The impact of crop rotation on peanut productivity in rainfed cropping systems

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Abstract

Peanuts are a high value crop in farming systems on Red Ferrosol soils in the inland Burnett, but one that also responds negatively to inadequate crop rotations. This paper reports results of a long term rotation study at Kingaroy designed to quantify the impact of various crop rotations and ley pastures on peanut productivity and crop value, as well as the incidence of known peanut pathogens. On average, peanut crops yielded 25% higher in rotations than in a monoculture, but quality of the harvested pods was unaffected by rotation. There was no additional yield response to rotation breaks longer than a single year, and no additional response to grass leys compared to alternate crops. The incidence of known peanut pathogens was significantly affected by rotation, but the impact of these pathogens on crop yield was strongly related to in-crop rainfall and the resultant seasonal yield potential. Gross returns from peanut crops were $177/ha lower per tonne of potential yield in a monoculture than in crop rotations. These findings can be used as a basis for optimising rainfed peanut farming systems for long-term viability and sustainability.

Key Words

soil diseases, ley pastures, maize, Red Ferrosols.

Introduction

Peanuts have always been an important part of the crop rotation in the red soil farming systems of the inland Burnett and Atherton Tableland. The relatively high yield potential of the crop (up to 5 t dry pods/ha in good seasons) and the excellent prices paid for quality produce (up to $850 /t dry pods) makes the crop very attractive to farm managers. However, this attractiveness often results in the crop being grown too frequently in the crop rotation in an effort to maximise returns, with a resultant increase in soil-borne pathogens and relatively poor crop performance.

The need for substantial breaks between peanut crops grown in the same field has been shown by a number of studies overseas. In Georgia for example, increasing periods without peanuts from 1 to 3 years resulted in commercial peanut yields that were 11-25% (dryland) and 7-36% (irrigated) higher than under a peanut monoculture (4). However, studies have also noted that rotations, particularly under irrigation, were often shorter than optimal as the most successful rotation crops (eg. cereals and grass leys) were generally of much lower economic value (5). As Australian farmers face increasing economic pressures, peanut producers are facing similar temptations to shorten the peanut rotation. This paper reports results of a crop rotation experiment conducted under rainfed conditions over a 10-year period at Kingaroy, in southern inland Queensland. The study investigated effects of break type (other crops versus ley pastures) and break duration on soil physical, chemical and biological fertility and on peanut yields and quality.

Materials and Methods

The trial was established at the Redvale field site of the Bjelke Petersen Research Station at Kingaroy, in the inland South Burnett region of Queensland, and spanned a 12-year period from 1983-1996. The Red Ferrosol soil type was typical of the soils on which the rainfed peanut farming system is based, with moderate soil fertility status, an effective rooting zone of 140cm and plant available water holding capacity of 100 mm. Further descriptions of physical and chemical properties of Red Ferrosols in this area appear in (2) and (3).

The initial study compared a peanut monoculture with peanuts grown after 1 or 2 years of cropping with maize (*Zea mays*), or after 1, 2, 3 or 4 years of grass pasture ley (*Chloris gayana* - Rhodes grass), with 2 replicate plots of each treatment sown in each of 3 consecutive seasons. The repeated treatment series was used in an attempt to sample the response across a range in climatic conditions. In the initial peanut crop after the rotation breaks, plots were split with 0 or 4 kg carbofuran/ha in an attempt to quantify the role of nematodes (*Pratylenchus brachyurus* [Lesion nematode] and *Meloidogyne hapla* [Root Knot nematode]) in crop productivity responses. Soil was conventionally tilled prior to sowing each crop and basal nutrients (N, P and K) were applied to meet crop requirements.

Once returned to peanuts, plots were maintained in a peanut monoculture for 3 successive seasons to quantify any residual effects of breaks. After the third consecutive peanut crop, subplots were either continued in that peanut monoculture or sown to a crop rotation comprising soybeans, maize and peanuts. Opportunity sowings of winter oats (*Avena sativa*) were made after each legume crop in this rotation whenever rainfall permitted, with biomass incorporated as a green manure at the early boot stage. The peanut monoculture plots were also split to 'with' and 'without' winter oats.

Soils (0-30cm, in 10cm increments) were collected from subsets of plots immediately prior to planting in each season, and used for assessment of nematode numbers and soil chemical properties. Plant establishment and mortality data were recorded during most seasons, numbers of nematodes in peanut roots were determined approximately 6 weeks after planting and plots were scored for the incidence and severity of symptoms caused by known soil-borne pathogens mid-season and at maturity. Gross returns from peanut cropping were determined using commercial grading standards and current crop values. Crop rotations (peanuts following 1 or 2 years of grass ley or maize, or following a rotation with soybeans, oats and maize) were compared with monoculture peanuts in terms of pod yields and gross margins (derived using average costs of production from each crop and current input costs).

Results and Discussion

Peanut yields and crop value varied markedly between growing seasons (Fig. 1a, b), with yields more responsive to breaking the monoculture than crop value. Collectively, these results showed average gross returns ($/ha) were 30% higher in the break treatments than in the peanut monoculture (data not shown). No aflatoxin was recorded in any year and this was reflected in consistently high crop values.

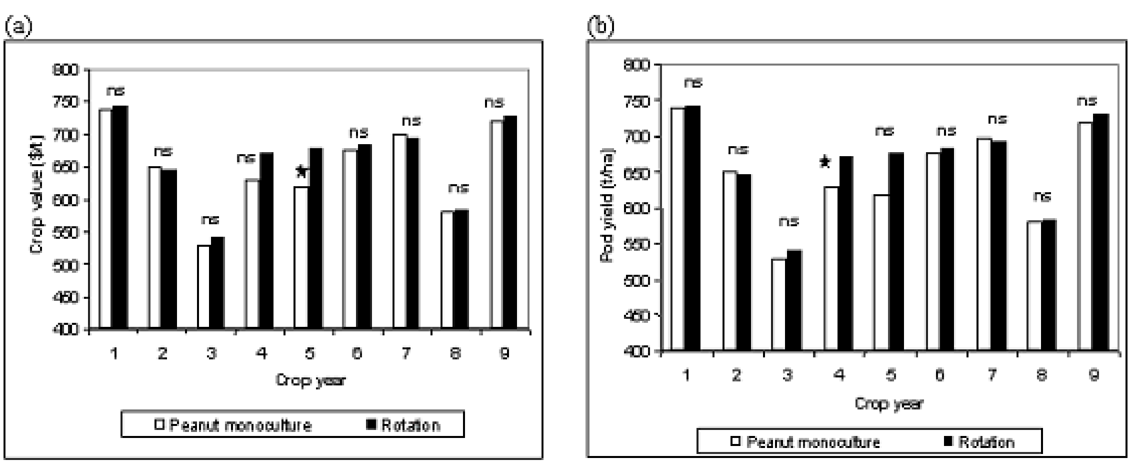

Figure 1. (a) Pod yield (kg/ha) and (b) crop value ($/t) for peanut crops in the study. Statistical significance (P<0.05) is indicated by a single star; ns denotes no significant differences.

This study produced no evidence to suggest that breaks of longer than one summer season (ie. peanuts grown every second year) were necessary to maximise crop yields and crop value (Table 1a). There was also no suggestion that grass leys were any more effective in raising peanut productivity than rotating to maize cropping, while the response to the alternate rotation in the second phase of the study (peanuts-oats-soybeans-oats-maize-fallow-peanuts) also produced significant increases in crop productivity, compared to continuous peanut cropping (Table 1b). Due to the wider range of break durations in the ley treatments, compared to the maize cropping (1 to 4 years, compare to 1 to 2 years), we were only able to directly compare the effect of longer grass leys (3 and 4 years) in 2 (3 years ley) or only 1 (4 years ley) cropping season. This limited sampling indicated that grass leys longer than 2 years produced no additional benefits in terms of peanut yield or crop value (data not shown).

Data clearly showed that introducing a winter green manure crop (oats) into a continuous summer peanut cropping pattern, as practiced in some of the newer production areas under irrigation, had no positive effect on yields or crop value. Yields were significantly lower than those in the peanuts/oats/soybeans/oats/maize rotation (Table 1b).

Table 1. Effect of break duration and break type on peanut yield (t pods/ha) and crop value ($/t).

Rotation	Years out of peanuts	Peanut yield (kg/ha)	Crop quality ($/t)
(a) Initial phase of study			
Continuous peanut	0	1.53	$643.2
Maize	1	1.86	$630.0
Maize	2	1.98	$635.9
Grass ley	1	1.88	$648.2
Grass ley	2	1.84	$653.2
LSD (0.05)		0.21	ns
(b) Second phase of study			
Continuous peanuts, winter fallow	0	2.28	$650.9
Continuous peanuts, winter oats	0	2.28	$659.7
Crop rotation (peanuts, oats, soybeans, oats, maize)	3	3.07	$670.4
LSD (0.05)		0.25	ns

Given the lack of differentiation between break types (grass or maize) on subsequent peanut productivity, data were pooled within years and an assessment was made of the residual effect of the breaks upon return to a peanut monoculture. This is an important issue, as growers recognise the need to grow break crops but also want to maximise the frequency of the high value peanut crop in the rotation. The analysis (Fig 2.) clearly showed that the maximum benefit of a break was captured in the 1st peanut crop, with an average yield increase of 26%. Significant residual benefits persisted for only the 2nd and 3rd peanut crops after the break, and these benefits were reduced to less than half those recorded in the initial peanut crop.

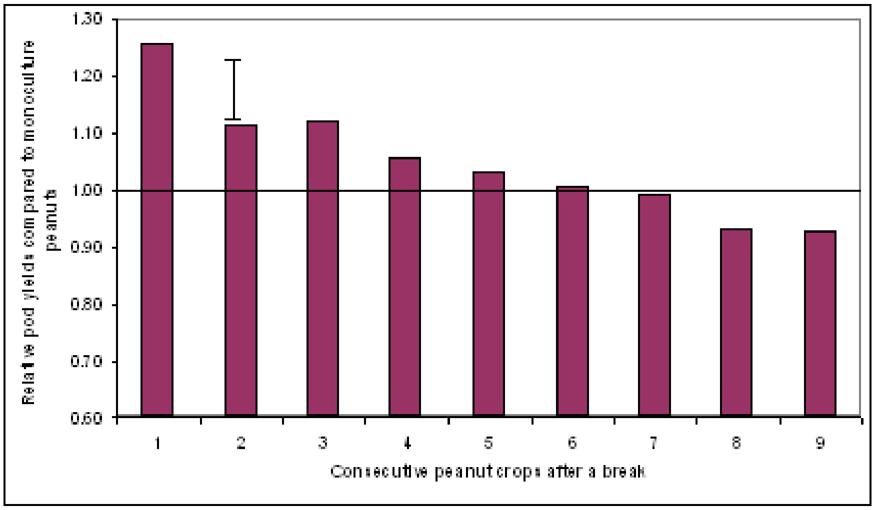

Fig. 2. Combined analysis of the residual effect of crop rotations on pod yields after a return to a peanut monoculture. Vertical bars indicate significant differences (P<0.05).

The relationships between the potential yields in each season (yields in rotated plots) and the loss in yield or gross returns (yield*crop value) resulting from employing a monoculture were derived using regression techniques. These relationships suggested that 0.24 t pods/ha or $177 gross return/ha would be lost for each tonne of peanut yield potential in a monoculture, compared to adequate rotations (R^2 = 0.81 and 0.80 for yield and $ loss relationships, respectively). Losses in gross returns would obviously increase in situations where crop values were greater than the average $640/t recorded during this study (eg. under irrigation).

There was no evidence of any rotation responses resulting from changes in soil chemical fertility, as evidenced by plant nutrient status (data not shown), and this was not surprising considering the generous fertiliser application strategies employed during the study. Grass leys were shown to impact on soil physical fertility – in particular the ability of soils to resist crusting and allow rainfall to infiltrate (1). However these changes had minimal impact on soil water during the subsequent growing seasons (measured using a neutron moisture meter – data not shown) and resultant yields of the peanut crops. This was due to a combination of intensive tillage after the ley minimising differences in soil structure, and the high rates of internal drainage and low plant available water storage in these soils (1, 2). Therefore, the measured peanut rotation responses were more likely due to impacts on soil health, and in particular to the incidence of soil-borne peanut pathogens.

There were a number of known soil-borne peanut pathogens present at the experimental site during the study, including lesion and root knot nematodes, crown rot (causal organism *Aspergillus niger*), Verticillium wilt (causal organism *Verticillium dahliae*), collar rot (*Lasiodiplodia theobromae*) and Sclerotinia (causal organism *Sclerotinia minor*). The incidence and severity of all these organisms varied with season (eg. Sclerotinia was only evident in the relatively wet 1993/94 season), but while the incidence of a number of these organisms was affected by crop rotation (eg. Table 2), the combined contribution of all these known pathogens to variation in peanut yield within any particular season ranged from 5-50%. The lowest contribution to yield variation by these organisms occurred in the very poor seasons (years 2, 5 and 8 in Fig. 1a), when the predominant yield-limiting factor was water deficit.

Table 2. Effect of crop rotation on the incidence of selected pathogens in the following peanut crop in crop years 7 and 9 (from Fig. 1). Different letters indicate significant differences between rotations for the particular pathogen in the respective growing season.

Pathogen	Continuous peanut, winter fallow		Continuous peanut, winter oats		Peanut rotated with soybean, oats and maize)	
	Year 7	Year 9	Year 7	Year 9	Year 7	Year 9
Root knot nematodes (/g dw root)	465a	1580a	690a	1775a	32b	29b
Lesion nematode (/g dw root)	480	215	668	63	376	201
Verticillium wilt at harvest (% plants)	16.5a	47.8a	4.4b	37.8ab	3.7b	23.1b
Sclerotinia at harvest (% plants)	0	5.8a	0	3.6a	0	15.9b
Plant mortality due to Crown Rot (% plants)	23.7a	20.7a	24.6a	17.8a	1.6b	6.3b

Conclusions

Seasonal rainfall conditions have the greatest impact on productivity of rainfed peanut crops in the inland Burnett. However, crop rotations involving a year without peanuts in each field will consistently result in greater peanut yields and gross returns than in peanut monocultures, with residual benefits persisting for a further 2 peanut crops. Rotations significantly reduced the incidence of known peanut pathogens, with the greatest benefits in terms of yield and returns occurring in high-yielding seasons. These findings will form the basis of economic analyses to determine the optimum peanut frequency in the cropping systems of this region.

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