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Growth Characteristics of Bambara Groundnuts *(Vigna subterranea)* and Nerica Rice *(Oryza sativa)* under Intercrop System

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Abstract: Intercropping offers advantages if well planned including improved soil fertility and yields. Bambara groundnuts have been shown to yield in low fertility soils and have been described as a complete food. Nerica rice has been reported to offer higher yields and shorter growing seasons. Cropping systems that combine both these crops in production systems will help alleviate malnutrition and food insecurity in many developing countries. Understanding the growth characteristics of the these two crop species is essential for optimization of their productivity. Therefore the main objective of this experiment was to evaluate the growth characteristics of bambara groundnuts and NERICA rice under sole and intercrop systems. Greenhouse experiments was set up involving root zone partitioning to allow the roots of the two crops grow separately and unpartitioning which allowed the roots of the two crops to intermingle and interact. Growth attributes including growth rates, relative leaf growth rates, specific leaf area and leaf weight ratio were evaluated. The curve fitting method in which polynomial functions were fitted to normal logarithmic values of total dry weight and total leaf area using the functional approach. The two crop species showed varied growth responses under sole and intercropping systems. The differential growth characteristics in the two crop species are essential for resource utilization in different niches both below and above ground.

Key words: Growth characteristics · Growth rates · Intercropping

INTRODUCTION

Bambara groundnut has been reported as one of the indigenous food crop found in western Kenya that has a potential for reducing food and nutritional insecurity [1]. It is an Indigenous African crop that has been cultivated in Africa for centuries [2]. It's a highly nutritious plant which plays a crucial role in people's diets and is currently grown throughout Africa. Despite its usefulness, Bambara groundnuts remain one of the neglected crop by scientific community and is commonly referred to as 'a poor mans crop'.

Rice is a staple food for nearly 2 billion people and Kenya produces around 1.7 tones of rice under rainfed conditions. Rice (*Oryza sativa L*) is a major source of food throughout Asia and other parts of the world and its consumed by half of the world population as a staple food [3]. Area under rice cultivation is approximated to be 150,000,000 ha worldwide while its production stands at 500,000,000 tonnes. Therefore evaluation of its performance when intercropped with a legume in this region is key to alleviating poverty and crops diversification

Legume-cereal intercropping is a method to obtain greater and more stable crop yields, improve the plant resource utilization (water, light, nutrients), increase the input of leguminous symbiotic nitrogen fixation to the cropping system and reduce negative impacts on the environment [4]. However, due to agricultural intensification of plant breeding, mechanization and fertilizer and pesticide use over the last 50 years, intercropping has received less attention in many farming systems. Motivations for reintroducing grain-legume-cereal intercropping relate to the problems faced by intensive farming systems. It has become evident that agricultural production systems often characterized by monocultures, nutrient surpluses and large external input of fertilizer, pesticides and feed concentrates are not sustainable in the long term. On the medium and long term this causes undesirable economic, ecological,

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environmental and social effects. Intercropping offers the potential for; generating more stable yields, due to self-regulation in the crop. This will give the farmer better insurance against crop failure and will safeguard the farmer's earnings, improving product quality such as greater protein content of cereals, via planned competition, providing an ecological method via competition and natural regulation mechanisms and planned biodiversity to manage weeds and pests, hence reducing the cost of energy for weed and pest control and improving the synchrony between microbial immobilization-mineralization and crop N demand, due to differences in the quality of the residues and thereby aiding in the conservation of N in the cropping system.

Despite all these benefits evaluation of the growth attributes of the crops species under intercropping is key to understanding their performance and estimation of productivity. A number of methods have been used to measure growth attributes. At the whole plant level the assimilation of carbon and mineral salts and its subsequent partitioning within the plant are the most commonly employed measures of growth [5,6].

Presently no work has been reported on growth attributes of nerica rice and bambara groundnuts under intercropping system. Therefore this experiment was conducted to determine the growth attributes of bambara groundnuts and nerica rice under intercropping system.

MATERIALS AND METHODS

The experiment was conducted in the research greenhouses at University Hannover, Germany of the Institute of Biological Production Systems. Plastic boxes measuring 30 cm by 40 cm and height of 60 cm were used. Six boxes were fixed with thin plastic barrier from the bottom to the top to simulate monocropping while other six boxes were not fixed with the barrier to allow crops interaction as in field intercropping system. All the twelve boxes were filled with sand media and randomized completely. They were then watered to 80% water holding capacity and then planted with the NERICA 11 and Bambara groundnuts. Boarder boxes were also installed to ensure the safety and less interference of the boxes to be harvested for evaluations. Three harvests were conducted and necessary data collected.

The curve fitting method (functional technique) was followed to determine different growth attributes. In the curve fitting method, polynomial functions were fitted to normal logarithmic values of total dry weight and total leaf area using the spreadsheet analysis program Microsoft Excel version 7.0. The $\log_e$ transformation was made in order to render the variance homogeneous with time [7]. The selection of appropriate polynomial regression model was done by 'lack of fit' method of Nicholls and Calder [8]. The different growth attributes were determined based on the formulae:

1. Crop growth rate (CGR) = $\dfrac{W_2 - W_1}{t_2 - t_1}$ (g m^{-2} land surface day^{-1})

2. Relative growth rate (RGR) = $\dfrac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$ (g kg^{-1} day^{-1})

3. Net Assimilation Rate (RGR) = $\dfrac{W_2 - W_1 (\log_e A_2 - \log_e A_1)}{A_2 - A_1 (t_2 - t_1)}$ (g m^{-2} day^{-1})

4. Leaf Area Ratio (LAR) = $\dfrac{A_2 - A_1 (\log_e W_2 - \log_e W_1)}{W_2 - W_1 (\log_e A_2 - \log_e A_1)}$ (m^2 kg^{-1})

5. Leaf Weight Ratio (LWR) = $\dfrac{Lw}{W}$

6. Specific Leaf area (SLA) = $\dfrac{A}{Lw}$ (m^2 kg^{-1})

7. Specific Leaf weight (SLW) = $\dfrac{Lw}{A}$ (kg^{-1} m^2)

Where
Lw is the leaf weight,
W = total dry wt,
A = leaf area,
t = time

RESULTS

Growth analyses of green house intercropped bambara and NERICA rice 11

Crop Growth Rate: The bambara groundnuts growth rate in both root zones was similar from 24 DAS and continued up to 38 DAS. Plants in both root zones were observed to reach their peak at the same time and consequently commenced achieving a constant growth rate at 46 DAS (Figure 1). Plants in unpartitioned root zone were observed to have a much lower growth at 52 DAS as compared to bambara groundnuts grown in partitioned root zone (Figure 1).

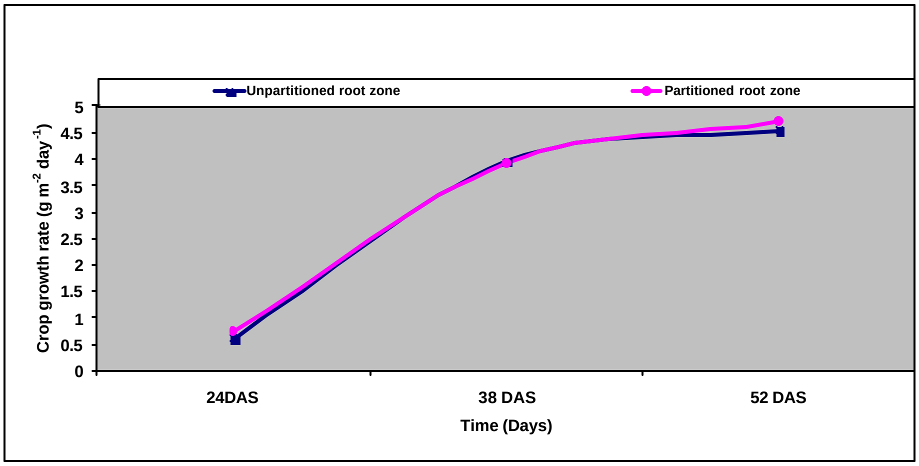

Fig. 1: Effect of root zone partitioning and unpartitioning on crop growth rate of bambara groundnuts when grown in sole and intercrop NERICA 11 rice in the greenhouse

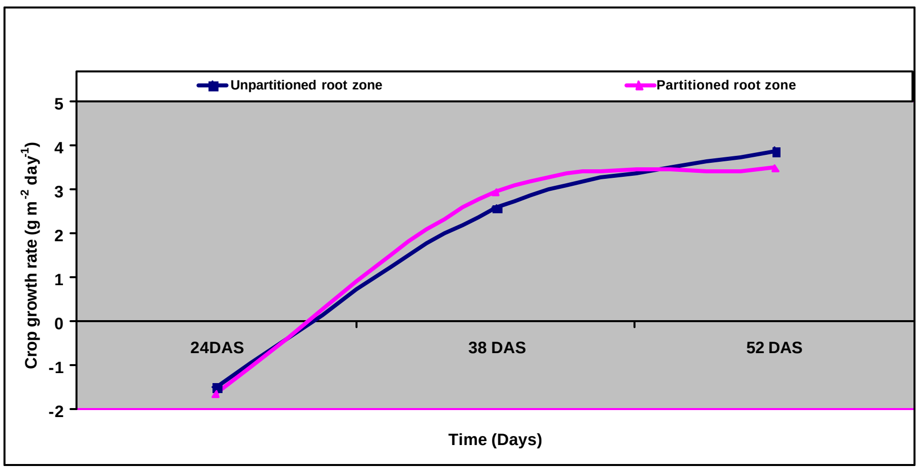

Fig. 2: NERICA growth rates when grown as sole crop and intercropped with bambara groundnuts in different root zones in greenhouse

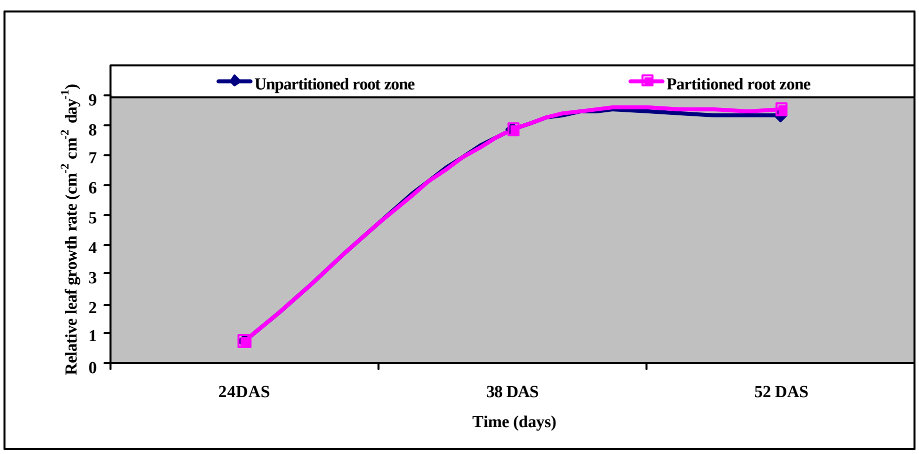

Fig. 3: Influence of partitioned and unpartitioned root zones on relative leaf growth rates of bambara groundnuts grown in combination with NERICA rice in greenhouse

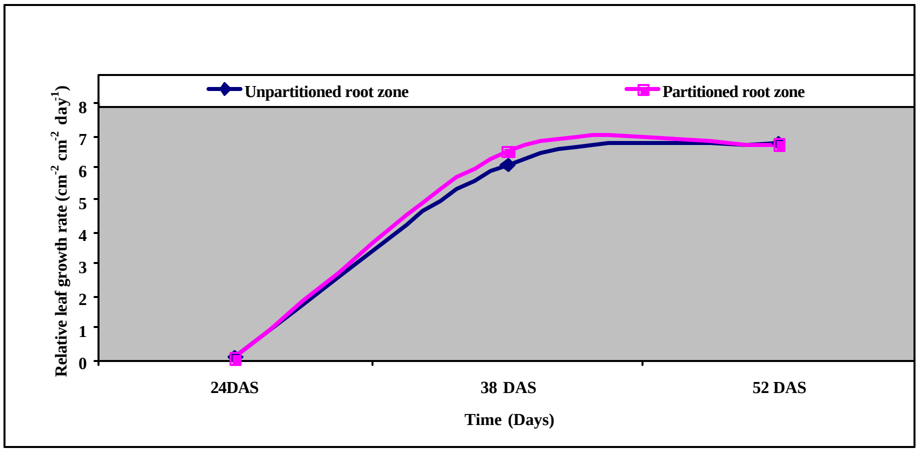

Fig. 4: Variation in NERICA rice 11 relative leaf growth rate when sole cropped and grown with bambara groundnuts in same root zone in greenhouse

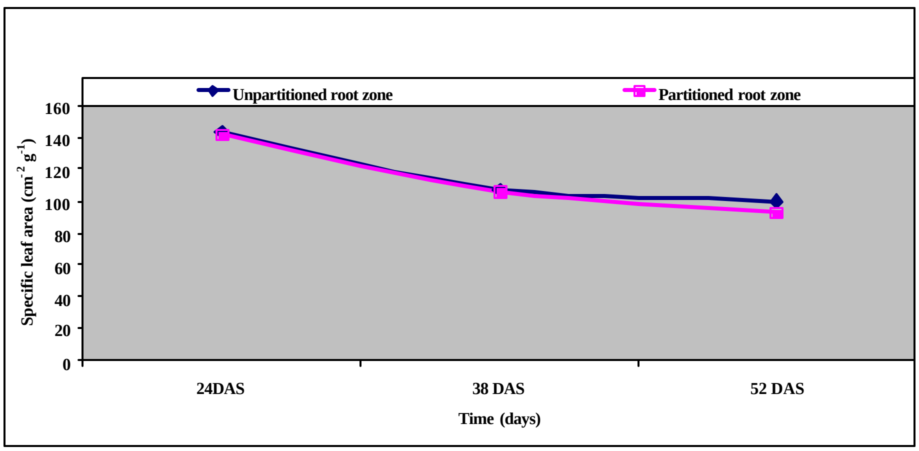

Fig. 5: Changes in specific leaf area of bambara groundnuts when grown in same and separated root zone with NERICA rice 11 in the greenhouse

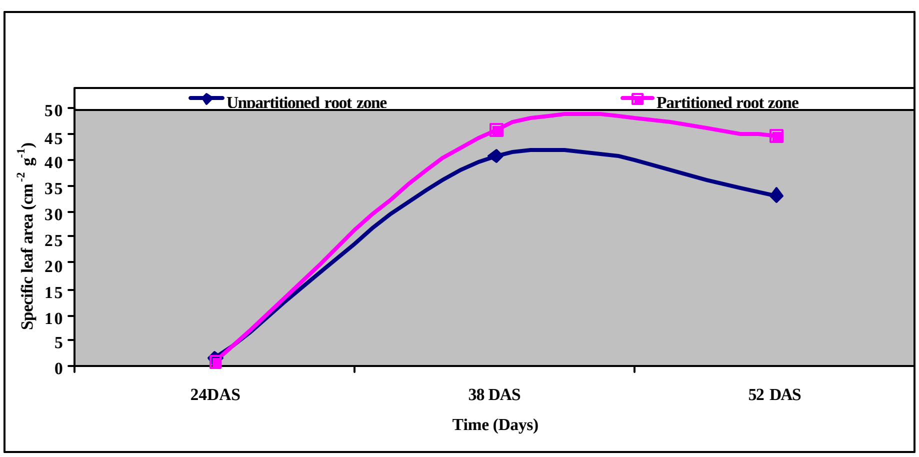

Fig. 6: Effect of root zone partitioning and unpartitioning on specific leaf area of NERICA rice 11 grown as sole crop or intercropped with bambara groundnuts in the greenhouse

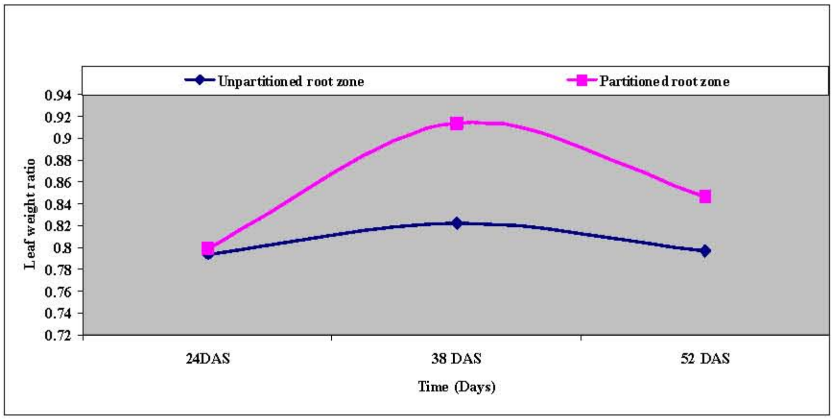

Fig. 7: Effect of root zone partitioning and unpartitioning on leaf weight ratio of bambara groundnuts when sole and intercropped with NERICA rice 11 in greenhouse.

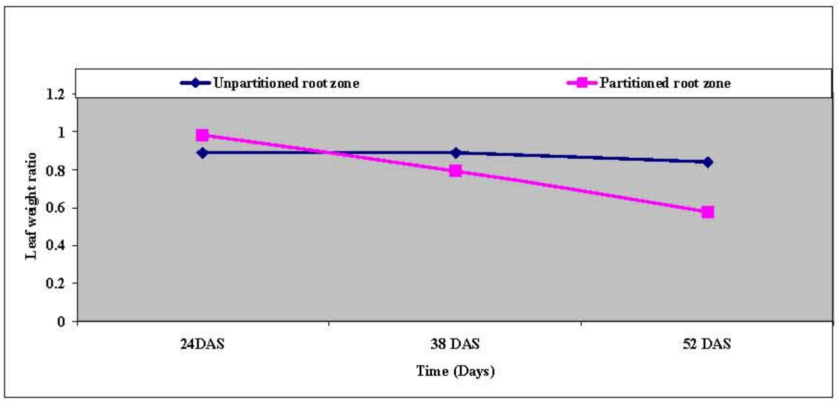

Fig. 8: Effect of partitioned and unpartitioned root zone on leaf weight ratio of NERICA rice 11 when sole and intercropped with bambara groundnuts in greenhouse

The NERICA rice growth rate in both root zones was similar from time of germination. Soon after 26 DAS NERICA rice grown in partitioned root zone was observed to have higher growth rate as compared rice in unpartitioned root zones. This differences in growth rate persisted until at 46 DAS when their growth rate was equal (Figure 2). Further growth resulted in NERICA rice grown in partitioned root zone reduce its growth while NERICA rice grown in unpartitioned root zone was now observed to have higher growth rate at 52 DAS (Figure 2).

Relative Leaf Area Growth Rate: The relative leaf growth rate of bambara groundnuts in both root zones was observed to increase with time from germination and at similar rate (Figure 3). This trend continued and at 38 DAS the relative growth rate was equal. The peak relative growth rate was achieved between 38 DAS and 45 DAS for both bambara plants grown in both root zones (Figure 3). At 52 DAS the relative leaf growth rate was constant and started to decline in plants grown in unpartitioned root zone (Figure 3).

The relative leaf growth rate of NERICA rice was observed to increase with time from germination. At 24 DAS the RLGR of both rice plants grown in the two different root zones was similar. With further growth at 31 DAS the RLGR of plants in partitioned root zone was above that of plants in unpartitioned root zone (Figure 4). This trend continued and at 52 DAS the RLGR of plants in both root zones was similar and constant (Figure 4).

Specific Leaf Area: The values of specific leaf area for bambara groundnuts in both root zones were similar and higher at the 24 DAS. These declined steadily with time up to 38 DAS after which bambara groundnuts grown in unpartitioned root zone showed some constancy while SLA of plants grown in partitioned root zone continued to decline steadily (Figure 5). At 52 DAS the SLA of bambara groundnuts in unpartitioned root zone was slightly above than that in partitioned root zone though both of them were on declining trend (Figure 5).

The SLA of NERICA rice in both root zones showed a complete opposite of what was observed in bambara groundnuts. The SLA was observed to increase with time (Figure 6). Plants in partitioned root zone had higher SLA soon after 26 DAS and this trend continued up to late in the growth cycle. SLA of plants in both root zones appeared to reach their peak at similar time and commenced to decline though SLA of plants in partitioned root zone was higher (Figure 6). At 52 DAS the SLA was declining in both root zones.

Leaf Weight Ratio: The leaf weight ratio of bambara groundnuts in unpartitioned root zone was steady showing some slight increase up to 38 DAS and then starting to decline steadily (Figure 7). The leaf weight ratio of plants in partitioned root zone showed a rapid increase in LWR and reached its peak at 38 DAS and declined rapidly late in the season (Figure 7).

The LWR of NERICA rice grown in unpartitioned root zone showed steady decline from 24 DAS towards late in the growth cycle. The LWR of NERICA rice in partitioned root zone was higher at 24 DAS and was equal to LWR of plants in unpartitioned root zone at 31 DAS. It was observed to decline rapidly and at 52 DAS it was much lower than LWR of NERICA rice grown in the same root zone with bambara groundnuts (Figure 8).

DISCUSSION AND CONCLUSION

Crop Growth Rate (CGR): Crop growth rates (CGR) is a growth function which represents the net results of photosynthesis, respiration and canopy area interaction. The results from the experiment indicated similar growth rates for bambara groundnuts grown in both partitioned and unpartitioned root zones. The NERICA rice 11 grown in partitioned root zone had higher growth rate but this declined to near constant as rice plants grown in one root zone with bambara groundnuts continued their growth at 52 DAS (Figure 2). The results on bambara growth rates are in accordance with Brink [9] who reported that the growth rates of bambara groundnuts grown as an intercrop and shaded by taller cereals was not different from that in sole cropped bambara groundnuts. Higher CGR has been linked to higher dry matter production and Williams *et al.* [10] reported that CGR is a representative of most common agronomic measurements such as yield and dry matter per unit land area. NERICA rice grown as sole crop in partitioned root zone had higher CGR in mid growth cycle (Figure 2) but this declined rapidly before 52 DAS. The highest NERICA CGR could be attributed to access to optimal below ground resources without competition during early stages of growth, but as resources are depleted the CGR rate declines rapidly. On the other hand NERICA rice grown in intercrop with bambara groundnuts experienced competition at beginning of growth but as the interaction between the two plants complemented each other, the CGR of NERICA rice was able to continue steadily than rice grown as sole crop. Similar results have been reported in other crops such as barley [11].

Relative Leaf Growth Rate (RLGR): Both the bambara groundnuts and NERICA rice 11 grown as either sole or sole cropped were observed to increase their RLGR) with time up to a point after which it was constant at 52 DAS and with further growth it would decline (Figure 3 and 4). Similar results have been reported by Saha and Paul [12]. Experiments on wheat have shown also similar results reported by Saha and Paul [12], Sarker and Paul [13] and Sarker *et al.* [14]. The major cause of constant and then declining of RLGR at later stages of growth is decline in production of new foliage and commencement of abscission of older leaves. The RLGR has been shown to be influenced by soil nutrients such as nitrogen availability [12](Saha and Paul, 1995).

Specific Leaf Area (SLA): Specific leaf area of bambara groundnuts grown in sole and intercrop with rice was higher at initial stages of growth but declined with the age of the plants. NERICA rice SLA increased with age until appoint where it started declining though rice in partitioned root zone was observed to maintain higher SLA (Figure 6). The SLA which is an index of leafiness of the leaf involves an assessment of the leaf's area in relation to its dry weight. The value of SLA gives an indication to the extend of demand for photosynthates for different plant organs in the growth cycle of the plant. Bambara crop showing higher SLA at beginning of growth demonstrated the high demand of photosynthates to roots for development. On the other hand, rice plant showed the greatest demand for photosynthates at 43 DAS when it had the highest SLA and this demand declined with time with limited sinks that required photosynthates except for reproductive structures at later stages of growth. [12, 13] reported the decline in SLA with increasing plant age. Alam and Haider [15] reported declining SLA with time overt the initial growth stages of barley but this trend changed and increasing tendencies of SLA were observed at later stages of growth. This could be attributed to active translocation of photosynthates to reproductive structures later in the growth cycle [16].

Leaf Weight Ratio (LWR): This offers an index of leafiness of the plant on a dry weight basis and is a measure of productive investment of the plant. The LWR of bambara groundnuts was observed to increase with time and decline sharply later at 52 DAS. The increase and decline of LWR was intense in bambara grown as sole, while the change in bambara grown in same root zone with rice was steady (Figure 7). The LWR in NERICA rice was on a downward trend from 24 DAS and was intense in rice sole cropped than in intercropped rice (Figure 8). These observations were also reported by Thorne [17]. Similarly Alam and Haider [15] reported increasing LWR during early growth stages and thereafter gradually declining pattern throughout the growth period. The initial increase in LWR in bambara groundnuts is related to high leaf production during the early growth stages and this continues up to appoint where leaf production declines. The other plant organs such as roots are further developed and this increases the overall total dry matter of the whole plant resulting in declining LWR of the bambara crop. The rice plant on the other hand has a balance of dry matter allocation between the roots and the leaves resulting in a steady LWR when intercropped (Figure 8). But when its sole cropped, this balance is lost and the total plant dry weight increases at the expense of the leaves. Therefore a sharp decrease in LWR at later stages of might be due to sharp increase of total dry matter but directed towards reproductive structures.

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REFERENCES

1. Obuoyo, Joyce. A., 2005. The role of traditional crops in promoting food security in the dry Siaya district, Kenya. M.A thesis, Maseno University.
2. Heller, J., F. Begemann and J. Mushonga, 1997. Promoting and conservation and use underutilized and neglected crops 'Bambara groundnuts', Proceedings of the workshop on conservation and improvement of Bambara groundnuts, pp: 14-16 Nov. 1995.
3. Pal, M., J. Deka and R.K. Rai, 1996. Fundamentals of Cereal Crop Production. Tata McGraw- Hill Publishing company Ltd.
4. Frye, W.W. and R.L. Blevins, 1989. Economically sustainable crop production with legume cover crops and conservation tillage. J. Soil and Water Cons. Jan-Feb., pp: 57-60.
5. Evans and Hughes, A.P., 1961. Plant growth and the aerial environment. I. Effect of artificial shading on Impatiens parviflora. New Phytologist, 60: 150-80.
6. Evans, G.C., 1972. The Quantitative Analysis of Plant Growth. Blackwell Scientific Publications, Oxford.
7. Hughes, A.P. and P.R. Freeman, 1967. Growth analysis using frequent small harvests. J. Appl. Ecol., 4: 553-560.
8. Nicholls, A.O. and D.M. Calder, 1973. Comments on the use of regression analysis for the study of plant growth. New Phytol., 72: 571-581.
9. Brink, M., 1999. Development, growth and dry matter partitioning in bambara groundnut (*Vigna subterranea*) as influenced by photoperiod and shading. J. Agric. Sci., (Cambridge). 133: 159-166.
10. Williams, W.A., R.S. Loomis and C.R. Lepley, 1965. Vegetative growth of corn as affected by population density. II. Components of growth, net assimilation rate and leaf area index. Crop Sci., 5: 215-219.
11. Yang, J.S., M.S. Lee, J.G. Kim and H.J. Han, 1990. Studies on the nutritive value of forage barley. I. The comparative analysis of growth and dry matter accumulation pattern in barley and rye. Research Reports of the Rural Dev Admin Livestock, 32(2): 42-48.
12. Saha, S.K. and N.K. Paul, 1995. Growth of five wheat (*Triticum aestivum* L.) cultivars as affected by soil moisture. J. Biol. Sci., 3: 103-112.
13. Sarker A.M. and N.K. Paul, 1998. Studies on growth attributes of wheat under irrigated and rainfed conditions. Bangladesh J. Bot., 27(2): 119-126.
14. Sarker, A.M., M.S. Rahman and N.K. Paul, 1999. Effect of soil moisture on relative leaf water content, chlorophyll, proline and sugar accumulation in wheat. J. Agron. Crop Sci., 183: 225-229. missing in the text
15. Alam, M.Z. and S.A. Haider, 2006. Growth attributes of barley (*Hordeum vulgare* l.) cultivars in relation to different doses of nitrogen fertilizer. J. Life Earth Sci., 1(2): 77-82.
16. Mondal, R.K and N.K. Paul, 1992. Growth and physiological characters of mustard under rainfed and irrigated conditions. Bangladesh J. Agric. Res., 17: 29-36.
17. Thorne, G.N., 1960. Variation with age in net assimilation rate and other growth attributes of sugar beet, potato and barley in a controlled environment. Ann. Bot., 24: 256- 272.