Green Manures Stimulate Root Development of Maize and Mungbean Seedlings

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Abstract

The impact of two tropical green manures, *Crotolaria juncea* and *Tithonia diversifolia* on root growth of two important food crops, maize and mungbean, having fibrous and tap root systems respectively was evaluated. Soils incorporated with the two green manures for three years were used for the study along with a control with no green manures, with and without inorganic fertilizers. Green manures, especially Tithonia stimulated root growth of both species and fertilizers increased this effect. In maize, green manures and fertilizers promoted the development of seminal and nodal roots. In mungbean, both the tap root and lateral roots were stimulated by green manures and fertilizers, highlighting the potential of green manures in promoting extensive roots for better crop establishment.

Media summary

Use of green manures in smallholder tropical farming systems will significantly enhance establishment of crops through the stimulation of root growth.

Key Words

Green manures, Root growth, Maize, Mungbean.

Introduction

Tropical smallholder farming systems lack sustainability due to infertility of soils and continued mining of nutrients (Zingore *et al,* 2003). Organic matter could help provide nutrients and enhance soil quality of these systems. However, available organic matter for inclusion is crop residues with high C: N ratios, although their addition could help enhance soil quality. Hence, green manuring with legumes are recommended to provide nitrogen, the most limiting nutrient in the tropics (Subbian *et al*, 2000), and increase crop yield and sustainability of smallholder systems. *Tithonia diversifolia* has been identified as a potential green manure, especially in African soils with low phosphorus contents (Nziguheba *et al,* 2002).In Asia; Sangakkara *et al* (2004) report the increase in maize yields by applying this species.

An extensive root system is vital for successful crop establishment, especially in drought prone rainfed farming systems. While green manures could help soil retain more moisture (Mandal *et al,* 2003), plant organic matter could also have allelopathic effects on seedlings (Chung *et al,* 2001). Hence, the impact of long term incorporation of *Crotolaria juncea* and *Tithonia diversifolia* to a soil under field conditions, on root development of maize (*Zea mays*) and mungbean (*Vigna radiata*) was determined. The effect of green manuring was assessed from root lengths, weights and rates of root elongation of the two species.

Materials and Methods

The soils for the study carried out at the University of Peradeniya, Sri Lanka, were obtained from field planted either with Crotolaria or Tithonia in one season and maize in the other for a period of three consecutive years (1999 – 2002). The mean quantities of Crotolaria and Tithonia added each season were 500 and 600 g/m^2. Soil from a fallow plot during the periods of green manure growth was used as the control. The three soils were sieved and divided into two. To one lot of each type, fertilizer equivalent to 25 Kg N, 45 Kg P and 30 Kg K per ha was added to develop 6 treatments, namely three soils with and without fertilizers, with 10 replicates per treatment.

Individual open ended PVC tubes (10 cm diameter X 50 cm height) were filled with 5 kg of a soil type, and two seeds of either maize (Var. Ruwan) or mungbean (Var. MI5) were planted in the 6 soil types and placed under 20% shade in a plant house. The pots were watered at 2 -3 day intervals. At V2, V3 and V4 growth stages, which corresponded to 5 harvests for maize (9, 13, 17, 21 and 24DAP) and 4 harvests for mungbean (8, 14, 18 and 22 DAP), the plants were removed from pots, soils washed and roots were seperated carefully and, packed in aluminum foil and stored at -5?C for transport to the Institute of Plant Sciences, ETH; Zurich, Switzerland. In Zurich, the samples were placed in warm water for 2 hours, maize roots were separated into primary, seminal and nodal roots, mungbean roots were separated into tap and lateral roots. The different roots were stained, scanned and lengths measured by image analysis as descried by Chassot and Richner (2002). Thereafter, roots were dried at 65?C for 48 hours and weights determined.

Results and Discussion

Green manures increased root lengths of maize, and the most significant impact was in Tithonia soils (Table 1), a species capable of stimulating Phosphorus availability in soil (Phiri *et al,* 2003). The stimulating effect of all green manures was most prominent in seminal roots of maize. Crotolaria had no impact on nodal root development. Fertilizers increased total root lengths of maize by 13% in soil, 21% in Crotolaria amended soils and by 15% in Tithonia amended soil. Fertilizers reduced the lengths of primary roots, while stimulating elongation of seminal and nodal roots in maize in all soils. This implies that increasing fertility of soil through green manures and fertilizers induced the elongation of secondary roots. In mungbean, green manures reduced the length of the tap root to similar extents (Table 1). Tithonia increased lengths of lateral roots to a greater extent, which again can be attributed to phosphorus dynamics in the rhizosphere due to this green manure. Fertilizers reduced the lengths of tap roots further and enhanced lengths of lateral roots significantly, irrespective of green manures. Hence, increasing fertility of soil enhanced lateral root development for better exploitation of the rhizosphere. Fertilizer application increased total root lengths of mungbean by 98% in green manure untreated soil, 45% in Crotolaria amended soil and 17% in Tithonia amended soil. Unlike for maize crop, the benefits of applying fertilizer in terms of total root length were highest in the soil without green manures. In mungbean, the benefits of fertilizer application are reduced by green manures, which is different to that observed in maize.

Table 1. Impact of green manures and fertilizers on root lengths (mm) of maize and mungbean at V4 growth stages.

Treatment	Maize			Mungbean	
	P	S	N	T	L*
Soil	2742	2085	622	48	854
Soil + F	2482	2854	815	34	1756
Crotolaria	3102	2415	542	42	1586
Crotolaria + F	2792	3721	835	33	2341
Tithonia	3035	2895	756	41	2082

Tithonia + F	2757	3924	995	34	2455
LSD P = (0.05) Fertilizer	44.2	215.6	60.3	4.22	264.3
LSD (P=0.05) Manure	53.47	114.06	40.68	2.03	140.62

*P, S, N, T and L refer to primary, seminal nodal, tap and lateral roots respectively. F = Fertilizer

Green manures increased dry weights of seminal and nodal roots of maize (Table 2), while that of primary roots were reduced. The most significant impact is with Tithonia manuring. This implies a greater partitioning of dry matter to the newly developed seminal and nodal roots in the green manures amended soil, which develop more conducive conditions (reducing soil water evaporation loss) in the rhizosphere (Mandal *et al,* 2003). Fertilizer increased dry weights of all maize roots grown in green manured soils. In contrast, fertilizers reduced dry weights of primary roots grown in untreated soil, which implies that in such soils, plants tend to partition dry matter to the new roots. In green manured soils, roots accumulated dry matter, with a greater increment in seminal and nodal roots. The overall increments in total root dry weights due to fertilizer were 33% in Tithonia amended soils, and 26% and 18% in Crotolaria amended and untreated soils respectively. This supported the data on root lengths, and the impact of fertilizer on root dry matter is stimulated by green manures.

Table 2. Dry weights of maize and mungbean roots (mg) as affected by green manures and fertilizers at the V4 growth stage

Treatment	Maize			Mungbean	
	P	N	S	T	L*
Soil	28.5	16.3	6.3	13.5	11.5
Soil + F	24.6	28.1	7.9	22.4	25.8
Crotolaria	26.1	22.5	7.6	19.3	15.8
Crotolaria + F	27.9	32.7	10.4	27.4	29.6
Tithonia	23.6	27.8	9.3	20.6	19.9
Tithonia + F	28.4	41.6	11.2	36.8	34.9
Probability (F)	1.94	4.93	0.88	4.08	2.52
(Manure)	0.98	2.02	0.66	1.83	0.57

*P, S, N, T and L refer to primary, seminal nodal, tap and lateral roots respectively; F = Fertilizer

In mungbean, tap and lateral root weights were increased by the green manures, and the greatest increment was in Tithonia amended soil. This indicated that dry matter accumulation in the tap root system of mungbean responded differently to that of the fibrous roots of maize, where the new seminal and nodal roots increased dry matter and not the primary roots. Fertilizers, as expected, increased the total dry weights of all roots and the greatest impact was observed in the untreated soil (92%), followed by the Tithonia amended soils (75%) and the Crotolaria amended soils (62%). Again, the stimulating effect of fertilizer on mungbean root weights was different to that of maize and the presence of green manures reduced the benefits of the applied fertilizers on root dry matter accumulation in this legume

The rates of increase in root lengths (Table 3) present the benefits of green manures and fertilizers. Green manures increased rates of elongation of all roots and the highest impact was in maize roots growing in Tithonia amended soil, confirming the data on lengths and dry weights at the V4 growth stage. Fertilizers reduced the rates of elongation of primary roots in maize, while enhancing that of seminal and nodal roots. The most significant increase in rates of elongation was in seminal roots. This implied that with increasing fertility of the soil either through green manures, fertilizers or both, maize plants tend to develop an extensive root system by stimulating the growth of seminal and nodal roots, which emerge later than primary roots. This enables greater exploitation of the rhizosphere. A similar phenomenon is also seen in rates of elongation in mungbean roots (Table 4). Green manures reduce the rate of elongation of the tap root while promoting the development of lateral roots. The most significant impact was in the Tithonia amended soil. Fertilizer application also reduced the elongation rates of the tap roots of plants in untreated and Tithonia amended soils, but has a marginal stimulating effect on tap roots of plants grown with Crotolaria green manure. However the most significant impact of fertilizer was in enhancing the elongation rates of lateral roots, again implying the development of a more extensive root system in mungbean.

Table 3. Impact of green manure and fertilizers on rates of development of maize roots (Log transformed data)

Treatment	Primary root	Seminal roots	Nodal Roots
Soil	Y^{1}=2003.7ln(x) -1170.7 (0.85)	Y=825.1ln(x) + 302.6 (0.93)	Y=241.4ln(x) + 24.6 (0.87)
Soil + F	Y=1146.8ln(x) + 426.6 (0.87)	Y=943.4ln(x) + 713.1 (0.87)	Y = 262.9 ln (X) + 143.9 (0.74)
Crotolaria	Y = 2149.6ln(X) – 1069.9 (0.91)	Y = 1023.5ln(X) + 611.86 (0.92)	Y = 244.9 ln (X) + 83.82 (0.95)
Crotolaria + F	Y = 1447.6 ln(X + 286.4 (0.76)	Y = 1315.2ln(X) + 830.74 (0.79)	Y =320.5 ln (X) + 189.7 (0.88)
Tithonia	Y = 2405.3ln(X) – 1195.2 (0.85	Y = 1231.8ln(X) + 777.64 (0.91)	Y = 395.7 ln (X) + 59.08 (0.70)
Tithonia + F	Y = 1591.8ln(X) + 469.1 (0.83)	Y = 1989.9ln(X) + 807.46 (0.88)	Y = 421.9 ln (X) + 175.4 (0.78)

Numbers in parenthesis refer to r^2. F = Fertilizer Y and X refer to Root lengths and time respectively.

Table 4. Impact of green manure and fertilizers on rates of development of Mungbean roots

(Log transformed data)

Treatment	Primary root	Lateral roots
Soil	Y=18.6ln(x) -16.8 (0.88)	Y=512.4ln(x) + 223.6 (0.89)
Soil + F	Y=15.6ln(x) + 9.1 (0.71)	Y=960.5ln(x) + 392.9 (0.92)
Crotolaria	Y = 16.6ln(X) – 13.4 (0.88)	Y=763.4ln(x) + 350.5 (0.90)
Crotolaria + F	17.2ln(x) + 10.754 (0.76)	Y=1257.3ln(x) + 366.6 (0.86)
Tithonia	y = 16.644Ln(x) + 13.411 (0.88)	Y=923.7ln(x) + 539.8 (0.86)
Tithonia + F	y = 13.1ln(x) + 11.649 (0.83)	Y=1079.0ln(x) + 792.7 (0.77)

F = Fertilizer Y and X refer to Root lengths and time respectively

Conclusions

Green manures stimulate root growth, especially the roost emerging later, such as seminal and nodal roots in maize and laterals in mungbean. The increments are both in terms of length and dry matter accumulation. This could be due to the more conducive environment provided by the green manures and also to the nutrients added. Tithonia green manures stimulated root growth to a greater extent than Crotolaria, a legume, which has higher nitrogen content, and could promote shoot development. Application of fertilizer stimulated root growth further in both species having different rooting patterns. Moisture is the most important stress factor in smallholder cropping systems of the tropics, and the development of an extensive root system helps plant mitigate this stress factor. Hence, the application of green manures, especially Tithonia a few weeks before planting, even without fertilizers will help plants develop more extensive and heavier root systems through the stimulation of secondary roots to overcome moisture stress.

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