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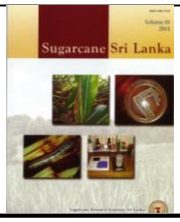

RESEARCH

Nutrient Absorption and Biomass Accumulation in Saccharum hybrid spp.

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ABSTRACT

This study examined the patterns of nitrogen, phosphorus, and potassium absorption and dry biomass partitioning in the sugarcane variety SL 96 128 grown under controlled shade house conditions over a 180-day period. Plants were sampled destructively at 20-day intervals to assess nutrient content and biomass distribution in leaf and stalk tissues. Dry biomass was initially concentrated in leaves but shifted to the stalks during the grand growth phase, with stalks comprising over 50% of the total dry biomass from 120 days after planting. The maximum biomass accumulation rate was observed between 120 and 140 days after planting at 3.04 g/plant/day. Relative absorption of K and P peaked at 80 days after planting, while nitrogen absorption was highest at 100 days after planting. Potassium showed the greatest total accumulation, followed by nitrogen and phosphorus. Nutrients accumulated predominantly in leaves during early growth, then progressively shifted to the stalks as plants matured. These results highlight the critical nutrient demand period between 40 and 160 days after planting, emphasizing the need for well-timed nutrient applications. The findings contribute to the development of improved fertilizer strategies and support the formulation of nutrient management practices for sugarcane cultivation in Sri Lanka

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INTRODUCTION

Sugarcane cultivation in Sri Lanka is predominantly concentrated in the dry and intermediate agro-ecological zones, managed under both irrigated and rain-fed systems. As the country aims to enhance self-sufficiency in sugar production, the efficient use of crop inputs particularly fertilizers plays a vital role in achieving long-term productivity and sustainability goals [1]. Among the 16 essential nutrients required for sugarcane growth, nitrogen (N), phosphorus (P), and potassium (K) are the primary macronutrients, typically supplied through urea, triple superphosphate (TSP), and Muriate of Potash (MOP) in Sri Lankan systems [2].

It is estimated that the production of one ton of millable cane removes approximately 1.18 kg of nitrogen, 0.29 kg of phosphorus, and 2.58 kg of potassium from the soil [3]. A nutrient replacement strategy replenishing the nutrients removed by the crop is widely adopted to formulate precise fertilizer recommendations. However, to be effective, such strategies must align with the plant's nutrient demand during critical growth stages to avoid deficiency-induced yield losses [4],[5].

Understanding the nutrient uptake pattern and partitioning in sugarcane provides critical understandings for optimizing the timing of fertilizer application and developing advanced formulations such as slow- or controlled-release fertilizers [6],[7]. The distribution of nutrients between leaves and stalks is especially important for calculating nutrient balance and minimizing environmental losses. However, nutrient uptake is influenced by several factors including genotype, water regime, climate, and management practices. These variables often introduce high spatial variability under field conditions, thereby necessitating controlled studies to obtain precise data.

Previous work by Bodhinayake [3] examined nutrient removal in the Co 775 variety, but limited information exists for SL 96 128, the most widely cultivated variety in Sri Lanka. Therefore, this study was conducted under controlled conditions to assess the accumulation and partitioning of N, P, and K in the above-ground biomass of SL 96 128 during the first six months of growth. The findings aim to inform site-specific fertilizer management and the development of nutrient-efficient agronomic practices for sugarcane cultivation in Sri Lanka.

MATERIALS AND METHODS

Experimental Condition

The experiment was conducted under controlled shade house conditions at the Sugarcane Research Institute, Uda Walawe, located in the low-country dry zone of Sri Lanka (6° 24′ N, 80° 49′ E; 76 m above sea level). The site is characterized by a mean annual temperature of 27.98 °C, annual rainfall of 1386 mm, and an average relative humidity of 76.33%. A Randomized Complete Block Design (RCBD) was employed, consisting of ten treatments with four replicates.

Soil used for the experiment was collected from sugarcane-cultivated Alfisols in the Uda Walawe area, sampled in two depth layers: 0–30 cm and 30–60 cm. Each pot, measuring 46 cm in diameter and 56 cm in height, was filled with the collected soils according to the respective layers, preceded by a 10 cm gravel base to ensure drainage. One-budded setts of the SL 96 128 variety, obtained from 10-month-old crops, were treated with recommended insecticides and planted at a density of two setts per pot.

Fertilizers were applied based on standard local recommendations from the Sugarcane Research Institute: urea at 300 kg/ha (N source), triple superphosphate at 200 kg/ha (P source), and Muriate of Potash at 225 kg/ha (K source). These applications were aimed at fulfilling the primary macronutrient requirements of the plants throughout the early growth period.

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Sampling and Analysis

Prior to planting, soil samples from each pot were collected using a mini auger to analyze baseline physicochemical properties. Samples were air-dried at room temperature for one week, and stones and debris were removed. The soils were then crushed and sieved through a 2 mm mesh. Initial analyses included total nitrogen (N), available phosphorus (P), exchangeable potassium (K), pH, and electrical conductivity (EC) using standard protocols [8].

Destructive plant sampling was conducted at 20-day intervals up to 180 days after planting (DAP), with four plants sampled per interval. Each plant was harvested at ground level and separated into leaf and stalk components. Leaves were removed by cutting at the base of the leaf sheath, and the remaining stalk was considered separately. Fresh weights of the leaf and stalk were recorded immediately after harvesting.

Dry weights were obtained by oven-drying samples at 70 °C until a constant weight was achieved. Dried samples were then ground using a mill equipped with a 2 mm mesh. For nutrient analysis, a wet digestion method was employed: 0.3 g of ground tissue was digested at 100 °C for 2 hours, followed by 330 °C for 3 hours until the solution became clear. Nitrogen and phosphorus concentrations were determined using a UV-VIS spectrophotometer (Shimadzu UV-2600), while potassium concentrations were measured via atomic absorption spectrophotometry (Shimadzu AA-6300).

$$\text{Nutrient conc. } (\text{mg kg}^{-1}) = \frac{\text{Read conc. } \times 50}{1000 \times \text{Plant weight}} \times \text{dilution factor}$$

Biomass and Nutrient Accumulation

The accumulation of nitrogen (N), phosphorus (P), and potassium (K) in the leaf and stalk tissues was calculated using the equation:

$$\text{Nutrient Accumulation (NA)} = \text{Dry Weight (DW)} \times \text{Nutrient Percentage (NP)}$$

Total above-ground nutrient content per plant was derived by summing the accumulation values from leaf and stalk components.

Relative biomass accumulation rate (RBR) and relative nutrient absorption rate (RNA) were calculated using the following equations [9]:

$$RBR = \frac{D_2 - D_1}{T_2 - T_1}$$

$$RNA = \frac{A_2 - A_1}{T_2 - T_1}$$

Where:

- D1 and D2 are dry or fresh weights at two successive sampling points,
- A1 and A2 are nutrient contents at two successive sampling points,
- T2–T1is the number of days between the two samplings.

Nutrient percentages were calculated by dividing total nutrient content by the total dry weight of the respective plant part at each sampling time.

Statistical Analysis

Data were analyzed using the PROC ANOVA procedure in SAS 9.1 statistical software. Dry biomass accumulation and nutrient content in leaf, stalk, and total above-ground parts were compared across sampling intervals. Means were separated using Duncan's multiple range test at the 5% probability level. Line graphs were generated to illustrate trends in dry biomass accumulation, nutrient accumulation, and partitioning throughout the experimental period.

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RESULTS AND DISCUSSION

Experimental Soil Condition

Table 01: Mean values of initial soil chemical properties

Depth (cm)	P (mg/kg)	K (mg/kg)	pH	EC (S/m)
0-15	4.27	176.4	6.73	0.0084

The initial chemical analysis of the soil revealed that available phosphorus, electrical conductivity, and pH values were higher than those reported for undisturbed Reddish Brown Earth (RBE) soils in the Uda Walawe region [10]. However, these values were within the range of optimum soil conditions for sugarcane cultivation [11].

Bio-mass Accumulation and Distribution

The highest dry biomass accumulation rate was recorded as 3.04 g/plant/day at 120 to 140 days after planting (DAP) when plants were at their early stage of the grand growth phase (Figure 01). Sugarcane plants begin their grand growth stage around 130 - 140 DAP where photosynthates accumulate inside the sugarcane stalk as sucrose [12]. Studies conducted under various field conditions concluded that the period between 130 – 270 DAP was characterized by a rapid growth that produced around 65% of the final aboveground biomass relative to harvest in sugarcane [13].

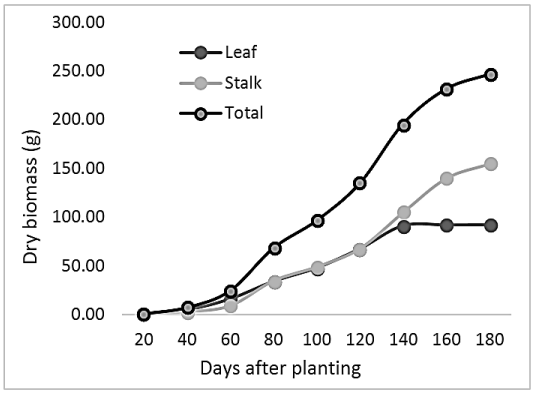

Figure 1: Dry biomass accumulation

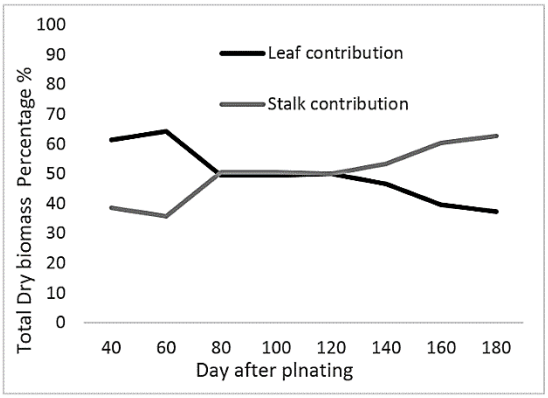

Figure 2: Total dry biomass accumulation percentage

Above ground total, dry biomass to total fresh biomass ratio was increased significantly after 120 DAP which coincides with the grand growth phase of the sugarcane plant. These results were similar to previous studies conducted with Co 775 sugarcane variety [3] where the highest dry biomass accumulation was recorded at 4 -6 months after planting. In dry biomass partitioning, 40 – 60 DPA period was marked by around 60-65% of the total dry biomass accumulated exclusively in the leaves (Figure 02).

During the 60 – 120 DAP period the dry biomasses of leaves and stalks were equally contributed to the total above-ground dry biomass of the plant. However, once the grand growth phase starts (120 – 140 DAP) opposite trend was observed where the majority of the dry biomass was accumulated in the stalk area (62% in stalk at 180 DAP). Similar patterns were observed in studies conducted for biomass accumulation in sugarcane plants [13],[14],[15],[16].

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Table 02. Mean values of total fresh, dry biomass and primary nutrient amounts in leaf and stalk sections of at different sampling dates.

Sampling Date (DAP)	Fresh biomass		Dry biomass		N		P		K	
	Leaf	Stalk	Leaf	Stalk	*Leaf	*Stalk	*Leaf	*Stalk	*Leaf	*Leaf
40	20.11^{a}±6.6	19.38^{a}±4.2	4.45^{a}±1.3	2.79^{a}±0.5	<0.01	<0.01	<0.01	<0.01	0.12	0.10
60	76.82^{b}±13.4	78.67^{a}±15.1	15.74^{b}±2.8	8.76^{a}±1.9	0.02	0.01	0.03	0.02	0.37	0.30
80	152.17^{c}±13.2	220.30^{b}±13.5	33.77^{c}±3.3	34.45^{b}±3.4	0.04	0.28	0.06	0.05	0.68	1.12
100	192.56^{c}±15.3	308.72^{c}±19.1	47.64^{d}±3.7	48.75^{c}±12.7	0.78	0.31	0.09	0.05	0.79	1.29
120	264.92^{d}±11.3	455.92^{d}±15.7	67.21^{e}±2.4	67.40^{d}±3.9	1.08	0.33	0.09	0.06	1.17	1.60
140	274.98^{d}±16.3	561.91^{e}±44.7	91.01^{f}±2.3	104.51^{e}±7.7	1.22	0.51	0.11	0.06	1.18	2.14
160	329.52^{e}±19.2	595.01^{ef}±30.8	91.69^{f}±6.0	139.60^{f}±7.8	1.23	0.59	0.13	0.08	1.25	2.33
180	357.74^{e}±13.1	641.42^{f}±51.7	91.09^{f}±8.1	154.50^{g}±2.7	1.35	0.61	0.17	0.09	1.44	2.46

DAP - date after planting
± - standard deviation
* - total per plant

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Nutrient Accumulation

The percentage of phosphorous and potassium in sugarcane plants were gradually reduced during the experimental period (Figure 03). This reduction trend of nutrient percentage indicates a greater biomass accumulation rate than the nutrient accumulation rate in sugarcane plants [17]. However, the plant nitrogen percentage gradually increased during 60 to 100 DAP and started to decline after 100 DAP (Figure 04). This trend revealed that the nitrogen accumulation rate in sugarcane plants were greater than that of the biomass accumulation rate during the onset of the vegetative phase.

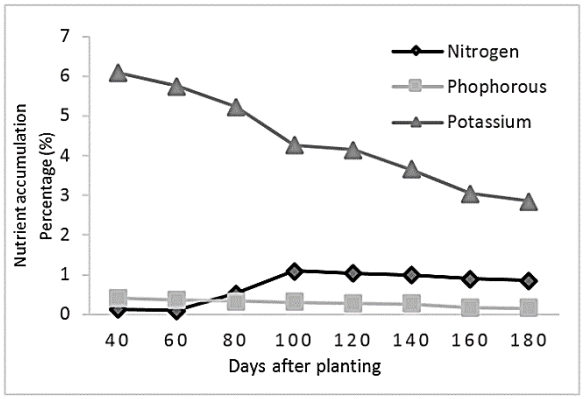

Figure 3: Dry biomass accumulation

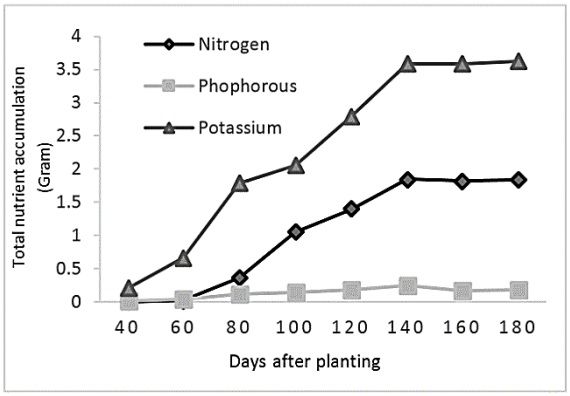

Figure 4: Total dry biomass accumulation percentage

Previous studies have shown that the majority of the nitrogen is taken up by the sugarcane plant during the first 180 days of the crop growth [18],[19],[6]. The highest accumulation was recorded in potassium nutrient among three major nutrients in the sugarcane plant followed by nitrogen and phosphorous (K>N>P).

The highest relative absorption for phosphorous and potassium was recorded between 60 to 80 DAP with 0.08 g and 1.125 g per plant and the highest relative absorption for nitrogen was recorded at 100 DAP with 0.69 g/plant. Sugarcane plants used in this experiment did not show a significant increase in total nitrogen accumulation during the first 60 DAP. However, after 60 DAP the total nitrogen content was significantly increased until 140 DAP (Figure 02) which indicates the importance of nitrogen during the vegetative phase where nitrogen is the major nutrient that contributes to the growth and tillering processes of the sugarcane plant [20].

Nutrient Partitioning

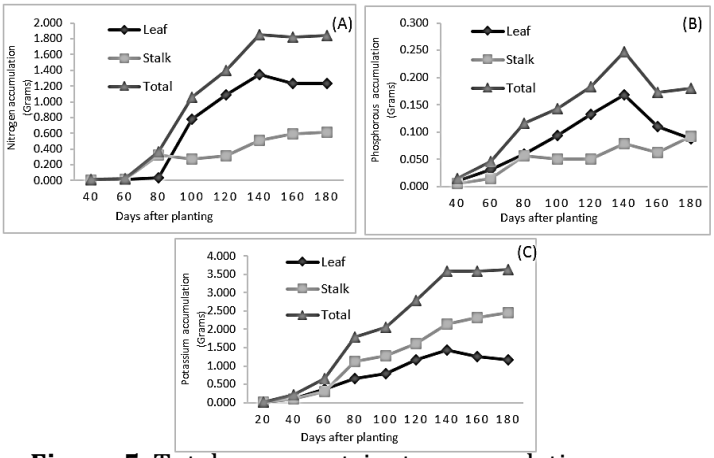

Figure 5: Total macro nutrients accumulation; (A) Total nitrogen accumulation, (B) Total Phosphorous Accumulation, (C) Total Potassium Accumulation

At the end of the experimental period, nitrogen and phosphorous content were highest in the leaf area than that of stalk area and P was highest in the stalk area than that of leaf area in sugarcane plants (Figure 05). However, total nitrogen content in sugarcane leaves was increased between 80 -140 DAP. After 140 days the nitrogen content in the stalk area was increased continuously until the end of the experimental period. A similar pattern was observed for the potassium and phosphorous amounts (Figure 05). This suggested that during the grand growth phase of the sugarcane plant, accumulated nutrients

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were transported from the sugarcane leaf to the stalk area. Several other studies on sugarcane nutrient partitioning also reveal that higher proportion of nutrients was accumulated in the sugarcane stalk area than in leaves during the grand growth phase [16][21].

CONCLUSIONS

The rate of accumulation of the total above-ground dry biomass was highest at 120 - 140 DAP where the experiment plants were at their early stage of the grand growth phase. During the vegetative phase, majority of the dry matter was accumulated in leaf area and stalks were accumulated higher proportion of aboveground dry biomass during the grand growth phase of sugarcane plant. Relative nutrient absorption of N, P and K was greater within 40 to 160 DAP. Therefore, optimum nutrient supply should be maintained during this period of sugarcane cultivation. The results of this study will be supportive for future fertilizer recommendations for optimizing the fertilizer schedule and the production of controlled released fertilizers for sugarcane cultivation in Sri Lanka.

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