Importance of Rotation with Groundnut for Cereal Productivity

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Abstract

In a rotation experiment conducted from 1981 to 1986, preceding groundnut crops led consistently to high maize yields. On the other hand, a maize/groundnut intercrop and maize and sorghum sole crops proved to be poor preceding crops for cereals.

Maize test-crops grown without N on all plots of the rotation experiment during 1987 and 1988 revealed strong favorable residual effects of preceding groundnut. However, an appreciable residual effect of maize/groundnut intercropping was noticed in 1987 only. Previous maize crops led to poor test crop yields. Sorghum cultivation before or during 1986 was detrimental to maize productivity in 1987 and 1988.

Sumário

Importancia da Rotação com Amendoim para a Produtividade do Cereal. *Num experimento sobre rotações, conduzido de 1982 a 1986, o amendoim, como cultura precedente, levou o milho a produzir rendimentos consistentemente maiores. Por outro lado, a consociação milho/amendoim e as culturas puras de milho e mapira, provaram ser pobres culturas precedentes para os cereais.*

Culturas-teste de milho, cultivadas sem N em todos os talhões do experimento de rotações, durante 1987 e 1988, revelaram haver fortes efeitos residuais favoráveis do amendoim precedente. Contudo, um efeito residual apreciável da consociação milho/amendoim, apenas foi notado em 1987. O milho, como cultura precedente levou a pobres rendimentos da cultura teste. O cultivo de mapira, antes ou durante 1986, foi prejudicial para a produtividade do milho em 1987 e 988.

Introduction

As cereals are the staple diet of subsistence farmers, they feel obliged to concentrate on cereal production when land availability and soil fertility are decreasing. In many countries, south of the Sahara and elsewhere, increasing population pressure on the land has thus led to extended cereal monoculture. Small-scale farmers usually cannot afford to counteract the negative effects of crop succession by adequate fertilizer application.

Replacement of the old fallow system with predominant cereal production including rotations with legumes and other noncereals in central Europe as

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from the middle of the previous century has been considered one of the most important factors responsible for the tremendous increase in cereal productivity in that area.

During recent years, cropping-systems research has been carried out in various African countries including northern Nigeria (Lombin 1981) and Ghana. In the northern and upper regions of Ghana, crop-rotation, intercropping, and alley-cropping experiments have been conducted since 1981 to identify cropping systems that will ensure the maintenance of high productivity of permanently cultivated soils. In this paper, beneficial residual effects of groundnut (*Arachis hypogaea* L.) cultivation on the productivity of the subsequent crop of maize (*Zea mays* L.) in an experiment lasting from 1981 to 1988 will be discussed.

Materials and Methods

The experiment was conducted at Nyankpala in the Guinea Savanna zone (9°25'N and 1°W, 200 m above sea level). There is one rainy season from April to October with a peak from July to September and the annual rainfall is 1069 mm. The soil is sandy loam (chromic Luvisol) over a skeletal phase developed over sandstone. Carbon (0.5%) and nitrogen (0.04%) contents are low and the pH is 6.3.

In 1981, maize, groundnut, maize/groundnut intercropping, yam (*Dioscorea rotundata* L.), and sor-

Table 1. Influence of preceding crops on the grain yield of maize at Nyankpala, Tamale, Ghana, in five seasons, 1982–86.

Preceding crop in rotation with maize	Nitrogen applied to maize (kg ha^{-1})	Maize grain yield (t ha^{-1})				
		1982	1983	1984	1985	1986
Maize	0	1.04	0.38	1.19	1.72	2.35
	60	2.80	1.58	4.72	4.47	3.74
	Mean	1.92	0.98	2.96	3.10	3.04
Groundnut	0	2.83	1.66	3.02	3.62	3.35
	60	4.12	3.20	6.36	5.55	4.06
	Mean	3.48	2.43	4.69	4.58	3.70
Maize/groundnut intercropping	0	0.94	0.86	1.45	2.64	2.98
	60	2.69	2.08	4.27	4.53	3.83
	Mean	1.82	1.47	2.86	3.58	3.40
Yam	0	2.30	0.84	1.66	2.04	2.70
	60	4.18	2.78	5.73	5.62	3.86
	Mean	3.24	1.81	3.69	3.83	3.28
Sorghum	0	0.75	0.26	0.58	1.40	2.07
	60	2.03	1.21	3.45	3.80	3.12
	Mean	1.39	0.74	2.01	2.60	2.59
SE	a[1]	±0.208	±0.146	±0.233	±0.145	±0.086
	b[1]	±0.079	±0.052	±0.112	±0.054	±0.076
	b/a[1]	±0.177	±0.117	±0.251	±0.121	±0.170
	ab[1]	±0.243	±0.168	±0.293	±0.168	±0.148
Mean	0	1.57	0.80	1.58	2.28	2.69
	60	3.16	2.17	4.91	4.79	3.72
	Mean	2.37	1.49	3.24	3.54	3.20
CV (%)	a[1]	25	28	20	12	8
	b[1]	15	16	15	7	11

1. a = Preceding crops (main plots); b = N application (subplots) levels; b/a = b within each a (or N levels within preceding crop treatments); ab = Interaction.

ghum [*Sorghum bicolor* (L.) Moench] were sown in adjoining strips. Spacings were 80 cm × 25 cm for maize, 60 cm × 15 cm for groundnut, 120 cm × 120 cm for yam, and 80 cm × 30 cm for sorghum (tall local). Intercropped maize and groundnut were sown in alternating rows 60 cm apart and at the sole-crop intrarow spacings. In 1982, the same crops were grown in strips at right angles, across those of 1981, so that all possible crop successions were realized. The direction of plant rows was not altered. Plots reserved for crop successions were divided into subplots, with and without N application. Thirty kg N ha^{-1} was applied to groundnut and 60 kg N ha^{-1} to all other crops. There were four replications. Annual repetition of these treatments until 1986 allowed evaluations of alternating horizontal and vertical crop sequences and N fertilizer effects.

During the 1987 and 1988 cropping seasons, maize without N fertilizer application was sown as a test crop on all the plots. For evaluations, the 1986 crops were the main plots in a split-split plot, the 1985 crops (grown in rotation with 1986 crops since 1981) were the subplots, and previous N treatments were the sub-subplots. Border effects were eliminated.

Prior to each season, 26 kg P_2O_5 ha^{-1} was applied as superphosphate and from 1984, 50 kg K ha^{-1} as KCl. Cereal residues were removed, but those of groundnut and yam were left in the experimental fields. Grain yields were calculated on a 12% moisture basis.

Table 2. Influence of various crop successions and nitrogen fertilizer application during 1981–86 on the grain yield of a maize test crop at Nyankpala, Tamale, Ghana, 1987.

		1985 crop in rotation with 1986 crop since 1981					
		Grain yields of maize (t ha^{-1})					
1986 crop	N application[1] 1981-86	Maize	Maize/ groundnut	Groundnut	Yam	Sorghum	Mean
Maize	Not applied	0.81	0.93	1.18	0.92	0.43	0.86
	Applied	1.43	1.40	1.52	1.21	0.98	1.31
	Mean	1.12	1.17	1.35	1.07	0.70	1.08
Maize/groundnut	Not applied	1.72	1.80	1.83	1.71	1.15	1.64
	Applied	2.12	2.16	2.13	1.90	1.78	2.02
	Mean	1.92	1.98	1.98	1.81	1.47	1.83
Groundnut	Not applied	2.62	2.69	3.10	2.64	1.10	2.43
	Applied	3.00	2.97	3.39	3.03	2.12	2.90
	Mean	2.81	2.83	3.24	2.84	1.61	2.66
Yam	Not applied	0.91	1.32	1.89	0.88	0.28	1.05
	Applied	1.94	2.11	2.18	1.88	1.22	1.86
	Mean	1.42	1.71	2.03	1.38	0.75	1.46
Sorghum	Not applied	0.51	0.80	1.11	0.68	0.38	0.70
	Applied	1.07	1.23	1.66	1.20	0.85	1.20
	Mean	0.79	1.02	1.39	0.94	0.62	0.95
Mean	Not applied	1.32	1.51	1.82	1.37	0.67	1.34
	Applied	1.91	1.97	2.18	1.84	1.39	1.86
	Mean	1.61	1.74	2.00	1.60	1.03	1.60
SE	a[2]	±0.073	b/a[2]	±0.120	ab[2]	±0.130	
	b[2]	±0.054	c/a[2]	±0.047	ac[2]	±0.080	
	c[2]	±0.021	c/a[2]	±0.047	bc[2]	±0.063	
					abc	±0.150	

1. 30 kg N ha^{-1} to groundnut; 60 kg N ha^{-1} to all other crops, 1987 no N application.
2. a = 1986 crops (main plots); b = 1985 crops (subplots); c = N application (sub-subplots).

Results and Discussion

Grain yields of maize obtained after various preceding crops between 1982 and 1986 are presented in Table 1.

In all the test seasons, maize yielded most when it followed groundnut and less when it followed maize or sorghum. The differences in yield were greatest when no nitrogen was added. The actual magnitude of the differences (average of five test seasons) was as follows: compared to maize following maize, yields of maize following groundnut were 2.2 times greater without nitrogen and 1.3 times greater with nitrogen. Similarly, compared to maize following sorghum, yields of maize following groundnut were 2.9 times greater without nitrogen and 1.7 times greater with nitrogen.

Maize/groundnut intercropping as preceding crops for maize was at first hardly superior to sole maize but improved subsequently and finally ranked between cereals and groundnut.

In 1987, the first test season for residual effects, maize yields were highest on the plots that had groundnut monoculture. The yields from plots that had groundnut in rotation with other crops, including maize, were only slightly lower than the highest (Table 2). However, yields were lower in plots that had sorghum in rotation with groundnut.

Table 3. Influence of various crop successions and nitrogen fertilizer application during 1981–86 on the productivity of a second maize test crop at Nyankpala, Tamale, Ghana, 1988.

1986 crop	N application[1] 1981-86	1985 crop in rotation with 1986 crop since 1981 — Grain yields of maize (t ha^{-1}) Maize	Maize groundnut	Groundnut	Yam	Sorghum	Mean
Maize	Not applied	1.00	0.92	1.00	0.98	0.41	0.86
	Applied	1.06	0.97	1.24	1.11	0.82	1.04
	Mean	1.03	0.95	1.12	1.04	0.61	0.95
Maize/groundnut	Not applied	1.04	1.02	0.74	1.00	0.55	0.87
	Applied	1.07	1.13	1.26	1.16	1.04	1.13
	Mean	1.05	1.08	1.00	1.08	0.79	1.00
Groundnut	Not applied	1.28	1.46	2.73	1.88	0.93	1.65
	Applied	1.32	1.82	2.92	2.14	1.22	1.88
	Mean	1.30	1.64	2.82	2.01	1.08	1.77
Yam	Not applied	0.68	1.02	1.41	0.76	0.22	0.82
	Applied	1.18	1.30	2.05	0.98	0.39	1.18
	Mean	0.93	1.16	1.73	0.87	0.30	1.00
Sorghum	Not applied	0.68	0.83	0.94	0.48	0.33	0.65
	Applied	1.16	0.84	1.13	0.43	0.66	0.85
	Mean	0.92	0.84	1.04	0.45	0.50	0.75
Mean	Not applied	0.93	1.05	1.36	1.02	0.49	0.97
	Applied	1.16	1.22	1.72	1.17	0.83	1.22
	Mean	1.04	1.13	1.54	1.09	0.66	1.09
SE	a[2]	±0.121	b/a[2]	±0.203	ab[2]	±0.218	
	b[2]	±0.091	c/a[2]	±0.057	ac[2]	±0.127	
	c[2]	±0.025	c/b[2]	±0.057	bc[2]	±0.099	
					abc[2]	±0.236	

1. 30 kg N ha^{-1} to groundnut; 60 kg N ha^{-1} to all other crops, 1987 and 1988 no N application.
2. a = 1986 crops (main plots); b = 1985 crops (subplots); c = N application (sub-subplots).

Yields were generally low where maize followed maize or sorghum directly. For these preceding crops, previous rotation with groundnut was favorable, but monoculture of sorghum or maize-sorghum rotation was unfavorable. Preceding maize/groundnut intercropping led to test crop yields that were between sole groundnut and sole maize.

In the second test season (1988), groundnut monoculture until 1986 was again the most favorable treatment (Table 3). The second best was yam-groundnut rotation and third, a rotation of maize/groundnut intercropping and groundnut. Rotation of groundnut and sorghum before 1986 tended to lead to low maize yields in 1988. These results show that groundnut cultivation, particularly repeated groundnut cultivation or yam-groundnut rotation, may increase the maize yield up to 2 or 3 years later. In the cases of groundnut rotation with maize or maize/groundnut intercropping, the favorable effect decreases when maize follows on the same land for a second time.

Negative effects of cereal successions are explained by very low nitrogen contents in cereal residues leading to pronounced nitrogen deficiency during decomposition (Schmidt and Frey 1988). However, a lasting negative effect of tall local sorghum on maize, even when other crops, including groundnut, follow the sorghum, is remarkable. Burgos-Leon et al. (1980) explained negative effects of sorghum on subsequent crops by allelopathy.

According to experience in various experiments, crop-rotation effects are strongest on light soils, in particular on soils with a poor nitrogen status. Groundnut does not need nitrogen fertilizer. If phosphorus fertilizer is not applied directly, this crop should at least be able to take advantage of residual phosphorus applied to preceding cereals. Replacing monoculture of maize by a maize-groundnut rotation may lead to such an increase in maize productivity that the same quantity of maize may be produced on the reduced area.

References

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Discussion

Rweyemamu: You mentioned that groundnut does not need any nitrogen fertilizer according to the experience in various experiments. Is this because the crop fixes enough N? If so, how much N is fixed by the crop in that area?

Schmidt: Studies have shown that in good years/seasons the groundnut crop does fix up to 70 kg N ha^{-1} a^{-1}. However, in bad years the crop can fix as low as 0–12 kg N ha^{-1} a^{-1}.

Mayeux: At which period was N applied? According to your results, do you think an application of potassium to sorghum can be recommended to expect a reasonable yield? Do you leave stover in the field after harvest?

Schmidt: N was applied at sowing as side-dressing. No experiment has been done in the way you suggested but it is certainly true that potassium can help sorghum production. Stover is removed from the field because of the difficulty to protect the field experiment from being burnt.

Ismael: You mentioned that groundnut preceded by groundnut and the application of fertilizer resulted in lower yield. Do you attribute this to weed infection? Did you notice any difference in canopy development compared to higher-yielding treatments?

Schmidt: We noticed luxuriant growth of weeds and attributed the lower yield to competition.

Subrahmanyam: Did you analyze the partitioning coefficients in groundnut after groundnut and N-fertilized groundnut crops treatments?

Schmidt: Apparently there were no differences in vegetative growth and yield in these treatments.