets tried, sorghum (1330 kg $ha^{-1}$) recorded the highest yield followed by pearl millet (1245 kg $ha^{-1}$) and the lowest yield was recorded in maize (1220 kg $ha^{-1}$). Among the pulses, red gram recorded high yield (735 kg $ha^{-1}$) than green gram (650 kg $ha^{-1}$).Under intercropping the yield of 420 kg $ha^{-1}$ and 2890 kg $ha^{-1}$ was observed in sesame and small onion respectively.

The magnitude of reduction in the yield of intercrops was 31 %, 24 %, 38 %, 30 %, 32 %, 23 % and 37 % in pearl millet, sorghum, maize, sesame, small onion, green gram and red gram respectively. Among the seven intercrops, highest reduction in the yield when compared to pure crop was observed in maize (38 %) and the lowest reduction was noticed in green gram (23 %).

Crop equivalent yield (CEY) of intercrops

maximum amount of crop equivalent yield was obtained from red gram (454 kg $ha^{-1}$) and the lowest crop equivalent yield was obtained from maize (201 kg $ha^{-1}$). Crop equivalent yield for the remaining crops are 269 kg $ha^{-1}$, 272 kg $ha^{-1}$, 350 kg $ha^{-1}$, 342 kg $ha^{-1}$ and 300 kg $ha^{-1}$ for pearl millet, sorghum, sesame, small onion and green gram respectively.

The mean light availability to the intercrops during morning and afternoon under tree canopy as well as open conditions were recorded. The results reported that the per cent light available to intercrops during morning varied from 50 per cent to 57 per cent. The per cent light available to intercrops during afternoon ranged from 79 per cent to 84 per cent.

***Effect of intercrops on tree growth***

The data with respect to tree height is presented in Table 5. The results revealed that the tree height varied from 4.42 m to 4.48 m and 6.23 m to 6.62 m before sowing and after harvesting of the intercrops respectively. The results showed that there was a meager difference in height increment in the tree after harvest of intercrops. Among the different tree crop combinations, maximum height increment in tree was recorded under red gram (2.17 m) and the lowest was reported under sesame (1.98 m). The height increment (1.8 m) in control (tree alone) is lower than all other treatments.

The data pertaining to the basal diameter of trees is presented in table 5. The results revealed that the basal diameter of Eucalyptus clone varied from 4.74 cm to 4.95 cm and 6.87 cm to 7.29 cm before sowing and after harvesting the intercrops respectively. The data with respect to diameter at breast height is presented in table 8. It varied from 3.76 cm to 3.93 cm and 5.65 cm and 5.86 cm before sowing and after harvesting the intercrops respectively. The results clearly indicate that after harvest of intercrops a significant difference in basal diameter and dbh was noticed in trees. Among the different tree-crop combinations, the maximum basal diameter and dbh increment in tree was recorded under red gram (2.34 cm and 1.93 cm respectively) and the minimum increment was found under sesame (2.16 cm and 1.88 cm) respectively. The basal diameter and dbh increment (2.02 cm and 1.75 cm) in control (tree alone) is lower than all other treatments.

The data with regard to tree volume is presented in table 6. The results revealed that the tree volume varied from 6.57 $m^3 ha^{-1}$ to 7.19 $m^3 ha^{-1}$ and 20.30 $m^3$ $ha^{-1}$ to 23.79 $m^3$ $ha^{-1}$ before sowing and after harvesting of the intercrops respectively. The result clearly shows that there was a significant difference in volume increment in the tree after harvest of intercrops. Among the different tree-crop combinations, highest volume increment in tree was recorded under red gram (16.60 $m^3$ $ha^{-1}$) and the lowest volume increment was reported under maize (14.91 $m^3$ $ha^{-1}$). In control (tree alone) the volume increment (13.50 $m^3$ $ha^{-1}$) is lower than all other treatments.

**DISCUSSION**

The results showed that among the seven intercrops tried, the highest reduction in plant height at all stages *viz*., 30 DAS, 60 DAS and at harvest were observed in maize with the reduction of 13 per cent, 16 per cent and 18 per cent respectively and sorghum at 30 DAS (13 %). The lowest reduction in plant height at all stages was reported in small onion with the reduction of 7 per cent, 7 per cent and 8 per cent respectively . The reduction in the plant height of intercrops in the present investigation might be due to competition for resources like light, moisture and nutrients. The maximum reduction in collar diameter was observed in sesame with the reduction of 15 per cent, 18 per cent and 21 per cent and the minimum reduction in sorghum with the reduction of 7 per cent, 12 per cent and 16 per cent respectively and maize at 60 DAS (12 %) Jamaludheen (2010) reported that among the seven intercrops, at the early stage of tree growth, the reduction in collar diameter varied in a very narrow range of 5 per cent (bhendi) to 11 per cent (cowpea) only. The highest DMP in the intercrops was recorded in red gram (2995 kg $ha^{-1}$) and the lowest in small onion (1225 kg $ha^{-1}$).With respect to the percent reduction of dry matter production in intercrops, the highest reduction was recorded in sesame and small onion (30 % each) and lowest reduction was noticed in sorghum with a reduction of 19 per cent over pure crop. The dry matter production of all the seven intercrops was lesser under intercropping when

compared to sole cropping. The reason for less dry matter production under intercropping might be due to non-availability of sufficient light for the process of photosynthesis and accumulation of dry matter. Among the seven intercrops, highest reduction in the yield when compared to pure crop was observed in maize (38 %) and the lowest reduction was noticed in green gram (23 %) . With respect to crop equivalent yield, highest was observed in red gram (454 kg $ha^{-1}$) and lowest was in maize (201 kg $ha^{-1}$).The yield of the intercrops was also lower under the tree canopy than in open condition. It might be due to reduced light interception ratio obtained in intercropping plots, the rate of dry matter production by a crop is primarily a function of the amount of solar radiation intercepted by its foliage, where moisture and nutrients are not limiting (Monteith, 1977).

**Table 1.** Details of different intercrops used in the study

| Sl. No. | Name of the intercrops | Variety |
|---|---|---|
| 1. | Pearl millet (*Pennisetum glaucum*) | CO 9 |
| 2. | Sorghum (*Sorghum bicolor*) | CO(S) 28 |
| 3. | Maize (*Zea mayz*) | COH(M) 5 |
| 4. | Sesame (*Sesamum indicum*) | CO 1 |
| 5. | Small onion (*Allium cepa*) | Local |
| 6. | Green gram (*Vigna radiata*) | CO 6 |
| 7. | Red gram (*Cajanus cajan*) | CO 7 |

**Table :2** Effect of intercropping with *Eucalyptus* clone on plant height of intercrops (cm)

| Sl. No. | Intercrops | 30 DAS | | 60 DAS | | At harvest | |
|---|---|---|---|---|---|---|---|
| | | Inter cropping | Pure cropping | Inter cropping | Pure cropping | Inter cropping | Pure cropping |
| 1 | Pearl millet | 22.4 (12%) | 25.5 | 98.9 (15%) | 116.4 | 145.6 (17%) | 175.4 |
| 2 | Sorghum | 20.7 (13%) | 23.8 | 76.2 (14%) | 88.6 | 138.3 (17%) | 166.7 |
| 3 | Maize | 17.8 (13%) | 20.5 | 81.8 (16%) | 97.4 | 123.2 (18%) | 150.3 |
| 4 | Sesame | 27.4 (8%) | 29.8 | 89.6 (9%) | 98.5 | 116.5 (12%) | 132.4 |
| 5 | Small onion | 18.2 (7%) | 19.6 | 26.4 (7%) | 28.4 | 30 (8%) | 32.7 |
| 6 | Green gram | 22.1 (10%) | 24.6 | 43.6 (10%) | 48.4 | 53.6 (11%) | 60.3 |
| 7 | Red gram | 28.5 (9%) | 31.4 | 80.3 (11%) | 90.2 | 164.1 (13%) | 188.6 |

**Table 3.** Effect of intercropping with *Eucalyptus* clone on collar diameter of intercrops (mm)

| Sl. No. | Intercrops | 30 DAS | | 60 DAS | | At harvest | |
|---|---|---|---|---|---|---|---|
| | | Inter cropping | Pure cropping | Inter cropping | Pure cropping | Inter cropping | Pure cropping |
| 1 | Pearl millet | 4.13 (9%) | 4.54 | 7.81 (13%) | 8.98 | 10.15 (17%) | 12.23 |
| 2 | Sorghum | 4.51 (7%) | 4.85 | 9.36 (12%) | 10.64 | 13.15 (16%) | 15.65 |
| 3 | Maize | 5.81 (8%) | 6.32 | 11.04 (12%) | 12.54 | 13.57 (19%) | 16.76 |
| 4 | Sesame | 3.88 (15%) | 4.57 | 9.73 (18%) | 11.87 | 11.27 (21%) | 14.27 |
| 5 | Small onion | - | - | - | - | - | - |
| 6 | Green gram | 2.46 (11%) | 2.76 | 5.01 (14%) | 5.83 | 6.39 (18%) | 7.81 |
| 7 | Red gram | 2.16 (13%) | 2.48 | 6.51 (15%) | 7.66 | 11.12 (19%) | 13.73 |

**Table 4:** Effect of intercropping with *Eucalyptus* clone on Dry matter (harvest) and yield of intercrops (kg $ha^{-1}$)

| Sl. No. | Intercrops | Dry weight | | Yield (kg $ha^{-1}$) | |
|---|---|---|---|---|---|
| | | Inter cropping | Pure cropping | Inter cropping | Pure cropping |
| 1 | Pearl millet | 2148 (20 %) | 2685 | 1245 (31 %) | 1800 |
| 2 | Sorghum | 2430 (19 %) | 3000 | 1330 (24 %) | 1760 |
| 3 | Maize | 1860 (27 %) | 2555 | 1220 (38 %) | 1960 |
| 4 | Sesame | 2450 (30 %) | 3500 | 420 (30 %) | 600 |
| 5 | Small onion | 1225 (30 %) | 1750 | 2890 (32 %) | 4250 |
| 6 | Green gram | 1240 (22 %) | 1590 | 650 (23 %) | 840 |
| 7 | Red gram | 2995 (25 %) | 3975 | 735 (37 %) | 1175 |

***Effect of intercrops on tree growth***

The results showed that there was a difference in height increment in the tree when grown along with intercrops than the trees were grown alone. Among the different tree crop combinations, maximum height increment in tree was recorded under red gram (2.17 m) and the lowest increment was reported under sesame (1.98 m). The height increment (1.8 m) in control (tree alone) is lower than all other treatments. Khistaria

**Table 5:** Effect of intercrops on Height(m), basal diameter and Diameter at breast height (cm) of *Eucalyptus* clone

| Sl. No. | Treatments | Height (m) | | | Basal diameter (cm) | | | Diameter at breast height (cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Before sowing | After harvesting | Incre-ment | Before sowing | After harvesting | Incre-ment | Before sowing | After harvesting | Increment |
| 1 | Pearl millet | 4.46 | 6.51 | 2.05 | 4.84 | 7.11 | 2.27 | 3.84 | 5.75 | 1.91 |
| 2 | Sorghum | 4.48 | 6.47 | 1.99 | 4.78 | 7.04 | 2.26 | 3.79 | 5.68 | 1.89 |
| 3 | Maize | 4.44 | 6.43 | 1.99 | 4.74 | 6.98 | 2.24 | 3.76 | 5.65 | 1.89 |
| 4 | Sesame | 4.48 | 6.46 | 1.98 | 4.88 | 7.04 | 2.16 | 3.85 | 5.73 | 1.88 |
| 5 | Small onion | 4.42 | 6.52 | 2.10 | 4.83 | 7.13 | 2.30 | 3.88 | 5.79 | 1.91 |
| 6 | Green gram | 4.42 | 6.58 | 2.16 | 4.92 | 7.24 | 2.32 | 3.91 | 5.83 | 1.92 |
| 7 | Red gram | 4.45 | 6.62 | 2.17 | 4.95 | 7.29 | 2.34 | 3.93 | 5.86 | 1.93 |
| 8 | Tree alone | 4.43 | 6.23 | 1.80 | 4.85 | 6.87 | 2.02 | 3.83 | 5.58 | 1.75 |

**Table 6.** Effect of intercrops on the volume growth of Eucalyptus clone

| Sl. No. | Treatments | Volume ($m^3$ $ha^{-1}$) | | |
|---|---|---|---|---|
| | | Before sowing of intercrops | After harvesting of intercrops | Increment |
| 1 | Pearl millet | 6.88 | 22.53 | 15.64 |
| 2 | Sorghum | 6.73 | 21.85 | 15.11 |
| 3 | Maize | 6.57 | 21.48 | 14.91 |
| 4 | Sesame | 6.95 | 22.20 | 15.25 |
| 5 | Small onion | 6.96 | 22.88 | 15.91 |
| 6 | Green gram | 7.07 | 23.41 | 16.33 |
| 7 | Red gram | 7.19 | 23.79 | 16.60 |
| 8 | Tree alone | 6.80 | 20.30 | 13.50 |

et al. (1998) stated that the intercrops have increased the height and vigorous growth of *B. vulgaris* in agroforestry system. Eucalyptus tree growth was better when grown with blackgram than when grown alone (Pal et al., 2000). From the findings it was noticed that a difference in tree basal diameter and dbh among treatments after harvesting the intercrops was observed. Among the different tree-crop combinations, the maximum basal diameter and dbh increment in tree crop was recorded under red gram (2.34 cm and 1.93 cm) and the minimum was found under sesame (2.16 cm and 1.88 cm). The basal diameter and dbh increment in control (tree alone) is lower than all other treatments (2.02 cm and 1.75 cm) respectively . Samraj et al. (1982) they reported

that when the crops like potato, scented geranium and grass-legume mixture raised in the interspaces of *Eucalyptus globulus*, compared to monoculture, trees in the potato plots registered an increase of 28 per cent in diameter at breast height.

The tree volume varied from 6.57 $m^3$ $ha^{-1}$ to 7.19 $m^3$ $ha^{-1}$ and 20.30 $m^3$ $ha^{-1}$ to 23.79 $m^3$ $ha^{-1}$ before sowing and after harvesting of the intercrops respectively. The results showed that there was a significant difference in volume increment in the tree after harvest of intercrops. Among the different tree-crop combinations, maximum volume increment in tree was recorded under red gram (16.60 $m^3$ $ha^{-1}$) and the minimum volume increment was reported under maize (14.91 $m^3$ $ha^{-1}$). The volume increment (13.50 $m^3$ $ha^{-1}$) in control (tree alone) is lower than all other treatments. Chaudhry et al. (2003) they observed wood yield was 29.4 per cent higher in intercropped stand compared to that of pure stand of poplar.

## CONCLUSION

The trees were eight month old, the following agricultural and horticultural crops *viz.*, pearl millet, sorghum, maize, sesame, small onion, green gram and red gram were raised as intercrops. Separate plots were maintained for *Eucalyptus clone* as well as the intercrops for comparison. The highest reduction in plant height at all stages *viz.*, 30 DAS, 60 DAS and at harvest was observed in maize and lowest reduction in plant height was reported in small onion. In collar diameter highest reduction in sesame and lowest reduction in sorghum was reported at all the three stages. Among the intercrops tried, the highest reduction in dry matter production was recorded in sesame and small onion, lowest was in sorghum. With respect to the yield of intercrops, the highest reduction in yield was found in maize and the lowest was in green gram. The highest crop equivalent yield was found in red gram and the lowest in maize. The results reported that the percent light available to intercrops during morning varied from 50% to 57% and during afternoon it ranged from 79 % to 84 %. In general, red gram had greater beneficial effect in increasing the tree volume followed by green gram.

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