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Full Length Research Paper

Influence of integrated soil nutrient management on cowpea root growth in the semi-arid Eastern Kenya

Kimiti, Jacinta M.

South Eastern University College (SEUCO), Kitui, Kenya. E-mail: jmkimiti@yahoo.com
Tel: +254-721-473-341, +254-733-881-582.

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The effect of integrated soil fertility management (ISFM) on root growth of selected cowpea varieties in two sites with contrasting rainfall amounts over two seasons was investigated. Nine cowpea varieties were used as test crop and the treatments applied include a control, farmyard manure at 2.5 t ha^{-1}, triplesuperphosphate (TSP) at 15 kg ha^{-1} as (P_2O_5, 0:46:0), and TSP mixed with farmyard manure at the singly applied rates. The experiment was laid down as a split plot design and it was replicated three times. Data collected include root and shoot biomass at 50% flowering, and shoot biomass at crop maturity. In addition, root to shoot ratios at 50%, correlations between root biomass and shoot biomass at 50% flowering, and correlations between root biomass at 50% flowering and shoot biomass at crop maturity were also determined. The data were analysed as a split plot design using GenStat for Microsoft windows. Results obtained revealed that addition of nutrient inputs enhanced root biomass at Ndunguni during both the long and short rains and only in two treatments at Kavuthu during the short rains. However, addition of nutrients relatively lowered root: shoot ratios in most treatments in both study sites during the two seasons indicating phosphorus (P) deficiency in the study sites. Furthermore, strong positive and significant ($p < 0.05$) correlations between root and shoot biomass were recorded during the long rain season which was relatively dry compared to the short rain season, indicating the dependence of shoot growth on root growth under limiting moisture conditions. These results revealed the need to add nutrients, especially P, to enhance cowpea root growth and the importance of moisture in root and shoot growth in the drylands.

Key words: Cowpea root, correlations, integrated soil fertility management (ISFM), manure, semi-arid, triplesuperphosphate (TSP), root: shoot ratio.

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] walp) is also known as black eye pea, southern pea and crowder pea. It is one of the earliest plants cultivated by man and is a legume indigenous to Africa. Cowpea was domesticated in sub-Saharan Africa, probably West Africa (Ng and Maréchal, 1985). Cowpea is a major component of traditional cropping systems in dry parts of the tropics and it is important because of its multiple uses. Common uses of cowpea include soil fertility improvement through biological nitrogen fixation, green manure, forage, production of high quality hay and silage, synthesis of nutritional products, suppression of weeds, food, and a source of protein and income generation (Imungi and Porter, 1983; Tarawali et al., 1997; Muli and Saha, 2002). Mean crude protein of cowpea leaves, grains and crop residues ranges from 32 to 34; 23 to 35 and 11 to 25%, respectively, and contains 62% soluble carbohydrates. Due to its high protein and carbohydrate content, cowpea

*Corresponding author. E-mail: jmkimiti@yahoo.com

Abbreviations: ISFM, Integrated soil fertility management; **TSP**, triple super phosphate; **P**, phosphorus; **ASALs**, arid and semi-arid lands; **N**, nitrogen; **IITA**, International Institute of Tropical Agriculture; **SED**, standard errors of differences of means.

is used in nutritional products (Imungi and Porter, 1983). Cowpea is one of the third most important grain legumes in Kenya after common beans (*Phaseolus vulgaris* L.) and pigeonpea (*Cajanus cajan* (L.) Millsp) (Kimiti, 2008). It is grown in the semi-arid areas, with most of it in the eastern province. The area under cowpea in Kenya is 18,000 ha excluding cowpea in home garden, with about 85% of the area under cowpea production being in the arid and semi-arid lands (ASALs) of eastern Kenya (Muthamia and Kanampiu, 1996). In eastern Kenya, cowpea is commonly grown in mixtures with maize (*Zea mays* L.), pearl millet (*Pennisetum glaucum* (L.) R. Br.), sorghum (*Sorghum bicolor* (L.) Moench), finger millet (*Eleusine corcana* (L.) Gaertn), common bean (*Phaseolus vulgaris* L.) and dolichos (*Lablab purpures* L.). Cowpea is cultivated for both grain and green leaves (Shakoor et al., 1984). Potential cowpea grain yield of most improved Kenyan cowpea cultivars ranges from 1170 to 1800 kg ha^{-1} (Audi et al., 1996) in pure stands. However, cowpea yields are limited by low plant population, low yield potential of local cultivars, insect pests and diseases, shading by the cereals, drought stress and low soil fertility. For example, cowpea growth is retarded by low soil P (Bationo et al., 1991).

Phosphorus is one of the seventeen nutrients essential for plant growth. In higher plants, P functions as a constituent of nucleic acids and proteins (Marschner, 1986). It is important in cell division and induces root growth, promotes seed formation and increases disease resistance (Tisdale and Nelson, 1975; Marschner, 1986; Owolade et al., 2006). Phosphorus is required by crops in relatively large amounts and is frequently deficient for crop production. Therefore, adequate supply of P is required for optimum plant growth and reproduction. Primary source of P is mineral apatite found in primary rocks. However, organic matter, inorganic fertilizers and secondary and complex compounds in the soil are other sources of P. Therefore soil P can be replenished by addition of inorganic fertilizers, organic matter in form of plant and animal residues or phosphate rocks such as Busumbu and Mijingu phosphate rocks (Chien and Menon, 1995).

Root growth is critical for P uptake especially when P is low in soil (Pellerin et al., 2000). Low soil P delays root emergence, lowers root hair numbers, affects root morphology and physiological characteristics that are important for P uptake (Hajabbasi and Schumacher, 1994; Pellerin et al., 2000). However, addition of P enhances overall plant growth rate and increases relative growth rate of roots (Hajabbasi and Schumacher, 1994). Cowpea growth can be improved by addition of inorganic P and nitrogen (N) (Audi et al., 1996) at a rate of 13-25 Kg ha^{-1} as diammonium phosphate or as triple Superphosphate and N at 10-15 kg ha^{-1} (Shetty et al., 1995; Audi et al., 1996; Subarao et al., 1999). Therefore, the objective of this study is to determine the effect of inorganic and organic soil amendments on cowpea root growth relative to shoot growth over two seasons in two sites with contrasting rainfall amounts.

MATERIALS AND METHODS

Study area

On-farm trials were established at two sites with contrasting rainfall in eastern Kenya. The trials were located at Kavuthu 1223 m.a.s.l., 01° 59' 52.7'' S, 037° 25' 23.6'' E and Ndunguni 1082 m.a.s.l, 02° 04' 44.2'' S, 037° 34' 44.3'' E. The sites receive bimodal rainfall with long rains falling in March to May and short rains in November to December. Average annual rainfall is 200 to 400 mm, varying with altitude. The mean annual temperature is 28°C and major soils are described as dark-red sandy loams (The Macmillan Atlas, 1997). Soil P (Olsen P) was 3 and 4 ppm at Kavuthu and Ndunguni, respectively, determined as described by Anderson and Ingram (1993).

Planting, treatment application and management

Cowpea planting was done in two seasons, during the long rains (March to May) and the short rains (November to December). Ox-ploughs were used to prepare land for planting during the long rains but hand hoes were used to prepare land during the short rains to avoid mixing up of the treatments applied during the long rains. Test crop were nine cowpea varieties, eight (IT97K-568-18, IT97K-570-18, IT97K-499-38, IT97K-499-35, IT97K-1073-57, IT95K-556-4, IT95K-52-34 and IT97K-1068-7) from International Institute of Tropical Agriculture (IITA), which were coded as E1, E6, E7, M7, M8, M10, M14 and CP21; and a local variety called Kanga'au. The experiment was arranged in a split plot design replicated three times. Cowpea was planted at a spacing of 20 x 60 cm within 3 m^2 sub-plots. Treatments applied included unamented control (treatment 1); farmyard manure at 2.5 t ha^{-1} (treatment 2); phosphorus as TSP (P_2O_5, 0:46:0) at 15 kg ha^{-1} (treatments 3 and 4); farmyard manure + TSP at the singly applied rates (treatment 4). Treatment application was done using banding method to ensure that the crop was in contact with the nutrients. Weeding was done as required to ensure that the plots remained clear of weeds over the cropping seasons.

Plant sampling

At 50% flowering cowpea, plant root systems were carefully dug out of the soil, washed in tap water and separated from the shoots at the shoot base. At crop maturity, shoots were separated from pods and cut at the shoot base. To determine shoot and root biomasses at both sampling times, the samples were dried at 60°C for 72 h in a Sanyo Convection oven (Model MOV-212 F, Sanyo Electric Company, Japan). The data were analysed as a split plot design and correlations between roots and shoot growth at 50% flowering and at crop maturity over the two seasons were determined. Treatment means were separated using standard errors of differences of means (SED).

RESULTS AND DISCUSSION

During the long rains, treatment application had no effect on root growth at Kavuthu but at Ndunguni root growth was enhanced by treatment addition (Table 1). However, during the short rains, addition of animal manure and TSP enhanced root growth at Kavuthu, and as was

Table 1. Treatment effect on root biomass (kg ha^{-1}) at 50% flowering during the long and short rains at two sites with contrasting rainfall amounts.

Parameter	Long rain		Short rain	
Treatment	Kavuthu	Ndunguni	Kavuthu	Ndunguni
Control	97	70	93	114
Manure	69	93	99	154
TSP	79	87	96	160
Manure +TSP	84	97	79	182
Treatment means	82	87	92	153
SED	12	12	9	28

SED, standard errors of differences of means.

Table 2. Treatment effect on root to shoot ratios at 50% flowering during the long rains and short rains at two sites with contrasting rainfall amounts.

Parameter	Long rain		Short rain	
Treatment	Kavuthu	Ndunguni	Kavuthu	Ndunguni
Control	0.064	0.123	0.09	0.056
Manure	0.061	0.109	0.088	0.057
TSP	0.057	0.116	0.082	0.065
Manure +TSP	0.055	0.117	0.059	0.064
Treatment means	0.059	0.116	0.08	0.061
SED	0.011	0.01	0.014	0.005

SED, Standard errors of differences of means.

observed during the long rains treatment addition again enhanced root growth at Ndunguni during the short rains.

During the long rains, treatment application had no effect on root to shoot ratio at both Kavuthu and Ndunguni (Table 2). However, during the short rains, application of TSP or a mixture of TSP and manure enhanced root to shoot ratio at Ndunguni.

Root biomass at 50% flowering significantly ($p < 0.05$) correlated positively with shoot biomass at 50% flowering at both Kavuthu (R^2 = 0.6778) and Ndunguni (R^2 = 0.7206) during the long rains (Figures 1 and 2). However, during the short rains, weaker and insignificant positive correlations between root and shoot biomass at 50% cowpea flowering were recorded in both sites (Figures 3 and 4). When root biomass assessed at 50% flowering was correlated to shoot biomass at crop maturity, it was observed that very weak correlations existed in both sites in the two seasons of assessment (Figures 5, 6, 7, and 8).

It was observed that the addition of nutrients in form of animal manure, TSP and a mixture of TSP and manure enhanced cowpea root growth at Ndunguni during both the short and long rains, and that only addition of manure and TSP enhanced cowpea root growth at Kavuthu during the short rains. These observations indicated that the addition of P in the form of animal manure, TSP or a mixture of TSP and manure was important for cowpea root growth in the study site. Similar observations were reported in a study by Mollier and Pellerin (1999). They observed that maize root growth was enhanced by P supply but the root growth was reduced when P supply to the roots was stopped. They also observed that the removal of P supply severely reduced lateral root emergence and development.

Root to shoot ratio is important for plant survival especially under drought conditions (Larson et al., 1986). Seedlings that have large amounts of foliage and transpirational surface area and a relatively small root system cannot support the demand for water replenishment and are susceptible to water stress. In addition, it had been documented that P deficiency generally leads to higher root: shoot ratio in plants (Atkinson, 1973; Rychter and Randall, 1994) through increased root growth. Studying the effects of phosphorus supply effects on maize root development, Anghinoni and Berber (1980) found out that maize root length and weight increased when phosphorus supply was reduced between 1 and 6 days. In this study, root : shoot ratio was higher in the controls relative to the treatment during both the short and long rains at Kavuthu and Ndunguni, most probably indicating an increased root growth relative to shoot growth under low P soil conditions in the study sites. However, relatively higher root: shoot ratios were observed at Ndunguni during the short rains, probably indicating that nutrient supply may not always reduce root growth relative to shoot growth.

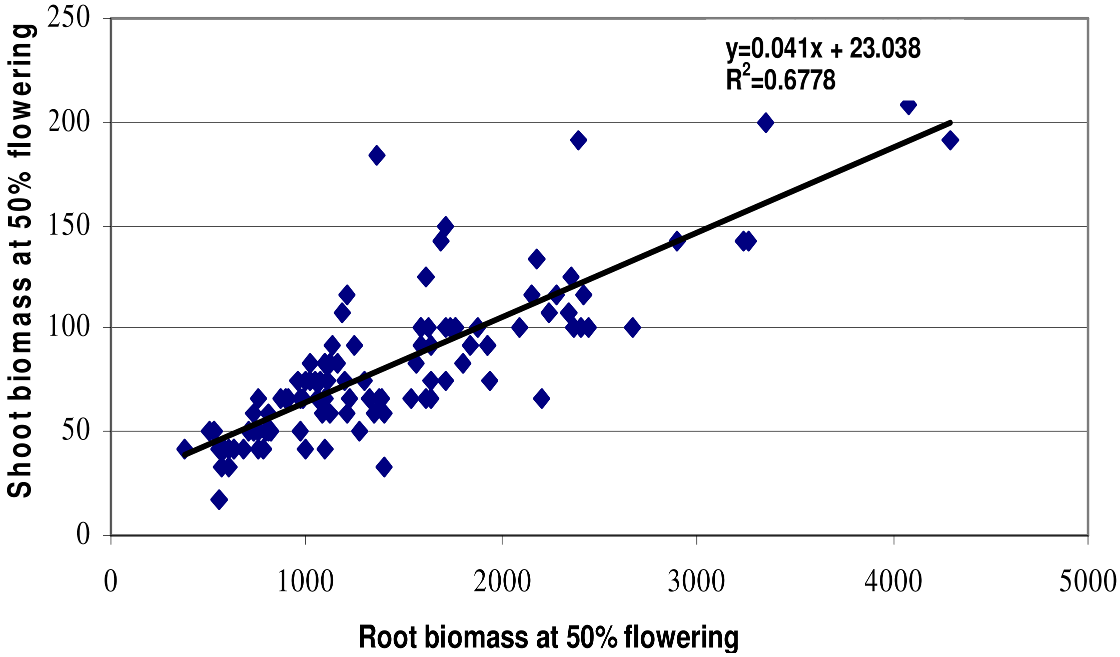

Figure 1. Root biomass versus shoot biomass at 50% flowering during the long rains.

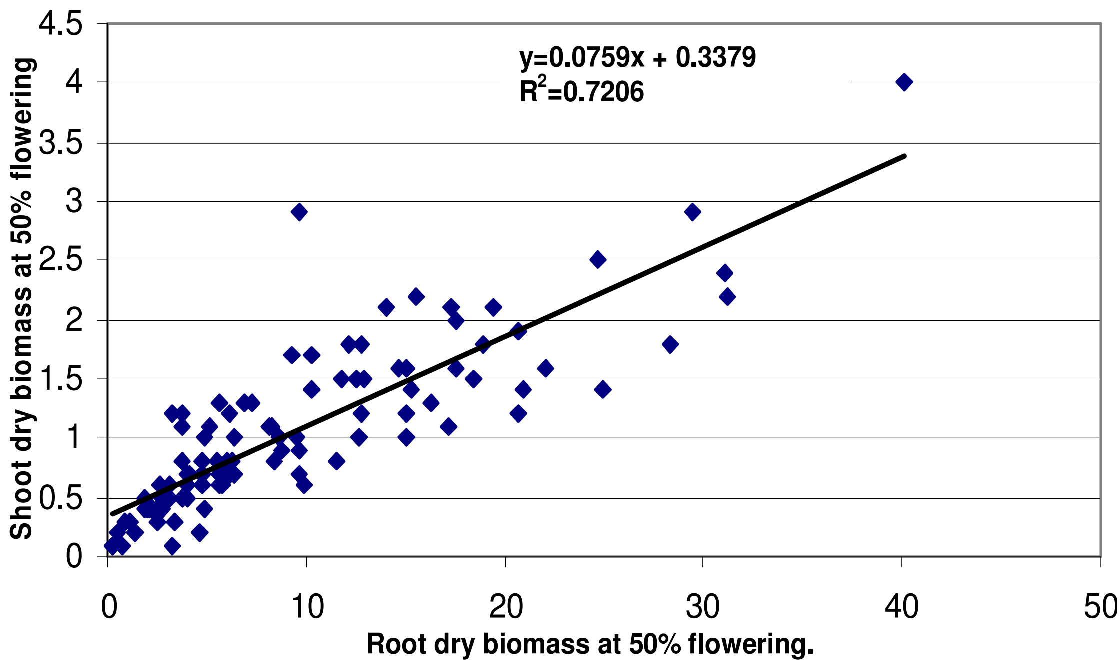

Figure 2. Root biomass versus shoot dry biomass at 50% flowering during the long rains.

Similar results were documented by Khamis et al. (1990) on maize, where they found no effect of P deficiency on root : shoot ratio of the crop. Correlation is a statistical measurement of the relationship between two variables. It shows whether and how strongly pairs of variables are related. In this study, positive correlations were documented in root and shoot biomass assessed at 50% flowering indicating that there were positive relationships between root and shoot biomass at 50% flowering. However, it appeared that the relationships were stronger and significant ($p < 0.05$) during the long rains than in the short rains. This was probably because during the long rains, a relatively lower rainfall was received in both study sites (Ndunguni recorded 194 mm and Kavuthu recorded

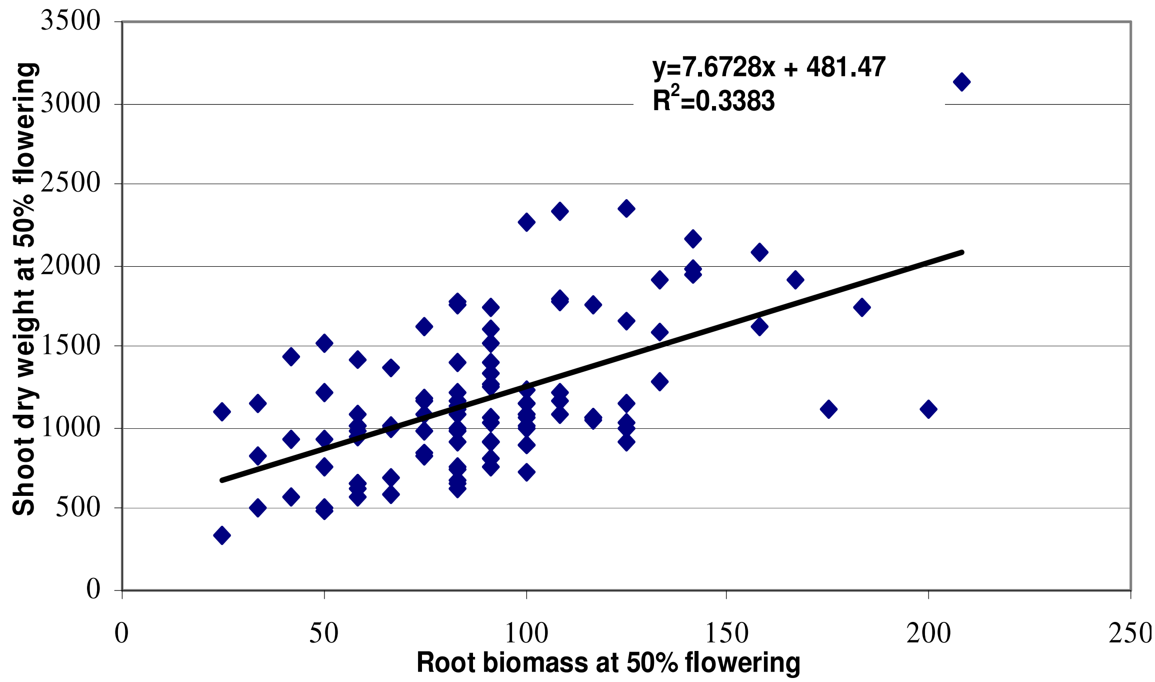

Figure 3. Root biomass versus shoot biomass at Kavuthu at 50% flowering during the short rains.

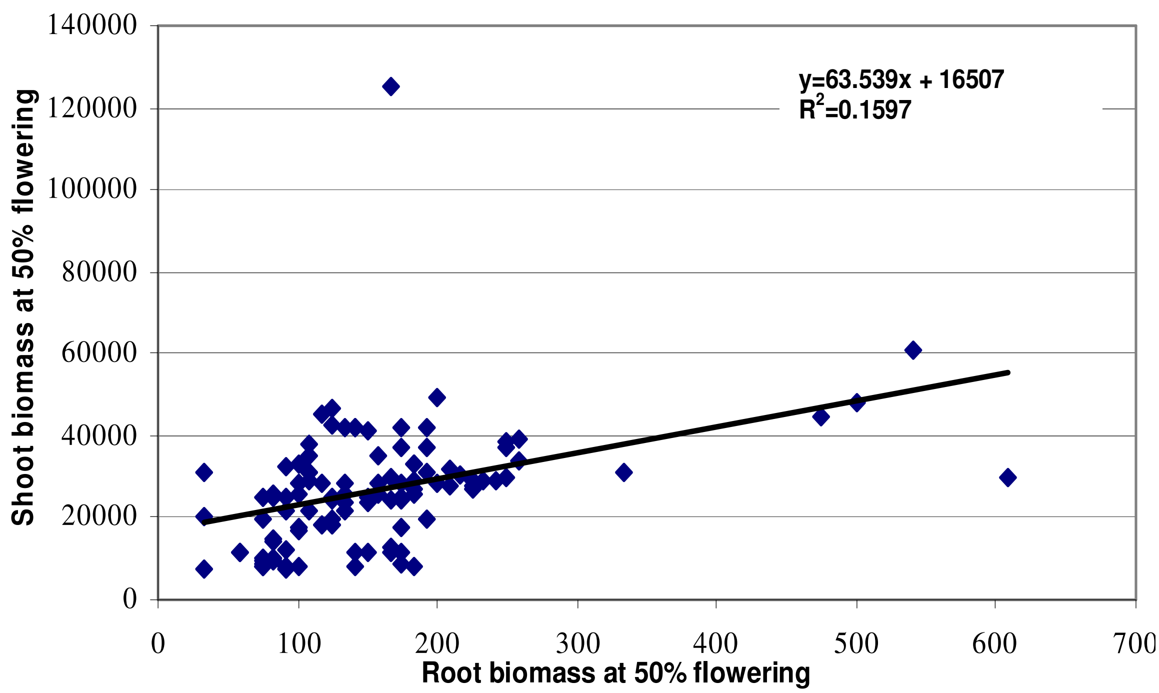

Figure 4. Root biomass versus shoot biomass at 50% flowering in Ndunguni during the short rains.

233 mm) relative to the short rains (Ndunguni recorded 386 mm and Kavuthu recorded 397 mm) implying that, shoot growth was strongly influenced by root growth under low rainfall and moisture conditions. Positive and significant correlations between shoot and root biomass were also reported in white clover (*Trifolium repens* cv. Haifa) after a period of water shortage (Blaikie and Mason, 1990).

Positive correlations between root biomass at 50% and shoot biomass at crop maturity were about zero except

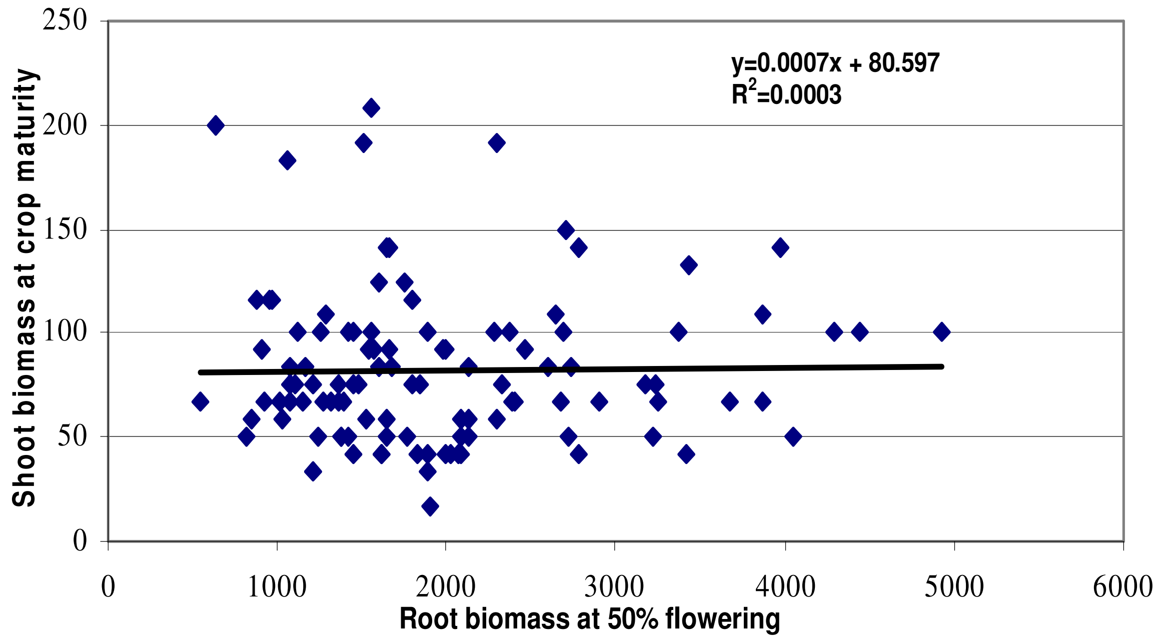

Figure 5. Root biomass at 50% flowering versus shoot biomass at crop maturity at Kavuthu during the long rains.

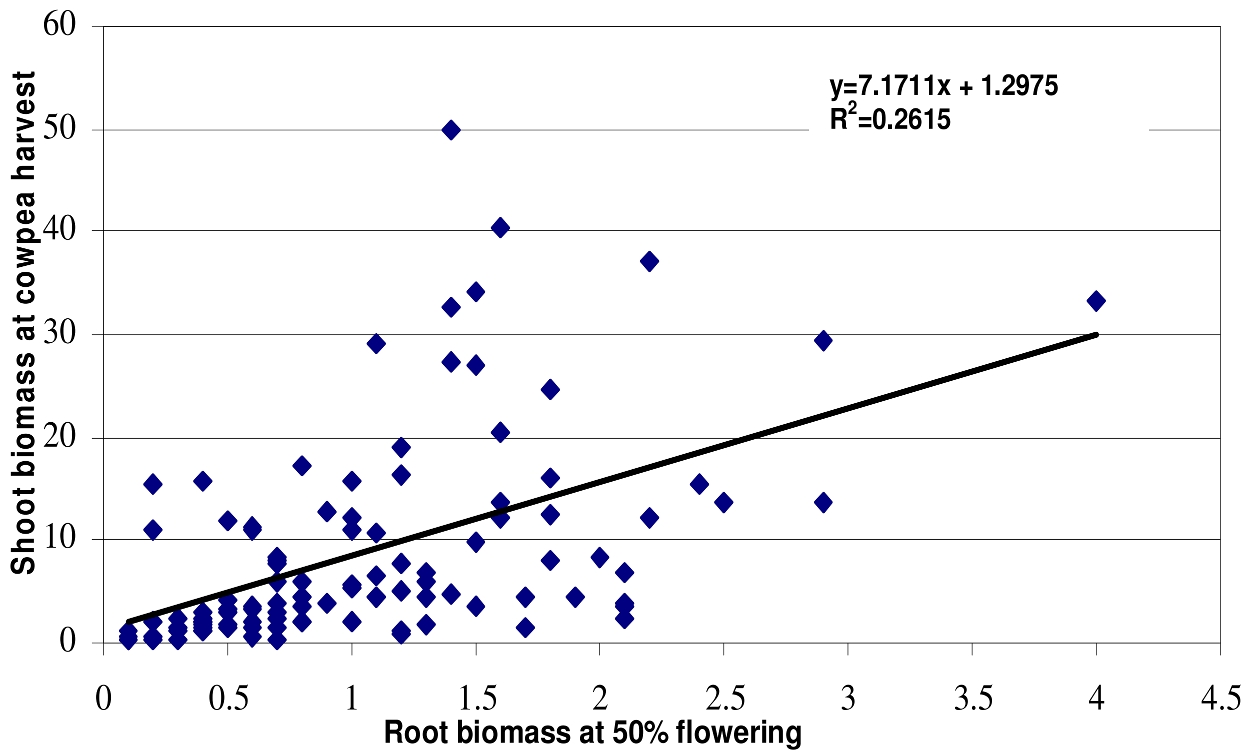

Figure 6. Root biomass at 50% flowering versus shoot biomass at crop maturity at Ndunguni during the long rains.

for Ndunguni where a slightly higher correlation (R^2 = 0.2615) was recorded. Weak and about zero correlations observed between root at 50% and shoot at crop maturity probably indicated that root biomass at 50% flowering may not relate to shoot biomass at crop maturity. A slightly higher correlation between root biomass at 50% and shoot biomass at crop maturity at Ndunguni during the long rains might have been due to severe drought

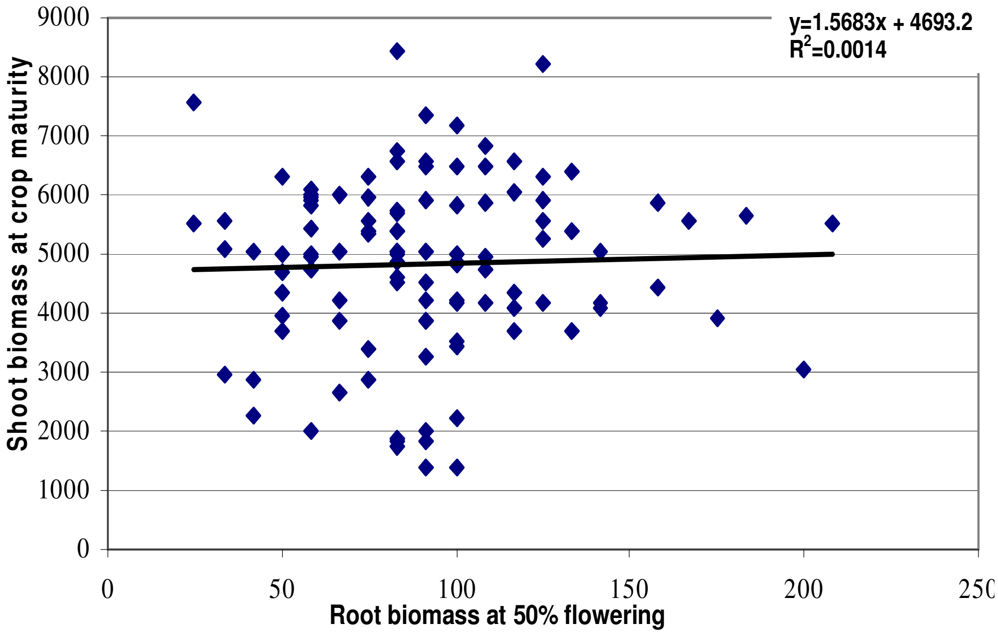

Figure 7. Root biomass at 50% flowering versus shoot biomass at crop maturity at Kavuthu during the short rains.

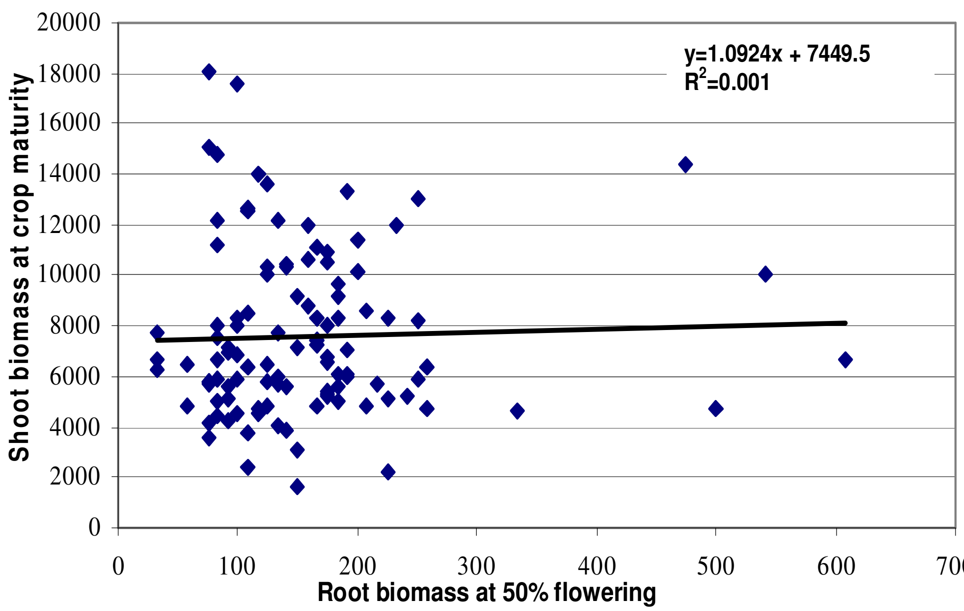

Figure 8. Root biomass at 50% flowering versus shoot biomass at crop maturity at Nudging during the short rains.

that prevailed during the season and biomass recovered at crop maturity was about the same as that sampled at 50% flowering at Ndunguni.

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