Feasibility study of the commercial production of biofuels from dedicated biomass crops on mined-out bauxite lands in Moengo, Suriname

MINISTERIE VAN NATUURLIJKE HULPBRONNEN
MINISTRY OF NATURAL RESOURCES

FINAL REPORT

By

IICA Delegation in Suriname

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LIST OF ACRONYMS

ADEKUS	Anton de Kom University of Suriname
Ag	Silver
Al	Aluminum
As	Arsenic
Aug	August
B	Beryllium
Ba	Barium
BIS	Bauxite Institute of Suriname
Br	Bromine
Ca	Calcium
CBO	Community based organization
Cd	Cadmium
CELOS	Center for Agricultural Research in Suriname
Co	Cobalt
Cu	Copper
Dec	December
Dry wt	Dry weight
EBS	National Electricity Company
EC	Electrical conductivity
Fe	Iron
Feb	February
g/plant	Grams per plant
Ge	Germanium
Ge	Geranium
ha	Hectare
Hg	Mercury
ICP	Inductive Coupled Plasma
IICA	Inter-American Institute for Cooperation on Agriculture
Jan	January
JBI	Jamaica Bauxite Institute
La	Lanthanum
LVV	Ministry of Agriculture, Animal Husbandry and Fisheries
M	Meters
Mar	March
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen

Na	Sodium
Nb	Niobium
NGO	Non-governmental organization
Ni	Nickel
Nov	November
Oct	October
P	Phosphorus
Pb	lead
pH	Potential of Hydrogen
S	Sulphur
Sc	Selenium
Sep	September
Sl	Antimory
Sn	Tin
Sr	Strontium
SURALCO	Suriname Aluminum Company
t/ha	Tonnes per hectare
T1	Thallium
Ta	Tantalium
Te	Tellarium
Ti	Titanium
UNDP	United Nations Development Programme
V	Vanadium
VITI	Variety treatment
W	Tungsten
Wet wt	Wet weight
Y	Yltrium
Za	Zinc
Zr	Zirconium

Project: Biofuel Production on Mined-out Bauxite Lands in Suriname

NAME OF RECIPIENT INSTITUTION: IICA

SUMMARY OF ACTIVITIES AND STATUS OF PROJECT

December 16, 2016

Proposed Project Activities	Status
Proposal and Desk Investigation	**Completed**
Sample and Analyze Soil	**Completed**
Harvesting/germination/importing	**Completed**
Prepare Nursery	**Completed**
Plant cuttings for seedling	**Completed**
Land Preparation	**Completed**
Planting	**Completed**
Data collection/Sampling	**Completed**
Biomass harvesting	**Completed**
Soil and Plant Tissue Testing	**Completed**
Knowledge Management for National Authorities	**Completed**
Community Sensitization and Awareness	**Completed**
Final Reporting	**Completed**

Over the period of the Project, eight (10) official events and visits to the project site, including the following:

- Two visits each by the Permanent Secretary of the Ministry of Agriculture, Animal Husbandry and Fisheries (LVV) and the Deputy Country Representative UNDP in 2015
- Staff of the Ministry of Natural Resources and the consultants
- Industry sectors representing the mining, agriculture and environment
- Visit to the experimental plots by the Environmental Department of the Cabinet of the President
- A stakeholder information session was also held on December 11, 2016
- Visit to the project site by the new IICA Representative to Suriname on June 21, 2016
- Stakeholders holders visit to the project site on June 23, 2016
- Final stakeholders report presentation and information session on June 24, 2016
- Visit to the rehabilitation mined out site and Experimental plots of the Project by Jamaica Bauxite Institute, Bauxite Institute Suriname and main stakeholders, November 2, 2016.

NAME OF RECIPIENT INSTITUTION: IICA

Performance Targets – December 16, 2016

<table>
<tr><th rowspan="2">PERFORMANCE TARGETS</th><th rowspan="2">BASELINE</th><th colspan="2">YEAR 1 (2015/2016)</th></tr>
<tr><th>Proposed</th><th>Actual up to December 16, 2016</th></tr>
<tr><td>Investigate and establish the best agronomic conditions for the growth of two varieties of Pennisetum purpureum (elephant grass and Napier grass) and Gynerium sagittatum</td><td>There is no knowledge about the growth of Pennisetum purpureum and G. sagittatum, in Suriname for bioenergy production.</td><td>By the end of the year, the agronomic conditions are investigated and the best conditions are established for the growth of Pennisetum purpureum (elephant grass – V3 and Napier grass – V2) and Gynerium. Sagittatum (V1). The investigation will be based on (1) 40 soil samples analyzed, (2) field trials with three plant species (Pennisetum purpureum (elephant grass and napier grass) and Gynerium. sagittatum) on 0.7 ha of land, (3) testing of three fertilizers (0g=T1, 10g=T2 and 21g=T3).</td><td>1. About 9000 plants of the three species were established in the nursery at Ministry of Agriculture (LVV) office in Moengo

2. 36 field plots (3 varieties, 3 fertilizer treatments and 4 replications) prepared and the plants were established on 0.7 ha of land provided by Suralco.

3. 10 soil samples have been collected from 5 regions of the field, and they will be analyzed to provide baseline information for comparison when additional 36 soils samples are collected at the end of the project.

4. The 36 plots were planted on

5. Fertilizers (0, 10 and 21g) were added to the treatment plots as per the proposal.

Results to date show that:
The best condition for the establishment of Pennisetum purpureum (elephant grass and Napier grass) and Gynerium sagittatum on mined out bauxite land involve the addition of NPK at minimum application rates per hectare of 40 kg of nitrogen, 20 kg of phosphorus and 10 kg of potassium. NPK application rates of 80, 40, and 20kg per hectare respectively produce the optimum biomass.</td></tr>
</table>

PERFORMANCE TARGETS	BASELINE	YEAR 1 (2015/2016)	
		Proposed	Actual up to **December 16, 2016**
			6. Bi-weekly data on plant height are being collected for 5 randomly selected plants in each plot. Data collection will continue till the end of the project Information being collected also include number of tillers per pant and qualitative data on plant height
Collect data on the comparative growth of *Pennisetum purpureum* (elephant grass and Napier grass) and *Gynerium. sagittatum*	No data available on the comparison of the growth of *Pennisetum purpureum* (elephant grass and napier grass) and *Gynerium. sagittatum*	By the end of the year data is collected on the comparative growth of *Pennisetum purpureum* (elephant grass and Napier grass) and *Gynerium sagittatum*. Both qualitative and quantitative information will be collected. Qualitative information will include (1) plant health, (2) leaf and plant colors and (3) symptoms of deficiencies in the plants. Quantitative parameters will be (1) plant survival, (2) growth - height, number of leaves, internode length and stem diameter and (3) biomass - wet and dry matter production and vegetation cover.	7. Monthly wet biomass samples were collected from July 2015, till March 2016. 8. The dry weights of biomass were determined. Results show that comparatively, *Pennisetum purpureum* (elephant grass and Napier grass) are better suited for growth and the production If biomass for biofuel on bauxite mined-out land than *Gynerium sagittatum*. Optimum time for the collection of biomass for use as biofuel is in October and January, and in the first week of September and January when used as forage. Addition of NPK fertilizer will be required as un -amended plots showed symptoms of nutrient deficiencies and significantly lower plant growth and biomass production.

PERFORMANCE TARGETS	BASELINE	YEAR 1 (2015/2016)	
		Proposed	Actual up to **December 16, 2016**
Evaluate the potential of using the selected species for biomass to energy, and as ground cover to mitigate soil degradation	No information available on the potential of the species for biomass to energy, and as ground cover to mitigate soil degradation	By the end of the year an evaluation has been conducted about the potential of the selected species for biomass to energy, and as ground cover to mitigate soil degradation. Indicators for the evaluation will be (1) the physical assessment of the designated plots, (2) biological and chemical soil profiling, and (3) biomass samples collected during the growth cycle of the plants.	Soil samples were collected from the plots at the beginning of the project to obtain baseline information on the physical and chemical profiles of the soil. Samples were also collected at the end of the project and analyzed for pH, EC, organic matter, and organic carbon, P and N. Plant tissue samples were digested and analyzed for Ag, Al, **As**, B, **Be**, Br, Ca, **Cd**, Co, **Cr, Cu**, Fe, Ge, **Hg**, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, S, Sb, Sc, Sn, Sr, Ta, Te, Ti, Tl, V, W, Y, Zn, and Zr using Inductively Coupled Plasma (ICP) spectroscopy. As, B, Ba, Cd, Co, Ge, La, Mo, Nb, Sb, Sc, Sn, Ta, V, W, Y and Zr were below detectable limits in all samples The results are analyzed Analysis of Variance (ANOVA)
			Only Ag, Al, Bi, **Cr, Cu**, Fe, K, Mg, Mn, Na, Ni, P, S, **Se,** Sr, Te, Ti and Tl appeared to be selectively accumulated in some of the plants at certain times of the year, for example, Sr, Se, Pb and Fe are accumulated in the plant tissues during the month of January. *G. sagittatum* (V1) showed significantly higher accumulation of Cr, Cu, S and Ti when compared to the other two varieties. In all, Ag, Fe and Se showed similar pattern of accumulation, which were significantly high in all species during November, January and March. Additionally, the treatment without NPK fertilizer (T1) showed significant accumulation of Al, Ca, Mn, S, and Sr. In summary based on accumulation of heavy metals, *G. sagittatum* is neither a good candidate for biomass for energy nor for animal feed. The least accumulation of heavy metals were in the months of September, November and March, which also coincided with high biomass production especially for V2 and V3.

PERFORMANCE TARGETS	BASELINE	YEAR 1 (2015/2016)	
		Proposed	Actual up to **December 16, 2016**
			Additional deliverables provided by the project to the GoS are the Greenhouse with irrigation system in Moengo, and the sterilization equipment (autoclave) for tissue culture facility in Paramaribo.
Engage in knowledge management activities for experience capitalization with other territories where mined out bauxite lands have been successfully managed.	Some exchanges had taken place between the Jamaica Bauxite Institute and the Suriname Bauxite Institute during the setting phase of the latter, however, there has been very little to no collaboration on rehabilitation of mined out sites and whether there is potential for crops	Transfer relevant knowledge, sensitization and awareness to national authorities and the private sector on the potential for Biofuel development in Suriname based on successful experiences of other territories, as well as the successful approaches to the rehabilitation of mined out bauxite lands. It also sought to incorporate tertiary level agriculture and environmental science/natural resource management students to the approaches and techniques utilized in this study.	1. Four (4) field visits were conducted for senior public sector officials, tertiary level educational institutions, Community based organizations, private sector and NGOs to the experimental site and to visit the rehabilitation efforts in adjacent communities on mined-out bauxite soils. 2. Four (4) knowledge management forums were held. 3. Two students from the Agriculture Faculty Anton De Kom University were invited to participate in sampling exercises of soil, plant tissue and other biometrics at the experimental plot in Moengo. The results under this activity are the following: • The field visits were aimed primarily at building sensitization and awareness and educating public sector officials, educational institutions, NGOs, CBOs and International Organizations in Suriname as the options for Biofuel production on mined-out bauxite lands, but also to impressed upon all concerned the broader environmental considerations surrounding the mining of bauxite as well as the socioeconomic considerations for nearby rural communities and the need for urgent and joint actions. A total of one hundred and fifteen (115) participants were involved in the various field trips.

PERFORMANCE TARGETS	BASELINE	YEAR 1 (2015/2016)	
		Proposed	Actual up to **December 16, 2016**
			• The knowledge management forums were aimed at experience capitalization particularly of successful interventions of bauxite mining in other territories on the rehabilitation of mined out bauxite lands and its potential for biofuel. Two (2) workshops were geared at updating the project progress, comparisons of interim results with other initiatives in other countries and inviting recommendations for improvements; A total of seventy-four (74) participants attended these workshops. Two (2) major workshops were held, the first sought to expose national authorities to the successes of the Jamaica Bauxite Institute and the Government for Jamaica in converting mined out bauxite lands into agricultural use and the overall framework for management; the second was directed at the private sector and sought to develop concrete recommendations for the development of a viable renewable energy sector in Suriname. A total of one hundred and twenty (120) persons from public and private sector and NGOs, Academia participated in these two events. • The incorporation of two students from the University of Suriname in the data collection was to transfer valuable knowledge on sampling techniques and agronomic principals for research and management of experimental lots for biofuels. This is critical component of the sustainability of the project.
Undertake a Community sensitization exercises for communities located in the vicinity of the project's experimental site.	This is a scheduled activity under the project to ensure that communities located near the site, and who had participated in the project were made aware of the findings and recommendations.	Present results to community residents on the findings of the projects and the recommendations for future actions.	1. One (1) forum was held with representatives of ten (10) communities in the vicinity of the research plot to present the findings of the project and the lessons learned. The participants included community leaders, local government officials, NGO's and Community Based Organizations, and central Government Officials.

PERFORMANCE TARGETS	BASELINE	YEAR 1 (2015/2016)	
		Proposed	Actual up to **December 16, 2016**
			The results under this activity are the following: Workshop participants displayed a keen interest in the findings of the project. Many had a positive view that solutions were being actively sought to address the issue of mined out bauxite lands in their community which has seriously curtailed their agricultural activities. Many expressed the view that specific legislation should be put in place to ensure that activities such as the biofuel project and other actions with income generating potential should be made a compulsory part of the agreement with the mining companies.

1 EXECUTIVE SUMMARY

This project is an agronomic study aimed at examining the feasibility of establishing selected grass species on mined-out bauxite lands within Suriname and determine their suitability for the production of bioenergy. The project was extended to accommodate a knowledge management component to sensitize national authorities on the approaches for dealing with mine-out bauxite lands and the potential value of renewable energy alternatives to the national economy. The SURALCO site in Moengo was selected for the investigation. The three species selected were *Gynerium sagittatum*, *Pennisetum purpureum (*Schumach) also known as Napier grass and *Pennisetum purpureum* (purple "Prince"). The plants were propagated by cuttings in a nursery and transplanted to the field in a replicated randomized block design trial on a 0.7 ha plot. Three levels of NPK fertilizers were tested on the selected plant species. Plant growth data were collected over a period of a year. Soil and plant tissues were also analyzed for accumulation of heavy metals to determine suitability of biomass use.

The results of data analyses showed that the best condition for the establishment of *Pennisetum purpureum* (elephant grass and Napier grass) and *Gynerium sagittatum* on mined out bauxite land involve the addition of NPK at minimum application rates per hectare of 40 kg of nitrogen, 20 kg of phosphorus and 10 kg of potassium. NPK application rates of 80, 40, and 20kg per hectare respectively produce the optimum biomass. The addition of fertilizer resulted in significant increases plant height for the three grass species. There were no significant differences in dry weights between the low levels of NPK (10g/plant) and the higher application rate of 21 g per plant for *P. purpureum* and Napier grass. The least accumulation of heavy metals in the plants were in the months of September, November and March, which also coincided with high biomass production especially for *P. purpureum* and Napier grass. *G. sagittatum* produced significantly lower biomass than *P. purpureum* and Napier grass, and also accumulates chromium, copper and sulfur. Therefore, *P. purpureum* (elephant grass and Napier grass) are better suited for growth and the production lf biomass for biofuel on bauxite mined-out land than *G. sagittatum*. Additionally, *G. sagittatum* is not recommended energy for animal feed due to potential toxicity of accumulated chromium and copper.

The knowledge management exercises focused on sharing the experiences of Jamaica in the rehabilitation of mined-out bauxite lands particularly as it relates to conditioning for agriculture, and allowed for the identification of the deficiencies in Suriname's approached to the rehabilitation of their own lands. The project also permitted a broadening of the scope of biofuel viewed within the context of a broader private sector driven renewable energy sector for Suriname, with positive implications for rural development.

2 INTRODUCTION

In July 2012, the Government of Suriname signed a Memorandum of Understanding (MOU) with Caribbean Renewal Oil Partners (CROP) to conduct a **feasibility study** about the commercial production of biomass for biofuel in the mined-out areas in Moengo, Suriname.
To begin the project, the United Nations Development Programme (UNDP) had agreed to provide part of the required funding for the implementation of this project. These funds were transferred to CROP in the hope that the implementation of the activities could be speeded up. This approach did not prove successful and a Steering Committee was conformed comprising of IICA, the Ministry of Natural Resources, the Ministry of Agriculture (LVV), SURALCO and UNDP to facilitate the implementation of the project. IICA assumed the role as the new executing agency for the project
Initially, concerns were raised by the Environmental Department of the Office of the Cabinet of Suriname, on the use of *Arondo donax*[1], an imported species which has invasive potential. This therefore, justifiable sought to look at the field comparism of three grass species with similar anatomical and physiolocal attrubutes to *Arundo donax. Pennisetum purpureum* (elephant grass), *G. sagittatum*, and Nappier Grass which is a variant of *Pennisetum purpureum*, all occuirng naturally in Suriname and are widely distributed within the various ecological zones in the country.

Following the successful implementation of the experimental phase of the project, an additional six months extension was granted, as it was deemed advantageous to broaden the scope of the project to strengthen the knowledge management actions and include a community sensitization component into the project so that consideration can be given to some of the potential socioeconomic implications for a project of this type in rural communities.

[1] *Arondo donax*, was initially identified by the Ministry of Agriculture, Animal Husbandry and Fisheries for potential production for Biofuel, but seeds would have to be imported, as it is not endemic to Suriname.

3 GENERAL AND SPECIFIC OBJECTIVES AND EXPECTED RESULTS

GENERAL OBJECTIVE

To determine the potential options for the rehabilitation and productive use of mined out bauxite lands and to establish baseline data for viable biofuel initiatives in Suriname.

SPECIFIC OBJECTIVES

1. To establish the agronomic viability of *P. purpureum* (elephant grass), *G. sagittatum*, and *giant king grass* in the mined out bauxite areas of the Moengo region;
2. To conduct a rapid assessment of the potential socio-economic and environmental impact that commercial scale implementation of the project will have on the region.
3. To support the Government of Suriname in the development of basic infrastructure for the propagation of plant species capable for use in biofuel production.

4 METHODOLOGY

4.1 Propagation of Selected Species

The seedling nursery and greenhouse were set up at the regional office of the Ministry of Agriculture (LVV) in Moengo depicted in Plates 1 to 3. Seedlings were developed from cuttings of the three selected species. Each cutting was made to have between 3 and 4 nodes with a minimum of two active buds. Three thousand cuttings of each of the species were made. The cuttings were planted in 2 L seedling bag filled with a 1:1 mix of top soil and compost. The cuttings were planted with two nodes buried below the soil surface. An irrigation system was installed for watering of the seedlings.

Plate 1: Seedling planting in the Nursery

Plate 2: Nursery with the greenhouse in the background

Plate 3: Plants in the nursery before planting

4.2 *Varieties and Treatments*

4.2.1 Plant Species

The three species used were available locally. The three species selected were *Gynerium sagittatum*, *Pennisetum purpureum (*Schumach) Napier grass (V2) and *Pennisetum purpureum* (purple "Prince") – Elephant Grass (V3). These varieties were selected based on recommendations of the Ministry of Agriculture, Animal Husbandry and Fisheries (LVV). All the species were propagated vegetatively through cuttings.

4.2.2 Fertilizer Treatments

Three treatment levels (T1, T2 and T3) of slow release fertilizer (N:P:K 20:10:5) were investigated. Three fertilizers levels were be tested, including a 0g control, 10 g and 21 g per plant of AgSafe 20-10-5 (N-P-K) tables. The slow release fertilizer used designed to provide nutrients in the root zones of the plants for up to 2 years, and would reduce any leaching of fertilizer into the environment. The fertilizer application rates and equivalencies are shown in Table 1.

Treatment	g/plant	Equivalent N:P:K kg/Ha
T1	0	0:0:0
T2	10	40:20:10
T3	21	84:42:21

Table 1: Fertilizer treatment application rates

4.3 *Field Layout*

A total of 0.7 hectares of land was used. The standard practices of SURALCO for land preparation prior to reclamation were followed. Thirty centimeters of soil cover was applied to the soil in the preparation of the land. Each plot was 7 m by 15 m, and the spacing between rows of 1m and plants 0.5m. Seven rows of plants and 30 plants per row was planted total of 210 plants per plot. This gives a density of 20,000 plants per hectare. The space between plots was 2.5m and a 3m guard at the perimeter to allow for the movement of equipment. The plot design is shown in Figure 1. Plates 4 to 7 show the planting of the seedlings in the plots by the planting crew.

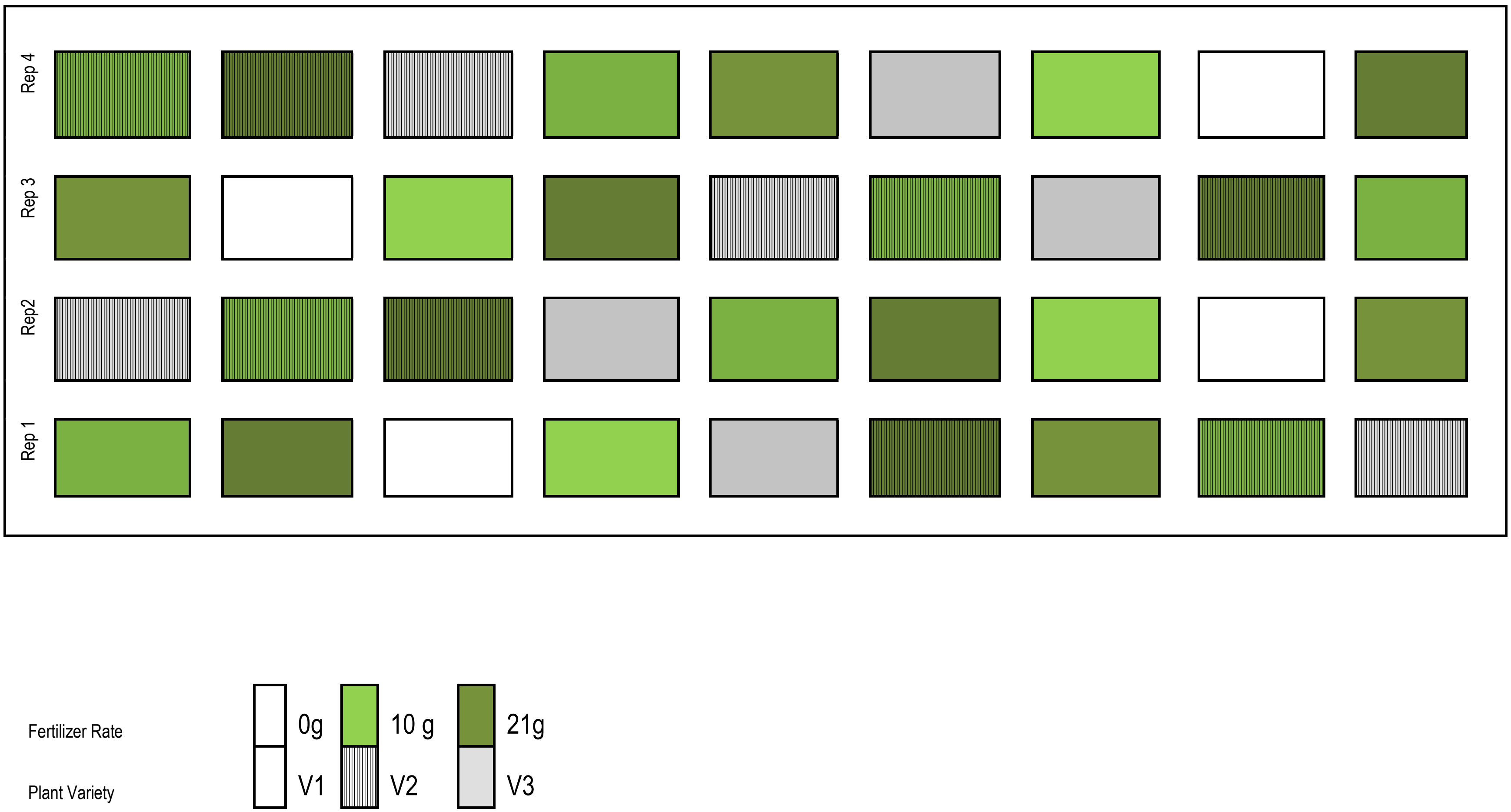

Figure 1: Experimental field layout of replicated trial for the three plant species at three rates of fertilizer applications in a randomized block design for an experimental unit

Field Preparation and Set Up

Plate 4: Land preparation and Plot set-up

Plate 5: Planting crew at work


Plate 6: Planting of the seedlings in the field


Plate 7: Planted plot

4.4 Data Collection, Sampling and Analysis

4.4.1 Data Collection and Sampling

Quantitative data were collected including plant survival and growth. Plant height data were collected initially on a biweekly basis from June to August, 2015, and later on monthly basis from June 2015 to March by measuring the heights of 5 randomly selected plants in each of the plot. It is assured that the plants selected were intact plants that were not regrowth from previously harvested plants. Biomass data were collected on a monthly basis from August 2015 to March 2015. Wet biomass was collected by cutting and collecting five randomly selected stands of plants in each plot. Efforts were taken to see that only sample only plants that have not been previously harvested. Wet biomass was determined by gravimetric method as the net weight of the fresh biomass collected. Dry biomass values of collected samples were determined by technicians at the CELOS laboratory at the Anton de Kom University of Suriname. Qualitative information were also collected including plant health, color of leaves and observations of symptoms deficiencies. Table 2 shows the sampling dates for plants heights and biomass collection.

Date	Plant Height	Biomass	Plant Tissue Analysis
June 17, 2015	X		
July 20, 2015	X		
August 7, 2015	X		
August 11, 2015		X	X
August 28, 2015	X		
September 3, 2015		X	X
September 16, 2015	X		
October 7, 2015	X	X	
November 7, 2015	X		
November 9, 2015		X	X
December 7 2015	X	X	
January 11, 2016	X	X	X
February 17, 2016	X		
February 18, 2016		X	X
March 29, 2016	X		
March 30, 2016		X	

Table 2: Plant height, biomass and plant tissue sampling dates

Two sets of soils samples were collected. A set of samples were collected at the beginning of the project in April 2015 to serve as the baseline. Another set of samples were collected from all the 36 plots on March 31, 2016. Soil samples were collected at 0-15 cm and 15-30 depths, using standard procedures

4.4.2 Sample Analyses

All soil samples were analyzed for pH, EC, organic matter, and organic carbon, Bray P and N at the Soil Science Laboratory of the Department of Agriculture of the Anton de Kom University of Suriname.

All plant samples were sent for analysis at FILAB Laboratory in Paramaribo, Suriname. The samples were digested and analyzed for Ag, Al, **As**, B, **Be**, Br, Ca, **Cd**, Co, **Cr, Cu**, Fe, Ge, **Hg**, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, S, Sb, Sc, Sn, Sr, Ta, Te, Ti, Tl, V, W, Y, Zn, and Zr using Inductively Coupled Plasma (ICP) spectroscopy.

5. RESULTS

5.1 Soil characteristics

	0-15 cm		15-30 cm	
	Mean	Std. Dev	Mean	Std. Dev.
EC (uS/cm)	74.4	44.22	63.75	30.18
pH	5.00	0.20	5.15	0.18
Bray P (ppm)	0.93	0.45	0.934	0.47
Total N (%)	0.066	0.03	0.056	0.03
Org C (%)	1.29	0.46	1.12	0.60
Org Matter (%)	2.59	0.93	2.232	1.20

Table 3: Baseline soil characteristics of the site

5.2 Wet and Dry Biomass Production

Figures 2 to 13 show the graphical depictions of the effects of the interactions of the treatments and the three selected species on the biomass produced while figures 14 and 15 are 3D special depictions of biomass production over the year.

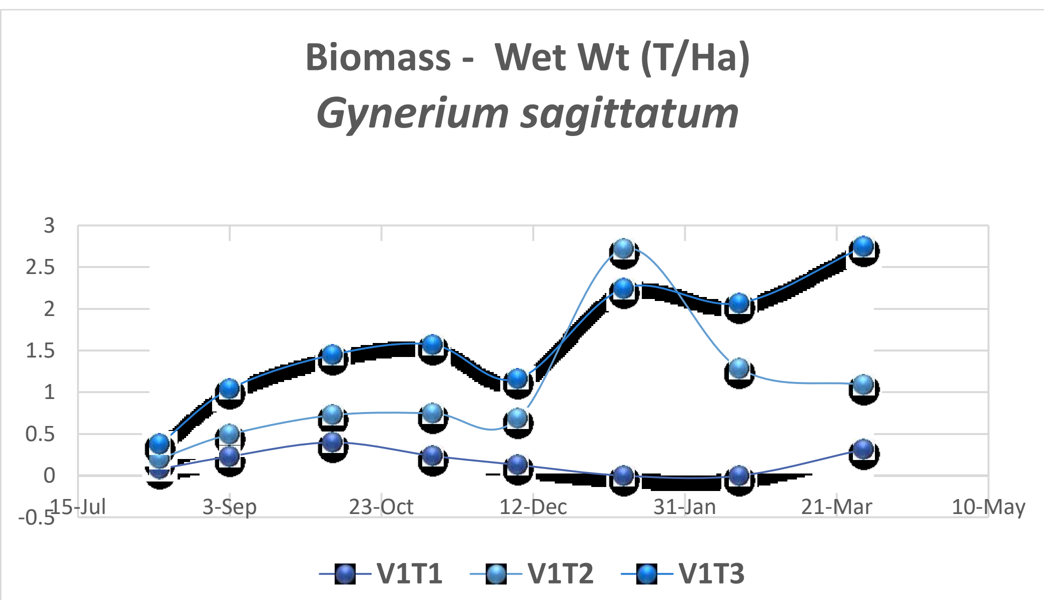

Figure 2: Wet biomass produced by *G. sagittatum* under three levels of NPK fertilizer

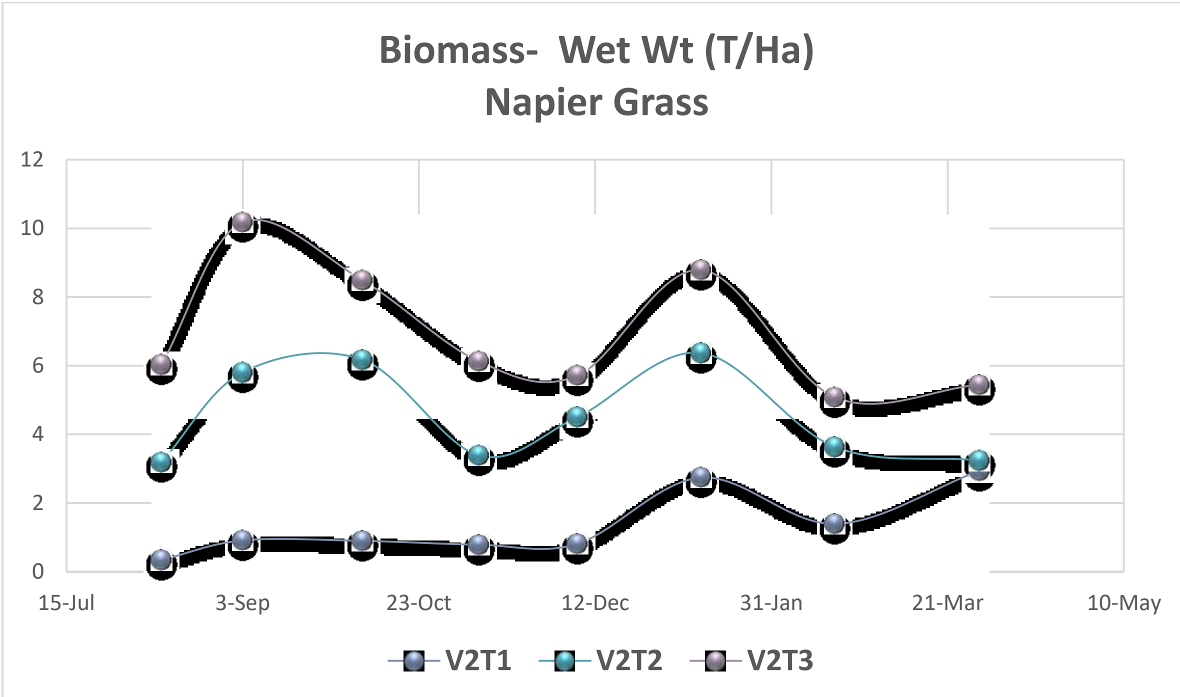

Figure 3: Wet biomass produced by Napier grass under three levels of NPK fertilizer

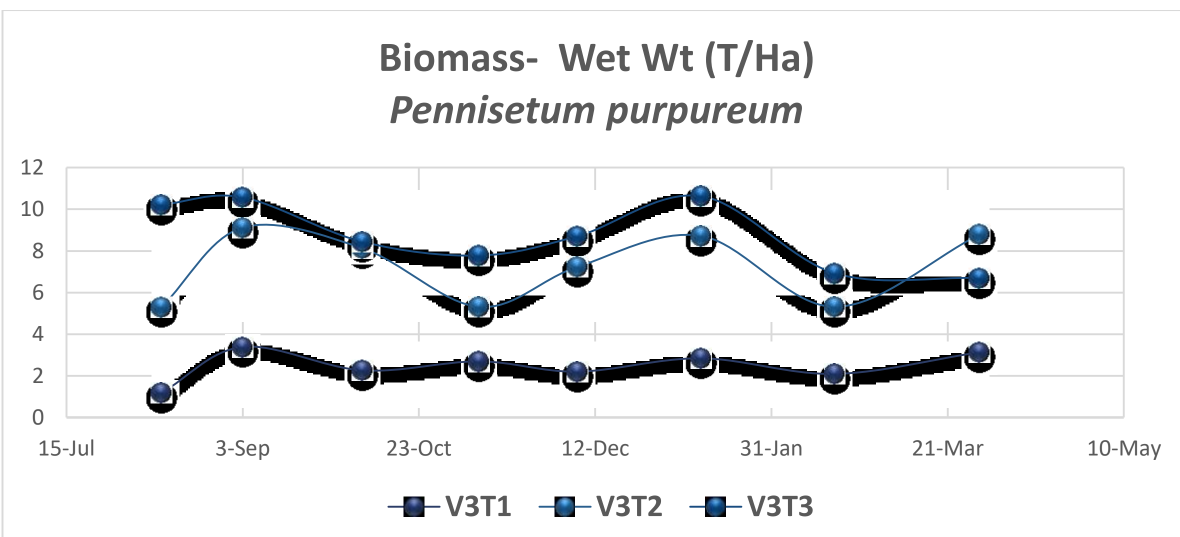

Figure 4: Wet biomass produced by *P. purpureum* under three levels of NPK fertilizer

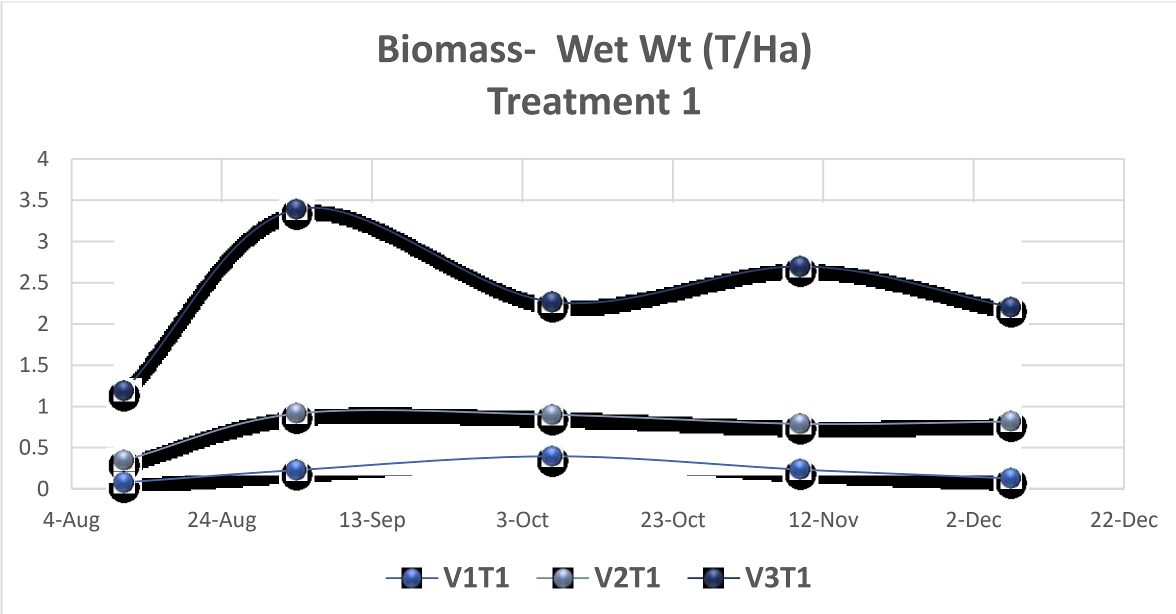

Figure 5: Comparative wet biomass produced by *G. sagittatum* (V1) Napier grass (V2) and *P. purpureum* (V3) treated with 0g/plant NPK fertilizer

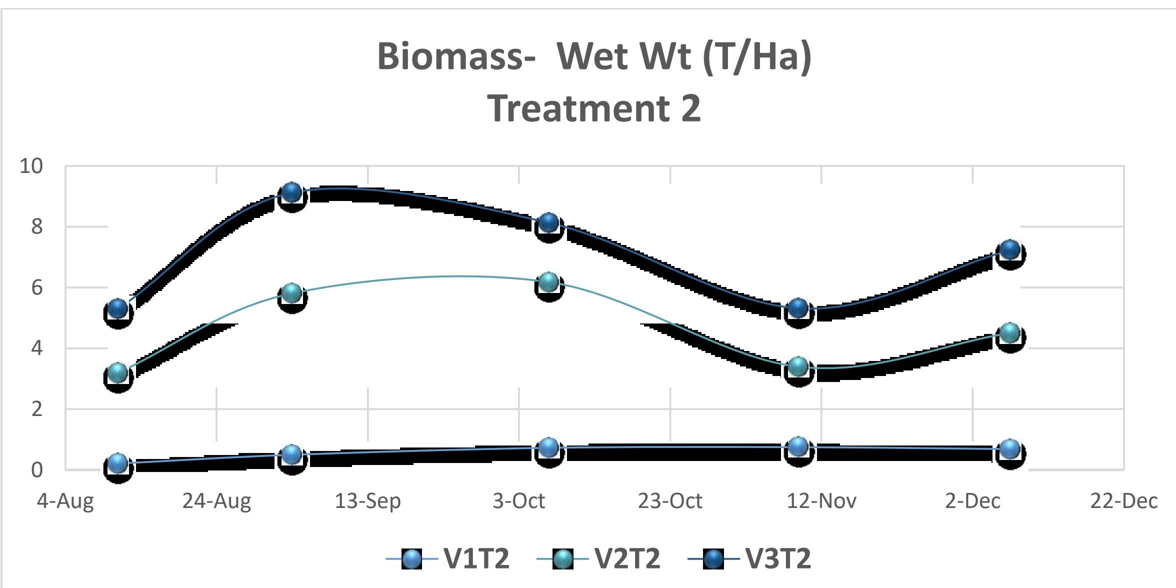

Figure 6: Comparative wet biomass produced by *G. sagittatum* (V1) Napier grass (V2) and *P. purpureum* (V3) treated with 10g/plant NPK fertilizer

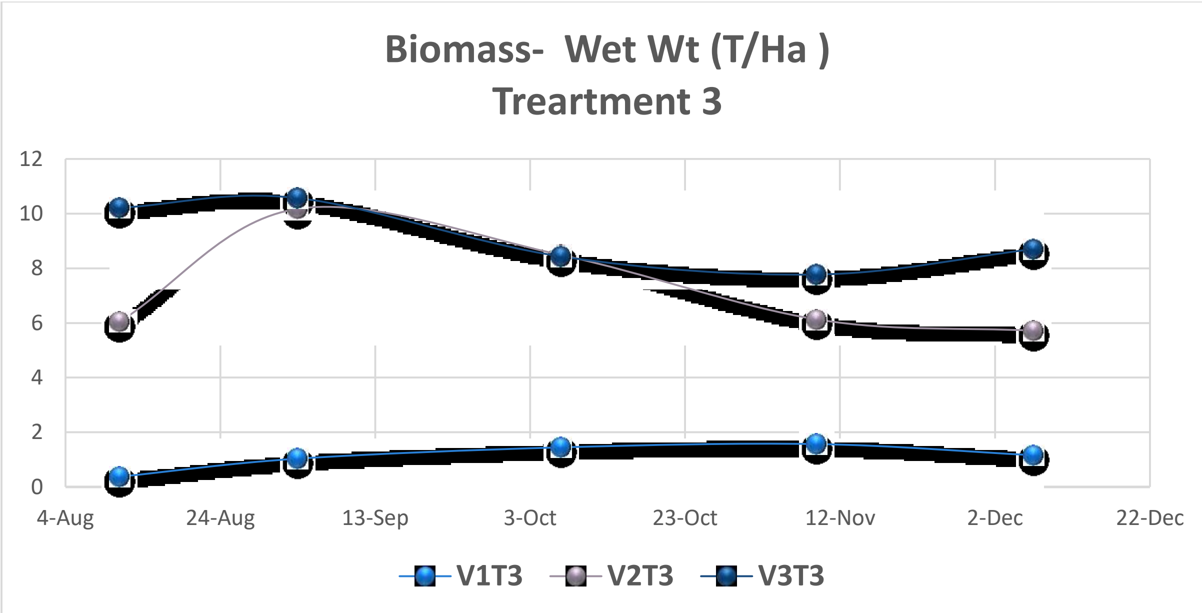

Figure 7: Comparative wet biomass produced by *G. sagittatum* (V1) Napier grass (V2) and *P. purpureum* (V3) treated with 21g/plant NPK fertilizer

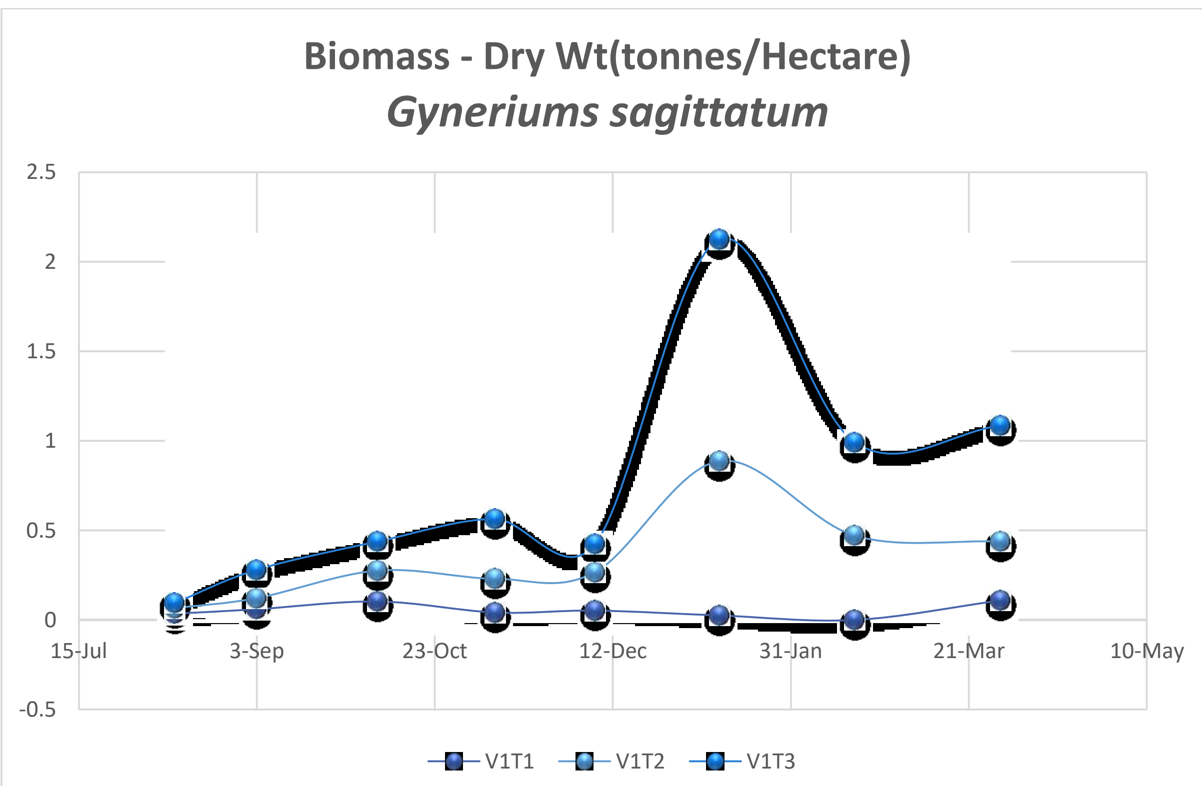

Figure 8: Dry biomass produced by *G. sagittatum* under three levels of NPK fertilizer

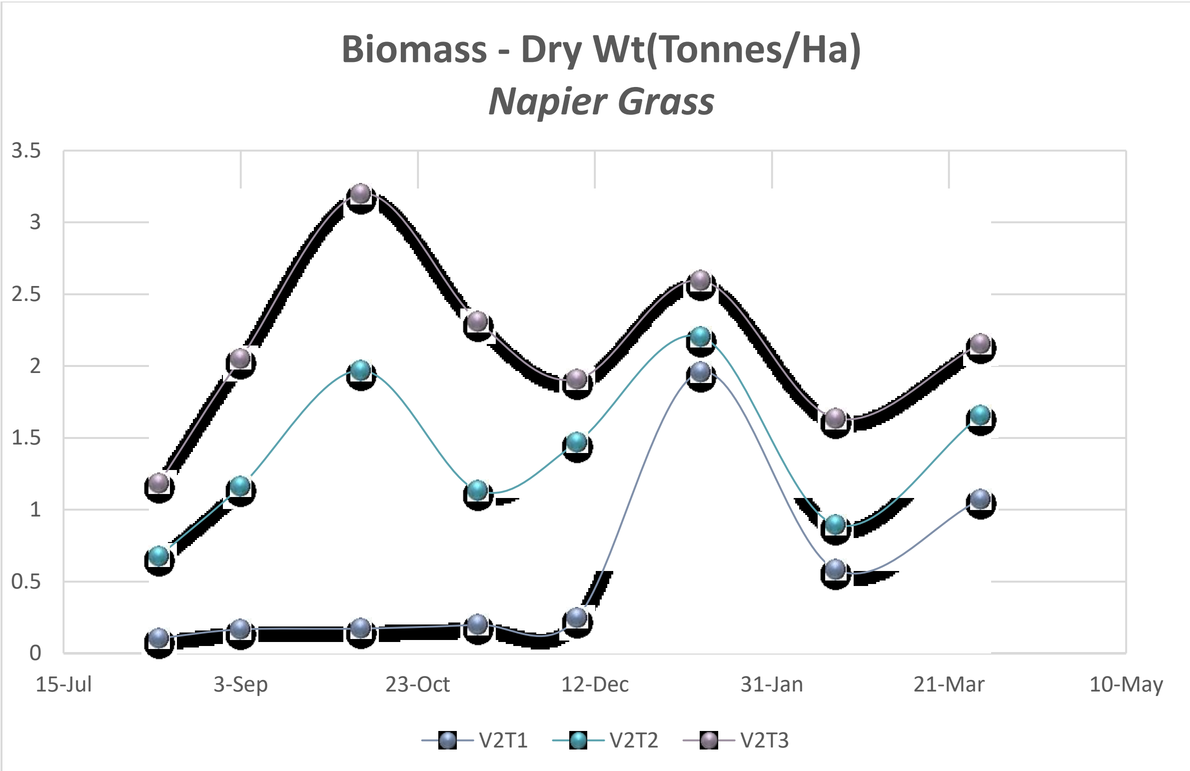

Figure 9: Dry biomass produced by Napier grass under three levels of NPK fertilizer

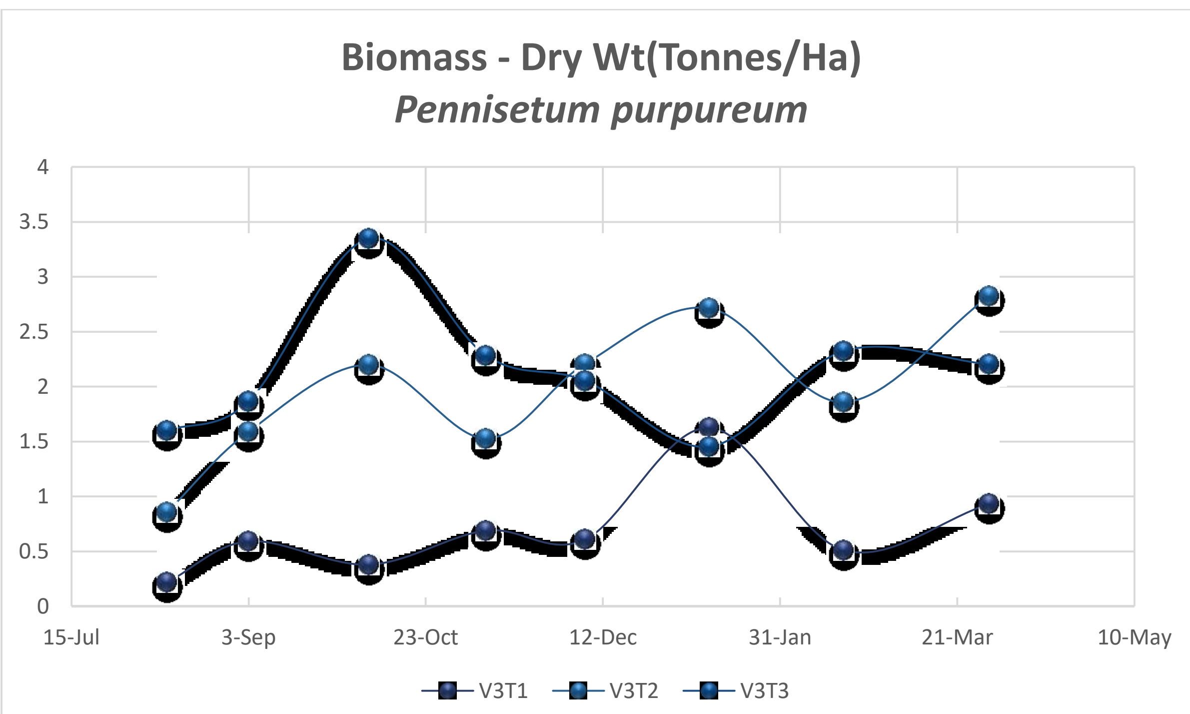

Figure 10: Dry biomass produced by *P. purpureum* under three levels of NPK fertilizer

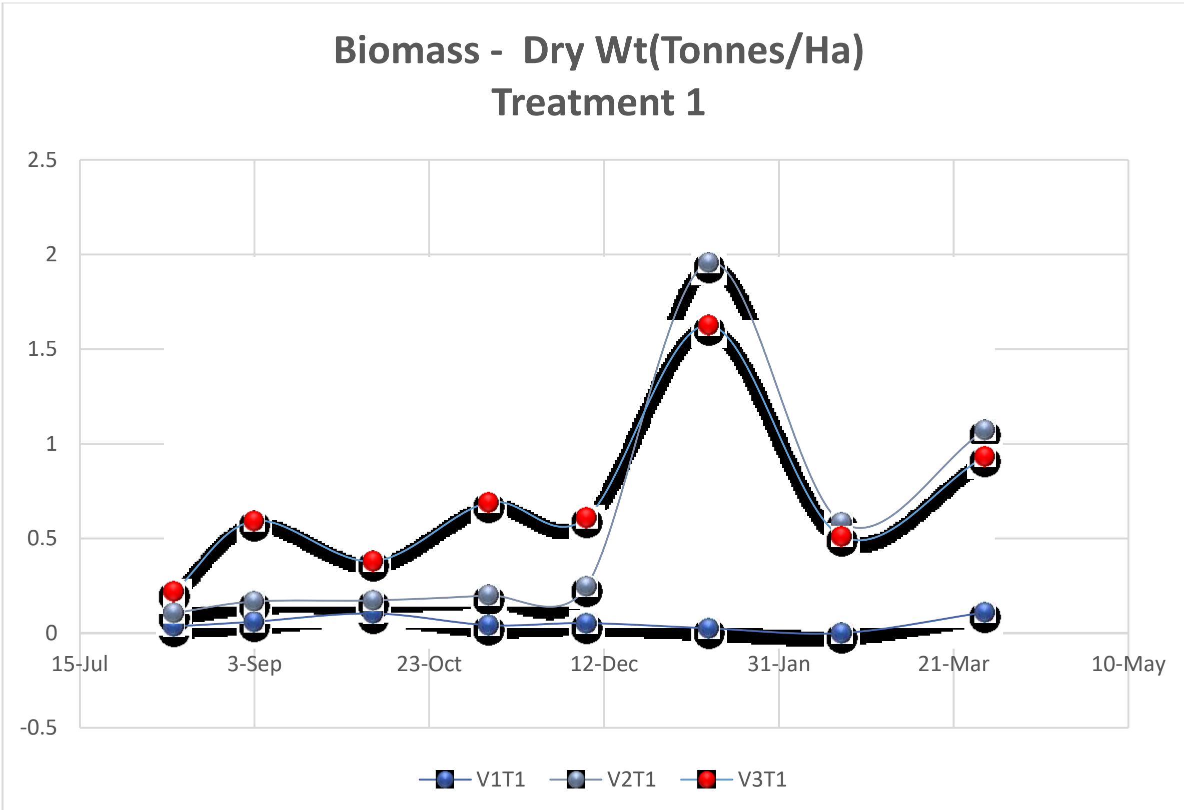

Figure 11: Comparative dry biomass produced by *G. sagittatum* (V1) Napier grass (V2) and *P. purpureum* (V3) treated with 0g/plant NPK fertilizer.

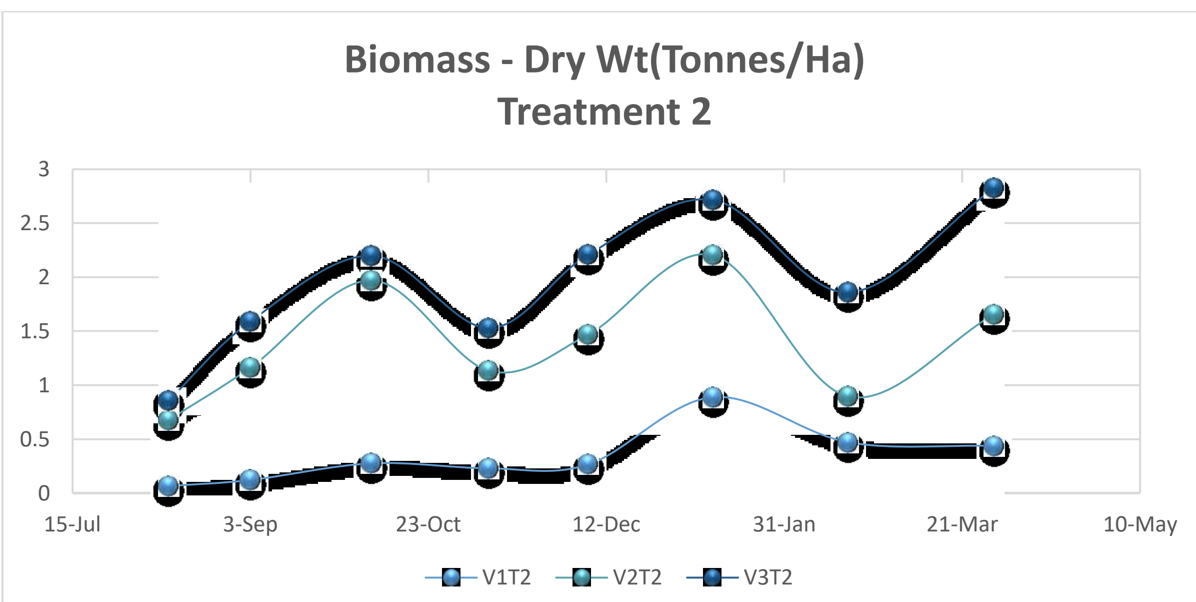

Figure 12 Comparative dry biomass produced by *G. sagittatum* (V1) Napier grass (V2) and *P. purpureum* (V3) treated with 10g/plant NPK fertilizer

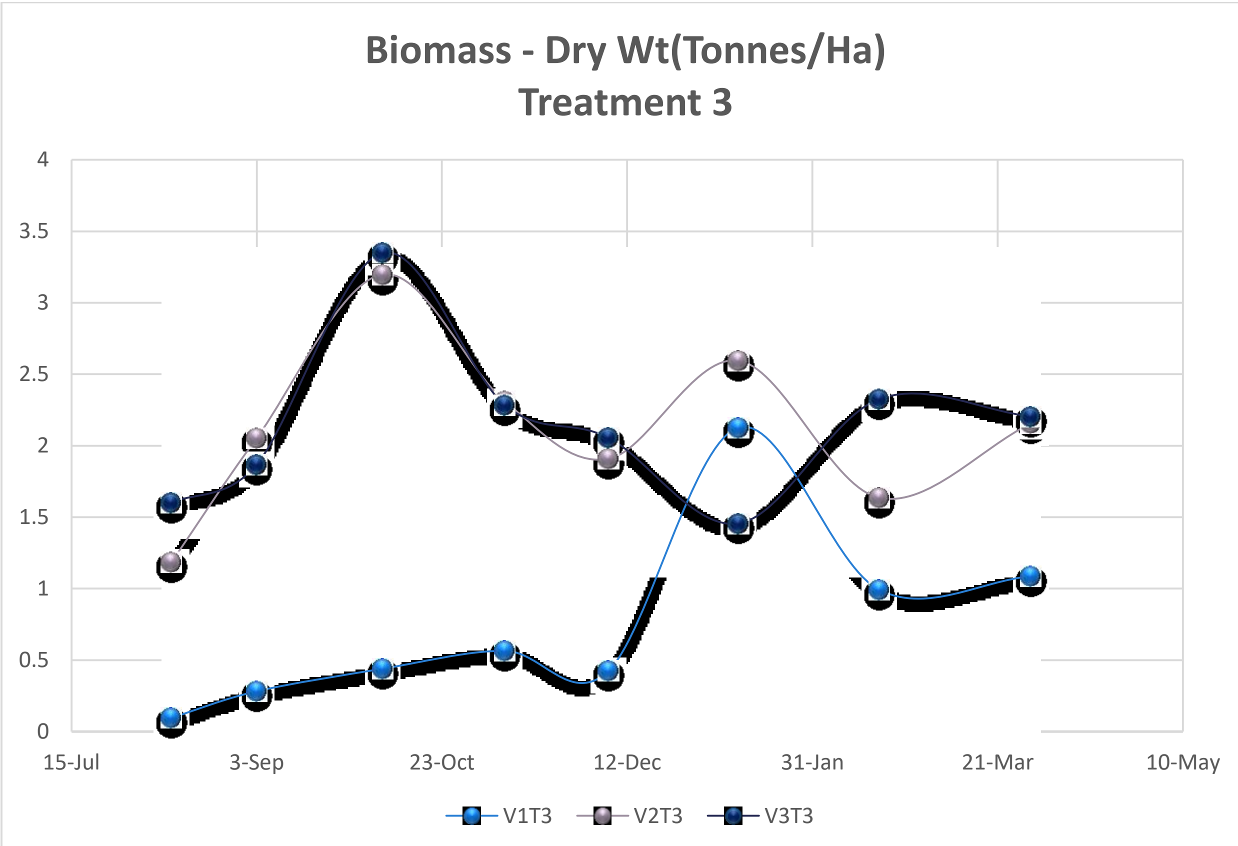

Figure 13: Comparative dry biomass produced by *G. sagittatum* (V1) Napier grass (V2) and *P. purpureum* (V3) treated with 21g/plant NPK fertilizer

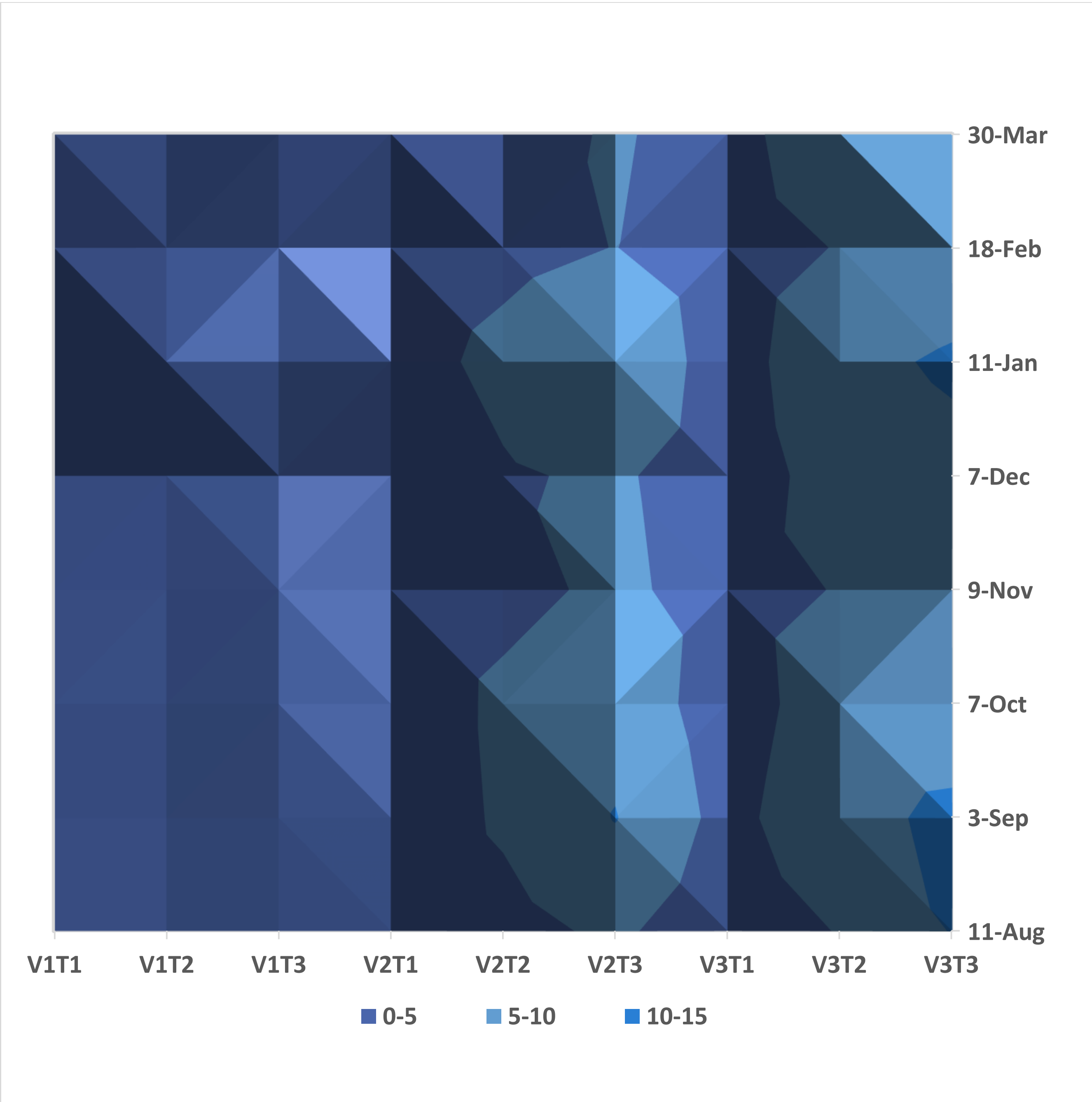

Figure 14: Biomass production (wet weight) of three grass species under three different nutrient regimes (tones/ha)

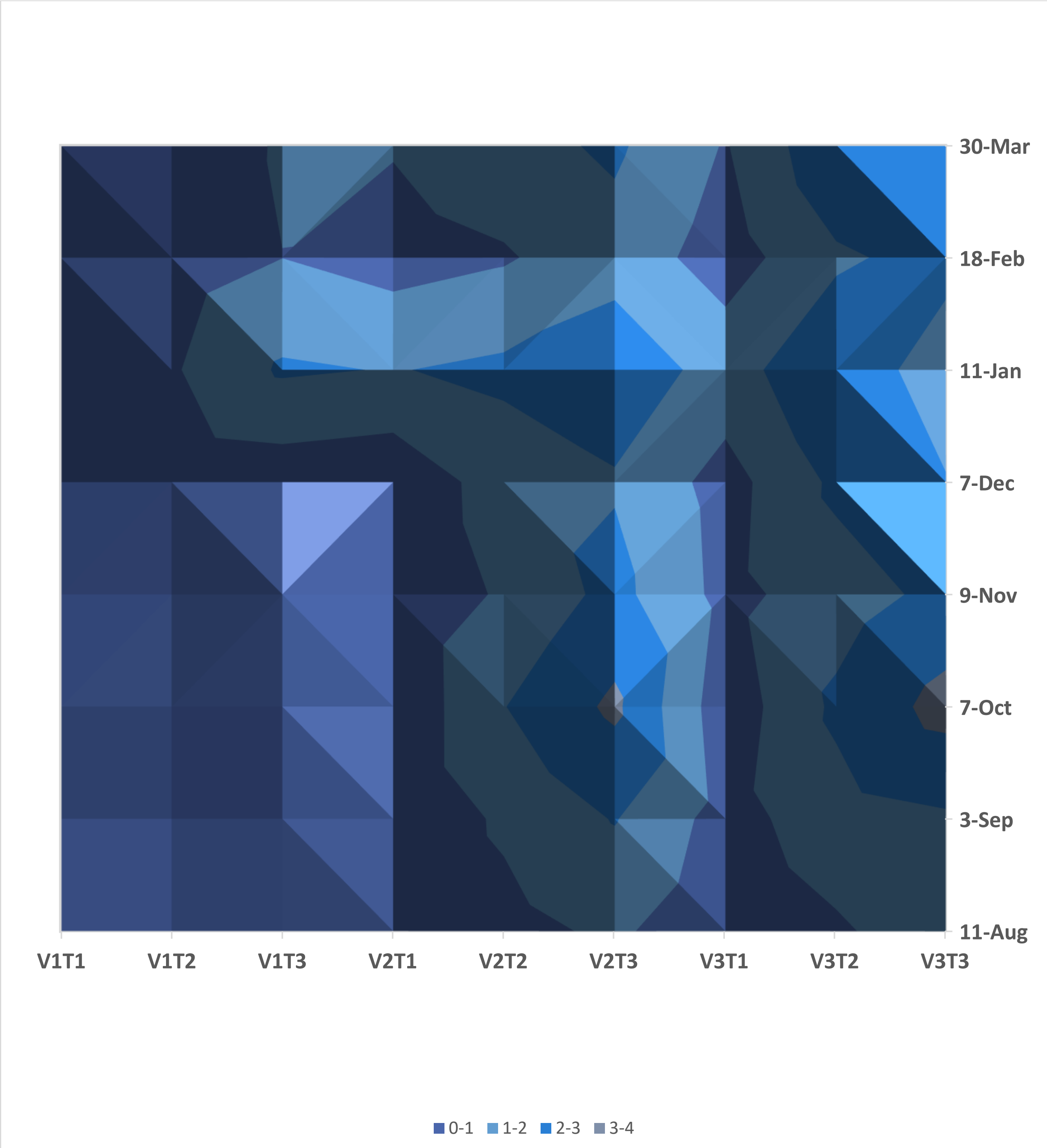

Figure 15: Effects of three levels of NPK fertilizer application on biomass (dry matter) production in selected grass species (tonnes/ha)

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Plate 8: *Gynerium sagittatum* (V1) with 0 g (T1) of NPK fertilizer per plant after 6 months of growth.

Plate 9: *Gynerium sagittatum* (V1) with 10 g (T2) of NPK fertilizer per plant after 6 months of growth.

Plate 10: *Gynerium sagittatum* (V1) with 21 g (T3) of NPK fertilizer per plant after 6 months of growth.

Plate 11: Napier grass (V2) with 0 g (T1) of NPK fertilizer per plant after 6 months of growth.

Plate 12: Napier grass (V2) with 10 g (T2) of NPK fertilizer per plant after 6 months of growth.

Plate 13: Napier grass (V2) with 21 g (T3) of NPK fertilizer per plant after 6 months of growth.

Plate 14: *Pennisetum purpureum* (V3) with 0 g (T1) of NPK fertilizer per plant after 6 months of growth.

Plate 15: *Pennisetum purpureum* (V3) with 10 g (T2) of NPK fertilizer per plant after 6 months of growth.

Plate 16: *Pennisetum purpureum* (V3) with 21 g (T3) of NPK fertilizer per plant after 3 months of growth

Plate 17: Comparative growth of *Gynerium sagittatum* (V1) with 0g (T1), 10g (T2) and 21 g (T3) of NPK fertilizer per plant after 6 months of growth.

Plate 18: Comparative growth of Napier grass (V2) with 0g (T1), 10g (T2) and 21 g (T3) of NPK fertilizer per plant after 6 months of growth.

Plate 19: Comparative growth of *Pennisetum purpureum*(V3) with 0g (T1), 10g (T2) and 21 g (T3) of NPK fertilizer per plant after 6 months of growth.

Plate 20: Luxuriant growth of *Pennisetum purpureum* (V3) to more than 2 meters height in amended mined-out bauxite soils.

5.3 Summary of Statistical Data

The tables below summarize the data from the statistical analysis accompanying this report. In each of the tables below, a>b>c, and cell in each column with the same letter are not significantly different at p=0.05.

Varieties	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16
Pennisetum purpureum	1392.5 a	1923.3 a	1569.1 a	1315.8 a	1512.3 a	1849.4 a	1195.2 a	1552.3 a
Napier Grass	797.9 b	1408.3 b	1297.1 a	858.8 b	919.8 b	1492.5 a	842.8 b	969.6 b
Gynerium Sagittatum	55.4 c	146.9 c	213.5 b	212.8 c	164.8 c	413.8 b	279.6 c	345.8 c

Table 4: Composite wet weight (g/plant) of all treatments combined for the three plant species. In each column, a>b>c, and cells in each column with the same letter are not significantly different at p=0.05.

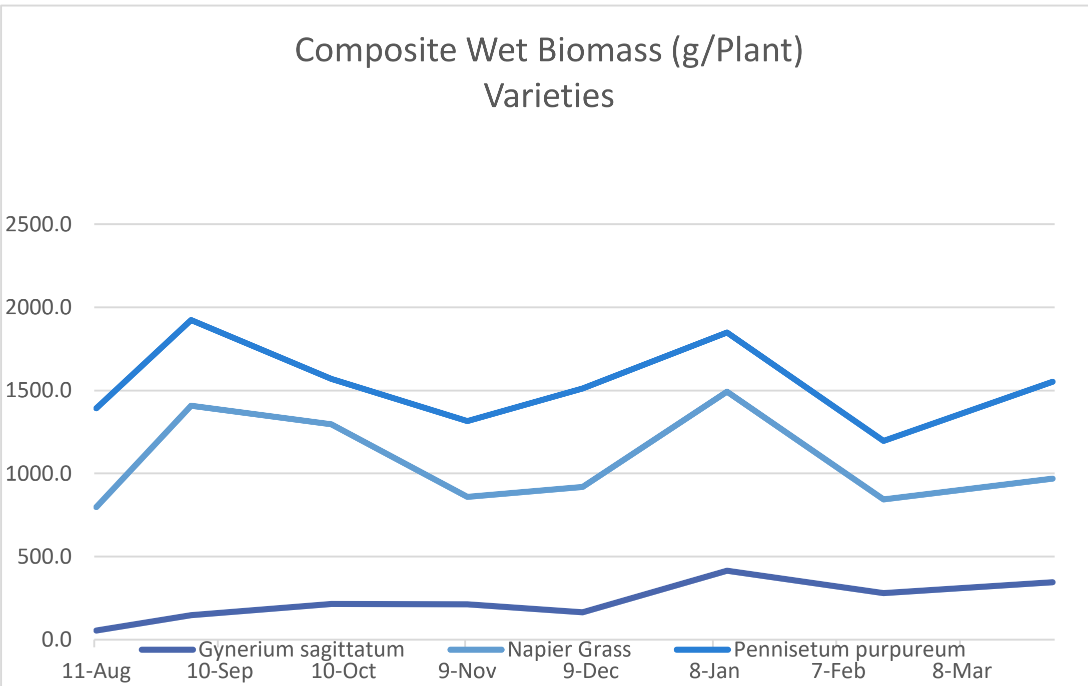

Figure 16: Composite wet weight (g/plant) of all treatments combined for the three plant species

Treatments	Aug-15		Sep-15		Oct-15		Nov-15		Dec-15		Jan-16		Feb-16		Mar-16	
20g/plant	1386.3	a	1815.7	a	1531.1	a	1289.5	a	1298.8	a	1805.8	a	1173.3	a	1240.9	a
10g/plant	725.0	b	1285.0	b	1252.4	a	787.7	b	1036.3	a	1484.4	a	853.3	a	1093.1	a
0g/plant	134.6	c	377.9	c	297.2	b	310.3	c	262.8	b	465.4	b	291.1	b	532.7	b

Table 5: Composite wet weight (g/plant) of all varieties combined for the three treatments. In each column, a>b>c, and cells in each column with the same letter are not significantly different at p=0.05.

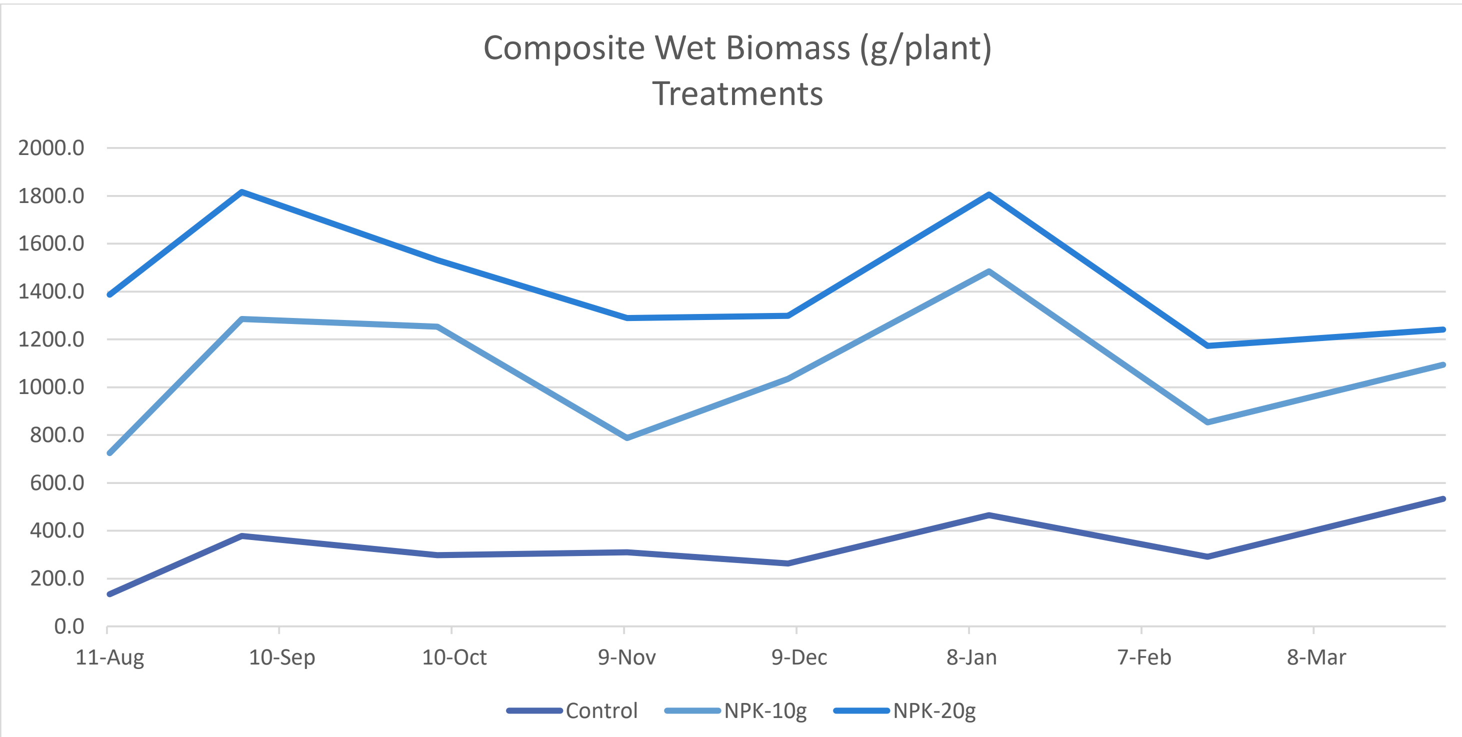

Figure 17: Composite wet weight (g/plant) of all varieties combined for the treatments

Varieties	Aug-15		Sep-15		Oct-15		Nov-15		Dec-15		Jan-16		Feb-16		Mar-16	
Pennisetum purpureum	223.3	a	337.4	a	493.9	a	375.3	a	406.1	a	483.0	a	391.3	a	496.9	a
Napier Grass	164.0	b	281.8	a	445.1	a	303.7	a	302.1	a	430.8	a	259.7	b	407.2	a
Gynerium Sagittatum	16.4	c	38.6	b	68.2	b	69.7	b	62.0	b	353.2	a	121.9	c	136.2	b

Table 6: Composite dry weight (g/plant) of all treatments combined for the three plant species. In each column, a>b>c, and cells in each column with the same letter are not significantly different at p=0.05.

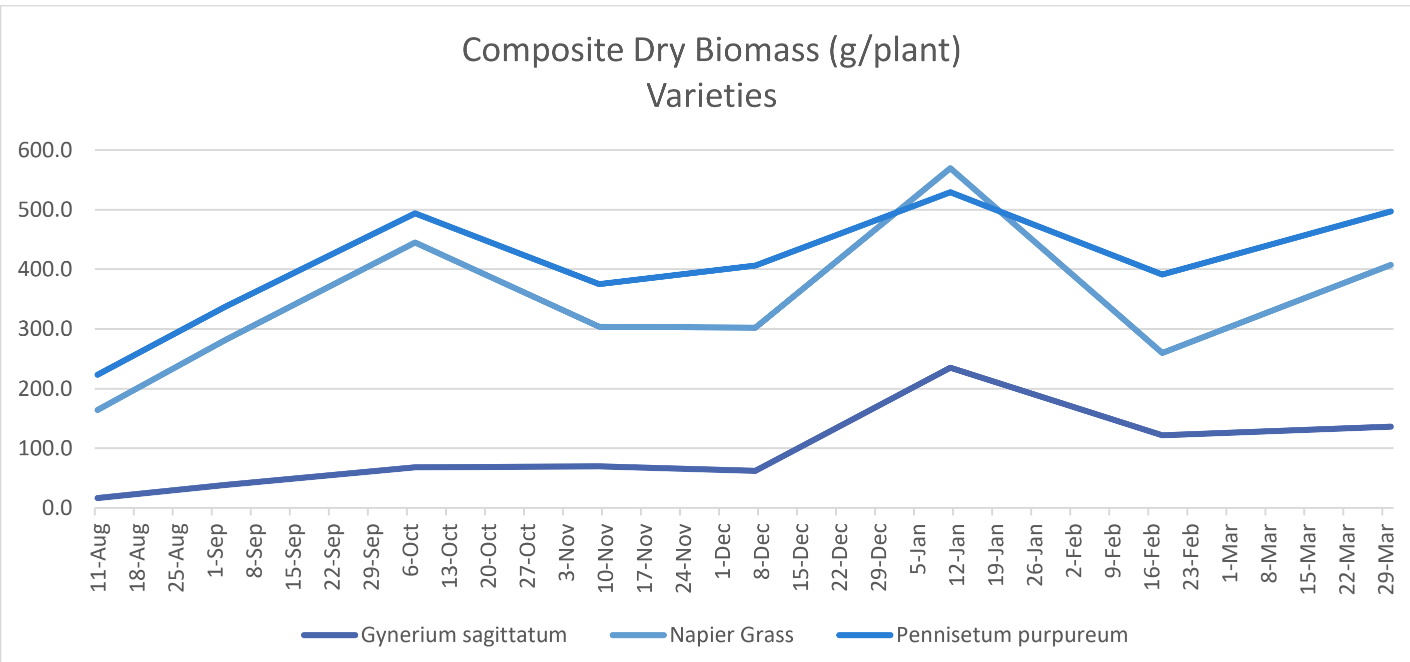

Figure 18: Composite dry weight (g/plant) of all treatments combined for the three plant species

Treatments	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16
20g/plant	240.1 a	350.1 a	582.2 a	429.8 a	365.6 a	514.7 a	412.8 a	453.8 a
10g/plant	133.6 b	239.5 b	370.4 b	241.1 b	328.8 a	483.8 a	268.9 b	410.1 a
0g/plant	30.0 c	68.3 c	54.7 c	77.7 c	75.8 b	168.7 b	91.3 c	176.3 b

Table 7: Composite dry weight g/plant) of all varieties combined for the three treatments. In each column, a>b>c, and cells in each column with the same letter are not significantly different at p=0.05.

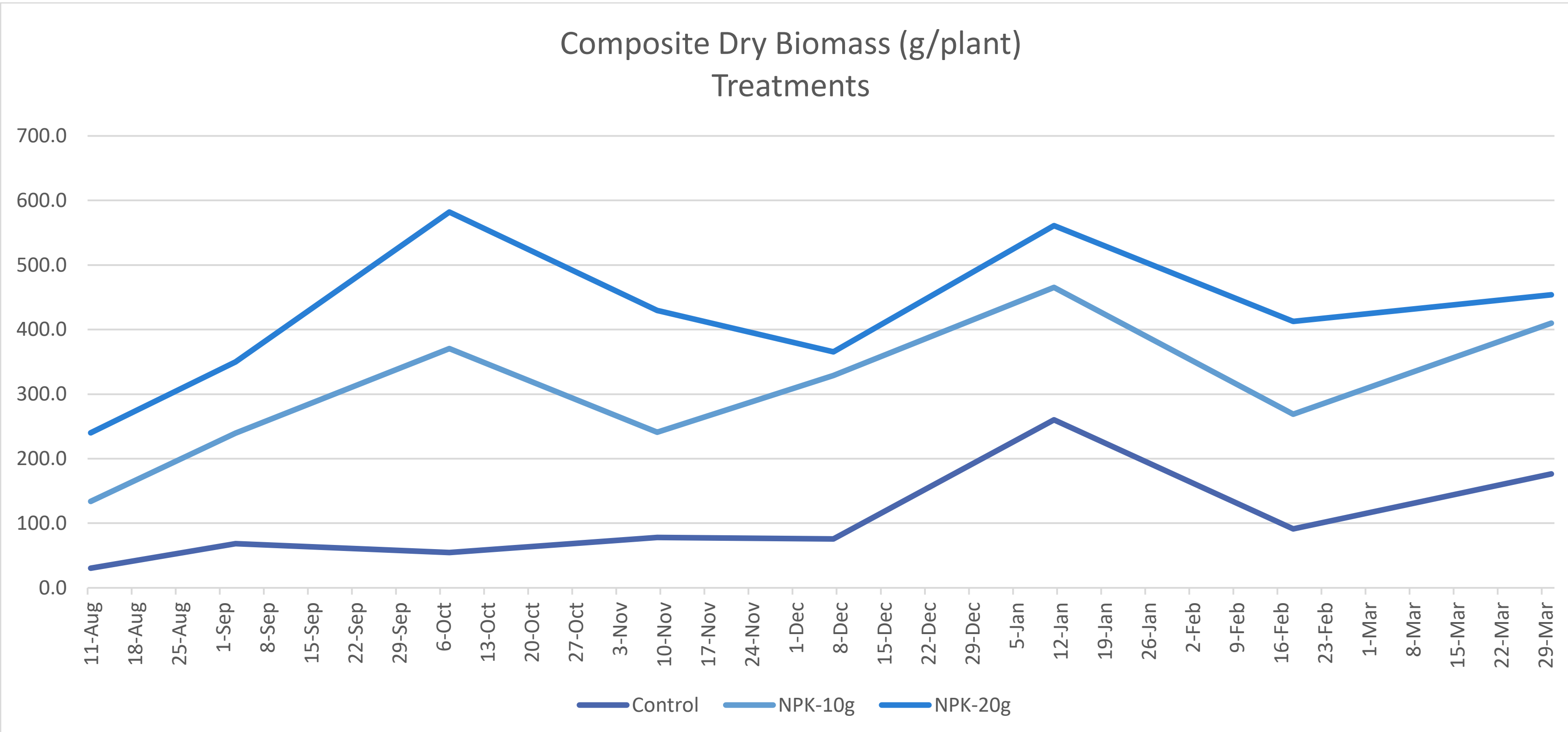

Figure 19: Composite dry weight (g/plant) of all varieties combined for the three treatments

Varieties	17-Jun-15	20-Jul-15	7-Aug-15	28-Aug-15	16-Sep-15	7-Oct-15	7-Nov-15	7-Dec-15	11-Jan-16	17-Feb-16	29-Mar-16
Pennisetum purpureum	0.82 a	0.99 a	1.15 a	1.35 a	1.50 a	1.49 a	1.53 a	1.26 a	1.86 a	1.35 a	2.15 a
Napier Grass	0.63 b	0.70 b	0.85 b	0.96 b	0.99 b	0.98 b	1.10 b	0.98 b	1.44 b	1.18 b	1.81 b
Gynerium sagittatum	0.30 c	0.32 c	0.37 c	0.44 c	0.45 c	0.45 c	0.52 c	0.40 c	0.49 c	0.40 c	0.87 c

Table 8: Composite heights (m) of all treatments combined for the three plant species over the year. In each column, a>b>c, and cells in each column with the same letter are not significantly different at p=0.05.

Treatments	17-Jun-15	20-Jul-15	7-Aug-15	28-Aug-15	16-Sep-15	7-Oct-15	7-Nov-15	7-Dec-15	11-Jan-16	17-Feb-16	29-Mar-16
NPK-20g	0.58 a	0.73 a	0.87 a	1.04 a	1.16 a	1.20 a	1.32 a	1.23 a	1.76 a	1.29 a	2.14 a
NPK-10g	0.58 a	0.69 a	0.82 a	0.97 a	1.06 a	1.07 a	1.14 b	0.97 b	1.46 b	1.23 b	1.84 a
Control	0.58 a	0.60 b	0.68 b	0.74 b	0.72 b	0.64 b	0.69 c	0.43 c	0.58 c	0.42 c	0.85 b

Table 9: Composite heights (m) of all varieties combined for the three treatments. In each column, a>b>c, and cells in each column with the same letter are not significantly different at p=0.05.

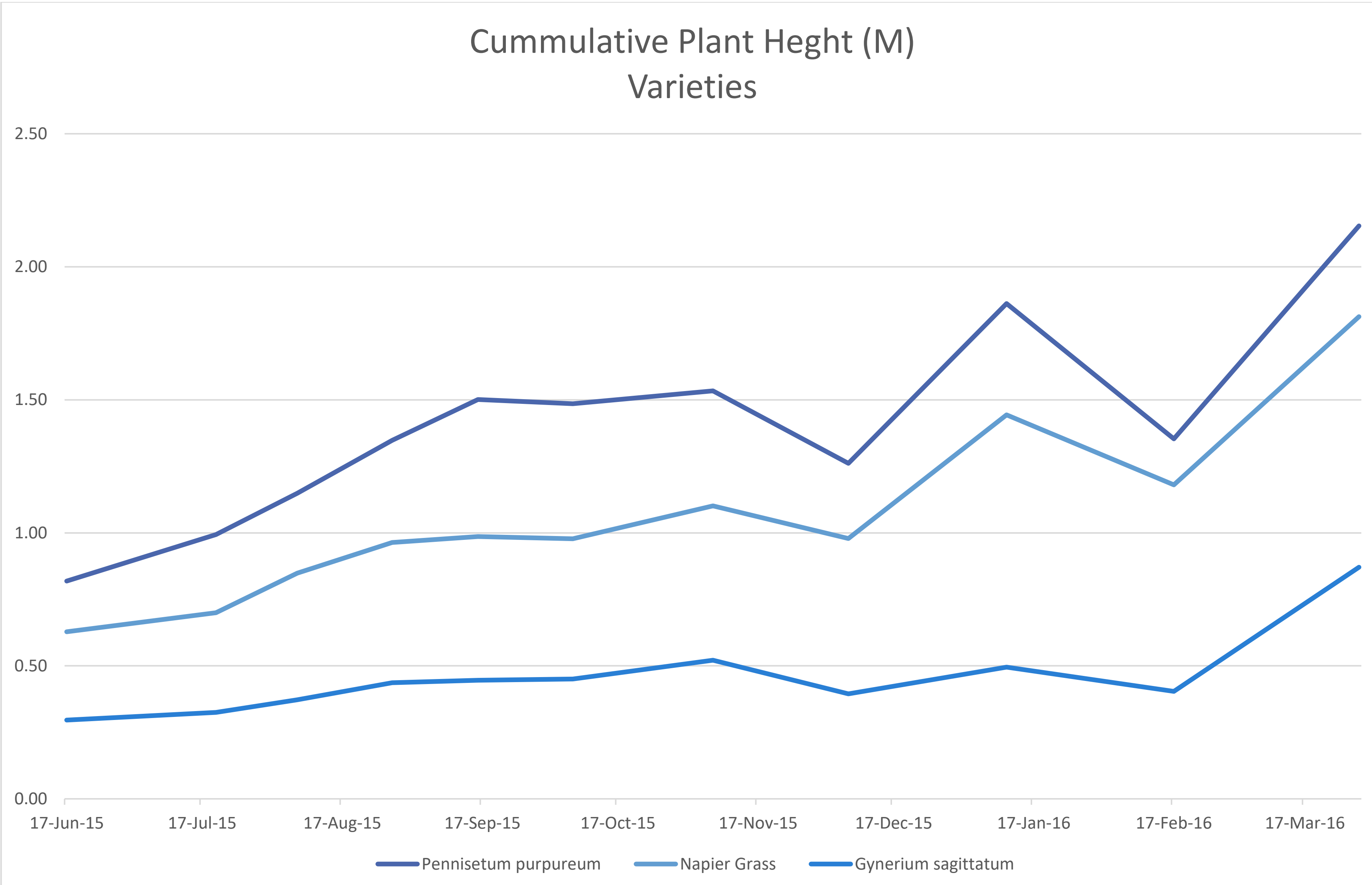

Figure 20: Composite height (m) of all treatments combined for the three plant species over the year:

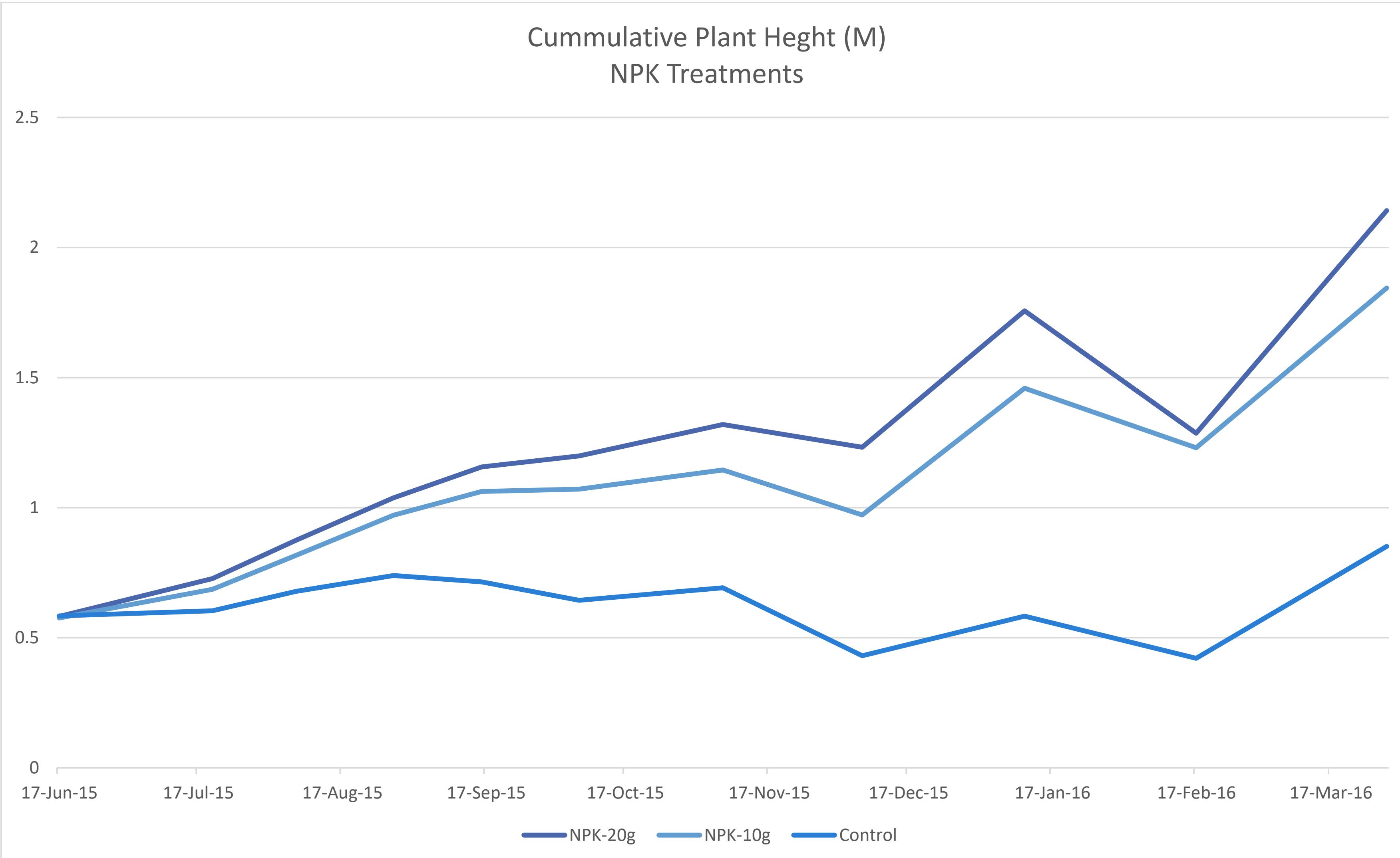

Figure 21: Composite height (m) of all varieties combined for the three treatments over the year

	Month					Variety			Treatment		
Element	Aug-15	Sep-15	Nov-15	Jan-16	Mar-16	V1	V2	V3	T1	T2	T3
Ag			*	*	*						
Al		*					*		*		
As											
Bi											
Ca				*					*		
Cr						*					
Cu						*					
Fe			*	*	*						
K	*	*					*	*	*		
Li											
Mg				*						*	*
Mn				*					*		
Na				*							
Ni	*										
P	*	*	*			*					
Pb	*			*							
S						*			*		
Se			*	*	*						
Sr				*	*		*	*	*		
Te	*	*				*					
Ti					*						
Tl	*	*									

Table 10 : Comparative accumulation of detectable elements in plant tissues based on month of harvest, variety and treatment. Asterisk (*) denotes significantly (p=0.05) high concentrations. Elements in bold denote heavy metals of concern.

5.4 Knowledge Management

The knowledge management activities focused on the exchange of knowledge, expertise and experience capitalization, particularly as it pertains to successful approaches for the reclamation of mined-out bauxite lands in other territories. A major workshop was held with resource persons from the Jamaica Bauxite Institute (JBI) and in collaboration with the Bauxite Institute of Suriname (BIS) to sensitize national authorities on the experience of the Jamaican model for mined –out bauxite land reclamation, as well as the legal and regulatory framework for its implementation and management.

The resource persons from the Jamaica Bauxite Institute included Agronomist, Clarence Osborne and Geologist, Yolanda Drakapoulos.

Plate 21: His Excellency, Regilio Dodson, Minister of Natural Resources addressing the participants at the Knowledge Management Workshop, Paramaribo, Suriname.

Plate 22: Dr. Abimbola of IICA in the field with the key stakeholders of the public and private sector

Six official field visits were organized during the duration of this project to the Biofuel experimental plots managed by IICA, and to surrounding mined-out areas with the aim of broadening the knowledge base of the public and private sector officials including tertiary level educational institutions on the rehabilitation activities and initiatives of SURALCO in Moengo and on the response of the selected grasses at the experimental plot to the mined out bauxite lands.

Officials were also exposed the importance of biomass production from a biodiversity and agricultural perspective and the potential implications of large-scale` actions of this type for local communities left in the wake of the closure of bauxite mines.

The incorporation of the educational institutions was also a major part of the knowledge management activity. Graduates students of the University of Suriname (Department Agriculture Production) were invited to work on the project assisting mainly with data collection of the plant height and dry matter content analysis. The main idea here was to repose the scientific knowledge and skills required for the establishment and management of experiments for biofuel of this type in the future professionals who are likely to work in public and private sector agencies in Suriname.

Plate 23: Student of ADEKUS determining the Wet weight of a sample taken in the experimental plot.

Plate 24: Armstrong Alexis, UNDP Deputy Resident Representative addressing the participants at the Renewable Energy Forum.

As part of the final actions under the project a major forum has held under the theme: *Renewable Energy: Towards a Broader Approach for a Viable Industry in Suriname.* UNDP and IICA agreed that there was need to place the biofuel initiative within a broader renewable energy perspective for the country, particularly based on a getting the private sector's involvement and positions as they the ones who will most likely be the key investors in the development of renewables. The forum was organized and implemented in collaboration with the Suriname Business Development Forum and targeted a wide cross section of the public and private sector, with key resource persons representing the UNDP, the Suriname Business Development Centre, the Inter- American Development Bank and the National Electricity Company (EBS). The workshop established some key short to medium term recommendations and priority actions which key stakeholder agencies pledged to work together n and effort to achieve them. These recommendations are as follows:

5.5 Community sensitization and awareness

The aim of the community sensitization and awareness activity was to inform and surrounding communities on the findings of the Biofuel experimental plots and as well potential future actions associated to biofuel related development for the area. The 5 communities of the Moengo area in the District of Marowijne (East-Suriname) actively participated in the initial stages of the project (Nursery set up), the Crop Management activities (planting, cleaning and harvesting) and the information activity with IICA. The viability and sustainability of future biofuel related initiatives on mined out bauxite lands in these communities requires local buy-in and therefore participatory approaches can lead to better results. There good relationships has be developed along with good communication/ transfer of information mechanisms establish between the rural service provider agencies and the local authorities to demonstrate the importance and potential benefits of such initiatives to the communities. The Biofuel project took a first step in establishing these mechanisms for future interaction, and the presentations and engagements with local community leaders and representatives was well received.

Plate 24: Participants at Presentation on Biofuel Project in Moengo, District Marowijne, Suriname

6. OBSERVATIONS AND CONCLUSIONS

- ✓ The best condition for the establishment of *Pennisetum purpureum* (elephant grass and Napier grass) and *Gynerium sagittatum* on mined out bauxite land involve the addition of NPK at minimum application rates per hectare of 40 kg of nitrogen, 20 kg of phosphorus and 10 kg of potassium. NPK application rates of 80, 40, and 20kg per hectare respectively produce the optimum biomass.

- ✓ The survival of the plants depended on the addition of fertilizer. In all cases, there were significant differences in plant height and biomass between the control plots and the fertilizer applied plots.

- ✓ The addition of fertilizer resulted in significant increases plant height for the three grass species. In In the early part of the season, the higher the fertilizer application rate resulted in heavier plants.

- ✓ There were no significant differences in dry weights between the low levels of NPK (10g/plant) and the higher application rate of 21 g per plant for *Pennisetum purpureum* and Napier grass.

- ✓ In all treatments, there are significant differences between the varieties in biomass production, and plant height

- ✓ *Pennisetum purpureum* and Napier grass are very responsive to nutrient treatment and are promising in terms of biomass and growth.

- ✓ *Gynerium sagittatum* produced significantly lower biomass than *Pennisetum purpureum* and Napier grass.

- ✓ *Pennisetum purpureum* (elephant grass and Napier grass) are better suited for growth and the production If biomass for biofuel on bauxite mined-out land than *Gynerium sagittatum*.

- ✓ Optimum time for the collection of biomass for use as biofuel is in early October, and in the first week of September when used as forage.

- ✓ As, B, Ba, Cd, Co, Ge, La, Mo, Nb, Sb, Sc, Sn, Ta, V, W, Y and Zr were below detectable limits in all samples.

- ✓ Only Ag, Al, Bi, **Cr, Cu**, Fe, K, Mg, Mn, Na, Ni, P, **Pb,** S, **Se,** Sr, Te, Ti and Tl appeared to be selectively accumulated in some of the plants at certain times of the year, for example, Sr, Se, Pb and Fe are accumulated in the plant tissues during the month of January. *Gynerium sagittatum* (V1) showed significantly higher accumulation of Cr, Cu, S and Te when compared to the other two varieties. In all, Ag, Fe and Se showed similar patterns of accumulation, which were significantly high in all species during the months of November, January and March. Additionally, the treatment without NPK fertilizer (T1) showed significant accumulation of Al, Ca, Mn, S, and Sr.

- ✓ In summary based on accumulation of heavy metals, *Gynerium sagittatum* is neither a good candidate for biomass for energy nor for animal feed. The least accumulation of heavy metals were in the months of September, November and March, which also coincided with high biomass production especially for *Pennisetum purpureum* and Napier grass;

- ✓ There is need to replicate the experiment to validate these results and afterwards for additional studies on the grass species with best potential for biofuel production to determine economic viability;

- ✓ There are many deficiencies in the legislative and regulatory framework for the rehabilitation of mined out bauxite lands in Suriname. Suriname can probably understudy Jamaica's framework or that of other countries with successful models in a bid to strengthen internal systems;

- ✓ The incorporation of students from the Anton de Kom University of Suriname is important to creating a new generation of nationals with the knowledge and capacities to deal with the challenges posed by mining and the potential alternatives like biofuel for overcoming them;

- ✓ There is need for greater public sector agency engagement and collaboration with private sector on the development of biofuels initiatives in Suriname;

- ✓ There is need for follow-up capacity building actions to strengthen local technicians in Suriname on evaluating alternative plant species for their biofuel potential.

7. LESSONS LEARNED

- Biofuel is an innovative idea for Suriname at this junction and pilots studies are required to established a suitable baseline for future action and to guide decision making;

- Without an effective model within the framework of a well-established and enforced legislation and regulation, rehabilitation of mined out bauxite lands, remains a major challenge with very few indicators upon which success can be monitored;

- There a viable and successful approaches for rehabilitation of mined-out bauxite lands in the Caribbean region which can inform national authorities in Suriname on the establishment of their own sustainable approach;

- The inclusion of affected communities in projects of this type helps build ownership and improves the probability for the sustainability of actions, some engagement of the community was in the initial phases of the project as residents were employed to carry out the land preparation and planting exercises, but engagement needs to take place sooner during the actual initial planning stages;

- The grass species selected have been classified and there is sufficient literature on their requirements for production and development. The results observed in the field during this project has indicated that the *gynerium saggitatum* needs wetlands to develop, not so with the two other grass species. The focus could have been directed or guided with the literature available at hand.

APPENDIX 1 – ANALYSIS OF VARIANCE TABLES

Wet Weight – Data

Variety	Treatment	11-Aug	3-Sep	7-Oct	9-Nov	7-Dec	11-Jan	18-Feb	30-Mar
1	1	10	50	39	0	0	0	0	0
1	1	15	55	78	98	41	0	0	132
1	1	30	65	218	50	70	0	0	108
1	1	25	60	62	88	18	0	0	75
1	2	55	90	115	114	61	232	71	133
1	2	45	115	199	212	275	522	651	377
1	2	60	155	173	264	285	401	251	274
1	2	45	135	240	159	64	1564	313	305
1	3	135	200	245	397	289	605	488	1110
1	3	50	208	519	483	482	477	739	524
1	3	70	260	323	477	291	644	433	669
1	3	125	370	363	212	101	520	409	443
2	1	115	190	178	163	221	425	431	446
2	1	80	340	443	345	296	411	316	1728
2	1	55	245	133	138	138	511	368	602
2	1	95	140	147	144	163	1394	279	165
2	2	700	1840	821	819	1309	1477	797	1169
2	2	970	1130	3005	1123	967	2415	1529	773
2	2	710	1575	1080	764	1135	1912	570	1202
2	2	810	1260	1269	680	1092	570	738	99
2	3	1600	1930	1538	1690	1113	2785	1362	1117
2	3	1405	4185	2513	1479	1759	2165	962	965
2	3	1865	1955	1660	1636	1445	2285	1642	1687
2	3	1170	2110	2778	1325	1399	1560	1120	1682
3	1	445	1745	992	1778	1486	1844	1182	1365
3	1	205	225	277	263	73	129	148	293
3	1	310	1080	511	376	155	611	316	362
3	1	230	340	488	281	492	260	453	1117

Variety	Treatment	11-Aug	3-Sep	7-Oct	9-Nov	7-Dec	11-Jan	18-Feb	30-Mar
3	2	1805	2980	3521	2567	2816	2300	2025	1807
3	2	910	1980	1902	855	1430	1900	415	3167
3	2	1165	2730	1624	1259	1955	2590	1850	2029
3	2	1425	1430	1080	636	1034	1930	1029	1782
3	3	2555	2935	2534	2711	2380	2501	2406	1350
3	3	2430	2390	2040	1397	1650	2932	1434	375
3	3	2340	3465	2313	2127	2169	2476	1377	2740
3	3	2890	1780	1547	1540	2507	2720	1707	2229

APPENDIX 2 – ANALYSIS OF VARIANCE

Dry Weight - Data

Variety	Treatment	11-Aug	3-Sep	7-Oct	9-Nov	7-Dec	11-Jan	18-Feb	30-Mar
1	1	5.5	12.7	6.7	0	0	0	0	0
1	1	9.1	16.1	21.6	18	19	16.4	0	46
1	1	12.4	17.7	60	11	26.5	0	0	41
1	1	8.4	13.8	15.7	13	7.2	9	0	23
1	2	12.5	21.3	41.7	25	25	93	24	41
1	2	16.7	29.6	73.8	62	105	0	217	155
1	2	19.7	41.1	90.7	93	112	164	89	116
1	2	17.6	30.1	69.9	50	24.8	409	141	126
1	3	28	71	69.8	151	119	944	202	418
1	3	14.2	49.6	150.5	157	160	720	489	224
1	3	19.8	63.7	99.9	186	101	264	143	267
1	3	33.4	96.7	118.6	70	45	198	158	177
2	1	28.9	41.4	42.8	39	58.4		336	163
2	1	23.7	51.8	46.6	100	98	807	70	723
2	1	23.3	40.6	44.7	29	43.9	147	109	142
2	1	29.9	33.6	39.2	32	46.7	514	69	45
2	2	149	378	259	290	489	508	289	558
2	2	179	212	1031	364	277	807	203	315
2	2	202	309	297	248	335	710	170	413
2	2	148	263	383	232	369	178	234	371
2	3	314	417	483	616	351	985	470	410
2	3	264	801	894	527	602	187	318	524
2	3	329.3	411	979	710	487	928	529	672
2	3	277	423	842	457	468	495	319	550
3	1	76	299	210	464	399	750	347	520
3	1	42.6	41.5	65.7	62	28.2	632	11	54
3	1	51.7	188	91.4	93	46.3	155	68	81

Variety	Treatment	11-Aug	3-Sep	7-Oct	9-Nov	7-Dec	11-Jan	18-Feb	30-Mar
3	1	49	63.8	12.4	71	136	90	85	278
3	2	265	483	979	707	955	246	616	605
3	2	155	370	382	253	429	920	368	1015
3	2	179	447	529	363	514	844	567	660
3	2	260	290	309	206	311	704	309	546
3	3	397	490	948	815	87.3	124	849	447
3	3	379	425	673	413	519	120	444	92
3	3	355	614	1120	600	617	847	514	895
3	3	470	338	608	456	831	920	518	770