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STRUCTURAL DEMOGRAPHY, MODULAR DYNAMICS AND GROWTH PATTERNS OF ABOVEGROUND POPULATIONS OF *SCIRPUS GROSSUS* L. ON PADDY FIELD

A. MAJRASHI*[1], A. N. BOYCE[1], A. M. JAAFAR, M. M. KHANDAKER[1] and B. B. BAKAR[1]
** Taif University, Faculty of Biological Science, Taif, Saudi Arabia*
[1] University of Malaya, Institute of Biological Sciences, Kuala Lumpur, Malaysia

Abstract

MAJRASHI, A., A. N. BOYCE, A. M. JAAFAR, M. M. KHANDAKER and B. B. BAKAR, 2013. Structural demography, modular dynamics and growth patterns of aboveground populations of *Scirpus grossus* L. on paddy field. *Bulg. J. Agric. Sci.,* 19: 536-543

Scirpus grossus L. is a principal rhizomatous weed in the rice fields, drainage and irrigation canals, riverbanks, abandoned rice fields and wasteland in Malaysia. This study describes the structural demography, modular dynamics, spatio-temporal growth patterns of aerial plant populations of this scourge on fertilized and unfertilized peat soils. The NPK fertilizer application at 100:30:30 ha^{-1} resulted in more robust aerial plant growth of *S. grossus* with gross population of 97.08 ramets m^{-2} (mean dry aerial biomass of 12.19 g $plant^{-1}$) compared with 83.67 ramets m^{-2} (10.89 g $plant^{-1}$) in unfertilized plots 24 weeks after planting of the mother plant. Mean ramets mortality was significantly higher in unfertilized plots at 8.58 ramets m^{-2} at %0.7, while in the fertilized plots this was only 5.67 ramets m^{-2}, hence the resultant net populations of 91.41 ramets m^{-2} and 75.09 ramets m^{-2} in fertilized and unfertilized plots, respectively. Flowering set in earlier among ramets in fertilized plots with 49.56 ramets m^{-2} *vis-a-vis* 47.79 ramets m^{-2}, 24 weeks after transplanting of the mother plant in unfertilized plots. Fertilizer applications did not register any significant difference in mean plant height, chlorophyll contents, and chlorophyll fluorescence measurements *vis-a-vis* those devoid of fertilizer application. The time- and space-mediated clonal growth of *S. grossus* did not register any significant preferential directionality and dispersion of aerial plants irrespective of fertilizer regimes, but rather displaying opportunistic resource capture by aerial and sub-terranean modules.

Key words: Scipus grossus, modules, modular growth, fertilizer application

Introduction

Rhizomatous plants grow and reproduce vegetative by rhizomes. Vegetative branches are formed from the reiteration of the basic units, while flowers and inflorescences come from the reiteration of units bearing modified leaves. The population dynamics of many rhizomatous plants is dominated more by the flux of clonal modules. The ability of a single genotype to form fragmented phenotypes is just one of the variants in the life patterns of modular organism (Harper and Bell, 1979; Alderman, 2011). The process of new growth is often subjected to different pressures, including the change in soil nutrients, and resource capture ability among individual plants and their modules.

E-mail: majrashiaah@gmail.com

It has been well documented in the literature that nitrogen, potassium, and phosphorous are important macro elements for healthy plant growth, in addition to other macro- and microelements (Daughtry et al., 2000). Nitrogen is present in all the macromolecules in the cell, such as amino acids, proteins, lipids and carbohydrates. Probably more importantly, nitrogen concentration in green vegetation is often related to chlorophyll content, and therefore indirectly to one of the basic plant physiological processes, namely photosynthesis (Daughtry et al., 2000). Recently, Huang et al. (2004) has shown in a study on rice seedlings that nitrogen deficiency brought about adverse effects on the chlorophyll content of the leaves and chlorophyll fluorescence, both of which are good indicators of photosynthetic capacity. Thus, nitrogen deficiency in soils will result in plants exhibiting limited growth and deficiency symptoms such as chlorosis. Many studies have shown that a significant increase in growth rate of plants will occur with the application of nitrogen (Ozer, 2003). Baki (1988) reported that additions of phosphate appeared to enhance the rate of flowering in *S. grossus.*

Alderman reported that increasing of nitrogen fertilization had an effect on the leaf, stem, rhizome, and root growth and thus caused an increase in the growth of the seedlings (Alderman et al., 2011). Similarly, it has been reported in *Panicum Virgatum* L., there was an increase in biomass at harvesting because of the increase in nitrogen in the soil (Young and Rattan, 2011). James et al. (2010) reported that on the long-term, NPK addition decreased mortality in the giant cane plant (*Arundo donax*) and observed that periodic burning can increase density and spread of this species (James et al., 2010). Fertilizing the soil is an important practice in affecting crop production. It is preferred over other methods of application due to the use of lesser amounts of fertilizer, which in turn avoid soil problems, less ground water pollution in addition to its profound effect on plant growth and productivity (Hamayun et al., 2011). Hamayun et al. (2011) observed that foliar application of NPK increased grain yield in lentils whilst Abdelhamid et al. (2011) reported that NPK application alone improved plant growth in cowpea.

Scirpus grossus is a pan-tropical weed in the rice fields, drainage and irrigation canals, riverbanks, abandoned rice fields and wastelands in Malaysia and elsewhere. There is a paucity of information on the population biology of this scourge in the literature. This study was initiated to assess allometry, modular dynamics, and spatio-temporal growth patterns of aerial plant modular populations of this weed on fertilized and unfertilized peat soil.

Materials and Methods

Plant establishment and care. Synthetic populations of *S. grossus* were established on peat soils in theMalaysian Agriculture Research Development Institute (MARDI) Research Station, Tanjong Karang, Selangor (N 3.28° / E 101.08°), Malaysia for 24 weeks commencing on 26 October 2010. Young ramets at 2-3-leaf stage of *S. grossus* were obtained from rice fields of Tanjung Karang, Selangor. Each ramet was planted in the centre of a plot measuring 2m x 2m, previously demarcated and lined with 5cm x 5cm grids and sub-plots (Figure 1). Fertilizer applications with Nitrophoska Blue Special NPK fertilizer at the rate of 100:30:30 were made one week prior to planting. A set of 3 replicated plots with fertilizer application was allocated with while another 3 sets devoid of fertilizer application served as control. Watering of the plots was made twice daily, one in the morning and the other in the late afternoon using a fine rose fitted to a water hose. No weeds were allowed to grow in the plots during experimentation. The rainfall and temperature data is shown in Figure 2, while the physico-chemical characteristics of peat soils are depicted in Table 1.

Data acquisition and management

The clonal growth of *S. grossus* based on the number of emerged plants in each plot, its position within the 5 cm x 5 cm grids, and their plant heights were recorded on a weekly basis for 24 weeks. Likewise for the number of dead plants and their positions in each plot within the 5 cm x 5 cm grids were also recorded. The phenology of *S. grossus* was also recorded, taking into account the time of first flowering after planting, and the number flowers were recorded on a weekly basis. The chlorophyll content in the leaves was determined at the end of planting using a Minolta SPAD meter. From each plot 15 leaves were randomly selected for measurement. In

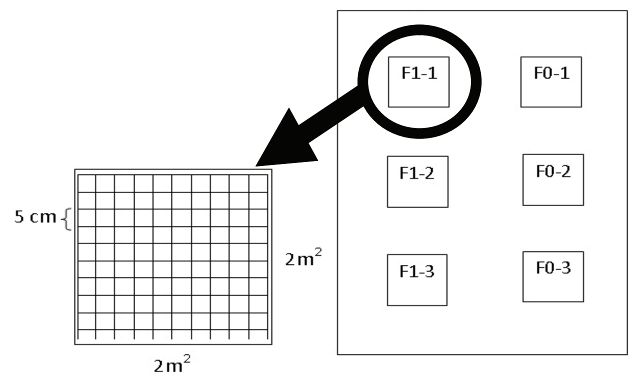

Fig. 1. Experimental design and quadrat arrangement at MARDI Research Station, Tanjong Karang, Selangor, Malaysia. F_0- No fertilizer application; F_1, NPK applied

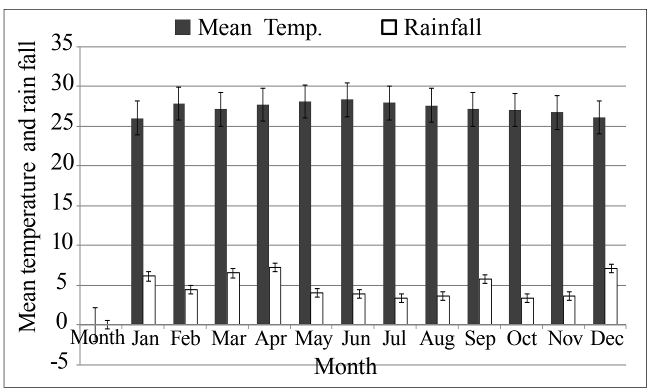

Fig. 2. Mean monthly rainfall (mm) and temperature (°C) readings in MARDI Research Station, Tanjong Karang, Selangor, Malaysia

the case of the chlorophyll fluorescence which has been well documented to be closely related to photosynthetic capacity and quantum yield was recorded using a Hansatech (UK) Photosynthetic Efficiency Analyzer. Variable (Fv) and maximum fluorescence (Fm) readings were taken and the Fv/Fm values, which correspond to quantum efficiency, were calculated. A minimum of five readings per plot for each treatment were taken and the average determined.

After 24 weeks of experimentation, the plants were harvested by dismembering them into leaf, stem, and inflorescence components, and their dry weights were determined. Ten flowering plants taken at random were harvested from each plot. These components were subjected to chemical analysis. The sub-terranean rhizomes remained intact by ensuring that no rhizome damage was inflicted during harvest of the aerial plant parts.

As for the spatio-temporal growth pattern of emerged plants (ramets), the precise spatio-temporal positions of emerged plants were transferred into the data logger. The computer generated time- and space-mediated emerged plant models in each plot were produced using the Computer Program AutoCAD10. The use of the AutoCAD software is prevalent in many areas of research because of its ability to transform recorded experimental data into three-dimensional models (Conway, 2011). The rates of spread (based on the number of emerged plants or ramets way from the mother plants) were also calculated. This was done based on the computer-generated maps described earlier. The plants were group according to their concentrations in six concentric circles, each circle representing the mean monthly individuals established from the single mother plants. This analysis is to assess whether the rates of emergence of individual ramets and their associated rhizomes were different or otherwise as they move away from the mother plant as a strategy to avoid self-crowding and minimize mean density of emerged individuals from each other with time.

Circular statistics is a subfield of statistics, which is devoted to the development of statistical techniques for the use with data on an angular scale. On this scale, there is no designated zero and, in contrast to a linear scale, the designation of high and low values is arbitrary. Circular statistics is employed to look at the circular distributions of emerged ramets around the mother plant of *S. grossus*. This is carried out for all replicates in both unfertilized and fertilized plots. Following this, Rayleigh's z test is conducted to test whether there is a significant mean direction in the emerged ramets with respect to the geographical north.

The response Surface Analyses is a method for studying geometric relations among responses generated by a mathematical model, often used in nonlinear regression (Bates and Watts, 1988). For a model with *p* parameters and *n* observations, the *response surface* is defined as a *p*-dimensional surface, formed by all possible response vectors that the model can describe. The response surface is embedded in the *n* dimensional *data space*, which is the set of all possible response vectors that could be generated independently of any model. The response surface is a hyperplane for a linear model but may be curved when the model is nonlinear (Myung, 2000). Many statistical concepts, including those of least squares estimation, have informative geometric interpretations in terms of response surfaces. In particular, the effects of averaging on model fit can be seen quite clearly, when averaged and individual data are plotted in the space of response surfaces (Myung, 2000). In this study shows the response of *S. grossus* to fertilizer NPK. The response surface function on plant density was also fitted to the data collected from the 2m x 2m plot using 3 parameters and 48 observations. For this purpose, the plot is divided into 16 subplots of 0.5m x 0.5m each. The parameters used are x-distance, y-distance that is the horizontal and vertical distance of the sub-plot densities, assumed acting at the centre of each sub-plot, measured from the centre of the main plot. The other important parameter studied is time. The objective is to relate density obtained at various locations in the plot with time to understand the geometry of growth as time progresses. The aim is also to identify where maximum density of emerged ramets occurs for the period of growth studied. The response surface function was fitted to both the unfertilized and fertilized plots.

Table 1
Physico-chemical characteristics of fertilized and unfertilized peat soils used at MARDI Research Station site, Tanjong Karang, Selangor, Malaysia

	Al %	B ppm	Ca %	Cu ppm	Fe ppm	K %	Mg %	Mn ppm	Na ppm	P %	S %	Zn ppm	Moisture content %	Total N, %	pH
Peat Soil without fertilizer (F_0)	3.66	00.00	0.31	10.61	32633.22	0.35	0.73	382.34	602.34	0.07	0.20	139.82	5.66	0.29	4.30
Peat Soil with fertilizer (F_1)	3.40	00.00	0.52	8.59	27848.68	0.37	0.91	556.99	1185.96	0.09	0.39	108.30	5.83	0.24	4.61

The appropriate data were subjected to ANOVA and their treatment means were tested for significant difference, if any, using HSD and *t*-tests (Zar, 2006).

Results

General clonal growth patterns

Scirpus grossus plant reiterates by rhizomatous growth and branches from a single mother plant. As shown in Figure 2, the best period of clonal growth in general is between 10-18 weeks. The best period of clonal growth in fertilized soils was at week 12th while in unfertilized soils it was at week 13th. At the end of the 24 weeks of study period, the total average gross number of emerged ramets in fertilized soils were 97.08 ramets m^{-2} and 83.67 ramets m^{-2} in unfertilized soils.

The mortality rate recorded was 8.58 ramets in unfertilized soils and 5.67 ramets in fertilized soils (Figure 3), while the real rate showed 75.09 ramets m^{-2} in unfertilized soils and 91.41 ramets m^{-2} in fertilized soils (Figure 4a, b).

The results for subsequent recruitment of shoot modules appeared convergent (Table 1) where the highest average plant height in unfertilized soils was 172.67 cm while in fertilized soils it was 175.33 cm.

Plants growing in unfertilized soils started to flower 16 weeks after transplanting, while in fertilized soils, *S. grossus* started to flower at week 13. At the end of the 24 weeks period study, the average number of flowering ramets in unfertilized soils stood at 16.42 ramets m^{-2} *vis-a-vis* 23.67 ramets m^{-2} for those devoid of fertilizer application (data not shown).

Table 1 show the dry biomass of selected plant parts of *S. grossus* taken after harvest at 24 weeks after transplanting displaying measurable differences according to fertilizer regimes. In unfertilized soils: the leaves were 12.72 g, and the stems, 17.56 g whilst the flowers were 2.38 g in weight. In fertilized soils, these were measurably higher with 14.84 g (leaves), 18.61 g (stems) and 3.13 g for flowers.

Chlorophyll content in leaves has always been regarded as a measure of the health status of a plant. For example, plants deficient in nitrogen will exhibit chlorosis and the leaves will be less green in color than a healthy plant. Table 2 shows that the chlorophyll content in leaves of plant growing in fertilized soil was slightly higher (49.56) than that recorded in leaves of the control plant (47.79). However this difference was not significant. Similarly, with regard to chlorophyll fluorescence, which is indicative of the tissue's photosynthetic capacity, the Fv/Fm ratios were very similar between the two set of plants. The Fv/Fm values recorded between the fertilized and non-fertilizer grown plants ranged between 0.799 to 0.793.

Directionality and dispersion analyses

Table 3 shows the circular statistics *r* (concentration), *s* (angular deviation), Rayleigh's *R* and Rayleigh's *z* computed on the emerged ramets of *S. grossus.*

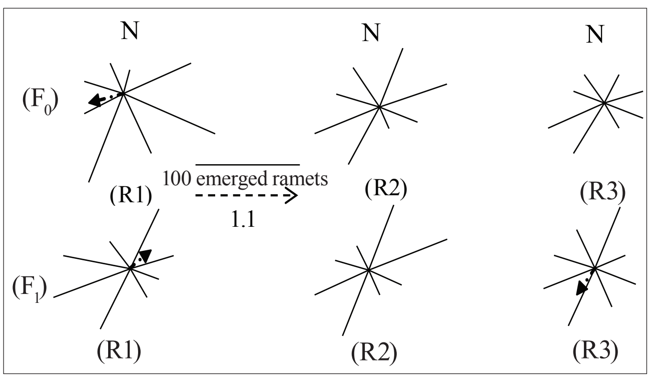

Fig. 3. Dispersion analysis of emerged ramets of *Scirpus grossus* by circular statistics in soil with no fertilizer (F_0) and soil with fertilizer (F_1).
N, geographical north; mean angle of dispersion

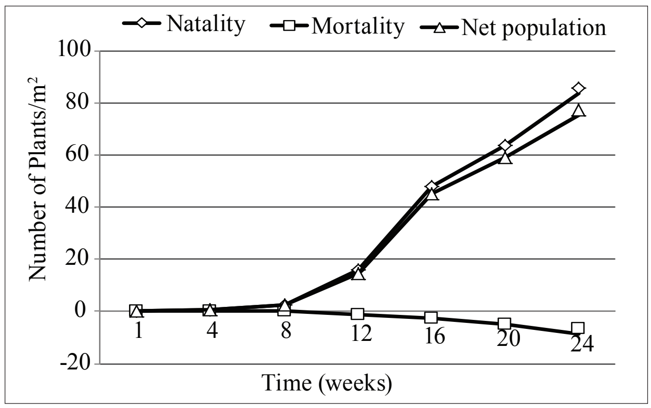

Fig. 4a. Population fluxes of *Scirpus grossus* grown on unfertilized paddy soil

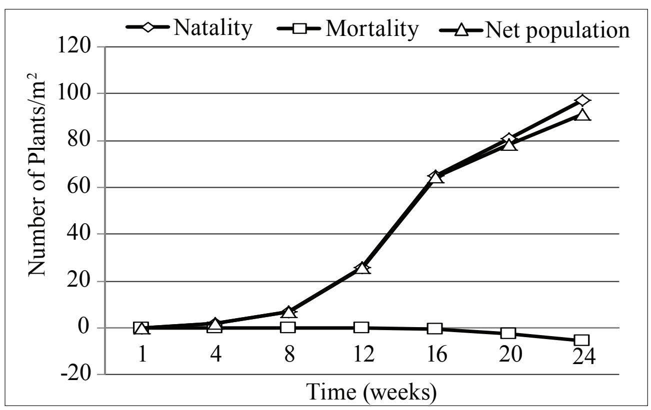

Fig. 4b. Population fluxes of *Scirpus grossus* grown on paddy soil with fertilizer

Results of Rayleigh's z test showed significant mean direction of ramets emergence for all replicates in the fertilized plots ($p > 0.01$). Significant mean direction is obtained only for replicate R1 for the unfertilized plots. No significant mean direction for replicates R2 and R3 of the unfertilized plots means that ramets emergence is distributed uniformly around the circle, that is originating from the mother plant. They occur when s, the dispersion given by the angular deviation is near the maximum (where $0<s<83.01$). Dispersion analysis of ramets by circular statistics on *S. grossus* generated no special preferences in the direction of modules or emerged ramets as explained by the Rayleigh's *r*, Rayleigh's z, and mean angle of dispersion (Table 3). However, there were heavier concentrations of ramets in the eastern sector of the plot, presumably due to phototropic effect of sunlight (Figure 4)

Phenology

The time-mediated flower emergence of ramets in both fertilized and unfertilized peat soils are shown in Figure 5a, b. Invariably, more ramets set flowers were recorded in fertilized soils than those in the unfertilized counterparts, indicating the stimulatory effects of fertilizer application of the growth, proliferation and enhancement of flowering of *S. grossus*.

Response surface analyses

The predicted response surface function on density fitted for the unfertilized plot, F0, is:

$$\text{Density} = 29.0 - 0.03\text{xdis} - 11.03\text{ydis} + 3.70\text{time} + 0.85\text{xdis*ydis} - 0.52\text{xdis*time} + 5.89\text{ydis*time} - 61.56\text{xdis}^2 - 56.89\text{ydis}^2 + 1.76\text{time}^2 \quad (R^2=51.07\ \%)$$

For the fertilized plot the function obtained is:

$$\text{Density} = 34.93 - 3.82\text{xdis} + 2.80\text{ydis} + 14.41\text{time} - 7.31\text{xdis*ydis} + 3.04\text{xdis*time} - 2.62\text{ydis*time} - 109.89\text{xdis}^2 - 61.0\text{ydis}^2 + 0.80\text{time}^2 \quad (R^2=62.59\ \%)$$

A significant fit is obtained for the two cases.

A reasonably good fit (R^2=51 %) is obtained with lack of fit found to be not significantly different for p<9%, where p is the percentage level of significant tested.

The stationary point obtained for the fitted surface is at x-distance=0m, y-distance= -0.14m and time= -0.82months.

Table 2
General growth patterns of *Scirpus grossus* in unfertilized and fertilized soils

Growth parameters	Unfertilized peat soil	Fertilized peat soil
Gross plant number	83.67 $\pm$ 95.75 /m^{-2}	97.08 $\pm$ 58.25/m^{-2}
Mortality number	8.58 $\pm$ 2.25 /m^{-2}	5.67 $\pm$ 2.25/m^{-2}
Net plant number	75.09 $\pm$ 93.5 /m^{-2}	91.41 $\pm$ 56.00 /m^{-2}
Flowers number.	16.42 $\pm$ 79.00 /m^{-2}	23.67 $\pm$ 103.00/m^{-2}
Plant height	172.67 $\pm$ 49 cm	175.33 $\pm$ 38.5 cm
Chlorophyll content	47.79 $\pm$ 4.57 SPAD	49.56 $\pm$ 3.64 SPAD
Chlorophyll fluorescence	0.793 $\pm$ 0.019	0.799 $\pm$ 0.028
Total plant weight (g)	10.89 $\pm$ 5.25	12.19 $\pm$ 5.73
No. inflorescence*	657 $\pm$ 70	665 $\pm$ 14

* after 24 weeks.

Table 3
Directional and dispersion statistics on the circular distributions of emerged ramets around the mother plant of *Scirpus grossus* in fertilized (F_1) and unfertilized peat soils (F_0) as measured by selected attributes

Parameter	Replicate	Attributes		
		R	Z	θ°
Fertilized soil	R1	76.04	15	262.79
	R2	28.61	1.61	*
	R3	25.72	2.16	*
Unfertilized soil	R1	137.44	37.26	31.08
	R2	25.23	1.71	*
	R3	31.74	8.13	214.38

* no mean angle. Raleigh z test showed that ramet emergence is distributed uniformly around the circle

This function predicted a density of 28 plants per m^2 to occur at the stationary point.

Results of canonical analysis, see Table 4, indicates that the predicted response surface is shaped like a saddle. Because the canonical analysis resulted in a saddle point, the estimated surface does not have a unique optimum.

However, results of ridge analysis, see Table 5, indicates that maximum density increases with time and location (x-distance and y-distance). The direction of density changes follows northeast from the mother plant during 3.5 to 6 months period.

This function, however, have a significant lack of fit for p> 0.01%. The stationary point obtained for the fitted surface is at x-distance= -0.13m, y-distance= 0.20m and time= -8.48 months. Canonical analysis, see Table 4, also indicates that the predicted response surface is shaped like a saddle. There is also no unique optimum.

However, results of ridge analysis, see Table 6, indicates that maximum density increases with time and location (x-distance and y-distance). The direction of density changes follows southwest from the mother plant during 3.5 to 6 months period.

Using the fitted function, a two dimensional contour of density was plotted with x-distance and y-distance as axis, at each monthly time. Looking at the contours for each time, higher density is concentrated around the stationary point and it decreases further away from that point. The density increases at each month. The pattern of the density contour is the same for both the unfertilized and fertilized plot.

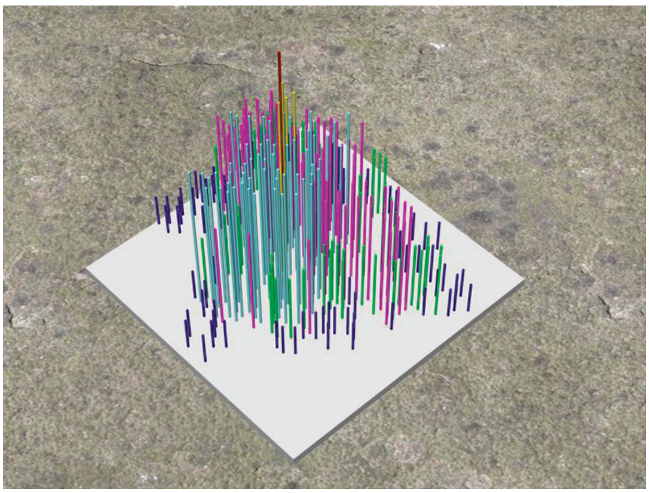

Fig. 5a. Time-mediated growth of ramets in *Scirpus grossus* in peat soil without added fertilizer (F_0) 6 months after planting of the mother plant. Keys: |, emerged ramets in the 1st month; |, emerged ramets in the 2nd month; |, emerged ramets in the 3rd month; |, emerged ramets in the 4th month; |, emerged ramets in the 5th month; and |, emerged ramets in the 6th month

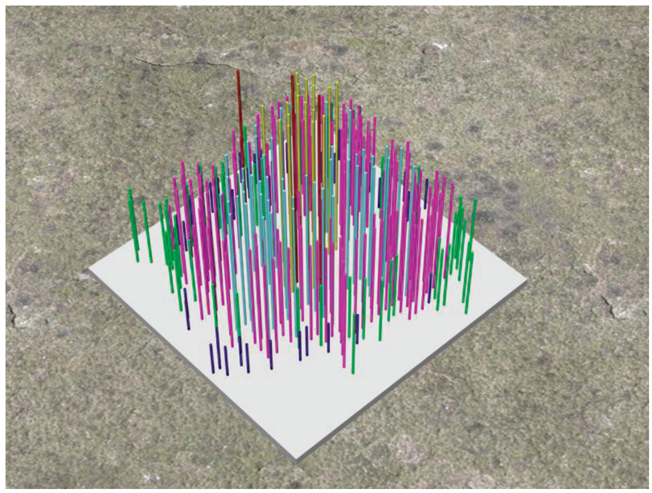

Fig. 5b. Time-mediated growth of ramets in *Scirpus grossus* in peat soil with fertilizer (F_1) 6 months after planting of the mother plant. Keys: |, emerged ramets in the 1st month; |, emerged ramets in the 2nd month; |, emerged ramets in the 3rd month; |, emerged ramets in the 4th month; |, emerged ramets in the 5th month; and |, emerged ramets in the 6th month

Table 4
Stationary point of fitted response surface on plant density (at x-distance. y-distance and time) of *Scirpus grossus* in soil with no fertilizer (F_0) and soil with added fertilizer (F_1) based on RSREG Procedure Canonical Analysis of Response Surface Based on Coded Data

Critical Values		
Factor	F_0	F_1
xdist	0.002215	-0.128095
ydist	-0.139144	0.197405
Time	0.815614	-8.479282
Predicted density value at stationary point	28.257389	-25.636676
Type of stationary point	Saddle point	Saddle point

Table 5
Output of RSREG Procedure showing estimated ridge of maximum response for the fitted surface on density of *Scirpus grossus* in unfertilized soil (F_0)

Coded radious	Estimated response	Standard error	Uncoded factor values		
			x dist	y dist	tim
0	63.51	4.902	0	0	3.5
0.1	67.7	4.885	-0.002	0.0125	3.746
0.2	72.12	4.839	-0.003	0.0241	3.993
0.3	76.78	4.773	-0.005	0.0352	4.24
0.4	81.87	4.701	-0.006	0.0458	4.488
0.5	86.79	4.65	-0.007	0.0562	4.735
0.6	92.15	4.65	-0.008	0.0664	4.983
0.7	97.74	4.739	-0.009	0.0764	5.231
0.8	103.56	4.954	-0.01	0.0864	5.478
0.9	109.62	5.326	-0.011	0.0963	5.726
1	115.98	5.871	-0.012	0.106	5.974

Table 6
Output of RSREG Procedure showing estimated ridge of maximum response for the fitted surface on density of *Scirpus grossus* in unfertilized soil (F1)

Coded radious	Estimated response	Standard error	Uncoded factor values		
			x dist	y dist	tim
0	95.108	5.1	0	0	3.5
0.1	100.202	5.083	0.006	-0.006	3.748
0.2	105.398	5.035	0.012	-0.0129	3.996
0.3	110.696	4.966	0.0166	-0.0186	4.245
0.4	116.098	4.893	0.0209	-0.0242	4.494
0.5	121.604	4.841	0.0248	-0.0295	4.743
0.6	127.214	4.845	0.0286	-0.0347	4.992
0.7	132.929	4.942	0.0322	-0.0398	5.241
0.8	138.748	5.174	0.0358	-0.0448	5.49
0.9	144.671	5.57	0.0392	-0.0498	5.74
1	150.7	6.147	0.0426	-0.0547	5.989

Discussion

This study was an attempt to determine the effect of NPK fertilizer on the structural life *S. grossus* L. on peat. It showed details of different growth patterns. The best period of clonal growth in general was between 10-18 weeks, an outcome similar to the results mentioned by (Baki, 1988). This phenomenon is probably due to the finite amount of resource in the soil, diminishing with time. In addition to this although there may be resources still available, the plants are ageing and the leaves start to show reduced effective photosynthesis. Furthermore, the assimilatory activity of the plant may have been approaching the compensation point with the respiratory burden of accumulated support tissue.

The results showed that the use of fertilizers had a significant impact on content in growth parameter but others did not show a significant impact. The addition of NPK fertilizer had a significant effect on clonal growth where it dramatically increased the population flux of the weed. Similarly, the NPK fertilizer caused a decrease in the number of deaths of ramets, and this was similar to the findings of Baki (1988) who studied the structural demography and growth patterns of *S. grossus.* The NPK fertilizer, which contains 30% of phosphate, also increased the flowering rate of the weed. Baki (1988) reported a similar observation. In addition, the NPK fertilizer helped to strengthen the plant and this was observed in the significant increase in the weights of the various plant parts in fertilized soils. Many previous studies have shown that the application NPK fertilizer can effect clonal growth of crop plants, such as wheat (Ognjanovic et al., 1994; Jelic et al., 1995; Jelic et al., 2004; Biberdzic et al., 2011). Philip et al. (2011) reported, in experiments that lasted 3 years, on the impact of different types of fertilizers on the growth of potato shoots and roots, where he observed that the highest percentage yield in NPK fertilizer treated plants. NPK affected the physiological health of the plant and increased the size of the leaves. In another study, phosphate played a significant role in affecting stages of plant growth (Hatem, 2011).

Conclusion

However, with regard to other measurements made, the fertilizer treatment did not have a significant impact and this included plant height. Baki (1988) explained the depths of inundation affected the height of *S. grossus*. In addition to this NPK fertilizer, treatment had minimal effect on the leaf chlorophyll content and chlorophyll fluorescence, both of which can be interpreted to mean that the plant is photosynthetic capacity was not significantly affected. The Fm/Fv values observed were slightly lower than that documented for healthy leaves, which is normally in the region of ~.0.82 (Murchie et al., 2009). This probably indicates that the soil on which the rice plants were grown had sufficient macro and micronutrients to support healthy growth during the period of experimentation.

The response surface analyses, dispersion and directionality analyses of subterranean rhizomes confirm the fertilizer treatment (at NPK 100:30:30) did have a significant impact, albeit small, on growth patterns of *S. grossus*.

Acknowledgement

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