STRUCTURAL DEMOGRAPHY AND GROWTH PATTERNS OF *SCIRPUS GROSSUS* L.

ALI ABDULLAH MAJRASHI

FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR
MALAYSIA

2014

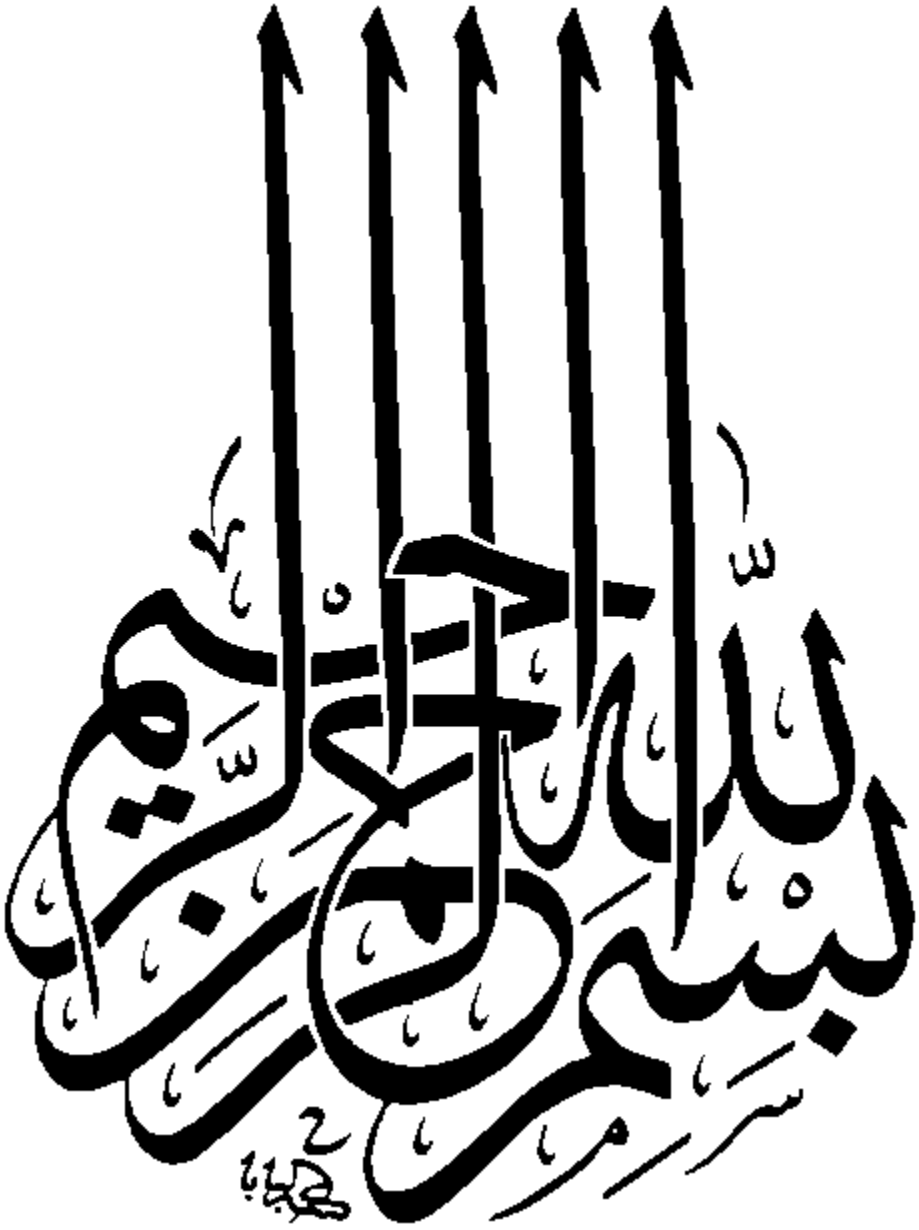
STRUCTURAL DEMOGRAPHY AND GROWTH PATTERNS OF *SCIRPUS GROSSUS* L.

ALI ABDULLAH MAJRASHI

Thesis submitted in Fulfillment of the Requirements for the Degree of *Doctor of Philosophy*

STITUTE OF BIOLOGICAL SCIENCES
FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR

2014


بسم الله الرحمن الرحيم

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of candidate: **Ali Abdullah Majrashi** Passport No.: **H972658(NEW L557173)**

Registration/ Metric No.: **SHC080062**

Name of Degree: **Doctor of Philosophy**

Title of Thesis:

STRUCTURAL DEMOGRAPHY AND GROWTH PATTERNS OF *SCIRPUS GROSSUS* L.

Field of Study: Weed Ecology

Do solemnly and sincerely declare that

1- I am the sole author/ writer of this work;
2- This work if original;
3- Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and extract from or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the work and its authorship have been acknowledged in this work;
4- I do not have any actual knowledge nor do I ought reasonable to know that the making of this work constitutes an infringement of any copyright work;
5- I hereby assigned all and every rights in the copyright to this work to the University of Malaya (UM), who henceforth shall be owner of the copyright in this work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
6- I am fully aware that is in the course of making this work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other as may be determined by UM.

Candidate's Signature
Subscribed and solemnly declared before Date

Witness Signature
Prof. Datuk Dr. Amru Nasrulhaq Boyce
Designation: Supervisor Date

DEDICATION

This dissertation is dedicated to my family: father, Abdullah Majrashi (May Allah bless his soul) and mother, Fatimah, brothers Kalid ,Hani, Mhamed, Juman, Majed, Sister's Fuziah, Jamilah, Nufe, wife, Salehah and childrens Shahad, Ahmed, Dana and Lana. Their love, support, and encouragement throughout this academic research journey meant everything to me.

ACKNOWLEDGEMENTS

SubhanaAllah! Alhamdulillah! I thank Allah the Almighty for His Grace in giving me the spiritual inspiration and strength to undertake this study. I would like to gratefully acknowledge the contributions of several people who have helped me to complete this study in time and make the documentation a reality. Two persons are keys to the completion of this tortuous doctoral journey, *viz.* Professor Dr. Baki Bin Bakar and Professor Datuk Dr. Amru Nasrulhaq Boyce. Primarily, I sincerely thank Professor Dr. Baki Bin Bakar, my Principal Supervisor for the past five years until his retirement from service in late December 2012. Despite his retirement, he took the social responsibility and constant personal interest to help in data management and the writing stages of the thesis up to the date of submission. My heartfelt thanks also goes to my co-supervisor, Professor Datuk Dr. Amru Nasrulhaq Boyce, who took the over the supervisory responsibility in the absence of Professor Dr. Baki Bin Bakar following the latter's retirement. I appreciate very much their invaluable contribution and consistent guidance during my research and thesis writing. Their frequent advice, encouragement, friendly persuasion, positive work ethics and constant prompting have all spurred me to complete my thesis on time. I wish to express special appreciation and thanks to Haji Abdul Munir Jaafar and Prof. Dr. Sithi Vinayakam Muniandy for their valuable advice and help on statistical analysis during my research and data management. Also, I wish to express special appreciation and thanks to Mr. Abdullah Marzouk Alnufaee for their valuable advice and help on AutoCAD 10 program.

I wish to record my thanks to Dr. Zainal Abidin Ahmad and Haji Mohammed Harun, the Director of MARDI, Selangor State and Head of MARDI Research Station, Jalan Kebun, Kelang, and Head of MARDI Research Station, Tanjung Karang Station, respectively, and all the staff members of both stations for their cooperation, help and

goodwill in allowing me to carry our my field experiments in their premises. Similar thanks are accorded to Prof. Dr. Abdul Shukor Juraimi, Dean, Faculty of Agriculture, Universiti Putra Malaysia for his help in my experiments in University's field sites. Their help was greatly appreciated and made possible due to their close links with my then principal supervisor, Prof. Dr. Baki Hj Bakar.

Special thanks also go to the Dean, Faculty of Science, and Heads of the Institute of Biological Sciences, University of Malaya for during their respective tenure as for providing a conducive working environment in the institute. Thanks are also due to other staff members of the Institute of Biological Sciences and Faculty of Science, who have in one way or another given me their cooperation, help and moral support. I wish to record my special gratitude and appreciation to Taif University, Saudi Arabia for generous financial support and advice given that enabled me to pursue my doctoral studies in the University of Malaya, Kuala Lumpur. I appreciate the research funds made available by the University Malaya Research Scheme throughout my tenure as a research student. Last but not least, I would like to take this opportunity to thank my beloved family members for their encouragement and moral support, which were so meaningful during my doctoral research and study.

STRUCTURAL DEMOGRAPHY AND GROWTH PATTERNS OF *SCIRPUS GROSSUS* L.

ABSTRACT

Scirpus grossus L. is a principal rhizomatous weed in the rice fields, drainage and irrigation canals, river banks, abandoned rice fields and wasteland in Malaysia. This study describes the modular dynamics, spatio-temporal growth patterns of aerial plant and sub-terranean rhizome populations of this scourge on fertilized and unfertilized peat and paddy soils. The NPK fertilizer application at 100:30:30 ha^{-1} resulted in more robust aerial plant growth with *ca.* 253.5 ramets m^{-2} (mean dry aerial biomass of 23.2 g $plant^{-1}$) compared with 235.6 ramets m^{-2} (16.3 g $plant^{-1}$) in unfertilized peat soils24 weeks after planting of the mother plant. The parallel figures for plants growing on paddy soils of the Jawa series were *ca.* 97.08 ramets m^{-1} (12.19 g $plant^{-1}$)(fertilized paddy soils) and 83.67 ramets m^{-1} (10.89 g $plant^{-1}$) (unfertilized paddy soils) 24 weeks after planting of the mother plant. Mean ramets mortality was significantly higher in unfertilized paddy soils at 121.3 ramets m^{-2}, while in the fertilized paddy soils this was only 34.7 ramets m^{-2}, resulting respective net populations of *ca.* 218.8 ramets m^{-2} and 114.3 ramets m^{-2} in fertilized and unfertilized plots. In paddy soils mean ramets mortality in unfertilized paddy soils was *ca.* 8.58 ramets m^{-2}, while this was only *ca.* 5.67 ramets $m^{-2,}$ leading to the respective resultant net populations of 91.41m^{-2} and 75.09 ramets m^{-2}. Flowering set in earlier among ramets in fertilized peat soils with 103.2 ramets m^{-2} *vis-a-vis* 77.5 ramets m^{-2}, 24 weeks after transplanting of the mother plant in unfertilized soil. Flowering set in earlier among ramets in fertilized paddy soils with 49.56 ramets m^{-2}*vis-a-vis* the unfertilized soil registering *ca*. 47.79 ramets m^{-2}, 24 weeks after transplanting of the mother plant. Fertilizer applications to either peat or paddy soils did not register any significant difference in mean plant height, chlorophyll contents, and chlorophyll fluorescence measurements *vis-a-vis* those plants devoid of

fertilizer application. No measurable differences were registered in rhizome lengths over time of *S. grossus* plants devoid of fertilizer application compared with those growing in fertilized peat soils. Similarly patterns were observed among *S. grossus* populations in both fertilized and unfertilized paddy soils. The time- and space-mediated clonal growth of *S. grossus* did not register any significant preferential directionality and dispersion of aerial plants and their sub-terranean rhizomes irrespective of fertilizer application or soil types, but rather displaying opportunistic resource capture by aerial and sub-terranean modules.

ANOVA and Tukey's HSD tests, response surface, fractal dimension and fractal topography analysis under fertilizer application factor and differences soils (peat soils - paddy soils) were used in the study from the first week to the 24^{th} week. Dispersion analyses of rhizomes was also employed.

In circular statistics *r* (concentration), *s* (angular deviation), Rayleigh's *R* and Rayleigh's *z* were computed on the emerged ramets of *S. grossus.* 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 was 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 in pest and paddy soils. However, there were heavier concentrations of ramets in the eastern sector of the plot, presumably due to phototropic effect of sunlight.

In response surface analyses in peat soils results showed the stationary points obtained for the unfertilized plots is at x-distance = 0.03 m, y-distance = - 0.06 m and time (t) = 9.8 months. This function predicted a maximum density of 178 plants m^{-2} to occur at the location and time. For the fertilized plot, the stationary point is at x-distance = 0.20 m, y-distance = -0.82 m and t = 11.31 months. The predicted density obtained was 291.02 plants m^{-2}. While in paddy soils the best location and time in unfertilized soil was between x- distance 0.00 m and y- distance -0.14 m at t = 8.16 month, while in fertilized soil the location was between x- distance -0.13 m and y- distance 0.20 m and the best time at t = 8.48 month.

In fractal topography analysis results showed value fractal dimension from gl=0 – gl=100 between area-covering and ranched network (1<D> 2). The area-covering concentrated at gl=0 and gl=40 in both peat and paddy soils (fertilized and unfertilized). While after gl=100 – gl=255 sporadic distribution (D- 0) in peat (fertilizer and unfertilized) and unfertilized paddy soils. While for fertilized paddy soil, gl=100 – gl=255.

The fractal dimension analysis method allows the structural complexity of such associations to be compared between plant communities, with regard to their potential for soil resource acquisition and utilization. In peat soil, distinct and partly not significant differences are found (fractal dimension between 1.52 ± 0.53 and 1.50 ± 0.59) in unfertilized and fertilized plots. In paddy soil, fractal dimension between 1.53 ± 0.55 and 1.52 ± 0.49) in unfertilized and fertilized plots. We found distinct and partly not significant differences between plant in peat and paddy soils, when analysing many small units of a complex root system association. In larger plant communities, a broad variety of below-ground structures are recorded in its entirety, integrating the specific features of single sub-structures. In that way, extreme fractal dimensions are lost and the

diversity decreases. Therefore, the analysis of larger units of root system associations provides a general knowledge of the complexity of root system structures for heterogeneous plant communities.

Under the prevailing experimental conditions in the studies, the following conclusions can be drawn, *viz:* (i) The optimal period of clonal growth for *Scirpus grossus*, in general was between 10-18 weeks after planting; (ii) Augmentation with different NPK fertilizer concentrations and at different water depths had the following effects on *S. grossus* growth in both fertilized and unfertilized peat and paddy soils, (a) Increased rate of natality and the population number of ramets, fortified by enhanced proliferation of subterranean rhizomes; (b) Decreased rates of ramets mortality; (c) Increased rate and production of inflorescence of the weed; and (d) Enhanced production of biomass *vis-a-vis* the control of various plant components. However, the NPK fertilizer treatment did not have a significant impact on the plant height; chlorophyll content; and chlorophyll fluorescence, registering non-significant difference in both fertilizer and control plants; (iii) Fertilizer concentration with water depth did have a significant impact on the following parameters; namely (a) plant height; and (b) inflorescence number; (iv) Aerial modular growth, dispersion, response surface, plant topography-fractal analyses on emerged ramets, and fractal dimension boxing analyses of subterranean rhizome modules confirmed that the fertilizer treatment (at NPK 100:30:30) did not have a significant and prevalent impact on the growth patterns of *S. grossus*.

DEMOGRAFI STRUKTUR DAN CORAK TUMBESARAN *SCIRPUS GROSSUS* L.

ABSTRAK

Scirpus grossus L. adalah rumpai rizomatous utama di sawah padi, parit dan terusan pengairan, tebing sungai, sawah padi terbiar dan tanah terbiar di Malaysia. Kajian ini menerangkan dinamik modular, corak pertumbuhan spatio temporal tumbuhan rumpai dan sub-terranean populasi rhizome hakisan ini di tanah berbaja, tidak berbaja dan tanah disawah padi. Penggunaan baja NPK 100:30:30 ha^{-1}telah menghasilkan tumbuhan rumpai yang lebih kuat dengan *ca*. 253.5 ramets m^{-2} (mean udara bioamass kering sebanyak 23.2 g $plant^{-1}$) berbanding dengan 235.6 ramets m^{-2} (16.3 g $plant^{-1}$) di tanah gambut tidak berbaja 24 minggu selepas penanaman ibu tumbuhan. Bacaan selari untuk tumbuhan berkembang pada tanah padi siri Jawa adalah *ca*. 97.08 ramets m^{-2} (12.19 g $plant^{-1}$)(tanah sawah padi berbaja) dan 83.67 ramets m^{-2} (10.89 g $plant^{-1}$)(tanah sawah padi tidak berbaja) 24 minggu selepas penanaman tumbuhan induk. Min ramets daya tahan adalah jauh lebih tinggi pada tanah sawah padi tidak berbaja di 121.3 ramets m^{-2}, manakala di tanah padi berbaja hanya pada 34.7 ramets m^{-2}, menghasilkan jumlah bersih populasi masing-masing pada *ca.* 218,8 ramets m^{-2} dan 114.3 ramets m^{-2} didalam plot berbaja dan tidak berbaja. Bagi tanah padi daya tahan min ramets pada tanah padi tidak berbaja adalah *ca*. 8.58 ramets m^{-2}, manakala ini adalah hanya *ca*. 5.67 ramets m^{-2}, menghasilkan jumlah bersih populasi berikut 91.41 m^{-2} dan 75.09 ramets m^{-2}. Pembungaan yang dilakukan pada peringkat awal dikalangan ramets tanah gambut berbaja dengan 103.2 ramets m^{-2} merujuk kepada 77.5 ramets m^{-2}, 24 minggu selepas dipindahkan dari tumbuhan induk ke tanah tidak berbaja. Pembungaan yang dilakukan pada peringkat awal dikalangan ramets pada tanah padi berbaja dengan 49.56 ramets m^{-2} merujuk kepada tanah tidak berbaja mencatat bacaan *ca*. 47.79 ramets m^{-2}, 24 minggu

selepas dipindahkan dari tumbuhan induk. Pengaplikasikan baja kepada tanah gambut atau padi tidak mencatatkan perbezaan yang ketara pada bacaan ketinggian tumbuhan purata, kandungan klorofil, dan ukuran klorofil florensens berbanding tumbuhan tanpa pembajaan. Tiada perbezaan ukuran rizom yang diperolehi bagi sepanjang tempoh tumbuhan *S. grossus* tanpa penggunaan baja berbanding dengan tumbuhan yang ditanam di tanah gambut berbaja. Persamaan corak dapat diperhatikan di kalangan populasi tumbuhan *S. grossus* di kedua-dua tanah padi berbaja dan tidak berbaja. Masa dan ruang-pengantara pertumbuhan klon *S.grossus* tidak mendaftarkan mana-mana arah keutamaan yang signifikan dan penyebaran *'aerial plant'* dan rizom sub-terranean mereka tanpa mengira pembajaan atau jenis tanah, tetapi memaparkan penangkap sumber oportunis secara udara dan sub-modul terranean.

Didalam tesis ini, kami menggunakan ujian ANOVA sehala dan Tukey HSD, respon permukaan, dimensi fraktal dan analisis topografi fraktal di bawah faktor penaplikasian pembajaan dan perbezaan tanah (tanah gambut – padi tanah). Kemudian faktor waktu yang digunakan adalah dari tempoh minggu pertama sehingga minggu ke 24. Kami juga menggunakan analisis penyebaran rizom.

Dalam *circular statistic* r (penumpuan), s (sisihan sudut), Rayleigh R dan Rayleigh z dikira pada kemunculan ramets *S. grossus*. Keputusan ujian Rayleigh z menunjukkan arah min yang signifikan kepada kemunculan ramets untuk semua replikasi dalam plot yang disenyawakan ($p>0.01$). Arah min yang signifikan diperolehi hanya untuk R1 tiruan untuk plot tidak berbaja. Tiada arah min yang signifikan untuk replikasi R2 dan R3 plot tidak berbaja bermakna bahawa kemunculan ramets diagihkan secara seragam di sekitar bulatan, yang berasal dari tumbuhan induk. Ini berlaku apabila s, penyebaran dengan sisihan sudut berhampiran maksimum (di mana $0 <s <83.01$). Analisis sebaran ramets oleh *circular statistic* mengenai *S. grossus* tidak menghasil

sebarang keistimewaan pada arah modul atau kemunculan ramets seperti yang dijelaskan oleh Rayleigh r, z Rayleigh, dan min sudut sebaran dalam perosak dan tanah padi. Walau bagaimanapun, terdapat kepekatan tinggi ramets di sector timur plot, ini mungkin disebabkan kesan phototropic cahaya matahari.

Daripada analisis respond permukaan untuk tanah gambut kami menunjukkan titik pegun yang diperolehi bagi plot tidak berbaja adalah jarak x = 0.03 m, y jarak = -0.06 m dan masa = 9.8 bulan. Fungsi ini meramalkan densiti maksimum 178 plant m^{-2} berlaku pada lokasi dan masa tersebut. Untuk plot berbaja, titik pegun adalah pada jarak x = 0.20 m, y jarak = 8.16 m *dan* masa = 11.31 bulan. Densiti yang diramalkan diperolehi adalah 291.02 plant m^{-2}. Bagi tanah padi lokasi dan masa terbaik bagi tanah tidak berbaja adalah diantara jarak x = -0.00 m, y jarak = 0.14 m dan masa terbaik pada = 8.16 bulan, sementara tanah berbaja, kedudukannya berada diantara jarak x = -0.13 m, y jarak = 0.20 m dan waktu terbaik adalah pada = 8.48 bulan.

Didalam analisis topografi fraktal kami menunjukkan dimensi nilai fraktal dari gl = 0 – gl = 100 diantara kawasan liputan dan rangkaian *ranched* (1 <D>2). Kawasan liputan bertumpu di gl = 0 dan gl = 40 di kedua-dua tanah gambut dan tanah padi (berbaja baja dan tidak berbaja).Sementara gl= 100 gl= 255 penyebaran spora (D-0) pada *'beat soil'* (berbaja dan tidak berbaja) dan tanah padi tidak berbaja. Sementara tanah padi berbaja gl = 100 – gl = 255.

Kaedah analisis dimensi fractal membolehkan kerjasama struktur yang rumit ini boleh dibandingkan antara komuniti tumbuhan, dengan mengambil kira potensi mereka untuk pemerolehan sumber dan penggunaan tanah. Di kawasan tanah gambut, perbezaan yang ketara dan sebahagiannya tidak penting telah ditemui (dimensi fraktal antara 1.52 ± 0.53 dan 1.50 ± 0.59) pada plot tidak berbaja dan berbaja. Dan dalam tanah padi, (dimensi fraktal antara 1.53 ± 0.55 dan 1.52 ± 0.49) pada plot tidak berbaja

dan berbaja. Kami menjumpai perbezaan ketara dan sebahagiannya tidak penting berbanding antara tumbuhan di tanah gambut dan padi. Ketika menganalisa jumlah unit-unit kecil dengan banyak kerjasama system akar yang kompleks. Didalam komuniti tumbuhan yang lebih besar, pelbagai hasil struktur bawah tanah direkodkan secara keseluruhannya, pengabungan ciri-ciri khusus sub-struktur tunggal. Melalui cara ini, dimensi fraktal melampau hilang dan kepelbagaian berkurangan. Oleh itu, analisis unit yang lebih besar kerjasama system akar menyediakan pengetahuan am tentang kerumitan struktur system akar bagi komuniti tumbuhan heterogen.

Di bawah keadaan percubaan yang sediada, beberapa kesimpulan boleh diperkatakan, iaitu: (i) Jangkamasa optimal bagi tumbersaran klonal bagi *S. grossus* pada amnya adalah di antara 10- 18 minggu slepas penanaman; (ii) tambahan baja NPK pada kepekatan berbeza serta kedalaman air juga berbeza menunjukkan kesan-kesan berikut terhadap tumbesaran *S. grossus* di dalam tanah sawah dan tanah gambut (a) penambahan kadar kelahiran dan populasi ramet, di tambah pula dengan penyebaran rizom bawah tanah; (b) pengurangan kadar kematian ramet; (c) peningkatan kadar dan pengeluaran bunga; (d) peningkatan pengeluaran biojizim berbanding dengan tanpa rawatan bagi semua komponen tumbuhan. Walaubagaimanapun, rawatan dengan baja NPK tidak mempunyai impak ke atas ketinggian pokok, kandungan klorofil and fluresen klorofil, dengan daftaran tidak signifikan terhadapa pokok yang dibaja dan tidak dibaja. Rawatan baja NPK dan kedalaman air memberi impak yang signifikan ke atas beberapa parameter berikut (a) ketinggian pokok, dan (b) bilangan bunga. Pertumbesaran aerial, penyerebakan, tindakan pemukaan, analisis fraktal-tofografi tumbuhan bagi ramet yang menjelma dan analisis dimensi fractal kotak bagi modul rizom bawah tanah mempastikan bahawa rawatan baja NPK pada kadar 100:30:30 tidak mempunyai impak yang signifikan ke atas corak tumbesaran *S. grossus*.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (*continued*)

LIST OF TABLES

LIST OF TABLES (*continued*)

ABREVIATIONS

3D	Three-Dimensional
Amine or Ester	2,4-D amine/ester
ANN	Artificial Neural Network
AutoCAD	Program from Autodesk C. From USA
Azimsulfuron	4-amino-3,5-dichloro-6-fluoro-2-pyridinyl)oxy)- aceticaci;4-amino-3,5-dichloro-6-fluoro-2-pyridyloxyaceticacid;ff404
BCD	Box-Counting Dimension
Benthiocarb	*S*-(4-Chlorobenzyl) diethylcarbamothioate
CR	Capacity to reduce
Cyclosulfamuron	1-[2-(cyclopropylcarbonyl)anilinosulfonyl]-3-(4,6-dimethoxypyrimidin-2-yl)urea
Cyhalofop-butyl	butyl (*R*)-2-[4-(4-cyano-2-fluorophenoxy)phenoxy]propionate
D1	Level water 0 cm (control)
D2	Level water 5 cm
D3	Level water 10 cm
D4	Level water 20 cm
DLA	Diffusion Limited Aggregation
ExG –ExR	Color index
F0	NPK concentration (control) (without fertilizer)
F1	Soil with fertilizer
F2	NPK concentrations (50g/500 ml)
F3	NPK concentrations (75g/750 ml)
F4	NPK concentrations (100g/1000 ml)
F5	NPK concentrations (125g/1250 ml)
FD	Fractal dimension Analysis

Flufenacet	4′-fluoro-*N*-isopropyl-2-[5-(trifluoromethyl)-1,3,4-thiadiazol-2-yloxy]acetanilide
FO	Soil without fertilizer
FS	Functional–Structural
Glufosiate ammonium	Ammonium (2-amino-4-(methylphosphinato) butanoate
GR	Garland chrysanthemum and edible amaranth
Imazapyr	*RS*)-2-(4-Methyl-5-oxo-4-propan-2-yl-1*H*-imidazol-2-yl)pyridine-3-carboxylic acid
IWM	Integrated Weed Management
KPI	Keratoconus Prediction Index
LAD	Leaf Area Duration
LAD	Liquid Anaerobic Digestate
LEI	Low-External-Input
LJ	Large Juveniles
MARDI	Institut Penyelidikan Dan Kemajuan Pertanian Malaysia
MCPA	4-chloro, 2-methyphenoxyacetic acid
Molinate	S-ethyl hexhydro-1 H-azepine-1-carbothiate
MPM	Matrix Population Models
NPK	Nitrogen: Potassium :Calcium (100:30:30)
PDSI	Palmer Drought Severity Index
Propanil	*N*-(3,4-Dichlorophenyl)propanamide
PSII	Purification of Two Consecutive Photosystem II
RCBD	Randomized Complete Block Design
RSAM	Response Surface Analysis
RYT	Relative Yield Total

SAS	Statistical Analysis System
SI	Sweet corn residue incorporated
SR	Sweet corn residue removed
WRA	Weed Risk Assessment System