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Contribution of Nodulated Legumes on the Growth of *Zea Mays* L. under Various Cropping Systems

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Abstract

Mucuna pruriens, Crotalaria juncea, Cajanus cajan and *Arachis hypogaea* are well nodulated by indigenous rhizobia of soils in the Congo. Nodule numbers per plant range from 8 to 147, nodule mass from 89 to 306 mg per plant and coloured nodules from 72 to 84%. Recent studies reveal that the nitrogen contribution of *A. hypogaea* on the growth of *Zea mays* in intercropping systems is equivalent to an application of 96 kg N fertilizer per ha at a ratio of plant population densities of one maize plant: four groundnut plants. In addition, crop N yield is higher with *M. pruriens* (340 kg/ha) compared to *C. cajan* (114 kg/ha), followed by *C. juncea* (72 kg/ha) and *A. hypogaea* (39 kg/ha). The values of N contribution of legume genotypes as green manure on the grain yield in maize crop are equivalent to an application of 97 kg N-fertilizer/ha, 91 kg N-fertilizer/ha, 89 kg N-fertilizer/ha and 78 kg N-fertilizer/ha for *M. pruriens, C. juncea, C. cajan,* and *A. hypogaea,* respectively. There is evidence of nitrogen contribution of nodulated legumes on the growth of maize crop.

Keywords: Cropping systems, green manure, intercropping, legumes, nodulation, nitrogen, *Zea mays*

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1. Introduction

Intercropping is the practice of growing two or more crops at the same time during the same season, and is a traditional and common practice in most developing countries (Giller et al., 1991; Pineda et al., 1994).

In *Arachis hypogaea* cv. Valencia Red of Loudima, Mandimba (1990) observed a high nodulation rate, due to native populations of soil rhizobia. A possible advantage of intercropping groundnut with maize may be the more efficient use of soil nitrogen in the traditional agricultural systems in the Congo, because the roots of intercrops are in close contact, suggesting a direct transfer of nitrogen (van Kessel and Roskoski, 1988).

On the other hand, the inclusion of legumes as a source of organic matter and N in the cropping system is also a common practice (John et al., 1992; Yano et al., 1994), and application of organic matter to soils is essential to improve soil fertility (Sanchez, 1976; Agboola, 1982; Hulugalle, 1992). Legumes managed as green manure have the potential to furnish all or part of the N needed by a succeeding non legume crop (Bowen et al., 1993), but the efficiency of N use might also be improved by selecting plant materials that decompose and release N in synchrony with plant demand (Bowen et al., 1993; Yano et al., 1994). This management practice, when applied to agricultural land, promotes sustain-ability because of the long-term positive effects on soil chemical and physical properties (Agboola, 1982) and, therefore, a decreased dependence on external sources of costly chemical fertilisers (King, 1990).

Our purpose was to evaluate the nitrogen contribution of nodulated legumes under various cropping systems like intercropping and green manuring for their capability to stimulate the growth of maize.

2. Materials and Methods

Experimental site

Field experiments were conducted at the Institut de Développement Rural, Kombé Brazzaville, (4° 19' S latitude; 15° 19' E longitude and 295 m altitude). The soil had the following characteristics in the top 15 cm layer: pH = 4.7, sand 87%, clay 10%, organic matter 1.3%, total N 0.068%, CEC 6.33 meq/100 g of soil.

Intercropping system (experiment 1)

Short duration genotypes of *Zea mays* cv. TZESR-W-1 and groundnut *Arachis* *hypogaea* cv. Valencia Red of Loudima were tested. The experimental design was a randomized complete block with six treatments and four replications.

The six treatments were: (i) maize without fertilizer (Control), (ii) maize fertilized with 100 kg N/ha (N-100), (iii) groundnut (A_0), (iv) mixed cropping with 1 maize + 4 groundnut as 1:4 ratio (M/A_4), (v) mixed cropping with 1 maize + 8 groundnut as 1:8 ratio (M/A_8), mixed cropping with 1 maize + 12 groundnut as 1:12 ratio (M/A_{12}). Crop culture was previously described by Mandimba et al. (1993).

The experimental intercropping system consisted of adopting a "hole planting method" (Mandimba et al., 1993), a narrow spacing arrangement in which, within each row, groundnut was planted at 15 cm intervals from each maize plant. Additionally, 4, 8 and 12 plants of groundnut, depending on treatments, were equally and symmetrically placed around each plant of maize, reflecting the fact that among intercropped treatments, spatial arrangements are different. Prior to planting, the experimental soil was limed with a recommended level of agricultural limestone (2 t/ha), and fertilized with 80 kg P_2O_5/ha and 80 kg K_2O/ha as superphosphate and potassium sulphate, respectively.

Five plants of the groundnut crop were sampled for determining nodulation and dry matter production at full bloom (33 DAP). Separate plant parts were oven dried at 105°C for 48 h and weighed. Nodules were separated from roots, dried at 70°C for 24 h and weighed. For yield component analysis, cob and grain yields of maize were determined at crop maturity. Yields of crops were adjusted to 14.5% moisture. Statistical analyses of the data were done by ANOVA and when significant differences were found, LSD and t-test were applied for comparisons between means.

Green manuring (experiment 2)

Four legume genotypes, groundnut (*Arachis hypogaea*), velvet bean (*Mucuna pruriens*), pigeon pea (*Cajanus cajan*), sunn hemp (*Crotalaria juncea*) were grown, randomized and replicated four times. Seeds were sown by hand on 10–12 November 1991 on plots of 3 m × 10 m in size. Row spacings were 40 cm × 10 cm for green manure except *C. juncea* whose rows were 30 cm × 10 cm. Plant population densities were 200,000 plants/ha for *A. hypogaea, M. pruriens* and *C. cajan*, and 300,000 plants/ha for *C. juncea*. Prior to planting, all plots were limed with 2.5 t CaO/ha of agricultural limestone, and fertilized with 20 kg P_2O_5/ha and 20 kg K_2O/ha as single superphosphate and potassium chloride, respectively. Fallow plots received manual weeding to keep them free of leguminous weeds like *Desmodium* sp. and *Calopogonium mucoides*. Manual weed control was applied in green manuring plots. *C. juncea* was grown to flowering and then incorporated as green manure. According to local practice, *A. hypogaea* was grown to maturity with pods and grain harvested and the remaining crop residue incorporated during land preparation as green manure for the maize crop. However, at time of incorporation, *M. pruriens* and *C. cajan* were in vegetative growth and incorporated to synchronise the maize crop with the second cropping season.

Prior to incorporation, 10 plants of each legume genotype were randomly selected to evaluate nodulation, dry matter production and N content in plant tops. Separate plant parts were oven dried at 105°C for 48 h and weighed. Nodules were separated from roots, dried at 70°C for 24 h and weighed. Total N was determined by the Kjeldahl method. N yield was expressed on an area basis by multiplying plant biomass/plant by the number of plants/unit of area.

Then green manure and crop residue were incorporated in situ 90 days after planting by plowing to 20 cm depth with a tractor-mounted rototiller. Plots were broadcast in sub-plots of 3 m × 4.5 m in size for maize crop. For estimating the maize response to green manure and inorganic N fertilizer, the treatments were: (i) unfertilized fallow as control; (ii) N fertilized fallow with 100 kg N/ha as N-100; (iii) *A. hypogaea* green manure as *Arachis*; (iv) *M. pruriens* green manure as *Mucuna*; (v) *C. cajan* green manure as *Cajanus* and (vi) *C. juncea* green manure as *Crotalaria*.

Treatments were randomized and replicated four times. Sub-plots were limed with 2.5 t CaO/ha of agricultural limestone, fertilized with 80 kg P_2O_5/ha and 80 kg K_2O/ha. Fertilizers were ammonium sulphate, single super phosphate and potassium chloride for N, P_2O_5 and K_2O, respectively. N fertilizer was applied at sowing (1/2), and at 23 days after sowing (1/2).

The maize crop was hand-seeded on 20 March 1992 with row spacing of 100 cm × 50 cm and a population density of 50,000 plants/ha. The maize was *Zea mays* cv. CC1, a short duration genotype with a life cycle of 80–90 days. The interval from biomass incorporation to maize sowing was 30 days. Seedlings emerged within 5 days and were thinned to one per site 3 days later. The site was maintained weed-free by manual weeding throughout the experiment. Statistical analyses were done by ANOVA. A test of Newman-Keuls was used to establish statistical differences between treatments.

3. Results

Nodulation

Under the intercropping system at time of flowering 33 days after sowing, no significant difference in nodule number between treatments was found.

Conversely, nodule mass of the M/A4 treatment was significantly higher than that of M/A8, M/A12 and control treatments (Fig. 1). In most cases, groundnut plants in all treatments produced more than 95% of coloured nodules (data not shown).

Nodule number among legume genotypes differed, as well as nodule mass (Table 2). *A. hypogaea* produced more nodules (147 nodules per plant) than did *C. juncea* (98 nodules per plant), followed by *M. pruriens* (31 nodules per plant) and *C. cajan* (8 nodules per plant).

M. pruriens exhibited more nodule mass (306 mg per plant) compared to the other legume genotypes. No significant difference was observed in nodule mass between *A. hypogaea, C. cajan* and *C. juncea*. The percentage of coloured nodules in *A. hypogaea, M. pruriens* and *C. juncea* was similar (82–84%), compared with 72% for *C. cajan* (Table 1).

Plant top mass, N in plant top and crop N yield of leguminous crops

Among legume genotypes, nitrogen content was similar (3.0–3.5%). However, plant top mass as well as crop N yield was significantly higher in *M. pruriens* (340 kg/ha) compared with *C. cajan* (114 kg/ha), followed by *C. juncea* (72 kg/ha). *A. hypogaea* exhibited a much lower crop N yield (39 kg/ha; see Table 1).

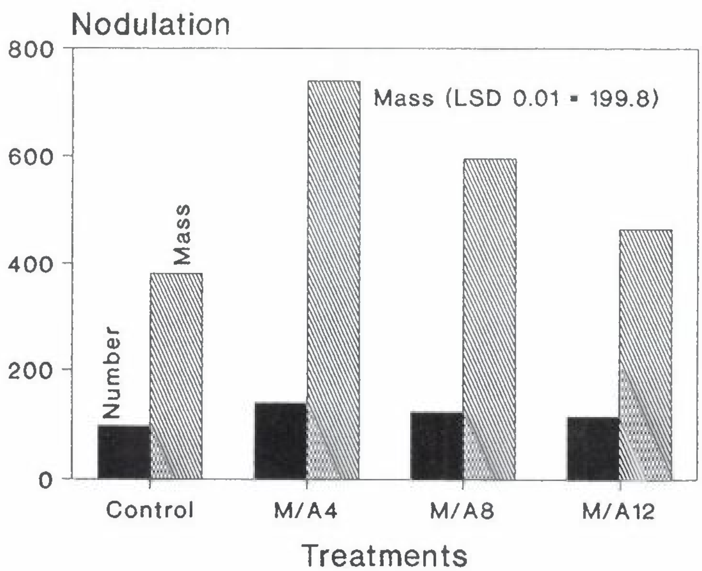

Figure 1. Nodulated plants of *A. hypogaea* under experiment 1. Number (per plant); Mass (mg/plant).

Table 1. Agronomic characteristics of leguminous crops at time of incorporation

Leguminous crops	Nodule number (per plant)	Colored nodule (%)	Nodule mass (mg/plant)	Plant top mass (g/plant)	% N in plant top	Crop N yield (kg/plant)
A. hypogaea	147 a*	84 a	111.40 b	5.74 d	3.46 a	39
M. pruriens	31 c	83 a	305.85 a	36.66 a	3.10 a	340
C. cajan	8 c	72 b	117.50 b	19.19 b	3.00 a	114
C. juncea	98 b	82 a	88.95 b	11.16 c	3.24 a	72
CV (%)	21.3	2	10.6	11.1	9.3	–

*Numbers followed by the same letter do not differ according to Newman-Keuls test at 5% of probability level.

Table 2. Cob and grain yields of maize crop, and nitrogen contribution of nodulated leguminous crops under various cropping systems

Treatments	Cob yield (t/ha)	Grain yield (t/ha)	Nitrogen contribution** (kg N/ha)
Intercropping			
Control	3.34	2.36	88
N-100	3.99 (19)	2.68 (13)	100
M/A4	3.88 (16)	2.59 (10)	96
M/A8	3.06	2.28	85
M/A12	3.03	2.26	84
LSD 0.01	0.88	ns	–
CV (%)	11.8	6.6	–
Green manuring			
Control	2.9 b*	2.3 d	62
N-100	4.1 a (41)	3.7 a (60)	100
Arachis	3.0 b (3)	2.9 c (26)	78
Mucuna	4.1 a (41)	3.6 ab (56)	97
Cajanus	4.0 a (37)	3.3 b (43)	89
Crotalaria	3.7 a (27)	3.4 b (47)	91
CV (%)	6.9	5.0	–

Values in brackets are the increase in percentage from the control. *Numbers followed by the same letter do not differ according to Newman-Keuls test at 5% of probability level. **As determined by procedure of Matos and Schröder (1989). ns, not significant.

Yields of maize crops

Under intercropping systems, no significant difference was observed in cob yields between maize fertilized with 100 kg N/ha and the same crop mixed with groundnut at 1:4 ratio (Table 2). Both treatments yielded more highly than the control. However, cob yields of intercropped maize with groundnut at both 1:8 and 1:12 ratios were lower compared to the control (Table 2). N fertilization at a level of 100 kg N/ha, and mixed crops at 1:4 ratio increased cob yields of maize crops by up to 19% and 16% for N fertilizer and mixed crops at 1:4 ratio, respectively.

N fertilizer at a level of 100 kg N/ha and mixed cropping systems at 1:4 ratio increased the grain yield of maize crops by up to 13% and to 10% for N fertilizer and 1:4 ratio, respectively. Similarly, grain yields under intercropping systems at 1:8 and 1:12 ratios were lower compared to the control (Table 2).

Maize showed a wide range of variation in response to legume green manures and fertilizer N (Table 2). Cob and grain yields of N-100 and *Mucuna* treatment had the largest values (Table 2). Among legume genotypes, *Mucuna* green manure increased the grain yield of maize by up to 56%, compared to *Crotalaria* (47%), *Cajanus* (43%) and *Arachis* (26%) as given in Table 2.

4. Discussion

The present study shows that nodulating legumes under intercropping and green manuring systems contribute to higher yields of the intercropped and succeeding maize crops. Groundnut produced more nodules than did the other legume genotypes. The four legume genotypes nodulated well even though they were not inoculated. These results illustrate that velvet bean, groundnut, pigeon pea and sunn hemp nodulate with indigenous soil rhizobia, eliminating the need for inoculation (Mandimba and Djondo, 1995).

According to works of Hikam et al. (1991) and Wang et al. (1993), nodule mass was a more reliable predictor of nitrogen fixation potential in legumes than nodule number. The legume genotypes exhibited more than 72 percent of coloured nodules with dark red interiors under experiment 2 and 95 percent under experiment 1 (data not shown).

The nodule mass decreased with increased plant population densities and the performance of groundnut was better in the M/A_4 treatment (Fig. 1). Probably in the rooting zone of intercrops, the removal of N by maize during the growth stage enhanced the nodule mass of groundnut, which was in the reproductive stage. These findings were consistent with previous results obtained by Salez (1986) in mixed cropping of soybean and maize without application of N fertilizer. In the present study, maize yields of N-100 and M/A_4 treatments were similar and greater compared to the control as well as M/A_8 and M/A_{12} treatments. In addition, nodulated groundnuts at M/A_4 ratio increased cob yield by up to 16%, and grain yields by up to 10%. N fertilization at a level of 100 kg N/ha increased cob yield of maize by up to 19% and grain yield by up to 13%. The performance of soil management in the intercropping system could be assessed by the procedure of Matos and Schröder (1989). Results suggest that benefits from groundnut to maize were equivalent to 96 kg N/ha applied to the maize crop, and provided an indication of the benefits of intercropping confirming that among intercropping systems, M/A_4 treatment resulted in the most efficient plant population densities under field conditions.

The screening of legume genotypes showed a wide difference in nodulation, plant mass production and N yield. These observations suggested that soil populations of rhizobia had various symbiotic effectiveness in the four legume genotypes. Besides, the differences on crop N yield among legume genotypes may be related to the genotypic variation in the crop growth, in agreement with results of Hairiah et al. (1993) who reported that *M. pruriens* was a fast growing, climbing leguminous.

The amounts of crop N yield that ranged from 39 to 340 kg/ha were similar with the values reported by Bowen et al. (1993) who found that crop N yield of ten legume genotypes ranged from 25 to 300 kg/ha. Among genotypes of legumes tested, *M. pruriens* had proved promising as source of N biofertilizer to the subsequent maize crop, followed by *C. cajan, C. juncea* and *A. hypogaea*.

The responses of maize crop to legume fertilization were evident at crop maturity and differed compared to the control. The best response was related to the grain yield of maize which achieved 3.7 t/ha for the N-100 treatment and 3.6 t/ha for the *Mucuna* one. Differences between *Mucuna* and N-100 treatments were not significant. The lack of significant difference on yields between *Mucuna* green manure and N fertilization may be mainly caused by the amount of nitrogen of *Mucuna* green manure incorporated into the plot.

Among the legume genotypes, *Mucuna* was the most efficient legume manure fertilizer. It increased grain yield of maize by up to 56%, with a performance level of 97%, followed by *Crotalaria* (47%), *Cajanus* (43%) and *Arachis* (26%). *Crotalaria* and *Cajanus* had similar performance level (89%) while *Arachis* was the less efficient green manure on grain yield of maize (76%) as shown in Table 2.

The relative poor agronomic performance of *Arachis* green manure could be attributed to the management practice as well as the N removed with the harvested seeds. These results suggest that in terms of fertilizer-N equivalence, *Mucuna* green manure substituted for 97 kg ammonium sulphate-N/ha in maize crop, followed by *Crotalaria* and *Cajanus* (89 kg N/ha) and

Arachis (78 kg N/ha). This agrees with results from similar works (John et al., (1992) who reported that cowpea green manure N substituted for 6–70 kg urea-N/ha on upland rice.

The crop response is indicative of available soil N and leguminous manure fertilization is strongly efficient for maize crop in the Congo. There is evidence of nitrogen contribution of nodulated legumes on the growth of maize crop.

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