4 The competition aspect of alley cropping

4.1 Introduction

Alley cropping is recommended as a strategy to increase productivity. The system aims to integrate soil amelioration with the production of wood and fodder by the production of cash crops or pastures between rows of trees that are periodically pruned. The prunings can be used as a fodder, or returned to the soil as a mulch or green manure in order to improve soil fertility.

The cultivation of these different crops in close proximity may entail some measure of competition between the crops. Shading of the alley crops is expected, as well as competition for nutrients and water. Especially in moisture deficient areas, the availability of and competition for water is an aspect to be considered when designing an alley cropping system.

4.1.1 Competition for light

Plants compete for the light that is available at a specific moment to be intercepted for photosynthesis. Light cannot be "accumulated" and stored, but that which is available at a given moment can be intercepted and used, or be lost. Light interception is influenced by factors such as the vertical distribution of the leaf surface area, leaf form and size, spatial arrangement of leaves and the number of leaves/lateral branches. More light will be intercepted by taller, fast growing plants. Other characteristics contributing towards successful light interception include C4-photosynthesis, creeping growth form, reduction in dark respiration and a high leaf:stem ratio (Trenbath, 1976, as cited by Van den Berg, 1987.)

The pruning of alley crops has the dual purpose of obtaining and stimulating biomass production, as well as reducing the shading effect of the trees on crops grown in the alleys. Based on light interception data, it has been inferred that the shorter the crops grown within the alley, the more frequent the need to prune in order to reduce the level of shading (Kang, Grimme & Lawson, 1985). Pruning of the alley trees/shrubs is, therefore, not only necessary to provide nutrient and dry matter for mulching the crop but also to reduce the competition for light.

A high degree of shading associated with leucaena and closer inter-hedgerow spacing resulted in corresponding decreases in crop yield. Larger amounts of hedgerow biomass production were found to be associated with significant decreases in crop yields owing to increased hedgerow shading (Lawson & Kang, 1990; Corlett, Black, Ong & Monteith, 1992). Competition in alley cropping is not only from the trees, but a mutual phenomenon. In a newly established plot, maize had a significant negative influence on the growth and yield of leucaena. At full maize canopy development, the photosynthetic active radiance (PAR) reaching the leucaena was reduced in all treatments, resulting in a 75% yield reduction in leucaena (Jeanes, Gutteridge & Shelton, 1996).

4.1.2 Competition for water

Competition for water actually refers to the competition between root systems. It is influenced by light, as shady conditions will induce less developed root systems. In the same way, drier conditions will result in a poorer plant that will not be able to compete sufficiently for light. With mixed cultivation, the soil profile is utilised more effectively (Trenbath, 1984, as cited by Van den Berg, 1987).

Through the phenomenon of "mutual avoidance", the deeper soil layers will increasingly be utilised by roots as population pressure increases. Plants with a deep root system will grow even deeper when cropped with plants with a shallower root system. The type of root also plays a role, as will the length of the root and the presence of root hairs (Mengel & Steffens, 1985, as cited by Van den Berg, 1987.)

In alley cropping, the deeper root system of leucaena appears to extract more soil moisture from the lower horisons (>50 cm depth) than maize, which taps the surface layers (<50 cm depth), and thereby reduces their competition for moisture. The repeated application of leucaena prunings also increased soil moisture retention capacity (Kang, Grimme & Lawson, 1985; Lawson & Kang, 1990) as well as increased yields (Gicheru, Gachene & Biamah, 1998). These results were obtained in more tropical environments. McIntyre, Riha & Ong (1997) noted that there may be little opportunity for increasing water uptake in hedgerow intercropping systems in semi-arid environments. Their results indicated that annual crops in monoculture took up water at similar rates and depths as the multistem hedge monoculture and intercropped systems. There was no evidence that root density restricted water uptake in the surface 0.45 m in any of the treatments and there was no increase in uptake below 0.45 m in intercropped treatments compared to monocropping systems

Szott, Palm & Sanchez (1991) found that yields generally increased with distance from hedges, suggesting that below-ground competition for water and nutrients reduce crop yields near the hedges. Supporting this, under water-limiting conditions, alley cropping was found to be detrimental to crop yield because competition of the trees for water outweighed the likely soil fertility or crop yield benefits (Govindarajan, Rao, Mathuva & Nair, 1996).

As part of an evaluation of the applicability of alley cropping in semi-arid South Africa, the possible competitive effects in an alley cropping system were investigated, with specific reference to water availability and light interception.

4.2 Materials and methods

An alley cropping field experiment was conducted on the Hatfield Experimental Farm of the University of Pretoria (Table 1). The study was laid out in a 2x3x3 factorial randomized complete block design with five replications, involving two alley widths (3m and 6m), three pruning treatments (Table 2), and a split plot for three alley crops (maize, grain sorghum, fodder sorghum). Within-row spacing was 1 m. No statistical analysis was conducted, as the purpose of the investigation was to determine possible trends between the different observations.

An existing leucaena stand, planted at a tree density of 3 333 trees per ha, was used. Before the start of the 1996/1997 growing season, the trial was converted to an alley cropping trial by removing selected alternate rows. The plant populations of the 3m and 6m treatments were 3333 and 1667 trees per ha respectively. Pruning of the trees started in November 1996 and was repeated at fixed intervals thereafter, until April 1998 (Table 2). Except for the first harvest, yields of the different pruning treatments were applied as mulch between the alley crops. No irrigation or fertilizer was applied.

Table 1 **Site description on Hatfield Experimental Farm**

Locality	28°16'E, 25°45'S
Altitude	1372 m
Annual rainfall	709 mm
Av. max. and min. temp.	30°C (Jan), 2°C (Jun)
Soil type	Sandy clay (37 % clay), Hutton, homogenous to a depth of 0.66 m after which it becomes gravelly (MacVicar, Loxton, Lamprechts, Le Roux, De Villiers, Verster, Merryweather, Van Rooyen & Von M. Harmse, 1977).

Table 2 **Pruning treatments applied to *L. leucocephala* in alley cropping systems**

S1	Control - no pruning
S2	Pruning to a single stemmed tree (± every 6 weeks), clearing the undergrowth up to 1 m. In 1998 the interval was changed to 8 weeks.
S3	Hedgerow (± every 4 weeks), cut back to 1m height and ±0.75 m width

An additional leucaena stand was established in order to compare different row orientations. Single rows of leucaena seedlings were planted at two orientations: north-south and east-west, replicated three times. The taking of measurements commenced one year after planting.

4.2.1 Light measurement

Fractional interception of PAR by leucaena trees was measured across both alley widths with a Sunfleck Ceptometer (1991), three times a day at the beginning, in the middle and towards the end of the growing season.

4.2.1.1 *Alley cropping trial*

Measurements were taken in all three pruning treatments of both alley widths immediately north of a tree row, immediately south of the next tree row, and in the middle of the alley between the tree rows. These readings were taken above the tree canopy and below the tree canopy, above the alley crops

4.2.1.2 *Orientation trial*

Measurements were taken at set distances on both sides of the leucaena row at 0.5m, 1.0m, 1.5m, 2.0m and 3m. The trees were not pruned. Readings were taken above the tree canopy and on ground level.

4.2.2 *Water measurement*

Available water content (volumetric) across two alley widths was measured with a neutron water meter. Measurements were taken at depths of 0-20cm, 20-40 cm and 40-60cm.

4.2.2.1 *Alley cropping trial*

Galvanised steel pipes were inserted in the S3 treatment at 0.5m, 1.0m, 1.5m, 2.0m and 3m to the north of a tree row and at the same distances to the south of the next tree row in the 6m alley; and at 0.5m, 1.0m and 1.5m in the 3m alley. Measurements were taken at three depths (0-20 cm, 20-40 cm, 40-60 cm). A reference measurement was taken in dry soil before the onset of the rainy season, and monitoring began after a rainy episode in December 1997 on day 1,3,5 and 12 after a precipitation of 42 mm was received.

4.2.2.2 *Orientation trial*

Measurements were taken at set distances on both sides of the leucaena row at 0.5m, 1.0m, 1.5m, 2.0m and 3m, at three depths (0-20 cm, 20-40 cm, 40-60 cm).

4.3 Results and discussion

4.3.1 Light penetration

4.3.1.1 Alley cropping trial

Results are presented in figures 1-9:

December

In both alley widths light interception by S1 was the highest, translating into less PAR being available for the alley crops. This was especially pronounced in the 3m alley where a shading effect in the middle of the alley was observed in the morning and afternoon readings. The lowest FI was observed in the S2 treatments, where the single stems of the trees had the least restrictive effect on light penetration and light was let through the stems.

February

By February the effect of the developing tree canopies could be more strongly observed. In the 3m alley, S1 intercepted most of the available PAR. Light penetration was only restricted in the mornings in S2 and S3. In the 6m alley light penetration in S1 was especially restricted in the mornings, more so just to the north of tree rows. S2 and S3 were not restrictive.

April

By April, canopy closure in the 3m alley restricted almost all light penetration in S1, and intercepted a large fraction in S2 and S3 in the mornings. In the 6m alley, FI was low in S2 and S3 and in S1 light penetration was only relatively successful in the middle of the alley. At this stage of the season, more of the available PAR was intercepted to the south of the tree rows.

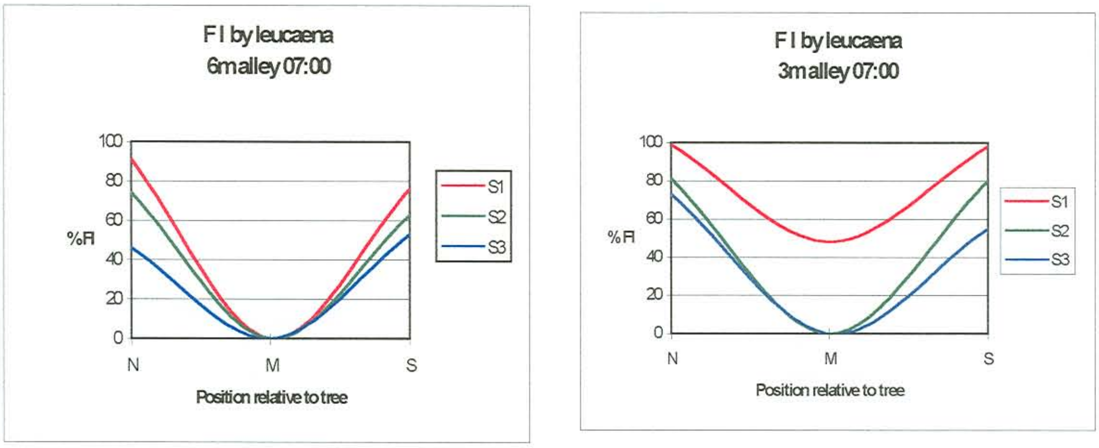


Fig. 1 Fractional interception by leucaena at 07:00 early in the growing season (December)

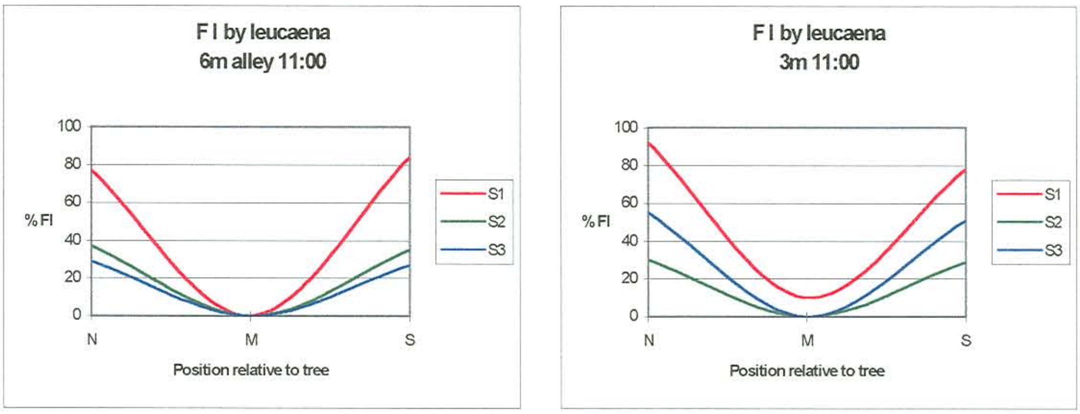


Fig. 2 Fractional interception by leucaena at 11:00 early in the growing season (December)

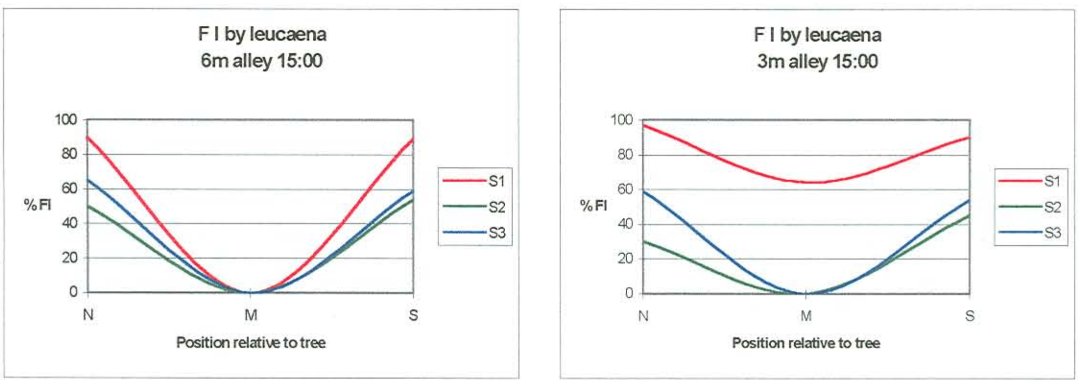


Fig. 3 Fractional interception by leucaena at 15:00 early in the growing season (December)

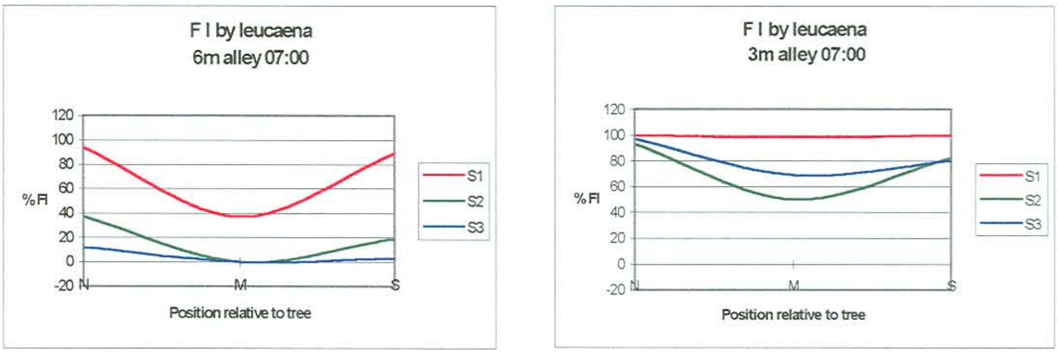


Fig. 4 Fractional interception by leucaena at 07:00 in the middle of the growing season (February)

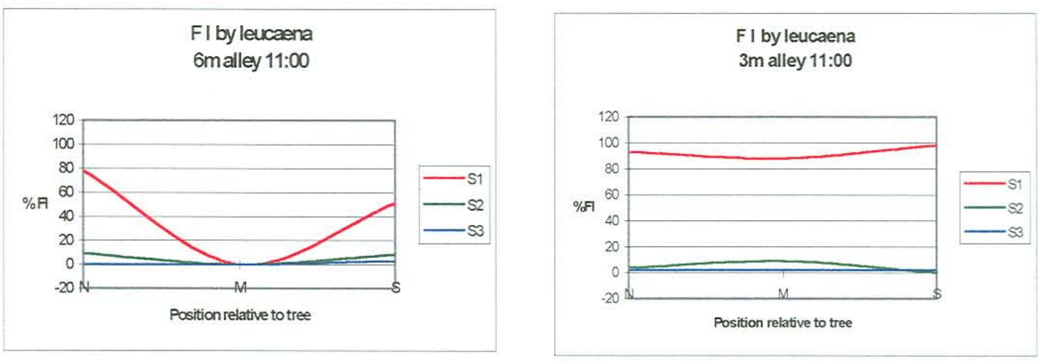


Fig. 5 Fractional interception by leucaena at 11:00 in the middle of the growing season (February)

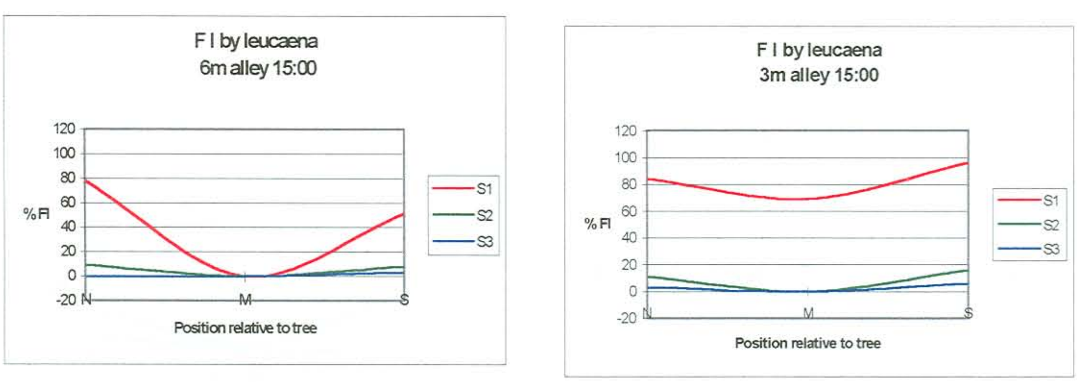


Fig. 6 Fractional interception by leucaena at 15:00 in the middle of the growing season (February)

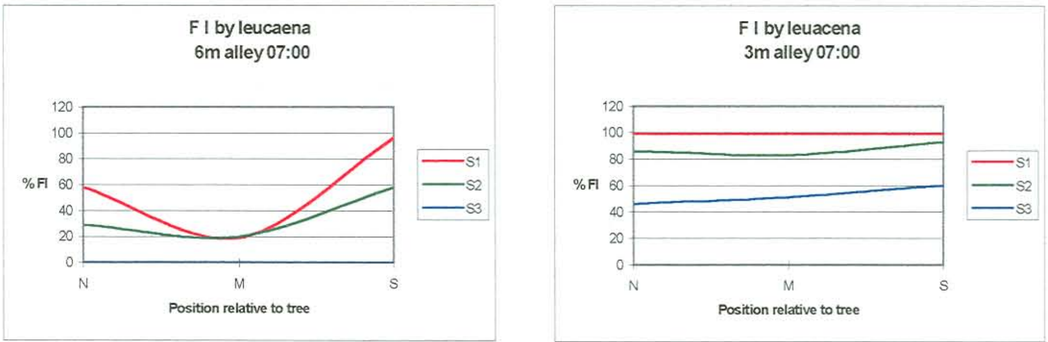


Fig. 7 Fractional interception by leucaena at 07:00 at the end of the growing season (April)

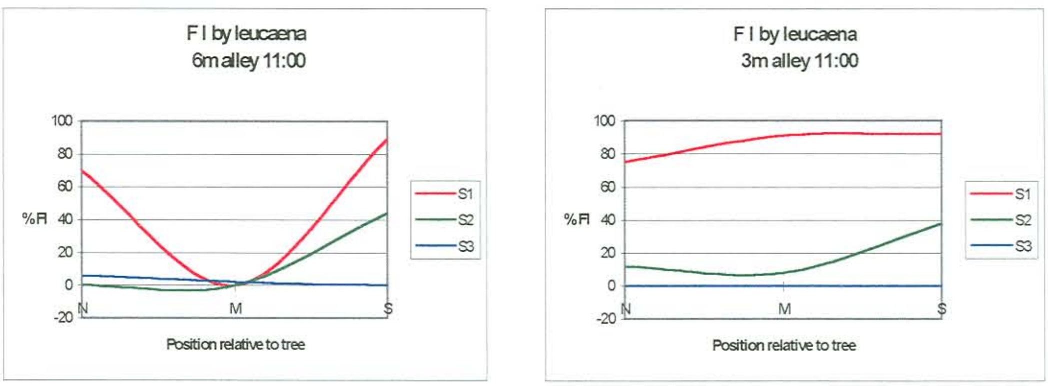


Fig. 8 Fractional interception by leucaena at 11:00 at the end of the growing season (April)

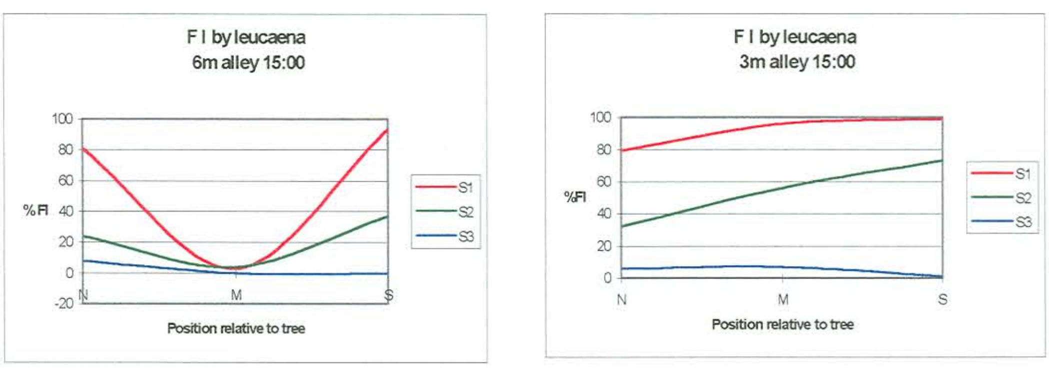


Fig. 9 Fractional interception by leucaena at 15:00 at the end of the growing season (April)

4.3.1.2 Orientation trial

Results are presented in figures 10-13:

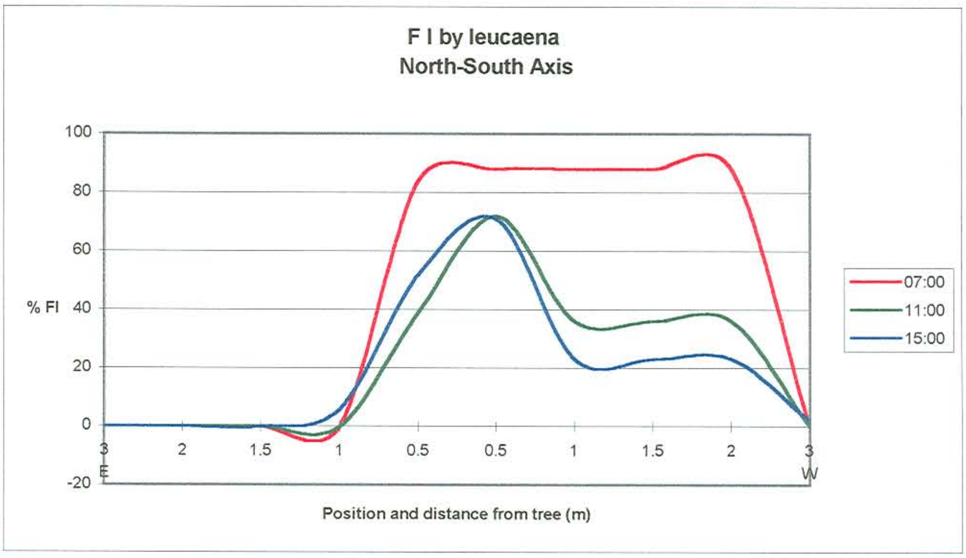


Fig. 10 **Fractional interception by leucaena in an north-south orientation (middle of growing season)**

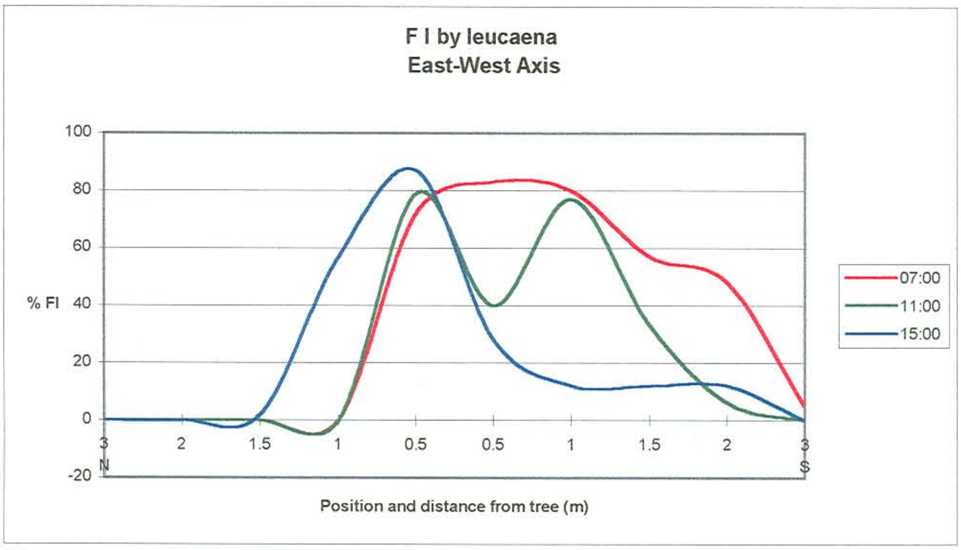


Fig. 11 **Fractional interception by leucaena in a east-west orientation (middle of growing season)**

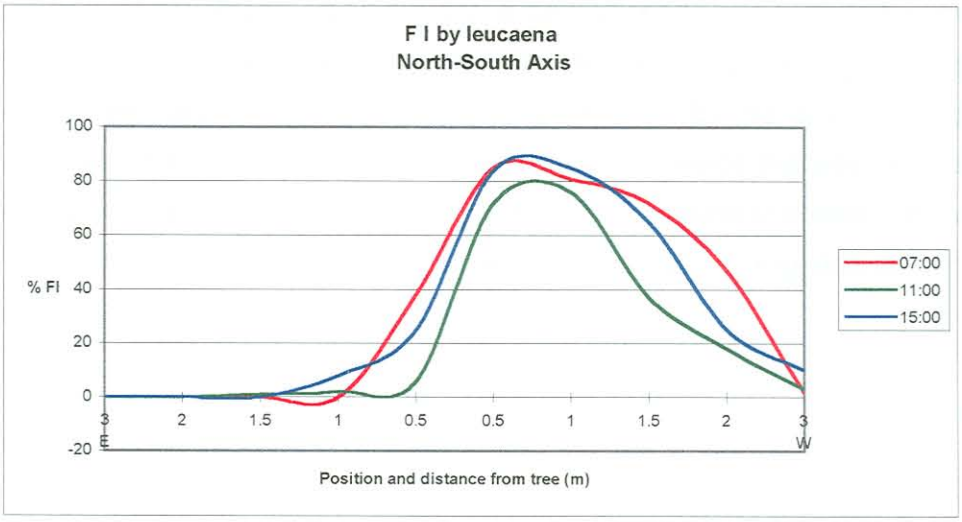


Fig. 12 **Fractional interception by leucaena in an north-south orientation (at the end of the growing season)**

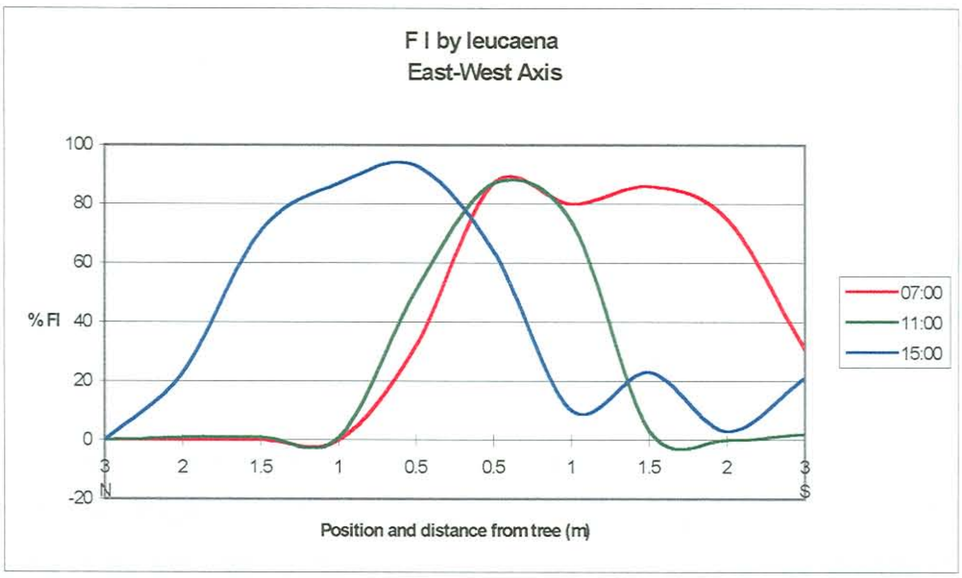


Fig. 13 **Fractional interception by leucaena in a east-west orientation (at the end of the growing season)**

Readings were not taken at the onset of the growing season, as the young leucaena did not yet cast any shade. By February, a definite shade effect could be observed, especially towards the west and south of the tree rows. The effect was the greatest in the mornings and lessened towards the afternoon. By the end of the growing season, the shade effect was still more pronounced towards the west and south of the tree rows. FI was very high throughout the day towards the west. In the east-west orientation, FI was high towards the south in the morning and at noon, and shifted towards the north in the afternoon.

4.3.2 Water availability

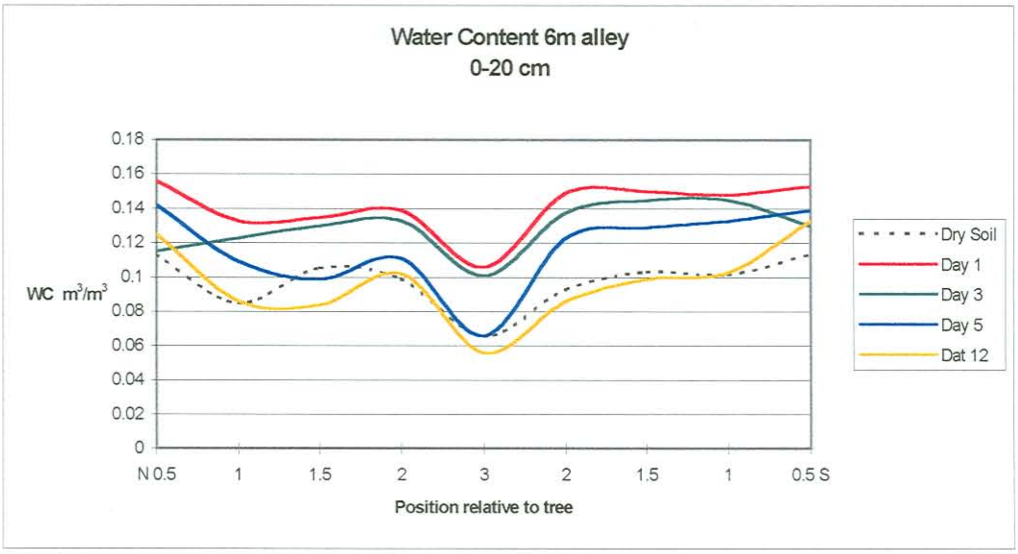
4.3.2.1 Alley cropping trial

Results are presented in figures 14-16:

Water content (WC) in the upper 20 cm of the 6m alley followed a fixed pattern. The highest WC was observed immediately next to the tree rows, declining slowly towards the middle and dipping at 3m from the tree. The distribution pattern stayed the same after the rainy episode, right through the drying-out period until 12 days after the rain. In the 3m alley, the distribution was more even.

The pattern was less pronounced at the 20-40 cm depth. Water content was higher in the dry soil than in the upper 20 cm, and after the drying-out period, was still higher by the same fraction. The increase in WC in the 3m alley was smaller.

At the 40-60 cm depth, the effect of the leucaena roots could be seen, where WC reached a minimum at 1.5m south and 1.0m north of the tree row. The effect of leucaena roots extended throughout the 3m alley with no marked change in WC at any distance from the trees.



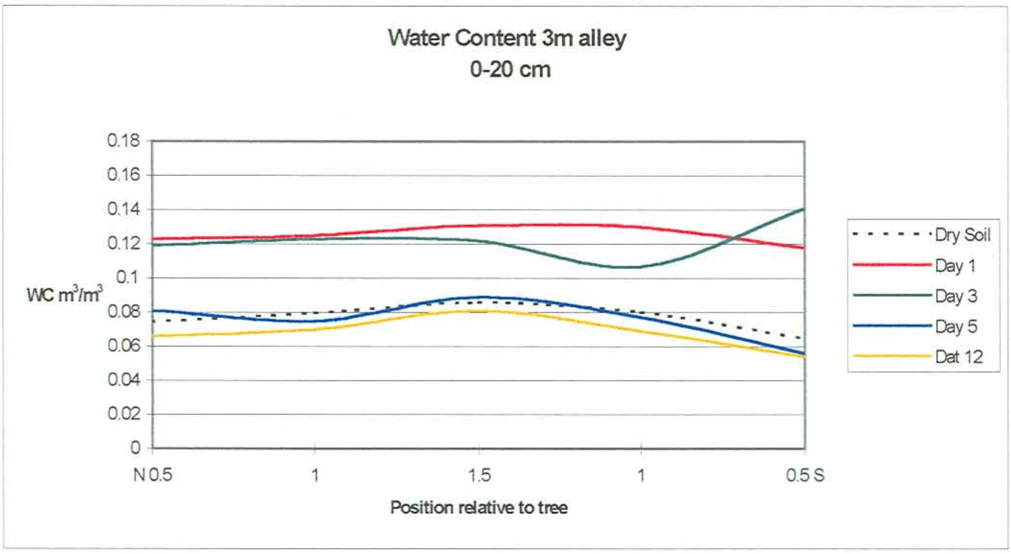
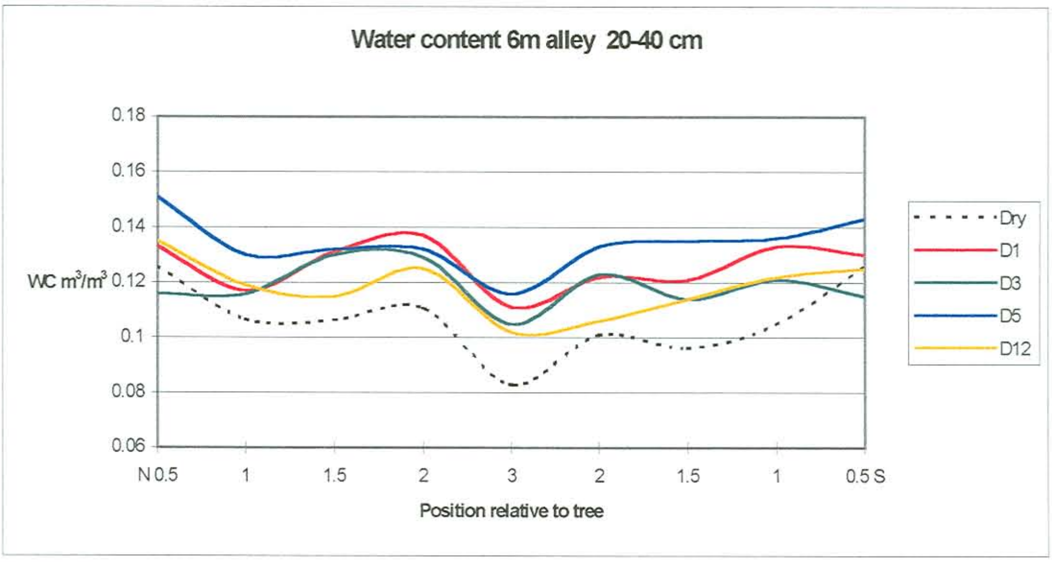


Fig. 14 **Comparative water content at a depth of 0-20cm : alley cropping trial**



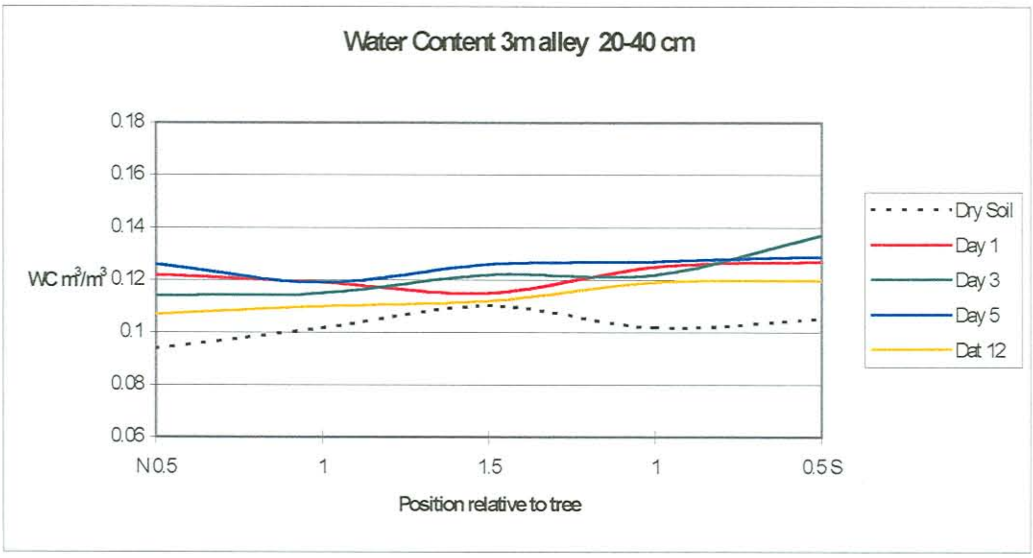
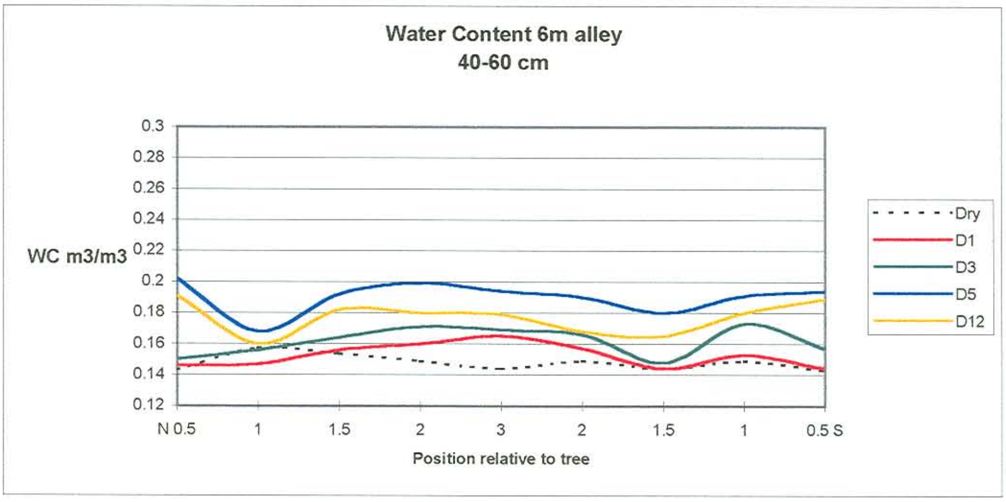


Fig. 15 Comparative water content at a depth of 20-40cm : alley cropping trial



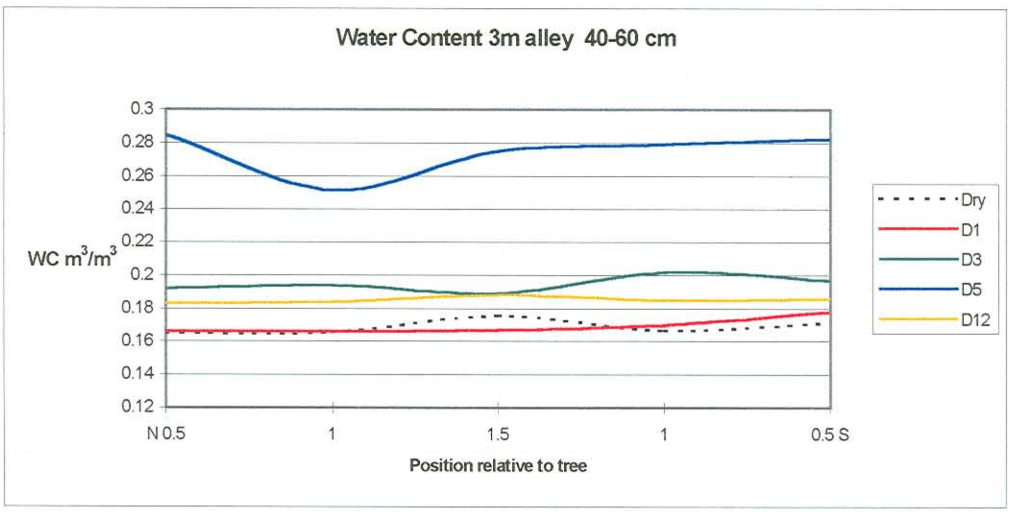
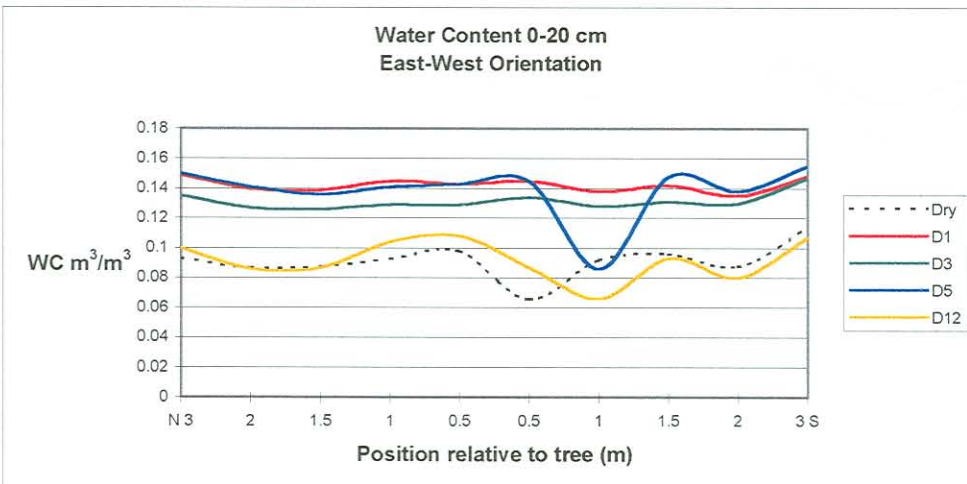


Fig. 16 **Comparative water content at a depth of 40-60cm : alley cropping trial**

4.3.2.2 Orientation trial

Results are presented in figures 17-19:



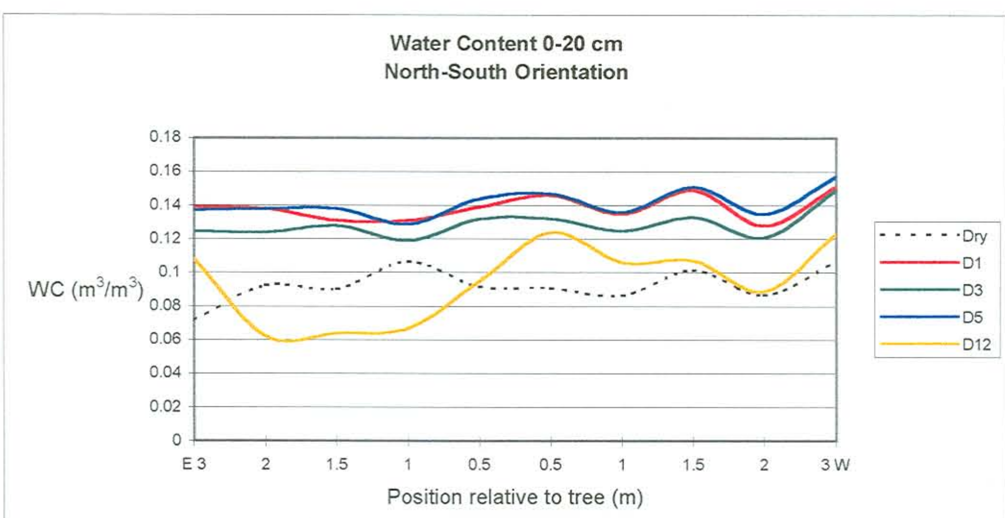
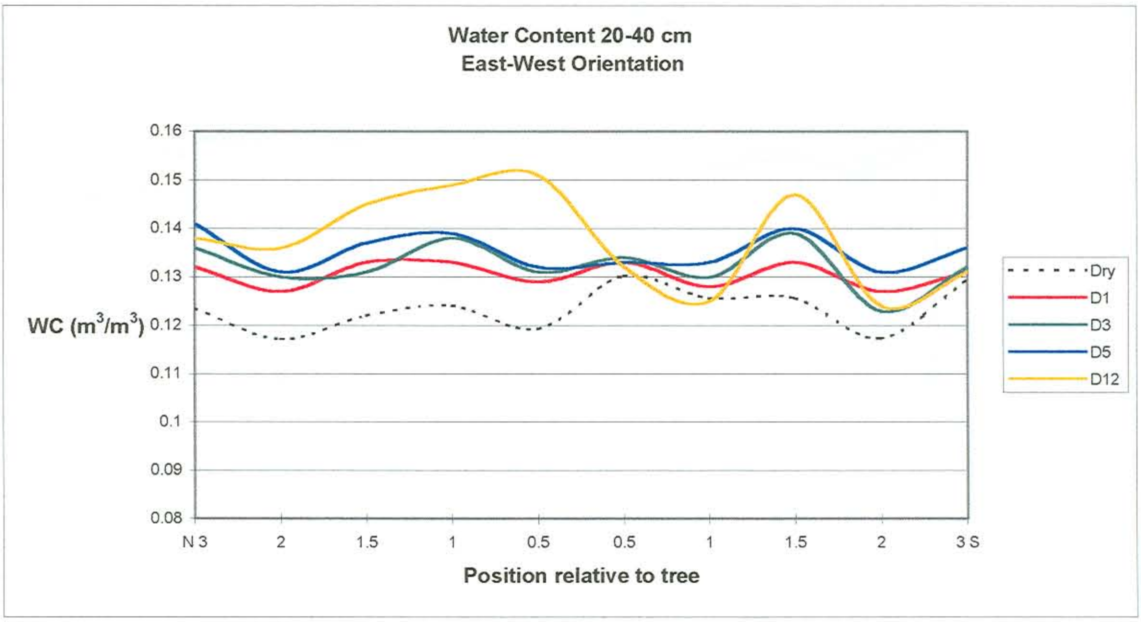


Fig. 17 Water content at a depth of 0-20cm : orientation trial



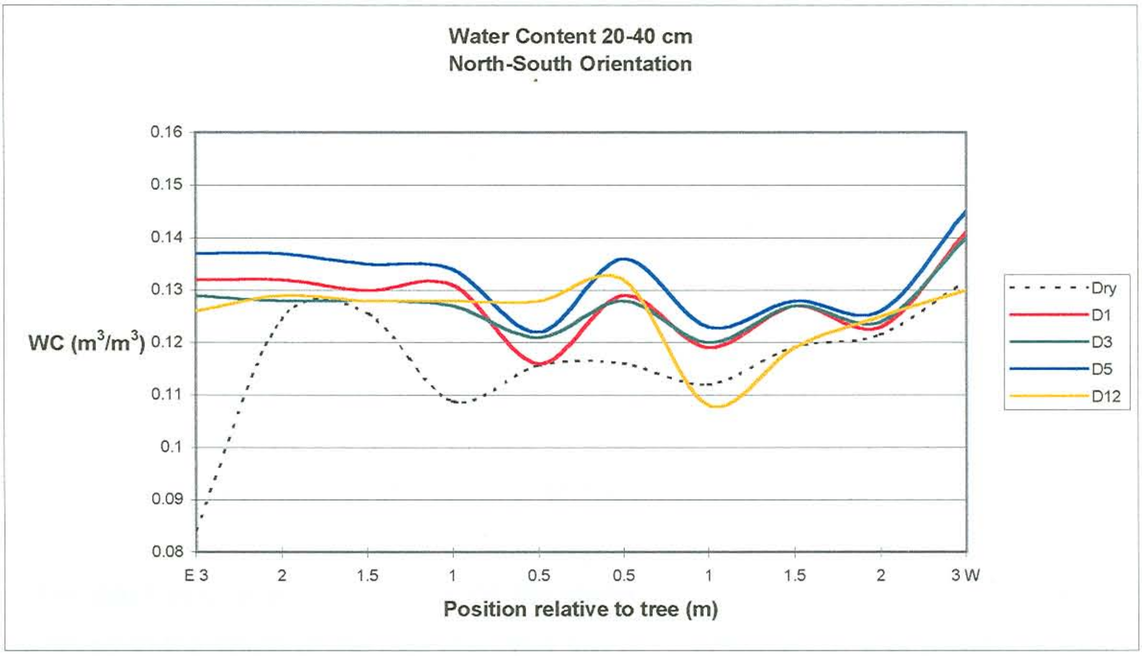
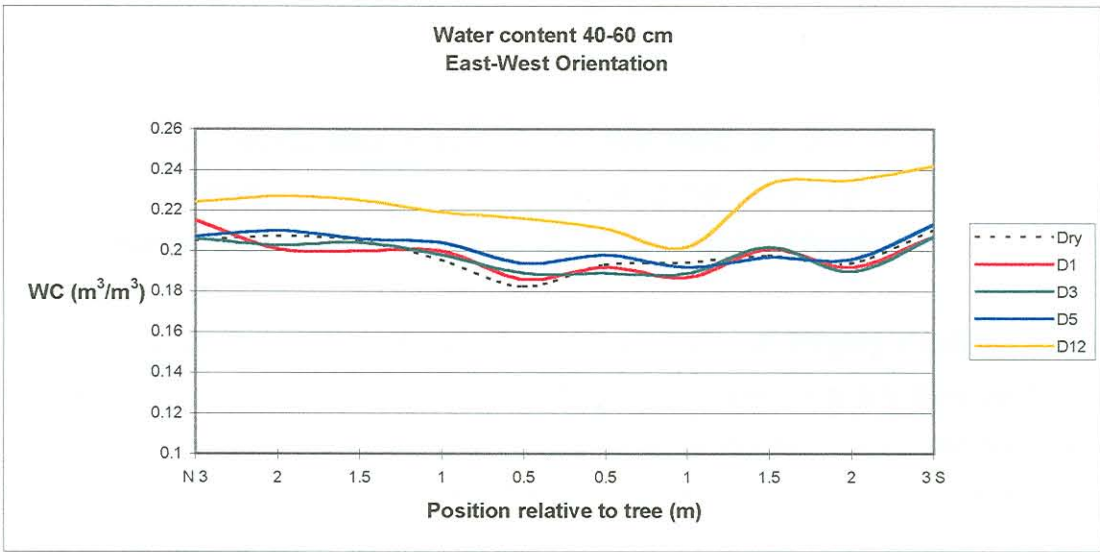


Fig. 18 Water content at a depth of 20-40cm : orientation trial



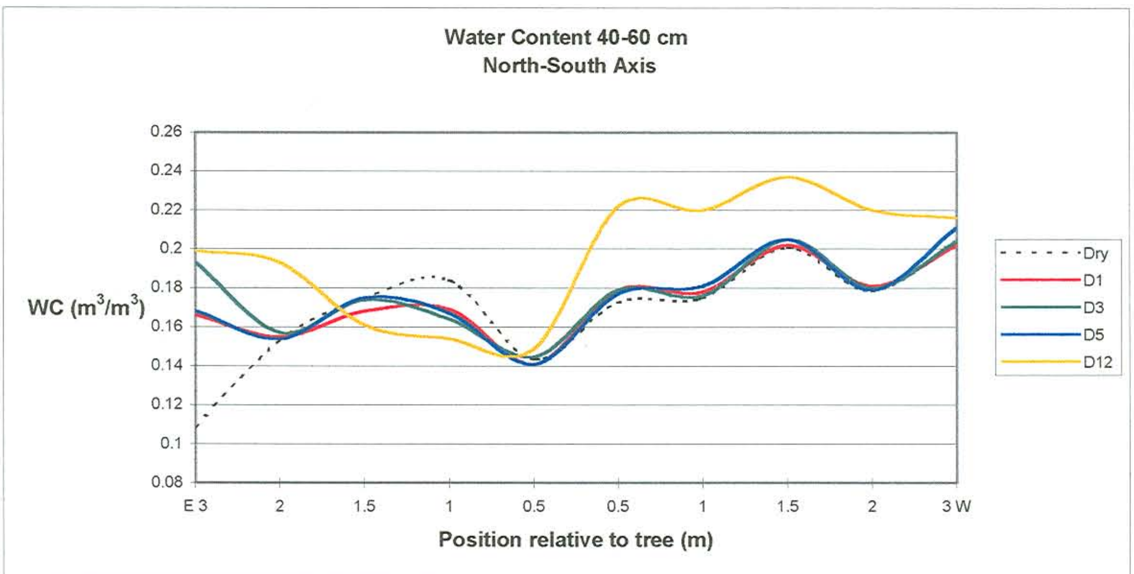


Fig. 19 **Water content at a depth of 40-60cm : orientation trial**

In the east-west orientation, a slight decrease in WC of the upper 20 cm was observed to the south of the tree row after day 5. The same dip was present in the dry condition. At the deeper levels, however, WC tended to be lower on the north of the tree row. In the north-south orientation, WC was lower by day 12 to the east of the tree row. This effect was, however, not observed at the 20-40 cm level but was again present at the 40-60 cm level.

4.4 Conclusion

Lindeque (1997) speculated about the possible effect of row orientation on light interception. Tendencies were observed indicating that horizontal distribution and/or development of the tree could be the critical factor in light interception.

From this study, it seems as if row orientation and alley width play a definite role in competition for water and light. The shading experienced in a 3m alley confirmed that this alley width is unsuitable to use under local conditions. During the first 2/3 of the growing season, more available PAR was intercepted to the northern side of the trees in the alley crops. During the latter part of the season the situation changed and more shading was experienced to the south of the trees. In the orientation trial, this was the case late in the season with afternoon sun. It was also clear that shading was more pronounced towards one section of the stand and that the east-west row orientation provided a more evenly spaced distribution of sunlight.

Available water content increased with depth, but distribution of this WC differed across the alley. In the upper horizon, distribution was more even, while in the lower horizon less moisture was available next to the leucaena trees. From approximately 1.5 away from the trees, WC increased. The distribution of WC did not differ much through the 3m alley, indicating that the effect of the leucaena roots reached at least up to 1.5 m on both sides of the tree rows.

With regard to the orientation trial, it would seem as if WC were slightly lower south of the tree row. A clearer trend could be observed in the north-south orientation, where a definite decline was observed towards the east of the tree row.

Distance from the tree rows played a definite row in competitive effects. From the results it could be concluded that cropping should only start at least 1.5 m away from tree rows in order to minimise competition, especially by shading. It was also concluded that competitive effects were influenced by different row orientations – a topic open for investigation. The purpose of the current investigations was only to observe trends, and more detailed surveys could provide useful information for the design of alley cropping systems.

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