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THE EFFECTS OF INTERCROPPING KALE WITH BEANS ON YIELD AND SUPPRESSION OF REDROOT PIGWEED UNDER HIGH ALTITUDE CONDITIONS IN KENYA

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SUMMARY

Two studies were conducted in Kenya during 1993 and 1994 to determine the yield responses of kale (*Brassica oleracea* var. *acephala* D.C.) intercropped with beans (*Phaseolus vulgaris* L.) under different redroot pigweed (*Amaranthus retroflexus* L.) densities. Redroot pigweed significantly reduced both kale and bean yields, the reduction being greater in 1993 than in 1994, and being greater for beans than for kale. Redroot pigweed growth was suppressed more by beans than by kale. Food output per unit area, measured by Land Equivalent Ratios, was increased by 22–115% by intercropping kale with beans and the increase was greater under weedy conditions (38–115%) than under weed-free conditions (22–74%). The presence of beans did not affect the leaf yield of kale. The presence of kale did not affect the seed yield of beans in 1994, but consistently reduced it by about 50% in 1993, though the difference was not significant.

INTRODUCTION

Intercropping, the practice of growing two or more crops simultaneously in the same area in a year (Andrews and Kassam, 1976) has continued to be popular in the developing world. Several advantages are associated with this ancient practice: (1) increased soil erosion control, (2) insurance against crop failure, (3) spreading labour requirement and harvesting more evenly throughout the season, (4) facilitating production of many commodities in a limited area, (5) efficient utilization of resources by plants with different growth periods, heights, rooting systems, and nutrient requirements, (6) transfer of nitrogen fixed by legumes to the companion grass species, and (7) controlling the spread of diseases and pests.

Beans are a major source of protein for most low-income communities in Kenya, while the smooth leaf kale (*Brassica oleracea* var. *acephala* D.C), including collard, has become the most popular leafy vegetable in Kenya. The two species are normally intercropped, often with other crops such as maize (*Zea mays*), tomatoes (*Lycopersicon esculentum*) or any other crop that the subsistence farmer may wish to include. No set pattern of intercropping has yet been developed in Kenya. There is little information available on the culture of kale, and so the current recommendations are based on those for cabbage (Ministry of Agriculture, Kenya, 1979; Swiader *et al.*, 1992).

Redroot pigweed (*Amaranthus retroflexus* L.) ranks among the most difficult weeds in cultivated fields in Kenya, especially in high rainfall areas. Control has been by hand weeding and use of machinery and herbicides, all of which are expensive for the small-scale grower. Hence, there is a need to search for alternative methods of pigweed control which minimize the use of chemicals and machinery.

The objectives of the studies were therefore to determine the yield responses of kale–bean intercrops and to determine if intercropping kale with beans suppresses the growth of redroot pigweed.

MATERIALS AND METHODS

Two studies were conducted at Egerton University Horticultural Demonstration Field, Tatton Farm, Kenya. The farm lies at lat 0°23′S, long 35°35′E at a mean altitude of 2200 m. The soil at the experimental site is sandy loam. At the time of experimentation in 1993, the soil had an average total nitrogen (N) of 0.21%, phosphorus (P) of 8.7 ppm, potassium (K) of 2.0 meq $100\,g^{-1}$, and pH (H_2O) of 6.1. In 1994, the site soil tests indicated an average total N of 0.19%, P of 8.0 ppm, K of 1.8 meq $100\,g^{-1}$, and pH (H_2O) of 6.2.

The mean temperatures during the experimental period ranged between 18.4 and 21.7 °C in 1993 and between 17.3 and 19.9 °C in 1994. The rainfall during the experimental periods was 244.7 mm in 1993 and 479.0 mm in 1994.

The first experiment started on 10 August 1993 and ended on 25 January 1994 (168 days). The second experiment started on 3 May 1994 and ended on 20 September 1994 (140 days). In both experiments, beans cv. Large Rosecoco were sown by hand, followed by hand transplanting of kale cv. Thousand Headed on the same day. Kale was spaced at 60 × 30 cm and beans were spaced at 45 × 10 cm in both monoculture and intercrops. The three cropping regimes were monocultured kale, monocultured beans and kale intercropped with beans. Redroot pigweed was sown a week later at sowing densities of 0 (control), 100, 300 or 600 seeds m^{-2}. All other weed species were controlled by hand weeding as they appeared, but the redroot pigweed was allowed to remain until the experiment was terminated. The experimental design was a split-plot, with redroot pigweed sowing density forming the main-plots and cropping regimes the sub-plots. Fertilizer applications, and control of insect pests, diseases and weeds were applied to all treatments uniformly according to local recommendations.

Kale-leaf picking was started six weeks after transplanting and continued on a weekly basis until the experiment was terminated. Beans were harvested when dry, then threshed and dried further in the sun; the yields were adjusted to a moisture content of 12%. A sample of 1000 seeds was drawn from each lot and weighed to determine the unit seed weight.

Redroot pigweed was sampled eight times, including the last day of harvest. Data on branching, population per unit area, and dry weight were recorded and the final height was measured at the end of the experiment.

Each season's data were subjected to analysis of variance and, where the F test was significant at $p = 0.05$, mean separations for kale and beans were done using

Duncan's Multiple Range test; for pigweed growth parameters standard error of the mean was used. Land Equivalent Ratios (LERs) were computed using the following formula:

$$\text{LER} = \frac{\text{Y Intercrop 1}}{\text{Y Monocrop 1}} + \frac{\text{Y Intercrop 2}}{\text{Y Monocrop 2}}$$

where Y is the yield per unit area of either Crop 1 or Crop 2 in either monoculture or intercrop at a specific redroot pigweed density.

RESULTS

Kale yield

Intercropping kale with beans did not influence the number of kale leaves per unit area, the unit leaf weight or the fresh leaf weight per unit area in either the 1993 or 1994 seasons (Tables 1, 2 and 3). The presence of redroot pigweed significantly reduced leaf numbers during both the 1993 and 1994 seasons (Table

Table 1. Effects of redroot pigweed sowing density and intercropping with beans on kale leaf numbers (10^3 leaves ha^{-1}).

Pigweed density (seeds m^{-2})	1993			1994		
	Monoculture	Intercropping	Mean	Monoculture	Intercropping	Mean
0	2499	2324	2412	1131	1126	1129
100	1459	1321	1390	987	1087	1037
300	1434	1413	1424	757	942	850
600	1612	1702	1657	899	964	932
Mean	1751	1690		944	1030	
s.e. pigweed density	—		191.23	—		45.28
s.e. cropping regime	49.84		—	52.95		—

Table 2. Effects of redroot pigweed sowing density and intercropping with beans on kale unit leaf weight (g $leaf^{-1}$).

Pigweed density (seeds m^{-2})	1993			1994		
	Monoculture	Intercropping	Mean	Monoculture	Intercropping	Mean
0	19.7	20.0	19.9	26.9	24.6	25.8
100	14.0	14.0	14.0	24.2	24.7	24.5
300	10.7	12.7	11.7	29.6	28.6	29.1
600	11.7	15.7	13.7	21.7	22.6	22.2
Mean	14.0	15.6		25.6	25.1	
s.e. pigweed density	—		1.07	—		1.57
s.e. cropping regime	0.50		—	0.73		—

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Table 3. Effects of redroot pigweed sowing density and intercropping with beans on kale leaf fresh weight (t ha^{-1}).

Pigweed density (seeds m^{-2})	1993			1994		
	Monoculture	Intercropping	Mean	Monoculture	Intercropping	Mean
0	48.7	41.0	44.9	21.7	18.7	20.2
100	20.2	20.0	20.1	16.5	18.2	17.4
300	14.9	17.7	16.3	15.5	18.7	17.1
600	19.0	27.0	23.7	13.5	15.0	14.3
Mean	25.7	26.4		16.8	17.7	
s.e. pigweed density	—		2.49	—		1.35
s.e. cropping regime	1.65		—	1.18		—

1), while leaf size (Table 2) and fresh leaf weight per unit area of kale (Table 3) were significantly reduced by pigweed in 1993.

Bean yield

Bean yield was significantly reduced by redroot pigweed in both seasons. The yield reduction in 1993 was more pronounced than in 1994 and bean yields were substantially higher in 1994 than in 1993 (Table 4); the difference in kale yield between seasons was less marked (Table 3). The differences were probably due to the rainfall which was 244.7 mm in 1993 compared with 479.0 mm in 1994. Beans suffered more weed and intercropping competition when moisture was low in 1993 than when it was higher in 1994 (Table 4).

Land Equivalent Ratios

Intercropping kale with beans was more beneficial under weedy than under weed-free conditions. Increases in food output per unit land area as a result of intercropping kale with beans under weedy conditions ranged from 38 to 95% in 1993 and from 102 to 115% in 1994 compared with 22% in 1993 and 74% in 1994 under weed-free conditions (Table 5).

Table 4. Effects of redroot pigweed and intercropping with kale on bean seed weight (t ha^{-1}).

Pigweed density (seeds m^{-2})	1993			1994		
	Monoculture	Intercropping	Mean	Monoculture	Intercropping	Mean
0	1.39	0.53	0.96	3.03	2.68	2.86
100	0.23	0.09	0.16	2.73	2.51	2.62
300	0.17	0.08	0.16	2.43	2.28	2.36
600	0.17	0.09	0.13	1.71	1.69	1.70
Mean	0.49	0.20		2.48	2.29	
s.e. pigweed density	—		0.06	—		0.13
s.e. cropping regime	0.09		—	0.05		—

Table 5. Land Equivalent Ratios (LERs) as influenced by redroot pigweed sowing density and intercropping kale with beans.

Pigweed density (seeds m^{-2})	1993 Relative yield Kale	1993 Relative yield Bean	1993 LER	1994 Relative yield Kale	1994 Relative yield Bean	1994 LER
0	0.84	0.38	1.22	0.86	0.88	1.74
100	0.99	0.39	1.38	1.10	0.92	2.02
300	1.19	0.47	1.66	1.21	0.94	2.15
600	1.42	0.53	1.95	1.11	0.99	2.10

Redroot pigweed

Beans appeared to suppress redroot pigweed more than kale in both the 1993 and 1994 seasons (Table 6); the lowest redroot pigweed height, number of weeds per unit area, and dry weight per unit area were usually recorded with monocultured beans, the highest values with monocultured kale which was the least competitive (Table 6).

DISCUSSION

Beans suppressed redroot pigweed more than kale, because beans grew faster and branched out, covering more ground than kale and reducing the light reaching the young redroot pigweed seedlings. Similar weed suppression was found by Kolo (1995) when intercropping melon (*Citrullus lanatus*) with yam (*Dioscorea rotundata*). However, despite their ability to suppress redroot pigweed, beans were unable to compete in 1993 when the moisture supply was low (244.7 mm) and this led to significant yield reductions. When moisture was not limiting in 1994 (479.0 mm), beans were not affected by redroot pigweed until the sowing density reached 600 seeds m^{-2}. On the other hand, kale is harvested by stripping off the leaves which causes kale not to reduce the light that reaches the redroot pigweed seedlings.

Our studies show that intercropping kale with beans is beneficial in increasing the output of food per unit of land area. The benefits were highest under weedy

Table 6. Redroot pigweed suppression as influenced by intercropping kale with beans.

Cropping regime	1993 Height (cm)	1993 Branches ($plant^{-1}$)	1993 Weeds (m^{-2})	1993 Dry wt ($g\ m^{-2}$)	1994 Height (cm)	1994 Branches ($plant^{-1}$)	1994 Weeds (m^{-2})	1994 Dry wt ($g\ m^{-2}$)
Kale monoculture	57.9	2.7	87.2	209.9	53.4	3.5	84.7	195.1
Bean monoculture	44.1	2.1	40.7	108.6	47.2	2.1	36.4	144.5
Kale intercropped with bean	51.0	1.4	47.4	140.7	59.2	1.6	48.9	187.7
s.e.	1.6	0.3	1.9	13.0	3.7	0.3	2.3	17.7

conditions with LERs ranging from 1.38 to 2.15, while under weed-free conditions, LERs ranged from 1.22 to 1.74. The interaction between weeds and intercropping tended to favour kale more than beans.

Previous studies of intercropping kale with beans (Itulya, 1995) have shown that beans are less competitive when moisture is limiting. Itulya (1995) observed that when the experimental site received 374.9 mm rainfall, bean yields were significantly reduced by intercropping with either smooth-leaf kale cv Thousand Headed or collards, while no significant effects were observed on beans intercropped with either Thousand Headed kale or collards when 451.9 mm rainfall were received. The practice of harvesting kale by stripping off the leaves makes it compatible with beans under an intercropping regime, because it allows light to reach the lower portion of the bean canopy while the companion beans provide ground cover for both crops. Also, in the presence of the right rhizobium, beans fix their own nitrogen from the atmosphere, thus easing competition for the nitrogen available in the soil.

Measured in terms of LERs it is evident that food output can be increased by intercropping beans with kale and that the companion crops can tolerate a certain degree of redroot pigweed infestation. In 1993, with redroot pigweed sown at 100, 300, or 600 seeds m^{-2}, benefits of 38, 66, and 95% respectively were obtained by intercropping kale with beans, when moisture was limiting (244.7 mm); in 1994 the benefits were 102, 115, and 110% respectively when moisture was not limiting (479.0 mm). This is one of the reasons why most small-scale farmers in Kenya have continued to intercrop kale with beans and other crops such as potatoes (*Solanum tuberosum*) and maize. Itulya (1995) found that the highest increase in food production was 48% in a kale–bean intercrop under weed-free conditions when the moisture received in the experimental area was 451.9 mm. Under limited moisture supply (374.9 mm) Itulya noted that the benefits of intercropping kale with beans were lower, the highest increase in food output being 11% and reductions ranging from 1 to 16%.

It is concluded therefore that intercropping kale with beans is beneficial both in suppressing redroot pigweed and in increasing the food output per unit area of land.

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