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Research Article

Residual Nitrogen Contributions from Grain Legumes to the Growth and Development of Succeeding Maize Crop

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Field experiment was conducted at the Institute for Agricultural Research Farm at Samaru, Nigeria in 2008 and 2009 rainy seasons to investigate the residual nitrogen contributions by four legume crops (soyabean, cowpea, lablab, and groundnut) to the growth and development of succeeding maize given four levels of nitrogen fertilizer (0, 40, 80, and 120 kg N ha^{-1}). In 2008, the treatments consisted of four legumes, maize and a fallow period. The six treatments were laid out using randomized complete block design replicated four times. In 2009, maize crop was planted on the previous crops' plots and fallow. The experimental design used was split-plot with previous legumes, maize, or fallow as main plots, and the four nitrogen fertilizer treatments as subplots. Results obtained showed that nitrogen availability in the top soils of the previous legumes and fallow compared with that of maize plot was increased by 250, 200, 170, 107 and 157% after lablab, groundnut, cowpea, soyabean and fallow, respectively. Maize grown on previous lablab plot significantly recorded higher growth characters compared with maize following other legumes and fallow. Growth of maize was highest with the application of lower rates of nitrogen after lablab and groundnut compared with maize after maize.

1. Introduction

Legumes play a wide role in contributing to food security, income generation, and maintenance of environment for millions of small-scale farmers in sub-Saharan Africa [1]. In most parts of sub-Saharan Africa, legumes are usually intercropped with cereals and improve land productivity through soil amelioration. In crop rotation, legumes contribute to a diversification of cropping systems and as N_2-fixing plant, it can reduce the mineral N fertilizer demand. Nitrogen is the most important nutrient element required for crop production especially for cereals, which have been reported to dominate cultivated land in the world [2]. For maximum maize grain yield to be realized in the northern Guinea Savanah of Nigeria, addition of 120 kg N ha^{-1} of inorganic fertilizer is required [3].

Although inorganic fertilizer is a convenient source of nitrogen for crop growth, its use is ultimately governed and regulated by economic and environmental considerations. In Nigeria, government inconsistent policies on fertilizer subsidiary had led to the problem of high price of fertilizer which was beyond what a peasant farmer could afford. It also led to adulteration. When subsidy was finally replaced, farmers were faced with the problems of hoarding which culminated in nonavailability of fertilizer at the right time [4]. The environmental problems associated with excessive use of nitrogen fertilizer is now a contentious issue. Recent studies have shown that application of inorganic N depletes soil organic carbon and N.

If agricultural production must be intensified, ways of making maximum use of the remaining agricultural land must be pursued without land degradation and pollution, which are often the result of intensive cultivation and fertilizer application. Grain legumes cause significant and positive yield effects on subsequent nonlegume crop when compared with rotations with nonlegumes [5]. In addition to these beneficial factors, other benefits such as improving soil structure, breaking pest and disease cycles and phytotoxic and allelopathic effects of crop residues are also derived. Crop rotation involving legumes was reported to have reduced the rate of applied nitrogen fertilizer in succeeding maize crop [6]. Previous researches in the Nigeria guinea savanna focused attention mainly on effects of forage legumes on cereal crop yields [7, 8]. This study therefore seeks to investigate the residual nitrogen contribution of edible grain legumes namely; cowpea, soyabean, and groundnuts together with pasture legume, lablab niger to soil nitrogen content and the growth of succeeding maize crop.

2. Materials and Methods

Experiments were conducted for two years (2008 and 2009) at the Teaching and Research Farm of the Institute for Agricultural Research (IAR), Samaru, Nigeria located at latitude $11^\circ 10'$N and longitude $7^\circ 38'$E 686 meters above sea level in the northern Guinea savanna agro ecological zone to evaluate the residual nitrogen contribution from four grain legumes to the growth and development of the succeeding maize crop. Samaru has a well drained leached ferruginous tropical sandy loam soil and a mean annual rainfall of 1100 mm distributed between May and October. In 2008, the experiment consisted of four different types of legumes (soyabean, cowpea, groundnut, and lablab), a fallow period and maize plots to which to which four levels of nitrogen in the form of urea (0, 40, 80, and 120 kg N ha^{-1}) were applied as treatments. The twenty-four treatments were laid out in a randomized complete block design and replicated four times.

Composite soil sample was taken to a depth of 30 cm and analyzed for their physical and chemical properties before ridging. The gross plot size was 27 m^2 (4.5 m × 6 m) while the net plot size was 15 m^2 (3 m × 5 m). The experimental area was disc-ploughed and harrowed twice to a fine tilt. This was then followed by ridging at 75 cm apart (between rows) and the field marked into plots and replications. The plots were separated by 1.0 m unplanted boarder while replications were separated by 2.0 m unplanted boarder. Seeds of cowpea, lablab, and groundnut were planted at 30 cm intrarow spacing while, soyabean was drilled at 5 cm, and maize was planted at 25 cm intra row spacing. After harvesting all the legumes and the maize, soil samples from each plot were collected and again analyzed for their physicochemical properties using standard procedures.

In 2009, maize was planted on plots of the previous legumes; fallow and maize plots after ridging. Each former legume, fallow, and maize plots were divided into subplots to which four nitrogen (N) levels (0, 40, 80, and 120 kg N ha^{-1}) in the form of urea were applied. The experimental design used was split—plot with legumes and fallow allocated to the main plot while nitrogen was allocated to the sub-plots. The treatments were replicated four times. Maize seeds were sown on plots consisting of six ridges, 75 cm apart and 6 m long. Two to three seeds of maize were sown 25 cm apart (intrarow spacing) and later thinned to one plant at two weeks after sowing (WAS).

All plots received a basal application of 22 kg P ha^{-1} as single super phosphate (SSP), 33.3 kg K ha^{-1} as muriate of potash (MOP). Half of each of the four nitrogen treatments was applied at two weeks after sowing, while the remaining half was applied at 6WAS. Manual hoe weeding was done at 3, 6 and 9 WAS to keep the experimental plots weed free.

Ten randomly selected plants samples from each plot were used to determine the treatment effects on parameters such as plant height, leaf area index and total dry matter per plant 8 and 10 weeks after sowing. Fodder yield was taken at harvest. The data collected were subjected to analysis of variance using the "*F*" test to estimate the significance in the effects of the treatments as described by Snedecor and Cochran [9]. Comparisons of treatment means were done using least significant difference.

3. Results and Discussion

Table 1 shows the nutrient status of the soil before and after the first experiment respectively. The result showed increased in the total nitrogen, after cropping any of the four legumes (soyabean, cowpea, lablab, and groundnut) and when the land was left fallow. For instance, previous lablab plots had the highest total nitrogen of 0.49% followed by groundnut, cowpea, soyabean, and fallow plots with 0.42%, 0.38, 0.29 and 0.26%, respectively. This represented increases of 250%, 200%, 171%, and 107% in the soil total nitrogen after cropping lablab groundnut, cowpea, soyabean, and when the land was left fallow respectively compared to the total nitrogen content of the soil before experiment in 2008. The total nitrogen content of the maize plots after experiment in 2008 decreased probably because maize is a high nitrogen demanding crop and might have used up almost all the applied N. The significant increase in the total nitrogen of the experimental plots to which legumes were grown could be attributed to the ability of legume to fix atmospheric nitrogen in the soil through symbiotic N fixation. The variation in the amount of nitrogen fixed by various legumes could be attributed to the amount of plant biomass produced by the various legumes because the higher the biomass produced, the higher the amount of N fixed. The higher Cation Exchange Capacity (CEC) which plots that were previously cropped to legumes had compared with the previous maize plot and fallow plots could be attributed to the leaf litter droppings, which more or less serve as mulch and later decomposed to add nutrient to the soil. It could also be attributed to less removal of inorganic N from the soil by the legumes, compared to the cereal—a phenomenon referred to as "N sparing" effect [10, 11]. Lablab added the highest soil nitrogen and CEC compared with other legumes. This could be attributed to its higher rate of growth compared with the other legumes, which made the plots where it was being cropped to be bushy. The leaf litter droppings, which decomposed was another factor. This is in conformity with the findings of Vasconcellous [12].

The effect of the previous crops, fallow, and nitrogen levels on the height of the succeeding maize crop at 8 and 12 WAS are shown in Table 2. At 8 and 12 WAS the tallest maize plants were obtained from the previous lablab plots followed by those from groundnut plots. The height of maize

Table 1: Physicochemical properties of soil of experimental site before planting and after harvesting in 2008 at Samaru.

Before planting in 2008		After harvesting in 2008					
Soil characteristics				pH ratio 1: 2.5			
		Soil samples	Textural class	H_2O	0.01 m $CaCl_2$	Total N (%)	CEC
Particle size (%)							
Sand	52	M_0	Loam	5.00	4.45	0.13	3.40
Silt	40	M_1	Loam	5.00	4.50	0.13	4.30
Clay	08	M_2	Loam	4.80	4.50	0.12	4.10
Textural Class	Loam	M_3	Loam	4.70	4.50	0.12	4.40
Chemical composition							
pH in water	5.10	Soybean plot	Loam	5.00	4.40	0.29	4.80
Organic carbon (%)	0.50	Cowpea plot	Loam	5.00	4.80	0.38	5.20
Total nitrogen (%)	0.14	Lablab plot	Loam	5.20	4.40	0.49	6.80
Available phosphorus (%)	2.44	g. nut plot	Loam	4.80	4.40	0.42	6.40
		fallow plot	Loam	5.00	4.70	0.26	4.10
Exchangeable bases							
Ca	0.60						
Mg	0.08						
K	0.21						
Na	0.36						
H + Al	0.40						
CEC	3.20						

Key
M_0: Maize plot without nitrogen fertilizer.
M_1: Maize plot with 40 kg N ha^{-1}.
M_2: Maize plot with 80 kg N ha^{-1}.
M_3: Maize plot with 120 kg N ha^{-1}.

Table 2: Effect of previous legume crops on the height (cm) of succeeding maize crop using different N-fertilizer levels at Samaru, Zaria Nigeria during 1988 cropping season.

Treatment	Weeks after sowing	
	8	12
Previous legume crop (P)		
Soyabean	83.91c	175.76c
Cowpea	88.40c	118.97e
Lablab	121.11a	215.63a
Groundnut	104.02b	190.51b
Previous maize	82.81c	173.32cd
Fallow	92.92bc	182.13bc
Nitrogen (N kg ha^{-1})		
0	64.81d	148.47d
40	85.30c	190.26c
80	114.11b	200.00b
120	118.01a	207.48a
Interaction (P × N)	NS	*

Means followed by the same letter(s) within the same treatment group and week are not statistically different at 5% level of significance.
NS: Not significant.
*: Significant at 5% level of significance.

Table 3: Interaction between previous crop and nitrogen fertilizer on the height (cm) of succeeding maize crop at 12 WAS at Samaru, Zaria, Nigeria during 2008 cropping season.

	Fertilizer rates (kg N ha^{-1})			
	0	40	80	120
Previous Legume crops				
Soyabean	137.7i	185.5e	188.6e	193.3d
Cowpea	148.9h	187.2e	193.4d	198.4d
Lablab	176.2ef	212.8c	239.7ab	243.8a
Groundnut	152.2h	195.5d	202.5cd	211.8c
Previous maize	135.5i	175.8fg	189.7de	194.3d
Fallow	142.3hi	186.7e	196.2d	203.3c

Means followed by the same letter(s) are not statistically different at 5% level of significance.

on previous maize and soyabean plots, fallow and cowpea plots, were statistically at par at both 8 and 12 WAS. The height of maize plant responded to nitrogen application up to 80 kg N ha^{-1} above which no discernible increase was observed at both 8 and 12 WAS.

Significant interaction occurred between previous crops, fallow and nitrogen fertilizer on maize height at 12WAS. The results obtained showed that the tallest maize plants were produced with the application of 80 kg N ha^{-1} on the previous lablab plots while the shortest maize plant was produced on the previous maize plots to which no N was applied (Table 3).

Table 4: Effect of previous legume crop and nitrogen fertilizer on leaf area (cm^2) per plant of succeeding maize crop at Samaru during 2008 cropping season.

Treatments	Weeks after sowing	
	8	12
Previous Crops (P)		
Soyabean	529.8b	677.2d
Cowpea	521.3b	686.2d
Lablab	668.8a	894.5a
Groundnut	563.1b	757.6bc
Previous maize	533.1b	687.9d
Fallow	548.0b	787.4b
Nitrogen (kg N ha^{-1})		
0	248.3c	450.1d
40	555.7b	774.3c
80	646.9a	850.0b
120	691.9a	919.5a

Means followed by the same letter(s) within the same treatment group and same week are not statistically different at 5% level of significance ($P \leq 0.05$).

Table 5: Effect of previous legume crops and nitrogen fertilizer levels on dry weight of succeeding maize crop at Samaru, Zaria, Nigeria during 1998 cropping season.

Treatments	Weeks after sowing	
	8	12
Previous Crops (P)		
Soyabean	52.21b	164.53e
Cowpea	49.52b	181.41cd
Lablab	65.85a	246.72a
Groundnut	52.41b	197.99b
Previous maize	36.80d	154.99e
Fallow	49.03bc	185.91bc
SE±	3.89	4.95
Nitrogen (kg N ha^{-1})		
0	36.82d	127.29d
40	44.55c	182.44c
80	56.93b	216.10b
120	65.62a	228.54a
Interaction (P × N)	NS	*

Means followed by the same letter(s) within the same treatment group and same week are not statistically different using DMRT ($P = 0.05$).

Leaf area per plant of maize as influenced by previous crops, fallow, and nitrogen application showed that the highest leaf area of maize were obtained from the previous lablab plot and the application of 120 kg N ha^{-1} at both 8 and 12 WAS compared with other previous crops, fallow, and other levels of applied nitrogen (Table 4).

Treatment effects on total dry matter per plant are shown in Table 5. At both 8 and 12 WAS, the previous lablab plots and application of 120 kg N ha^{-1} significantly increased the TDM per plant of the succeeding maize crop compared with the other previous legumes, previous maize, fallow plots, and other levels of applied nitrogen.

Table 6: Interaction between previous crops and nitrogen fertilizer rates (kgN/ha) on dry weight of succeeding maize crop at 8 and 12 WAS at Samaru, Zaria during, Nigeria 1998 cropping season.

Treatments	Fertilizer rates (kg N ha^{-1})			
Previous crops	0	40	80	120
	8 weeks after sowing			
Soyabean	43.8d	44.4d	56.0c	64.7b
Cowpea	35.2e	44.6d	55.4c	63.1b
Lablab	46.3d	58.2c	74.4ab	84.5a
Groundnut	39.2d	42.2d	61.0bc	67.3b
Previous maize	23.9f	35.7e	38.4de	49.2cd
Fallow	32.5ef	42.2d	56.4c	65.0b
	12 weeks after sowing			
Soyabean	109.2j	177.1hi	187.3gh	190.1fg
Cowpea	111.1j	173.2hi	218.1dc	223.0dc
Lablab	207.4ef	239.3cd	264.3ab	277.1a
Groundnut	123.31i	191.1fg	226.2dc	252.3bc
Previous maize	104.5j	138.1i	189.4gh	198.4fg
Fallow	119.0ij	181.2gh	213.1ef	254bc

Means followed by the same letter(s) within the same week are not statistically different at 5% level of significance ($P \leq 0.05$).

Interaction between previous crops, fallow, and nitrogen fertilizer rate on the TDM per plant of succeeding maize crop at 8 and 12 WAS showed that the previous lablab plots and the application of 80 kg N ha^{-1} significantly increased the TDM per plant of maize compared to other previous plots, 0 and 40 kg N ha^{-1}. Increasing N application from 80 kg N ha^{-1} to 120 kg N ha^{-1} shows no significant increase in TDM (Table 6).

Treatment effects on the fodder yield of maize are shown in Table 7. Fodder from the previous lablab plots were significantly higher compared with other previous crop plots. The previous maize plots produced the least fodder yield. Nitrogen application significantly increases the fodder yield up to 120 kg N ha^{-1} (i.e., an increase in N rate resulted in a significant increase in maize fodder yield.

Table 8 shows the interaction between previous crop and nitrogen levels on the fodder yield of succeeding maize crop. The interaction showed that application of 120 kg N ha^{-1} to maize crop on the previous lablab plot produced significantly the highest fodder yield of maize compared to other previous crops plots and applied nitrogen levels.

Plant height, leaf area per plant, total dry matter per plant, and fodder yield were significantly influenced by the previous lablab plots compared to other legumes, previous maize plots and fallow plots. This could be attributed to higher nitrogen fixed into the soil by lablab through symbiotic nitrogen fixation, compared to other previous crops plots. This also confirms the fact that nitrogen is

Table 7: Effect of previous legume crops and nitrogen fertilizer on fodder yield of succeeding maize crop at Samaru, Zaria, Nigeria during 1998 cropping season.

Treatments	Fodder yield kg ha^{-1}
Previous Crop (P)	
Soyabean	3628c
Cowpea	4347b
Lablab	5778a
Groundnut	4653b
Previous maize	3134d
Fallow	3742c
Nitrogen kg ha^{-1}	
0	3169d
40	3902c
80	4513b
120	5192a
Interaction (P × N)	*

Means followed by the same letter(s) within the same treatment group are not statistically different at 5% level of significance ($P \leq 0.05$).
*: Significant at $P = 0.05$.

Table 8: Interaction between previous crop and nitrogen fertilizer on fodder yield of succeeding maize crop at Samaru, Zaria, Nigeria during 1998 cropping season.

Previous Crops	Fertilizer rates (Kg N ha^{-1})			
	0	40	80	120
Soyabean	2663jk	3200i	3800gh	4850de
Cowpea	3150i	4200fg	4900d	5138cd
Lablab	4663e	5263c	6000b	7188a
Groundnut	3325i	4575e	5225c	5488c
Previous maize	2213k	2950j	3400hi	3975g
Fallow	3000ij	3225i	3750h	4513ef

Means followed by the same letter(s) are not statistically different at 5% level of significance ($P \leq 0.05$).

the most essential element needed for plant growth and development [13].

The significant response of leaf area, plant height total dry matter per plant and fodder yield kg ha^{-1} to applied nitrogen fertilizer could be due to its role in promoting rapid vegetative growth and its direct effect on cell division, expansion, synthesis of enzymes, and chlorophyll [14].

4. Conclusion and Recommendation

From the foregoing, it can be concluded that previous lablab plots to which reduced inorganic nitrogen fertilizer was applied (80 kg N ha^{-1}), significantly increased the growth and development of the succeeding maize crop and is therefore recommended.

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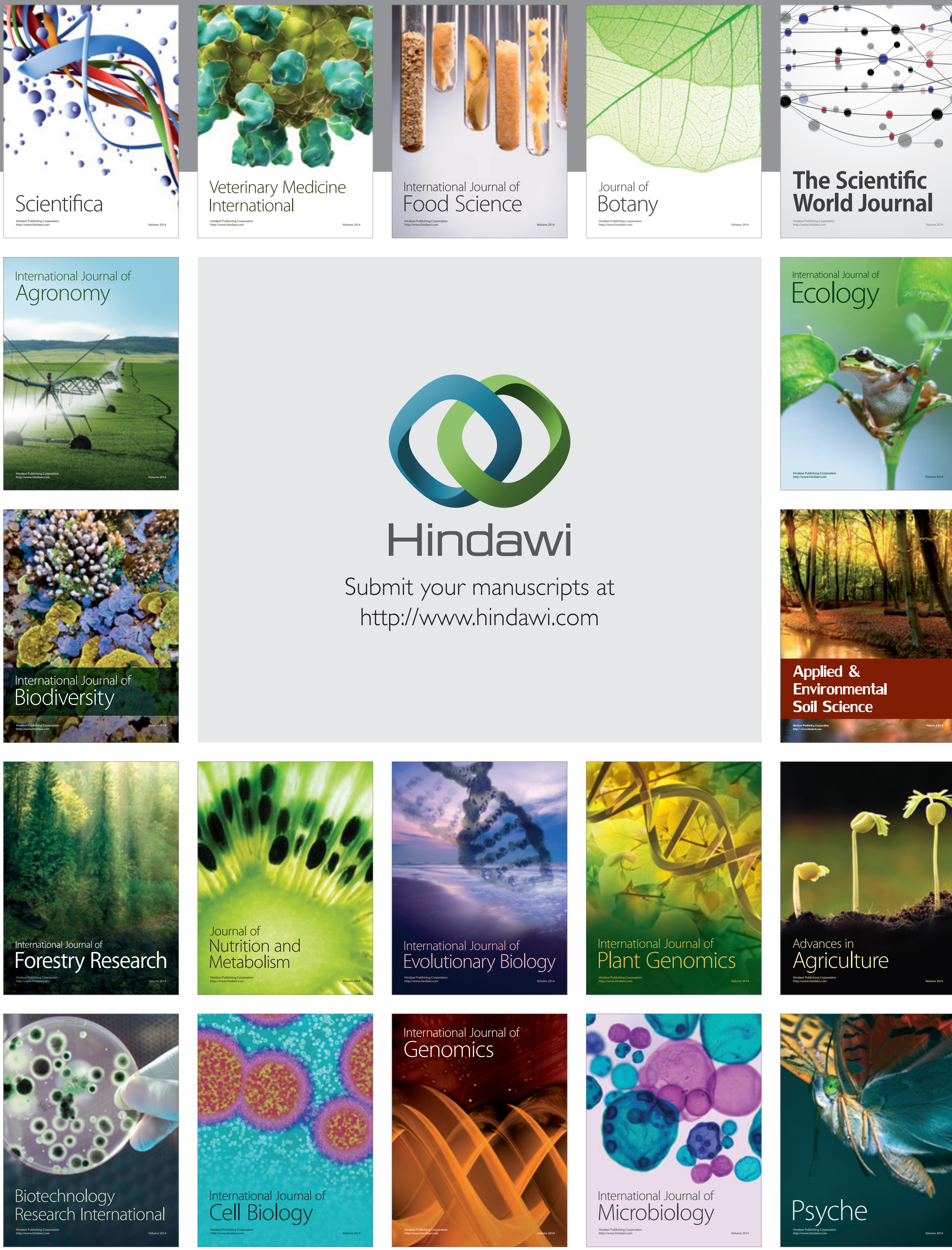
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