*Journal of Environmental Sciences* Vol. 11, No. 4, pp. 462—467, 1999

ISSN 1001—0742
CN11—2725/X

**Article ID**: 1001-0742(1999)04-0462-06

# Competition of the active roots of *Cassia siamea* Lam. and *Zea mays* L. (cv. Katumani Composite B) in an alley cropping trial in semi-arid Kenya

G. O. Umaya[1], J. N. M. Macharia[1], J. C. Onyango[1], C. J. Stigter[2], C. L. Coulson[1]

(1. Department of Botany, University of Nairobi, P. O. Box 30197, Kenya; 2. Department of Meteorology, Wageningen Agricultural University, Duivendaal 2, 6701 AP Wageningen, The Netherlands)

**Abstract**: A study on root competition in alley cropping was carried out in an agroforestry system, involving *Cassia siamea* Lam. and maize (*Zea mays* L. cv. Katumani composite B). The existence and intensity of root competition in the top soil as manifested by the distribution of the active roots of cassia and maize, in space and time, was assessed. The root length density of maize was far greater than that of cassia in the upper 10 cm, implying that cassia was not competing with maize for water and/or nutrients at that depth. However, at maize crop tasselling and grain filling stages there was a marked overlap of roots of the two plants at lower depths (20—50 cm). This varied with distance from the cassia hedge in a way that there was a tendency for highest overlap near middle maize rows. This partly explained observed yield differences. Therefore cassia may not be a suitable choice for alley cropping with maize under semi-arid conditions on non-sloping land, unless most of its active roots can be properly managed to absorb resources below the feeding rhizosphere of the active maize roots.

**Key words**: agroforestry; *Cassia siamea*; *Zea mays*; root competition; semi arid

**CLC number**: S181 **Document code**: A

## Introduction

One of the major drawbacks of alley cropping systems in semi-arid low fertility conditions is competition for available water and nutrients. Competition is to be expected if the tree and the crop have overlapping active root systems in space and time. A knowledge of the spatial distribution of roots is essential to assess the location of water and mineral nutrients available to the plant (Mengel, 1974; Tardieu, 1988; Pages, 1989). If alley crops are to be suitably selected and managed optimally, the distribution of roots of the associated components in space and time must be understood (Huck, 1983). Thus, root length per volume of soil is a relevant parameter with respect to water and nutrient uptake (Böhm, 1979; Anderson, 1989; Van Noordwijk, 1989).

Relatively more research has been carried out on the above ground parts of plants than on the below ground components. This is because studies of plant root systems are expensive, labor intensive and time consuming (Böhm, 1979; Haynes, 1980). Separation of the living roots from the soil material and debris, and measuring root parameters is extremely difficult (Collins, 1987; Habib, 1988). Tree root systems present extra problems because of their size and number, and great depth. Thus, more emphasis has been put on crop shoot system, because they are easier to study. Comparatively very little is known about the distribution of roots in agroforestry systems because, in the past, the two disciplines, agriculture and forestry, were rarely combined. The distribution of the active roots of cassia and maize in an alley cropping system in relation to competition is the subject of this paper.

## 1 Materials and methods

### 1.1 Experimental site characterization

The field site was at Katumani Dryland Research Station in Machakos District, Kenya. It is in the sub-humid to semi-arid zone (1°3′S, 37°4′E, Altitude of 1560 m. a. s. l). The long-term average precipitation of 715 mm falls mainly in two seasons, "Long Rains", lasting from March to May, with an average of 265 mm, and the "Short Rains", from October to December, with an average of 245 mm. The mean annual temperature is 19.2℃ with the lowest monthly average in August (17.1℃) and the highest in March (21.3℃; ICRAF, 1988).

The predominant soil type is a well-drained dark brown to red brown sandy clay (Nadar, 1984). It belongs to the class Luvisols according to FAO category (Ministry of Economic Planning and Development, 1981), order Alfisols and suborder Ustalfs (US Soil Taxonomy), as cited by ICRAF (1988).

### 1.2 Layout of the experiment

There were six experimental blocks, each 10m by 3.6m. *Cassia siamea* Lam. hedgerows had been established in 3 out of the 6 blocks, while the 3 remaining blocks had no cassia hedgerows. Blocks with or without cassia hedgerows are referred to as agroforestry system (AF), and non agroforestry system (NAF) blocks respectively. Within each AF block there were 2 established cassia hedges, 3.6m apart. The within-row spacing of cassia was 0.25m. In between the two cassia hedges, three rows of *Zea mays* L. (cv Katumani Composite B) were sown 0.3m apart, within rows that were 0.9m apart. The three maize rows in the AF blocks were designated as follows: $R_{1AF}$ = maize row planted next to the cassia hedgerow on the eastern side of the experimental layout; $R_{2AF}$ = maize row planted in the middle; $R_{3AF}$ = maize row planted next to the other cassia hedgerow on the western side of the experimental layout.

In the NAF blocks, each tree row (hedge) was replaced by a row of maize, giving a total of five maize rows. Only 3 rows in the NAF blocks, which corresponded to the other 3 rows, $R_{1AF}$, $R_{2AF}$ and $R_{3AF}$ in the AF blocks, were considered for the purpose of this experiment. The 3 corresponding rows in the NAF blocks were designated as $R_{1NAF}$, $R_{2NAF}$ and $R_{3NAF}$.

Maize was planted for two successive seasons. Maize for the first experiment was planted during the short rainy season of October 1989—January 1990. Maize for the second experiment was planted during the long rainy season of March—June 1990. The alleys were hand hoed and cassia hedges were lopped to 50 cm height before planting maize. Prunings were incorporated into the soil.

A two-factor factorial experiment was used in the agroforestry system. There were 3 replicates. One of the factors investigated was the effect of distance from the cassia hedgerow on the distribution of active roots of cassia and maize in the alley. The distance factor was assessed at four levels, where each level was a specific distance from the cassia hedgerow towards the alley. The four levels of distance were: Distance 1 ($D_1$) = 45 cm from the cassia hedgerow towards the alley; Distance 2 ($D_2$) = 90 cm from the cassia hedgerow; Distance 3 ($D_3$) = 135 cm from the cassia hedgerow; Distance 4 ($D_4$) = 180 cm from the cassia hedgerow. Distance 2 and 4 lay within the maize rows, $D_1$ in the middle between cassia hedge on the eastern side and maize row, and $D_3$ in the middle between maize rows.

The other factor was depth of soil layer from the surface, it had 3 levels: Depth 0—10 cm (L1) from the surface; Depth 20—30 cm ($L_2$) from the surface, Depth 40—50 cm ($L_3$) from the surface. All the three levels of depth were measured over all levels of distance. Therefore in total there were twelve factorial combinations ($D_1L_1$ to $D_4L_3$), resulting from the 4 by 3 factorial experimental arrangement.

An auger (corer) was used to remove 385 $cm^3$ of soil core containing both roots of cassia and maize from these positions. The auger was a hand driven type consisting of a 15 cm steel tube with a serrated cutting edge mounted on a 100 cm shaft with a plunger to remove the core (Böhm, 1979). It had an internal diameter of 7.0 cm, and the soil was extracted in 10 cm segments. Cores were removed in between two maize plants within a row. Sampling frequency was two weeks, commencing approximately four weeks after the emergence of maize seedlings and continuing upto when maize matured. At each particular sampling time, thirty six soil-root cores were removed and each placed in a labelled 10 liter plastic bucket.

### 1.3 Sampling, washing, separating the roots and data analysis

A modified version of the Gottingen method, described by Böhm (Böhm, 1979), was used for washing the roots. This operation was sped up by using water flowing at a constant low pressure through hose pipes connected to a nearby water tank. Washed roots were floated in dissecting basins. Then using a pair of forceps (Schuurman, 1971; Böhm, 1979) and a fine brush with pointed tip, roots were separated from the organic matter and put in clear plastic petri-dishes. Cassia roots were separated from maize by color, *Cassia siamea* roots are black (Ball, 1985; Umaya, 1991) while maize roots are usually white.

Color, turgidity and flexibility were used as criteria of separating the live roots from the dead (Berish, 1988; Anderson, 1989). Roots which had diameters less than or equal to 0.5 mm, and those roots with diameters greater than 0.5 mm but less than or equal to 1.5 mm were taken to represent very fine and fine roots respectively. The method suggested by Tennant (Tennant, 1975) was used to estimate the length of roots with diameter less than or equal to 1.5 mm. The accuracy of Tennant's method was checked by comparing with values obtained by measuring root lengths using a linear vernier microscope (Griffin & George Ltd. U.K). Analyses of variance were done on the root length data. The variances of the raw root length data were heterogeneous and thus logarithmically transformed (Little, 1978; Steel, 1981; Gomez, 1984). The heterogeneity was due to the functional relationship between the means and the standard deviations of the treatments (Umaya, 1991). A number of cases concerning transformation of raw root data in order to achieve variance homogeneity have been reported (Berish, 1988; Sylvia, 1990).

## 2 Results

Analyses of variance showed that depth, but not distance, significantly ($p \leqslant 0.01$) influenced distribution of cassia root length during the two crop seasons. There was no significant interaction between distance and depth. Cassia root length in $L_2$ and $L_3$ were statistically the same at any particular sampling time during the two seasons. However, the length of cassia roots in $L_1$was significantly ($p \leqslant 0.01$) less than the length at either $L_2$ or $L_3$ throughout the seasons. Analyses of variance also showed that distance and depth concurrently affected the distribution of the length of maize roots only at 59 days after sowing (DAS). Distance alone influenced the maize root distribution only at 89 DAS during the same crop season. During the second season, distance and depth together affected the distribution of maize root length in the agroforestry at 36 DAS, again only once, as in the previous season. Distance alone affected the root distribution at 56, 84 and 98 DAS.

Distributions of maize and cassia root lengths at reproductive and maturity stages of growth during the two seasons are shown in Fig. 1, 2, 3 and 4 respectively. A general trend showed that there was little overlap between the roots of cassia and maize in $L_1$. However, relatively more overlap of the root systems of the two plants was observed in $L_2$ and $L_3$ soil layers. The apparent greater root overlap at these depths 20—30 cm and 40—50 cm was consistent throughout the two crop seasons, with little exception, largely dúe to the little amounts of cassia roots in the top layer. Competition may be seen as high to relatively high when (relatively) high maize root density is found in combination with (relatively) high overlap with cassia roots. For a combination of the Fig. 1, 2, 3 and 4 this leads to a tendency of higher competition for the combination $D_3/D_4$ compared to the combination $D_1/D_2$ for these depth layers $L_2/L_3$.

## 3 Discussion

Depth of soil layer influenced the distribution of cassia root length in that the density in the top 0—10 cm soil layer was comparatively sparser than the distribution within other depths. Similar patterns of cassia root distribution have been reported (Balasubramanian, 1986). Kang *et al*. (Kang, 1981) also noted that *Luecaena leucocephala* has few roots distributed in the top 0—20 cm

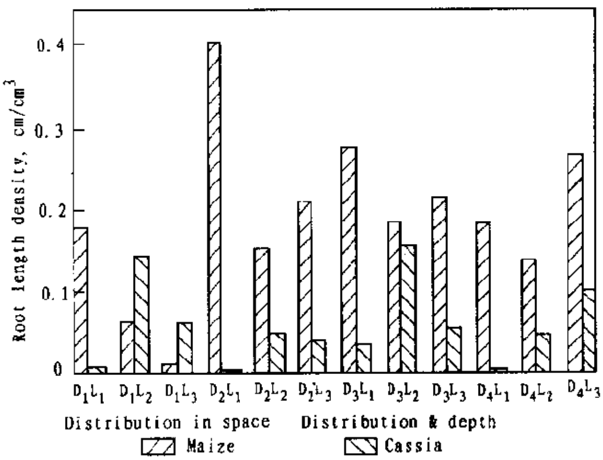


Fig. 1 Distribution of maize and cassia root length at silking and grain filling (59 DAS) stage, during 1st crop season 1989/90

Distances: $D_1$. in the middle between cassia and maize; $D_2$. within maize bordering cassia; $D_3$. in the middle between maize rows; $D_4$. within middle maize rows. Depths: $L_1$. 0—10 cm; $L_2$. 20—30cm; $L_3$. 40—50 cm

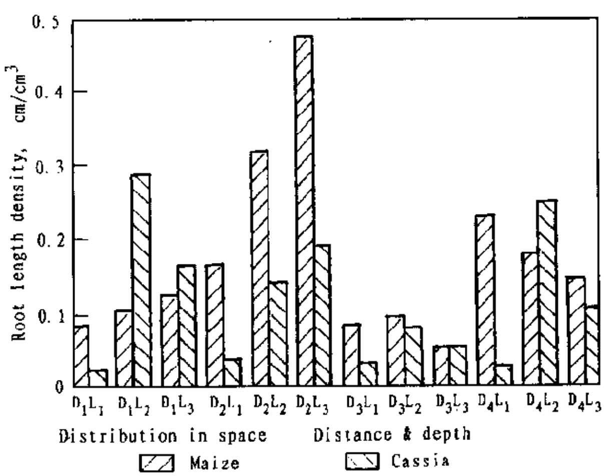


Fig.2 Distribution of maize and cassia root length at maturity (89 DAS) stage, during 1st crop season 1989/90

For D and L specifications, see Fig. 1

soil space. Probably cassia grows more roots in the deeper wetter soil horizons as an inherent strategy to avoid water stress.

Age and stage of development of maize, depth of soil layer and relative position to the maize row were found to influence the distribution of maize root length in space and time. On average, more maize root length was found in the upper 0—10 cm layer than in either soil depths 20—30 cm or 40—50 cm. It has been reported that maize root length is abundantly distributed in the top soil space (Follet, 1974; Aina, 1986; Anderson, 1987; Junying, 1988).

The overlapping of the roots at greater soil depths would possibly have led to competition for

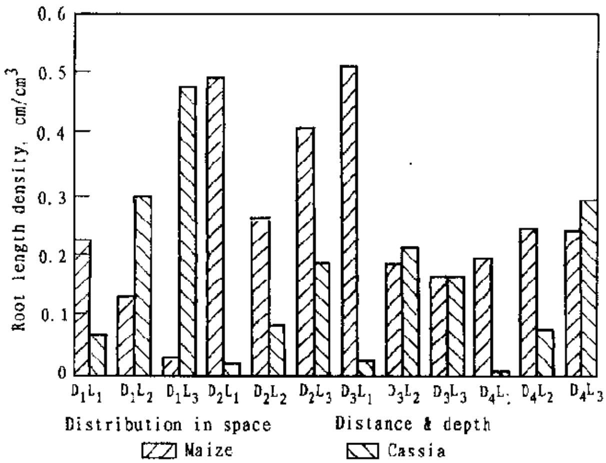


Fig. 3 Distribution of maize and cassia root length at silking (56 DAS) stage during 2nd crop season 1990
For D and L specifications, see Fig. 1

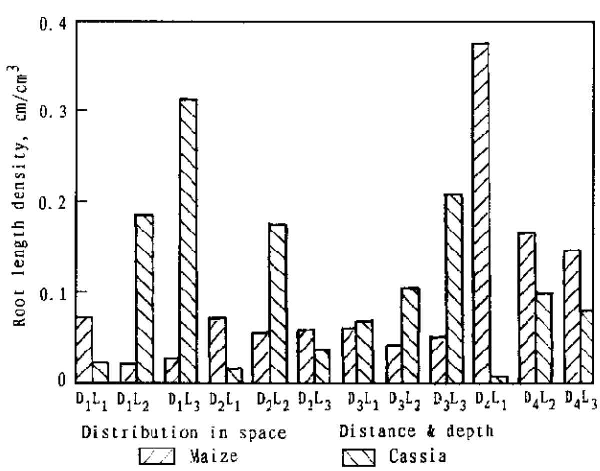


Fig. 4 Distribution of maize and cassia root length at maturity (98 DAS) stage, during 2nd crop season 1990
For D and L specifications, see Fig. 1

water between cassia and maize, had the rainfall amount been below the average requirement for successful growth of the Katumani maize variety, and certainly led to nutrient competition under our condition (Mungai, 1992). The observed pattern in overlapping, with the tendency of relatively higher competition further away from the hedge, at least partly explains the lower yields observed in the middle rows of this alley cropping system (Mungai, 1992).

# 4 Conclusion

*Cassia siamea* Lam. is not a suitable alley tree/shrub to be intercropped with *Zea mays* L. under semi-arid condition on non-sloping land under the pruning regime applied.

**Acknowledgements:** This work was financially supported by a scholarship awarded by the

University of Nairobi, Kenya. Partial aid from the project Traditional Techniques of Microclimate Improvement (TTMI) funded by the Government of The Netherlands is also appreciated. The co-operation received during the study from the Kenya Forestry Research Institute (KEFRI) and the International Center for Research in Agroforestry (ICRAF) is gratefully acknowledged.

## References:


Aina P O, Fapohunda H O, 1986. Plant and Soil [J], 94: 257—265.

Anderson E L, 1987. Agron J [J], 79: 544—549.

Anderson J M, Ingram J S, 1989. Tropical soil biology and fertility: a handbook of methods [M]. Wallingford: CAB International. 59—69.

Balasubramanian V, Sekayange L, 1986. Alley cropping: root distribution pattern of three alley shrubs at Kagasa, Rwanda [R]. ISAR-IITA FSR PROJECT. 1—2.

Ball B, 1985. Root distribution and nutrient cycling of some tree- shrubs suitable for cropping in humid tropics [D]. Canada: University of Guelph. M.Sc thesis.

Berish C W, Wewll J J, 1988. Plant and Soil [J], 106:73—84.

Böhm W, 1979. Methods of studying root systems [M]. New York: Springer-Verlag.

Collins R P, Gregory P J, Rowse H R *et al.*, 1987. Plant and Soil [J], 103: 277—280.

Follet R F, Allmaras R R, Reichman G A, 1974. Agron J [J], 66:288—292.

Gomez A K, Gomez A A, 1984. Statistical procedures for agricultural experiments [M]. Toronto: John Wiley and Sons.

Habib R, 1988. Plant and Soil [J], 108: 267—274.

Haynes R J, 1980. Adv Agron [J], 33: 227—262.

Huch M G, 1983. Plant research and agroforestry [M] (Ed. by Huxley P A). Nairobi: ICRAF Press.

ICRAF, 1988. ICRAF field station Machakos, Kenya, Part I [M]. General Account. Nairobi: ICRAF Press.

Junying D, Yujing E, Wellian G, 1988. Acta Agron Sin [J], 14:310—314.

Kang B R, Wilaon G F, Sipkens L, 1981. Plant and Soil [J], 63: 165—179.

Little T M, Hills J F, 1978. Agricultural experimentation, design and analysis [M]. Toronto: John Wiley & Sons.

Mengel D B, Barber S A, 1974. Agron J [J], 66: 341—344.

Ministry of Economic Planning and Development, 1981. Machakos integrated development programme, Kenya [C]. Volume 3.

Mungai D M, 1992. A micrometeorological investigation of yield differences in alley cropping trials in the semi-arid areas of Machakos District, Kenya [D]. University of Nairobi, Kenya, PhD thesis.

Nadar H M, 1984. East Afr Agr for J Special Issue [J], 44: 52—56.

Pages L, Jordan M O, Picard D, 1989. Plant and Soil [J], 119: 147— 151.

Schuurman J J, Goedewaagen M A J, 1971. Methods for the examination of root systems and roots [C]. Wageningen: Center for Agricultural Publishing and Documentation.

Steel R G D, Torrie J H, 1981. Principles and procedures of statistics. A biometric approach [M]. London: McGraw-Hill Book Co.

Sylvia D M, Neal L H, 1990. New Phytol [J], 115: 303—310.

Tardieu F, 1988. Plant and Soil [J], 107: 259—266.

Tennant D, 1975. J Ecol [J], 63: 995—1001.

Umaya G O, 1991. The spatial and temporal distribution of the active roots of *Cassia siamea* Lam. and *Zea mays* L. (cv,. Katumani composite B) in alley cropping under semi-arid conditions in Machakos district, Kenya[D]. University of Nairobi, Kenya, M.Sc thesis.

Van Noordwijk M, 1989. Methodology in soil-K research [C], Proc. 20th collq. IPI, Baden Bei Wien, 263—281.


(Received for review October 6, 1998. Accepted December 14, 1998)