CHAPTER 5

COMPARISON OF ROOT AND SHOOT COMPETITION BETWEEN SUGAR CANE AND *PASPALUM PANICULATUM* OR *PASPALUM URVILLEI*

5.1 Introduction

Weeds compete with crops for environmental resources available in limited supply, i.e. nutrients, water and light. Competition has been defined as the tendency of neighbouring plants to utilise the same quantum of light, ion of mineral nutrient, molecule of water, or volume of space (Grime, 1979). In sugar cane, it has been demonstrated that critical periods of weed competition with natural weed infestations started 12 WAH and ended 26 WAH, under normal growth conditions, in ratoon cane and control measures may need to be maintained up to 29 weeks after planting to keep yield losses below 5% in plant cane (Chapter 2; Seeruttun & Lutman, 2004). It was also shown that weed competition in plant cane starts earlier and this would depend on the rate of cane and weed growth, weed species, density of weed infestations, etc.

The success of weed management programmes which are directed towards minimization of herbicide use, largely depends upon the ability to predict the effects of weeds on crop yield (Kropff & Spitters, 1991). Weeds emerge in numerous flushes and the number of species present at any time in a sugar cane field may vary from 10 to more than 25; therefore the relative competitiveness of each individual weed is important for predicting impact on growth and yield. The simple descriptive regression model developed by Kropff and Spitters (1991), based on the hyperbolic yield loss – weed density model (Cousens, 1985), provides a good description of crop yield loss, expressed in total aboveground biomass, as a function of the relative leaf area of the weeds early in the development of the crop. Using this model, the 'relative damage coefficient' or relative competitiveness value q for several weed species in sugar cane has been derived (Chapter 3). However, in Chapters 3 and 4, the relative competitiveness of *P. urvillei*, a tussocky mostly erect perennial reaching 150-200 cm in height and leaves 12-50 cm long (Mc Intyre, 1991), was found to be lower than from the shorter *P. paniculatum* (reaching a maximum height of 100-150 cm with lanceolate leaves 20-40 cm long and 1.0-2.5 cm broad). The less competitive *P. urvillei* also produced relatively more leaf area per unit area. This result suggested that weed competition in sugar cane cannot be explained solely by aboveground mechanisms (relative leaf area) and competition for belowground resources may also be a source of interference between the crop and the weeds.

The importance of root competition and the relationship between root and shoot growth have been demonstrated by many researchers in several crops including rice and cereals. Gibson *et al.* (1999) suggested that root competition may be the primary mechanism determining competitive outcomes between water-seeded rice and *Echinochloa phyllopogon* (Stapf) Koso-Pol, confirming similar conclusions in this crop published by Assemat *et al*. (1981) and Perera *et al*. (1992). In a comprehensive review of shoot and root competition, Wilson (1988) reported that in 33 out of 47 studies root competition had a greater effect on plant growth than shoot competition. For several cereal crops, including spring wheat, barley and oats, root competition was reported to be more important than competition for light (Aspinall, 1960; Irons & Burnside, 1982; Gamboa & Vandermeer, 1988; Satorre & Snaydon, 1992). Abdollahian and Froud-Williams (2005) showed that root competition by *Chenopodium album* L. caused greater reduction of shoot and root yield of sugar beet than shoot competition 16 weeks after transplanting. Root competition from an established grass sward was also demonstrated to affect shoot dry weight of *Rumex longifolius* DC. and *Taraxacum officinale* (Web.) Marss. much more than did shoot competition (Haugland, 1993). Using the divided box technique in an additive design, Tuor and Froud-Williams (2002) showed that root competition from purple nutsedge (*Cyperus rotundus* L.) for soil resources was more severe than competition for aerial resources in retarding the growth of maize and soyabean.

For a better understanding of the different mechanisms of competition between sugar cane and weeds, two experiments have been conducted to compare root and shoot competition between *P. paniculatum* and *P. urvillei* when grown with sugar cane. The objectives were to separate the effects of competition for aboveground and belowground resources by the two weed species and to elucidate the differences observed between the relative competitiveness of the two *Paspalum* species.

5.2 Materials and methods

Experimental method

The divided box technique of Schreiber (1967), as described by Satorre and Snaydon (1992), was used to separate the effects of aboveground (shoot) and belowground (root) competition between sugar cane and two *Paspalum* species. The technique provides conditions of no competition, shoot competition only, root competition only and both shoot and root competition between crop and weed (Fig. 5.1). The density of the crop (sugar cane) and weeds (*Paspalum* species) at planting were established according to the 1:1 additive design described by Satorre and Snaydon (1992). Keeping the number of buds on the cane stems per tray similar to the number of weeds transplanted would allow the effects of inter-specific competition between crop and weed to be measured without the confounding effects of intra-specific competition, as occurs in replacement designs (Firbank & Watkinson, 1985).

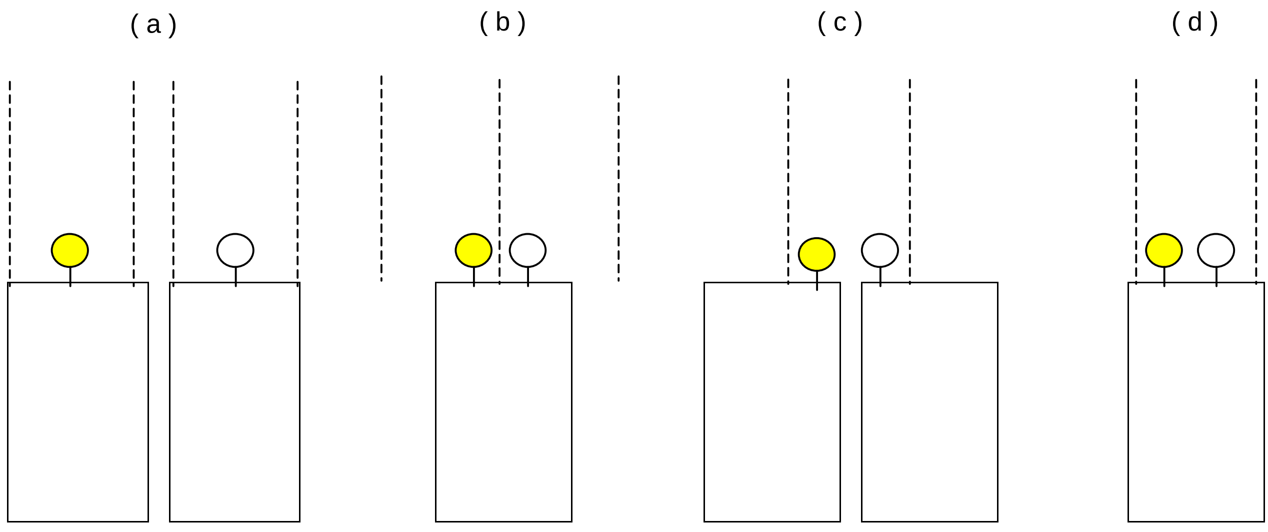

Fig. 5.1. The planting arrangement (side view) of sugar cane (⚲) and *Paspalum* species (⚲) to give (a) no competition; (b) root competition only; (c) shoot competition; and (d) both root and shoot competition (Satorre & Snaydon, 1992).

Trials site and plant material

Two trials/experiments were carried out, using the above technique, to compare root and shoot competition between sugar cane and two *Paspalum* species, namely *P. paniculatum* and *P. urvillei*. Trial I was carried out inside a glasshouse at Réduit experiment station whereas the second trial (Trial II) was established outside the glasshouse. The conditions inside the glasshouse were similar to those prevailing outside as all openings (with a wire mesh to prevent insects, etc.) were left opened to maintain almost the same temperatures and natural light was used. Sugar cane was planted using two eyed-cuttings (cane setts with two buds each) obtained by cutting cane stems 9 to 11 months old (plant cane) from fields on the station or nearby nursery. The cane variety used in both trials was R 570. Seedlings or young plants of *P. paniculatum* and *P. urvillei* were uprooted and collected from an abandoned sugar cane field in the neighbourhood of the station.

Containers and growing medium

The sugar cane setts and weeds were planted in fibre glass containers 1.0 m long x 0.4 m wide X 0.3 m deep; an extension using iron sheets 0.3 m high was inserted on the top of each tray to increase the total planting depth to approximately 0.5 m (Fig. 5.2). For the treatments having root competition, only one tray was planted with both plants while for the other two treatments (no competition and shoot competition only) two trays were placed next to each other along the longer sides.

The trays were filled with topsoil collected from the fields on the station; the soil group at Réduit consists of Low Humic Latosols (L group according to Parish & Feillafé, 1965). Pre-experimentation soil analysis of the soil used as filling medium showed amounts of total N at 5100 kg ha^{-1}, 3900 kg ha^{-1} of total P and 2100 kg ha^{-1} of total K; the soil pH was 6.2, and CEC was 16.6 cmol kg^{-1}.

Fig. 5.2. Arrangement of trays (with iron sheet extensions placed on top of the trays to increase depth) for planting cane and weeds.

The aerial partitioning of the trays with respect to shoot competition was set by fixing black plastic sheets 1.0 m wide (giving a partitioning height of approximately 0.9 m) on 'bamboo' sticks placed at each corner of the trays (Fig. 5.3). The plastic sheets were placed along the longer side of the trays to limit the aerial space and assure same amount of light reaching the plants. The distance between the two sides for the control (no competition) and the treatment imposing root competition only were kept at approximately 0.8 m whereas the partitions for the two treatments having shoot competition were fixed at 0.4 m apart. The partitions were put into position four weeks after planting cane and provided a complete separation for most of the study period; a few sugar cane leaves grew above the top of the barriers for the last three to four weeks but were considered to have negligible effect on the results.

Fig. 5.3. Arrangement of trays with aerial partitions showing no competition (right picture at back); shoot competition only (left picture in front); and root + shoot competition (right picture – in front).

Planting sugar cane and transplanting of weeds

Sugar cane was planted at a density of four cuttings per tray in a single row either at the centre of the tray or side depending on the treatment; each two-eyed cane sett was pre-treated (cold dip) against 'pineapple' disease (caused by *Ceratocystis paradoxa*) with a solution of benomyl at 0.3 g per litre.

The weeds were transplanted one or two weeks after planting when the cane setts had started germination; the weed density used was eight plants/stools per container and they were evenly distributed and planted in a single row parallel to the cane. The weed leaves were partly pruned to reduce transpiration at transplanting and both cane and weeds were irrigated regularly to field capacity. The trays were kept free of other weed species by regular manual weeding which were carried out at the seedlings stage to avoid any additional competition. The dates of planting and transplanting of cane and weeds respectively are given in Table 5.1.

Table 5.1 Treatment dates in trials assessing root and shoot competition between sugar cane and two *Paspalum* species.

Trial	Dates			
	Cane planted	Weeds transplanted	Start of cane measurements	End of trial
Trial I	15 April 2006	28 April 2006	15 May 2006	6 October 2006
Trial II	16 November 2006	29 November 2006	30 December 2006	10 June 2007

Experimental layout and data collection

Treatments in Trial I were unreplicated because of the limited space inside the glasshouse, therefore, this is a preliminary trial in which treatment effects should be regarded as tendencies. In Trial II each treatment was replicated four times. In both trials the trays were disposed in a split-plot design with main-plots consisting of the two weed species. Data collection consisted of measuring dewlap heights of the primary cane shoots in each treatment at regular intervals; the dates of the first and last measurements are shown in Table 5.1. At the end of the experiments, all cane shoots were cut and measurements were taken for stalk height and dry weight separately for all cane shoots from each tray. In both trials, the aboveground biomass was collected and samples taken for dry weight measurements. The plant material was weighed before and after being oven-dried at 105^{o}C for 48 hours. Root biomass of cane and weeds were also measured in both trials after the trays were emptied and roots of cane and weeds separated, washed and dried.

Statistical design and analysis

Genstat (Discovery Edition 2) was used for all the statistical analyses with respect to Trial II. Data for cane dewlap height, aboveground and root biomass were subjected to analysis of variance (ANOVA) by using a split-plot design, and main effects and interactions were tested for significance. The two weeds were the main-plots and the sub-plot treatments consisted of the four combinations of root and shoot competition. Treatment means obtained by ANOVA were compared using LSD procedures at $P < 0.05$ level of significance.

5.3 Results

5.3.1 Trial I

5.3.1.1 Effect of root and shoot competition on shoot elongation and mean cane dewlap height

Cane growth was slower in Trial I, as it was conducted mostly through the winter period and shoot elongation was less than 2 cm per week between the periods early June to mid-August. When a relatively faster cane elongation resumed with higher temperatures as from the end of August, root competition between *P. paniculatum* and sugar cane apparently caused an adverse effect on cane growth (Fig 5.4). Shoot competition was found to have no effect on shoot elongation. This was also confirmed with the treatment where the cane shoots were exposed to both root and shoot competition and its effect being similar to that of root competition alone.

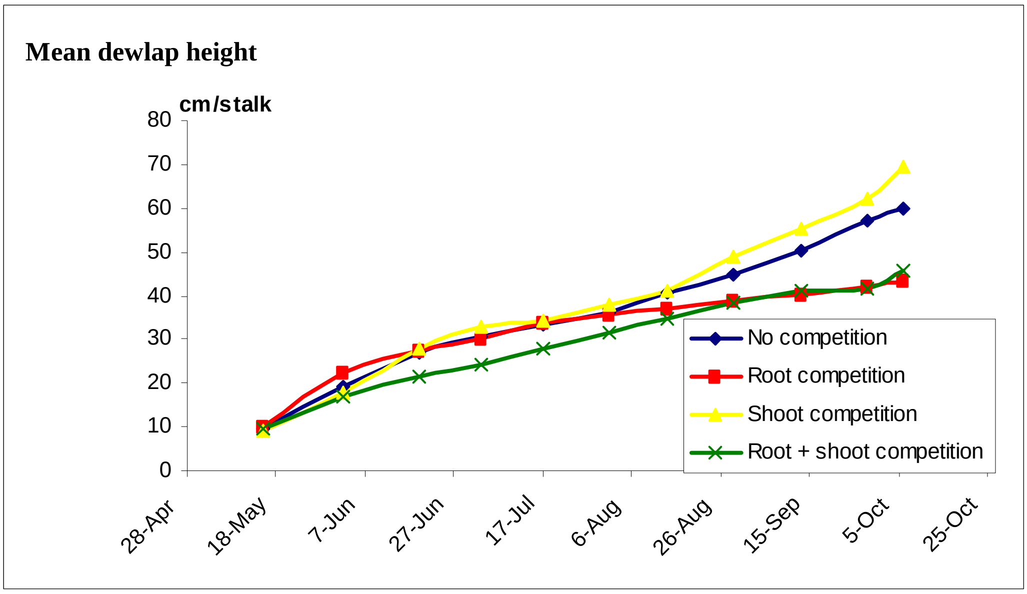

Fig. 5.4 Tendencies in root and shoot competition effects from *P. paniculatum* on elongation and mean dewlap height of cane shoots (mean of three primary shoots) in Trial I.

Data from this preliminary trial indicated that root competition between *P. urvillei* and sugar cane caused a reduction in shoot elongation of the crop (Fig 5.5); the effect was more apparent when cane shoots in the control (no competition) treatment had reached a mean dewlap height of 35 cm. Like *P. paniculatum*, shoot competition between *P. urvillei* and sugar cane did not cause any reduction in cane elongation. Similarly, combining shoot competition with root competition appeared not to be more damaging than root competition alone.

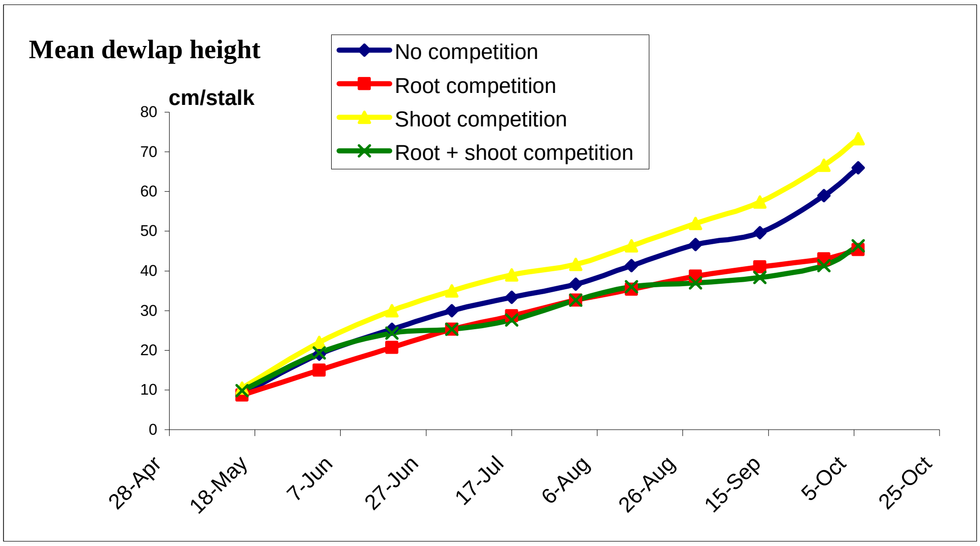

Fig. 5.5 Tendencies in root and shoot competition effects from *P. urvillei* on elongation and mean dewlap height of cane shoots (mean of three primary shoots) in Trial I.

5.3.1.2 Effect of root and shoot competition on aboveground biomass

The apparent effect of root and shoot competitions on cane elongation and dewlap height was confirmed with data obtained from the dry weight analysis of aboveground biomass. Root competition appeared to cause an adverse effect on cane development (Table 5.2). The dry weight of sugar cane biomass seemed to show a slightly more pronounced effect of root competition when it occurred in combination with shoot competition. The reduction in cane biomass with root and shoot competition also seemed to be greater with *P. urvillei*.

Table 5.2 Tendencies in shoot and root competition effects from *P. paniculatum* and *P. urvillei* on total aboveground biomass of weeds and sugar cane 25 WAP (Trial I)

	Aboveground biomass (dry weight - g m^{-2})			
	P. paniculatum		*P. urvillei*	
	Weed	Sugar cane	Weed	Sugar cane
No competition	423.9	809.9	622.3	862.0
Root competition	196.9	653.8	238.4	541.6
Shoot competition	187.5	974.8	408.9	749.6
Root + shoot competition	102.3	526.5	71.4	470.4

The aboveground biomass of the weeds tended to be adversely affected by root and shoot competition in this preliminary trial. Unlike the effect on sugar cane biomass, shoot competition between the weeds and sugar cane apparently caused a reduction in the development of the *Paspalum* species; *P. paniculatum* seemed to suffer more from shoot competition than *P. urvillei*. Root competition was more severe than shoot competition with *P. urvillei*. The effects of both root and shoot competition on the weed species were more marked on the biomass of both weeds when the treatments were combined.

5.3.1.3 Effect of root and shoot competition on root development of crop and weeds

Irrespective of the weed species, the root biomass of sugar cane tended to be reduced by both root and shoot competition; root competition caused greater reductions than shoot competition (Table 5.3). The higher reduction in root biomass of sugar cane observed when both competitions occurred simultaneously confirmed the adverse effects of both root and shoot competition.

Table 5.3 Tendencies in shoot and root competition effects from *P. paniculatum* and *P. urvillei* on root development of weeds and sugar cane 25 WAP (Trial I)

	Dry weight of roots (g m^{-2})			
	P. paniculatum		*P. urvillei*	
	Weed	Sugar cane	Weed	Sugar cane
No competition	94.9	342.2	180.9	314.2
Root competition	76.0	253.5	91.4	192.8
Shoot competition	64.0	290.9	84.4	245.3
Root + shoot competition	17.4	160.9	14.4	103.5

In absence of any competition, the amount of roots produced by *P. urvillei* tended to be higher than that of *P. paniculatum*. Irrespective of the weed species, both root and shoot competition caused a reduction in the biomass of weed roots produced. The amount of roots was further reduced when both types of competition occurred simultaneously. Weeds were apparently more affected by competition than the cane with regard to both shoots and roots.

5.3.2 Trial II

5.3.2.1 Effect of root and shoot competition on shoot elongation and cane growth

Paspalum paniculatum

Cane shoot elongation, measured from the end of December (seven weeks after planting), revealed no differences between the various combinations of root and shoot competition treatments and the control, i.e., no root or shoot competition until the first week of April 2007 (21 WAP) when a significant reduction in mean dewlap height from root competition between sugar cane and *P. paniculatum* was observed (Fig. 5.6). This difference was maintained until the end of the trial, i.e., for another two months. Shoot competition did not seem to affect cane elongation and the adverse effect of root competition on cane elongation was not apparent when sugar cane was exposed to both root and shoot competition from *P. paniculatum*.

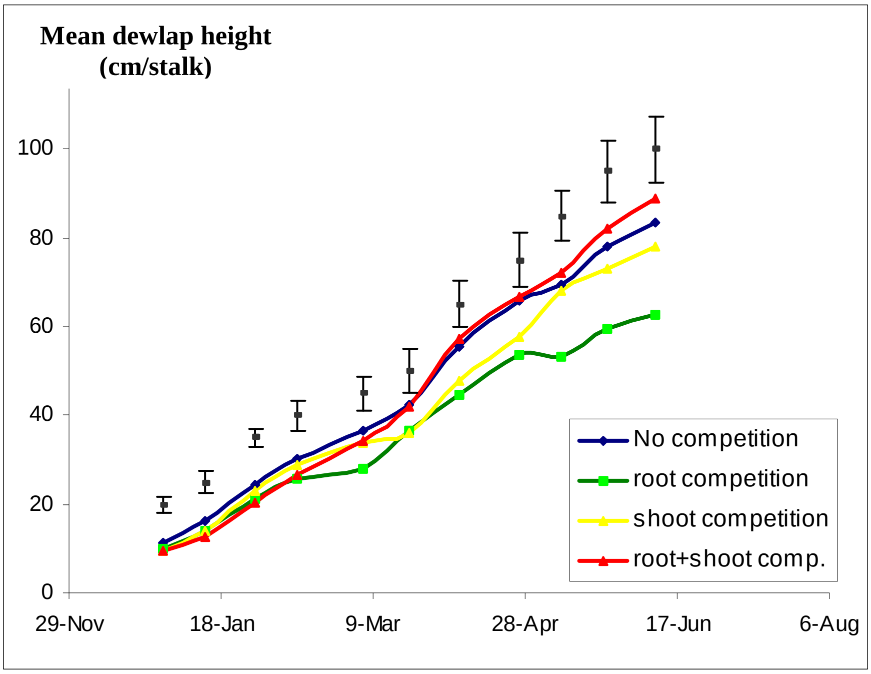

Fig. 5.6 Effects of various combinations of root and shoot competition from *P. paniculatum* on mean dewlap height of cane shoot. The vertical error bars indicate 2 x s.e.d. at each observation date.

Paspalum urvillei

The effects of root and shoot competition from *P. urvillei* were similar to that observed with *P. paniculatum*; the mean dewlap height was also found to be significantly reduced some 21 weeks after the start of the trial by root competition (Fig. 5.7). Similarly, no difference in mean dewlap height was observed between the control and the treatments causing shoot competition. Combining root and shoot competition did not result in a significant decrease in mean dewlap height of the cane shoots.

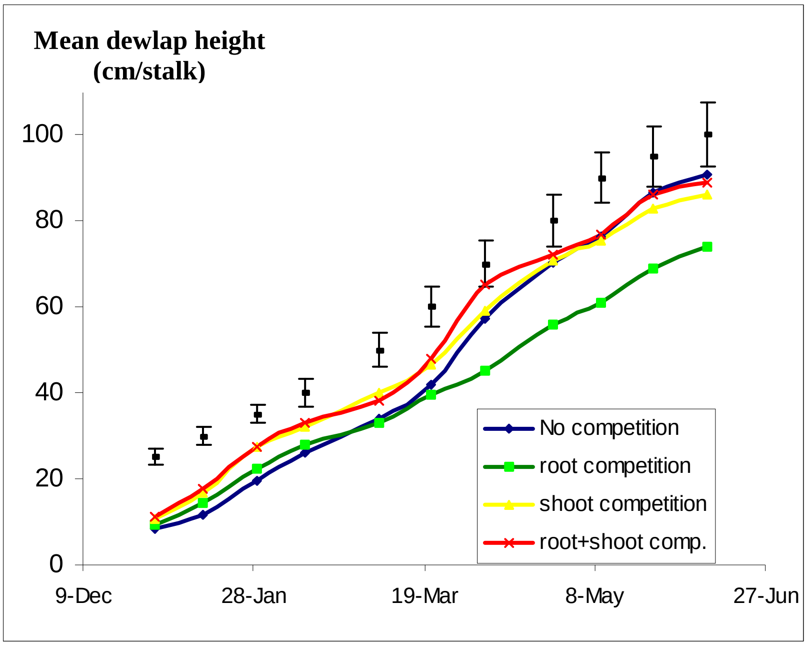

Fig. 5.7 Effects of various combinations of root and shoot competition from *P. urvillei* on mean dewlap height of cane shoots. The vertical error bars indicate 2 x s.e.d. at each observation date.

<u>5.3.2.2 Effect of root and shoot competition on aboveground biomass</u>

Cane shoot

The mean stalk weight (dry) of the three primary shoots which were tagged for elongation measurements confirmed that root competition had a significant adverse effect on stalk development of cane (Table 5.4). Unlike the effect on mean dewlap height, shoot competition caused a reduction in mean stalk weight of cane compared to its growth in the control trays (Table 5.4).

Irrespective of the weed species (main-plot means), root competition caused a higher reduction of mean stalk weight (of the primary shoots) than the shoot competition treatment. However, root competition effects from both weeds were not more pronounced than the effects of both types of competition combined. It appeared that shoot competition had an alleviating effect on root competition when they occurred together; most probably shoot competition adversely affecting root development and thereby reducing root competition.

Table 5.4 Effects of shoot and root competition from *P. paniculatum* and *P. urvillei* on mean dry weight of cane stalks (3 primary shoots) 30 weeks after planting in Trial II

Weeds	Mean weight (dry) of cane stalks (g)				
	No competition	Root competition	Shoot competition	Root + shoot competition	*Mean variety*
P. paniculatum	62.1 a	30.3 c	45.8 b	37.4 bc	*43.9*
P. urvillei	70.7 a	36.3 c	55.1 b	47.4 bc	*52.4*
Mean competition treatment	*66.4 a*	*33.3 c*	*50.5 b*	*42.4 bc*	

Values are means of four replications. Standard error of difference of means for main plot – weeds (d.f.=18) = 4.64 and standard error of difference of means with same level of weed (d.f. = 18) = 6.57. Mean values in the same row not sharing the same lower-case letter are significantly different at $P < 0.05$ (LSD test).

Total aboveground biomass

Total aboveground biomass (dry weight) data confirmed a greater adverse effect from root competition on cane development than from shoot competition (Table 5.5). The effect was not worsened by both effects occurring in combination.

Table 5.5 Effects of shoot and root competition from *P. paniculatum* and *P. urvillei* on mean total aboveground biomass of stalks (primary shoots) 30 weeks after planting in Trial II.

Weeds	Mean weight (dry) of total aboveground biomass per cane stalk				
	No competition	Root competition	Shoot competition	Root + shoot competition	*Mean variety*
P. paniculatum	76.6 a	40.4 c	57.7 b	51.1 bc	*56.5*
P. urvillei	85.1 a	48.2 c	69.0 b	61.7 bc	*66.0*
Mean competition treatment	*80.8 a*	*44.3 c*	*63.3 b*	*56.4 b*	

Values are means of four replications. Standard error for main plot – weeds (d.f.=18) = 5.02 and standard error of means with same level of weed (d.f. = 18) = 7.10. Mean values in the same row not sharing the same lower-case letter are significantly different at $P < 0.05$ (LSD test).

5.3.2.3 Effect of root and shoot competition on root development

Root biomass of weeds

The amount of roots produced per tray by the two weeds differed as *P. urvillei* produced significantly higher root biomass than *P. paniculatum*. Irrespective of weed species, shoot competition had no significant effect on root formation of the weeds (Table 5.6). Root competition between sugar cane and *P. urvillei* caused a significant reduction on root biomass of the weed; this reduction also occurred when root competition was coupled with shoot competition. A similar trend was observed for *P. paniculatum* but the differences were not significant, which may have been due to the relatively lower amount of roots produced by *P. paniculatum.*

Table 5.6 Effects of shoot and root competition between *Paspalum* species and sugar cane on weed root development (mean dry weight) 30 weeks after planting in Trial II

Weeds	Mean dry weight of weed roots (g m^{-2})				
	No competition	Root competition	Shoot competition	Root + shoot competition	*Mean variety*
P. paniculatum	127.7 a	85.4 a	91.0 a	64.8 a	*92.2*
P. urvillei	249.3 a	87.7 b	188.7 a	40.4 b	*141.5*
Mean competition treatment	*188.5 a*	*86.6 b*	*139.8 a*	*52.6 b*	

Values are means of four replications. Standard error of difference of means for main plot – weeds (d.f.=18) = 24.33 and standard error of difference of means with same level of weed (d.f. = 18) = 34.41. Mean values in the same row not sharing the same lower-case letter are significantly different at $P < 0.05$ (LSD test).

Root biomass of cane

Root development of sugar cane was adversely affected by root competition from both weed species. Shoot competition caused a reduction in cane root biomass when sugar cane was exposed to competition to *P. urvillei* (Table 5.7). The latter also caused a more severe loss in cane root biomass when both root and shoot competition were imposed.

Table 5.7 Effect of shoot and root competition between *Paspalum* species and sugar cane on cane root development (mean dry weight) 30 weeks after planting in Trial II

Weeds	Mean weight (dry) of cane roots (g m^{-2})				
	No competition	Root competition	Shoot competition	Root + shoot competition	*Mean variety*
P. paniculatum	534 a	343 b	374 ab	257 b	*377*
P. urvillei	789 a	571 b	582 b	352 c	*573*
Mean competition treatment	*661 a*	*457 b*	*478 b*	*304 c*	

Values are means of four replications. Standard error of difference of means for main plot – weeds (d.f.=18) = 63.3 and standard error of difference of means with same level of weed (d.f. = 18) = 89.5. Mean values in the same row not sharing the same lower-case letter are significantly different at $P < 0.05$ (LSD test).

5.4 Discussion and conclusions

Results showed that the mechanisms responsible for growth reduction in sugar cane in presence of *Paspalum* species seem to include root competition. In fact, for many of the parameters measured, root competition was found to be more severe than shoot competition. This finding supports those of other studies that compared shoot and root competition in rice (Assemat *et al*., 1981; Perera *et al*., 1992; Gibson *et al*., 1999) and in cereals (Aspinall, 1960; Satorre & Snaydon, 1992).

The effect of root competition on mean dewlap height of sugar cane was visible only after several weeks of exposure to the treatments or when the cane stems had reached more than 35 to 40 cm in dewlap height (Figs 5.4-5.7). Although the mean dewlap heights did not reveal major differences between combinations of shoot competition and the full (root + shoot) competition on the last day of the respective trials, bigger differences were noted between the control (no competition) and the root and shoot treatments for mean weight of the same ‘tagged’ stems measured. This may partly be explained by the etiolating effect of cane stems for light resources under shoot competition and may also explain the relatively lower damage observed in some cases by the full competition effect compared to root competition only.

Haugland (1993) reported an increase in specific leaf area by shading from shoot competition, which made target plants less susceptible to competition for light. An increase in plant height due to shoot competition by *E. phyllopogon* on rice was also observed by Gibson *et al*. (1999); the ability to increase plant height could have limited the effect of light competition on the target plant.

Root development of sugar cane was impaired by both root and shoot competition. A more severe reduction was not recorded when both occurred simultaneously which may suggest that they were not affecting root development in the same manner. Haugland (1993) reported that shoot competition reduced root dry weight and increased shoot/root ratio, which in turn probably can reduce plant survival. Root competition also reduced the amount of weed roots and this was significant for *P. urvillei*, which produces more roots than *P. paniculatum*. The reduction in root biomass of weeds by shoot competition was not significant in Trial II although there was a tendency that it was more important than shoot competition in Trial I.

The divided box technique has been criticised because of the restricted soil volumes often employed and the possibility of greater resources availability to those treatments involving no competition (Froud-Williams, 2002). However, due to the relatively large size of the tray used in this study and the planting density imposed, the percentage of crop and weed roots occupying the volume of soil placed in the tray should have been lower than that under field conditions. Therefore, cane root development in the root competition treatment was not the result of limited space, and therefore resources, in the trays. This conclusion is supported by the fact that the sum of the amount of weed and cane roots was lower in the boxes with root competition than in the no competition control (Tables 5.6 and 5.7; Fig. 5.8).

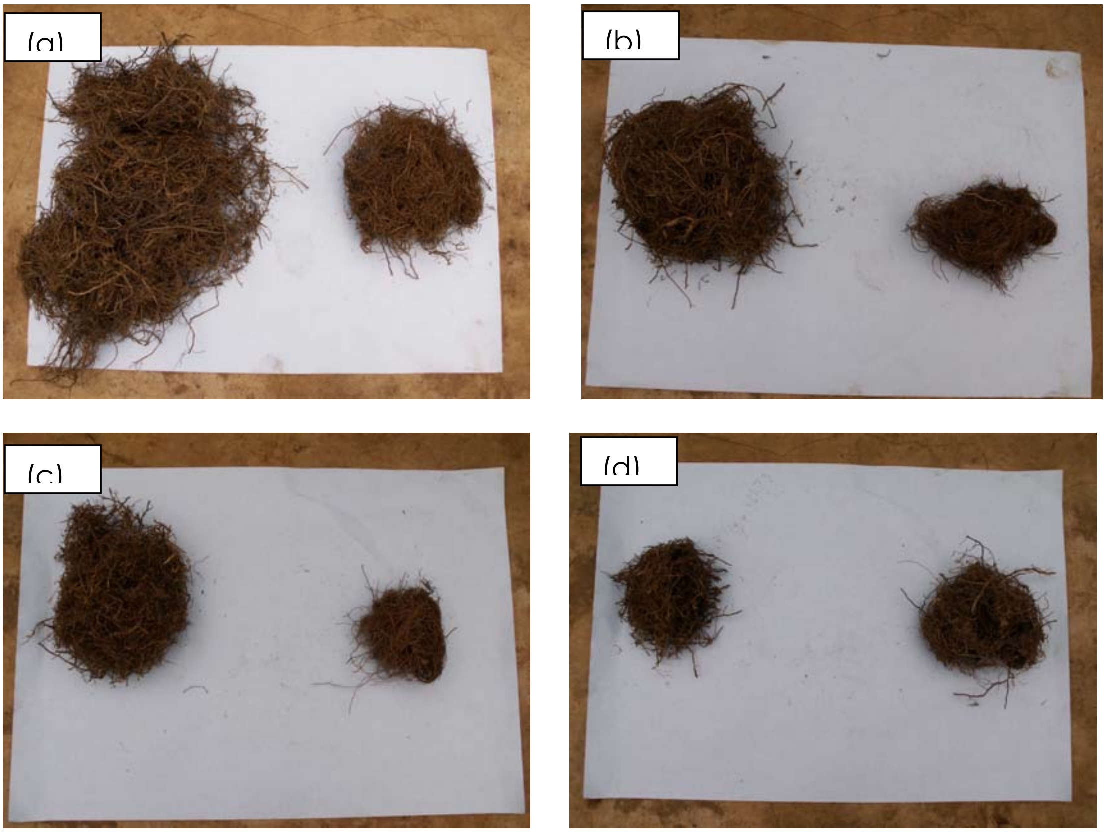

Fig. 5.8 The effect of various combinations of (a) no competition, (b) root competition, (c) shoot competition and (d) root and and shoot competition from *P. paniculatum* on amount of roots of cane (left) and weed (right) per tray placed on a A4 size paper.

Several researchers have associated the effect of below-ground competition to availability of nutrients, particularly N, although the contrary has also been demonstrated. Satorre and Snaydon (1992) found that root competition was still more important than shoot competition when higher levels of N were applied. For Suzuki (2002), who reported shoot competition being more important than root competition in rice, root competition might be an important factor in the competition with weed of rice cultivars under crucially nitrogen-limited conditions. In the present study, N should not have been a limiting factor as only 5% of the total N present in the soil would represent some 225 Kg ha^{-1} of mineral N available to the plants. Sugar cane that produces a total biomass of more than 100 t ha^{-1} over a one year period requires between 120 and 140 kg ha^{-1} of N (STASM, 1990). In the present study, cane was grown for only seven months and biomass produced was much smaller than for a normal crop cycle. Similarly, the available amount of P_2O_5 should not have been a limiting factor influencing root development. In the absence of competition for N or other nutrients, there is a need for other explanations for root reduction. It is possible that allelopathy could have played a role in determining the growth of cane and weeds. However, several other factors not amenable to testing in the box experiments can also play a role in determining competition in the field. For example, the rooting depth and root distribution of some crops and weeds differ appreciably, causing considerable difference in competitive effects, due to differences in nutrient and water scavenging ability between the different root systems.

Findings presented in this chapter reveal (no previous work studying this aspect reported) that weed competition in sugar cane is caused by both root and shoot competition and the relative competitiveness of an individual weed is more complex and cannot solely be described by aboveground competition mechanisms, e.g., weed competition models based on relative leaf areas.