IMPROVING COWPEA PRODUCTION USING HUMATES AND SEAWEED EXTRACT BIO-STIMULATORS

JUDITH ONDISO OYOO

MASTER OF SCIENCE
(HORTICULTURE)

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

2018

Improving Cowpea Production using Humates and Seaweed extract bio-stimulators

Judith Ondiso Oyoo

Thesis submitted in Partial fulfilment for the Degree of Master of Science in Horticulture in Jomo Kenyatta University of Agriculture and Technology

2018

DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

Signature……………….…… Date……..……………

Judith Ondiso Oyoo

This thesis has been submitted for examination with our approval as University Supervisors

Signature…………………..……… Date……………………

Prof Edward G. Mamati

JKUAT, Kenya

Signature……………………… Date……………………

Dr Paul Kinoti

JKUAT, Kenya

DEDICATION

This work is dedicated to my husband, Isaacbob Ilukol and my entire family for the love, care, patience, encouragement and patience during this study.

ACKNOWLEDGEMENT

First and foremost I thank Almighty God for the life, health from the beginning of this study to this moment. I am grateful for the scholarship I received through KAPAP towards this study and the funding of my research work.

I am grateful to my supervisors Prof. Edward G. Mamati and Dr. Paul Kinoti for their insight, assistance and guidance from the process of choice of project, to proposal writing and the final writing of this research thesis. I would also wish to acknowledge Jomo Kenyatta University of Agriculture and Technology, Faculty of Agriculture and Department of horticulture and all the academic staff for their great assistance. A lot of gratitude goes to Dr George Ong'amo of University of Nairobi and Mr Thuranira of KALRO Kabete for their support and constructive suggestions especially during data analysis and interpretation. I also acknowledge partial support of the research project by the Reseearch, Production and Extension (RPE) division of JKUAT through 'The Cowpea Seed Production Innovative Project'. Last but not least, I thank my family members particularly my husband and children for the love, understanding and patience which they showed and expressed to me during the study. They fortified and inspired me greatly especially during times of fatigue and discouragement.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

A study was carried out in Jomo Kenyatta University of Agriculture and Technology, Juja and Kenya Agricultural and Livestock Research organization (KALRO) Katumani to evaluate the effect of bio-stimulators; seaweed extracts of *Ecklonia maxima* and potassium humates, on four cowpea varieties K80, Kenya Kunde, KVU 27-1 and M66 for leaf and seed production from March to August 2013 and short rain season 2014/15. The treatments were designed in factorial structure laid out in randomized complete block design and replicated thrice. The plots measured 2.5m by 2.5m at a spacing of 60cm by 20cm. Bio-stimulators were applied in planting holes except seaweed extracts foliar spray which was applied after emergence to flowering. Treatments were nine (humates, seaweed extracts (SWE), biofix, control, humates+SWE basal application, humates+SWE basal application+SWE foliar spray, humates+SWE foliar spray, SWE basal application+SWE foliar spray and SWE foliar spray) and the four cowpea varieties. Data was obtained for rate of emergence, days to emergence, survival rate, plant height, stem thickness, root length and nodule formation, number of leaves produced, leaf weight, leaf area and chlorophyll levels. The experiment for cowpea seed production was split plot design, with cowpea varieties as the main plots while bio-stimulators as sub-plots, replicated 6 times. The plots measured 2m by 2m, at a spacing of 60 cm by 20 cm. Treatments included SWEs, humates, biofix and control. Data was obtained fordays to flowering, days to podding, number of pods, length of pods, number of seeds per pod and total weight of seeds produced per plot. The data was taken every week and recorded in Microsoft excel sheet, where it was cleaned, organized and subjected to analysis of variance. Treatments which showed significance were separated using Fischer's Protected LSD at 95%. Rate of emergence, days to emergence, survival rate, plant height, chlorophyll levels, leaf weight, stem thickness (weeks 1, 3, 6 and 8), root length (week 8), nodules formed (weeks 6 and 8) and number of cowpea leaves formed were significantly different between Juja and Katumani but not in leaf area at $p \leq 0.05$. Highest rate of emergence (61%), survival rate (70 plants), chlorophyll levels (54.4), leaf area (50.7cm^2), longest roots and highest number of nodules formed (week 6 and 8) were in Juja and highest leaf weight (2.5g) and earliest emergence of 4 days were recorded in Katumani. Bio-stimulators were significantly different in rate of emergence, days to emergence, survival rate, leaf area, plant height (weeks 2, 4 and 5), root length (week 5), nodules formed (weeks 5 and 8) and number of leaves formed but not in chlorophyll levels, leaf weight and stem thickness at $p \leq 0.05$. In Juja, humates caused high emergence rate, high survival rate, higher plant height and improved number of leaves whereas in Katumani, it improved leaf weight and high number of nodules formed in week 8 compared to control. SWE basal application+SWE foliar spray caused early emergence, high rate of emergence and survival rate, enhanced chlorophyll levels, higher leaf weight and longer roots besides improving cowpea leaf production in Katumani and in Juja, longer roots and high number of nodules. Humates+SWEs caused early germination, high cholorophyll levels and higher number of nodules formed in Juja. K80 had the highest rate of emergence, survival rate, leaf weight and area. In addition, K80 produced the highest number of leaves from week 3 to 8 in Juja (315, 784, 1036, 1424 and 2139) while in Katumani, Kenya Kunde produced the highest number of leaves in weeks 3 and 5 (211, 417), KVU 27-1 in weeks 4 and 6 (361, 436) and K80 in week 8 with 618. In cowpea seed production, there were significant differences between bio-stimulators in number of pods, length of pods, number of seeds produced per pod and total weight of seeds but not in days to flowering neither were there any interactions between bio-stimulators and varieties at $p \leq 0.05$. Varieties were significantly different in days to podding and length of pods but not in number of pods formed, number of seeds per pod or total weight of seeds formed at $p \leq 0.05$. KVU 27-1 and K80 produced the highest number of seeds and pods in humates while M66 and K80 produced the longest pods and highest seed weight in SWEs respectively. Based on findings from this study, use of seaweed extracts and potassium humates is recommended to boost cowpea leaf and seed production in marginal areas. Further work should investigate the potency of nodules formed in marginal areas under water stress conditions and use of bio-stimulators with fertilizers to boost vegetable production.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Bio-stimulators are natural substances derived from plants and animals that stimulate plant processes at very low concentrations. When applied to the plants and have been found to influence plants' metabolic processes such as respiration, photosynthesis, nucleic acid synthesis and ion uptake (Khan *et al*., 2009). They have been used all over the world to improve crop yields when applied alone or in combination through directly improving plant metabolic activities or indirectly through soil conditioning (Mancuso *et al*., 2006; Van Tonder, 2008).

Biotic (e.g. pests and diseases) and abiotic stresses (e.g. drought, salinity, extreme temperatures, and ultra violet radiation and ozone exposure)slow plant growth as they divert photosynthates and food reserves, impacting negatively on plant growth resulting to crop losses, low crop yieldsand plants' death (Gawronska *et al*., 2008).Extremely high heat and drought causes plants to undergo morphological and physiological changes to withstand moisture deficit while maintain high tissue moisture through stomatal closures, reduced leaf sizes and numbers, increased leaf waxiness and thickness, leaf rolling or folding, increased length and surface area of roots, change in root structure inorder to grow deeper in search of moisture and reach further for immobile nutrients among others (Lobato *et al*., 2009; Huang *et al*., 2012; Fahad *et al*., 2017). In addition, droughtalso causes biochemical changes such as a drop in endogenous cytokinins levels and increases proline accumulation, reduced protein synthesis and reduced activity of nitrate reductase with eventual plant senescence (Singh and Raja Reddy, 2011; Fatokun *et al*., 2012).

In reducing the drought stress, bio-stimulators promote endogenous synthesis of plant growth susbstances that support plant life, whose levels are usually diminishing during abiotic stress. In addition, they protect plant pigments such as chlorophyll, proteins, lipids and nucleic materials from disintegration by reactive oxygen species (ROS) which are produced in high quantities during abiotic stress, through scavenging for these ROS. This results to lengthened plant life which boosts biomass accumulation and hence high crop yields (Fan *et al*., 2011; Giri, 2011). In mitigating abiotic stress further, bio-stimulators contain macro molecules that enhance water holding capacity of the soils by binding soil particles together through gel formation. They also increase soil aeration and builds soil structure, improve nutrient availability boosting proper root grow, promote soil microorganisms, soil organic matterand plant utilization of applied fertilizers besides preventing leaching of mineral nutrients hence promoting growth (Rothova *et al*., 2006; Thirumaran *et al*, 2009; Mahmoud and Hafez, 2010).

Bio-stimulators also enhance plant tolerance to biotic factors such as pests and diseases through invoking 'systemic acquired resistance' in plants which is correlated with accumulation of pathogenesis related proteins influencing plant metabolism,either through structural strengthening thereby creating mechanical barrier to pathogen invasion or by activating vigorous growth leading to escape (Chojnaka *et al*., 2012). When bio-stimulators are applied early during plant growth before pathogenic invasion or pest attack, the plants become stronger resisting or tolerating the attack (Gawronska *et al*., 2008). Bio-stimulators work in synergy with plant nutrients to enhance plant processes, boost plant vigor and health through structural strengthening or plant escape leading to improved overall growth hence the plant is able to fight infections or invasions (Van Oosten *et al*., 2017). Studies have shown that a combination of bio-stimulators and inorganic fertilizers such as humic acids and nitrogen promoted root growth more when nitrogen nutrient elements were applied alone. They are not substitutes for fertilizers or manure or any other source of mineral nutrients though they mimic fertilizers in action (Gawronska, 2008).

Vegetables have gained value globally as they are considered essential sources of micronutrients required for healthy living. Vegetable production has increased in volume from 2010 to 2016 by 17% from 921.5 to 1075.2 million tonnes. In 2016, the leading continent in vegetable production was Asia producing over 250 million metric tonnes, followed by Africa with 20, Europe with 11, America with 8 and Oceania with 0.6 million metric tonnes (**www.statista.com** Accessed on 9th June 2018). Leading vegetable produced in 2016 was tomatoes with 177 million tonnes, followed by brassicas with 96, onions with 93 and cucumber with 80 (Schreinemachers *et al*., 2018). Cassava leaves was the only traditional vegetable ranked with a production of 0.07 million tons (**www.statista.com** Accessed 9th June 2018). Africa boasts of 397 indigenous vegetables types, of which 71 % are cultivated and less than 1% are foreign introductions (Smith and Eyzaguirre, 2007). In sub Saharan Africa (SSA), South Africa has the highest share of fruits and vegetable production of above 50% due to its horticultural export orientation (Chauvin *et al*., 2012). West Africa follows with 50% share, East Africa with 18 % and Central Africa with 10%. Vegetable consumption has been the lowest in sub-saharan Africa (SSA) and has been on the decline over the years despite Africa having many indigenous vegetable types.Traditional vegetables had been abandoned for the exotic vegetables as they are usually branded 'poor man's crop' though the trend is changing to increasing their consumption. Ruel *etal* (2005) showed that fruits and vegetables consumption in 10 SSA countries ranged between 27 and 114kg per person per year which is way below the FAO/WHO recommendations of 146kg per capita per year (400g per person per day). Inadequate vegetable and fruit consumption is the 6th risk factor for the high children mortality in the world (Ruel *et al*., 2005). In Eastern Africa cultivation of fruits and vegetables has experienced exponential growth over the last decade in Kenya, Ethiopia, Rwanda and Uganda (Joosten *et al*., 2015). Most common vegetables produced include tomatoes, cabbages, onions, carrots, potatoes and traditional vegetables (Ochieng *et al*., 2016).In Kenya, vegetables contributed 36 %to the domestic value of horticulture in 2014; 4.1 million metric tons worth KES 70.9 billion was produced in area of 326,837 ha. The leading vegetables in production and value werepotatoes, tomatoes and cabbages (Anon, 2014). Local or traditional vegetables have also gained popularity in Kenya because of the high nutritional value and phytochemicals not present in exotic vegetables, which help to protect against non-communicable diseases such as diabetes and cancer (Ruel *et al*., 2005). They include amaranth, slender leaf, spider plant, vegetable cowpea, pumpkin leaves and jute mallow, with the leading vegetables in production being cowpea (Abukutsa, 2007). Vegetables, particularly traditional vegetables have gained attention recently in research programs and in the market place though challenges that exist along the value chains such as lack of certified seed, poor crop stands, lack of technical information on agronomic practices and nutritional value, declining soil fertility, climate change among others may be a setback to development of market demand for them.

1.2 Problem statement

Environmental stresses are inherent to changing climate with subsequent great negative impact on crop production leading to crop losses and low yields (Mukhongo *et al*., 2016). Climate change and emergence of new pests and diseases pose a great challenge to cowpea vegetable production in ASALs. This situation is worsened by exponential population growth rate, which necessitates expanding areas of production to obtain higher yields to meet the food and nutritional security needs (Sithole and Murewi, 2009). Land has become very limited since population pressure has forced allocation of agricultural land for construction of buildings and other structures for modest human settlements and industrial commercial growth. This means that cowpea yields by improving per unit area production, boosting performance of the crop in the midst of the environmental stresses and/or reducing elements that lead to lower yields or losses (Nkaa *et al*., 2014). Kenya has only 20% of high potential land with the remaining 80% categorized as arid and semi-arid lands (ASALs) although they are suitable for agriculture (Joosten *et al*., 2015). In addition, ASALs are characterized with low soil fertility worsening the situation. Most small scale farmers do not use inorganic fertilizers in cowpea vegetableproduction due to exorbitant prices of the fertilizers, even though research has shown that legumes such as cowpea do require fertilizers for high yields (Sheahan & Barrett, 2014). Interventions to improve vegetable production particularly cowpea in ASALs has been done with little success. Integrated nutrient management program (INMP) such as use of organic and inorganic fertilizer materials have improvedsoil fertility, built soil structure, enhanced water holding capacity of the soils, boosting crop performance (Mazouk and Kassem, 2011). Organic resources are not commonly used because of high labor required in processing, transporting and application due to the bulk quantities required to supply sufficient quantities of nutrients. In addition, farmers' prioritization on the use of INMP like use of legume crops as green manure suitable for food and incomes creates conflict of interest.Use of plant remains as animal feed/fodder other than improving soil fertility is usually the obvious choice of animal keeping farmers, leaving little or no options for improving soil fertility other than use of inorganic fertilizers. Inorganic fertilizers are a challenge in the tropics since smallholder farmers are unable to access adequate quantities due to high costs of to purchase (Jaetzold *et al*., 2006). Also, during rainfall failure, application of inorganic fertilizers may not be helpful since they need sufficient soil moisture to dissolve and be available for plant uptake, hence they become toxic to the soils and may end up scorching the seed or plants. Biotechnological interventions have also been done to mitigate against environmental stresses such as use of microbial innoculants like 'Biofix', bio-fertilizer. Though inexpensive, distribution of this microbial inoculant is poor hence unavailable in agro-vet shopswhen needed, requires technical knowledge to apply and information about the optimal ecological requirement for establishment of the rhizobia and proper nodulation for maximum nitrogen fixation may not be easily accessible and understable to a local small scale farmer. Balume *et al*. (2015) established that the key to ensuring high quality legume inoculants is through promotion of an effective quality control system from manufacture through distribution to final use. Otheroptions of enhancing tolerance of cowpea to these harsh environmental conditions and boost production exists through application of bio-stimulators. Bio-stimulators are organic substances, sold in concentrated form, easy to apply and transport, non toxic to users, relatively cheaper as they cost approximately Ksh 25,000 to purchase for applying in an acre, compared to the cost of obtaining manure to achieve similar results. They are also environmentally friendy and ecologically safe besides having a fast mode of action, thus can be used on any farming system; in inter-croppings or monocropping systems, whether large or small scale. Bio-stimulators do not perform optimally in areas where the conditions are optimal for crop growth. They have been used to produce other plant and tree crops such as fruit trees, flowering and ornamental crops, cereals, horticultural crops such as tomatoes, onions and capsicum among others (**www.organix-agro.com**. Accessed 4th September 4, 2018).Challenges in use of bio-stimulators is that the nutrient quanties do not remain stable in the extract during storage though information about how long they should be stored for stability is not available. In addition, bio-stimulator is not expansively distributed in the country which limits its availability despite its immense potential in crop production.Bio-stimulators are expected to boost plant growth by mitigating physiological processes that reduce biomas accumulation, enhance water holding capacity of the soil, nutrient availability and uptake, proper nodulation resulting to better cowpea plant growth and development under sub optimal environmental and increased yields.

1.3 Justification

Vegetables have been found to supply 50% of the protein required in human diets as vegetable proteins, contributing more to world total protein than fish. Traditional vegetables have been found to be a good reliable source of micronutrients not present in exotic vegetables (Galy and Alkoaik, 2016). There's need to invent new methods of producing more vegetables especially traditional vegetables that will guarantee a continuous supply of proteins and micronutrients. Bio-stimulators have been found globally to have great potential in enhancing crop productivity and particularly improving vegetative growth leading to better yields but there's little, data on vegetable production in Kenya. Similarly there is no supporting evidence to show the effect of bio-stimulators on the quality and yield of vegetables as leaves, shoots, sprouts or flowers under Kenyan agro-ecological conditions.Bio-stimulators are catered for different agro-ecological conditions, different crop responses, are available in small packets, are user friendly and available in Kenyan markets. In addition, they do not require sophisticated technology to apply and are suitable for small-scale farmers in Kenya. There's need for more research to be done on use and adaptability of bio-stimulators on vegetable production in marginal areas and awareness creation to enhance their demand. The findings will mostly benefit the small-scale farmers who make up 80% of agricultural production in Kenya, in line with the country's agenda of ensuring food and nutritional security as indicated in the government development plans, Agricultural Sector Development Strategy (ASDS) 2010-2020 (GoK, 2010). In addition, women will benefit more since 80% of women are actively involved in production, harvesting, packaging and marketing ofvegetables such as cowpea in Kenya through creation of employment and increasing household incomes when excess supply of vegetables are sold (Hallensben *et al*., 2009).

1.4 Objectives

1.4.1 General Objective

Assess the effect of bio-stimulators on production of cowpea in marginal areas.

1.4.2 Specific Objectives

1. To evaluate the performance of bio-stimulators on growth of cowpea
2. To evaluate the effect of bio-stimulators on rooting and nodulation of cowpea
3. To evaluate the effect of the bio-stimulators on leaf production of cowpea.
4. To evaluate the influence of bio-stimulators on seed production of cowpea.

1.5 Hypotheses

1. Bio-stimulators do not have an influence on growth of cowpea
2. Bio-stimulators have no effect on the rooting and nodulation of cowpea
3. Bio-stimulators do not have an effect on leaf production.
4. Bio-stimulators do not have an influence on seed production of cowpea

CHAPTER TWO

LITERATURE REVIEW

2.1 Cowpea – origin and morphology

Cowpea is an annual warm season herbaceous vegetable legume crop that originated from Africa and is widely grown in the United States of America (USA), South East Asia, Latin America and Africa (Chiulele, 2010). Cowpea is characterized with erect, semi-erect, prostrate and climbing features and growth habits varying from determinate to indeterminate while possessing a tap root system which may develop laterals (Singh *et al*., 2003). The leaves are trifoliate and alternate; smooth ranging from dull to shiny, not pubescent, with the terminal leaflet being usually longer than adjacent leaves. The stalks may be striate, smooth or hairy with some shade of purple colouration. Cowpea flowers are borne in multiple racemes of 8-20 inches on the flower stalks at the diastal end of the peduncle that arises from leaf auxil. This crop is self-pollinating since flowers form and open above the foliage attracting pollinators such as insects.They areborne on short pedicels and with the bright coloured petals as white, dirty yellow, pink, pale blue or purple (Chiulele, 2010). Cowpea produces 2-4 pods per peduncles which are smooth, 6-10 inches long (15 to 25 cm), cylindrical and semi-curved. At maturity, the pods are usually green, yellow or purple depending on the cowpea variety which turns brown or tan after drying (Dugje *et al*., 2009). Seeds in the pod vary in number from eight to twenty, measuring 2 to 12 mm long and weighing 5 to 30 g per 100 seed weight (Anon, 2011). Seed may also be speckled, mottled or blotchy and the seed coat either smooth, wrinkled with colours ranging from cream, green, red, brown and black. Cowpea exhibits epigeal germination similar to common beans (Chiulele, 2010).

2.2 World Production of Cowpea

Cowpea is widely grown all over the World on approximately 12.3 million ha with 85% of the acreage being in Africa (FAO, 2015). In Africa, 10.6 million ha was grown in West Africa in Niger, Nigeria, Burkina Faso, Mali and Senegal. Cowpea is also grown in East and Central Africa for leaf and grain production hence contributing significantly to food and nutritional security (Hallensben *et al*., 2009). Cowpea is drought tolerant (Ngugi *et al*., 2007), has a short growing period and its culinary versatility makes it a very attractive alternative vegetable for farmers in marginal, drought-prone areas with low rainfall and less developed irrigation systems (Hallensleben *etal*., 2009). It is also normally intercropped with cereals thus contributing to soil fertility through nitrogen fixation and through controlling wind erosion as a cover crop, besides suppressing weeds hence reducing the labour costs required leading to reduced costs of production. In addition, droppings of leaves and plant parts contribute to soil organic matter as humus upon senescence and decomposition (Saidi *et al*., 2010).Cowpea is an important leafy food legume and source of dietary protein and nutritious fodder in the semi-arid tropics (Dugje *et al*., 2009). Young cowpea leaves are utilized as pot herb and enjoyed in many countries of Africa as an accompaniment of cereals (maize, rice or wheat) or root tuber (cassava, yams) meals (Abukutsa, 2007). The freshly harvested leaves are sold in local markets and retail stores in many parts of Ghana, Mali, Benin, Cameroon, Ethiopia, Uganda, Kenya, Tanzania and Malawi (Pottorff *et al*., 2012). Cowpea shoots and leaves are rich sources of proteins, calcium, phosphorous and vitamin B and are utilized as high protein pot herb hence forming a delicacy among communities in Africa and in Kenya (Kimiywe, 2007).

Despite its immense potential to alleviate hunger and increase household incomes, cowpea leaf production has not been fully exploited particularly to supply the vegetable protein for the 'poor man' while grain yields in farm fields are below 300kg/ha (Takim and Uddim, 2010). This has been attributed to biotic (pests, diseases and weeds) and abiotic stresses (drought, high temperature, low soil fertility, low soil pH, toxicity) with drought identified as the major constraint limiting production (Majengo *et al*., 2016). Cowpea crop still suffers substantial grain loss when exposed to severe drought stress especially at flowering, podsetting, pod filling and grain filling leading to reduced number of pods per plant and seed weight, and consequently low grain yields while leaf production suffers through reduced leaf area, stunted growth and shortened growth cycle where the vegetative phase is shortened to give way to reproductive phase to produce seeds for continuity (Ndiso *et al*., 2016).Cowpea leaves have great nutritional significance especially to women, lactating mothers and growing children although the leaves have been down played and neglected in reseach programs, making cowpea leaves to be underutilized as food security crop. Cowpea breeding research programs have focused on releasing varieties which are tolerant to biotic and abiotic stresses with high grain yields (Hallensben *et al*., 2009). There is therefore need to intensify research on development of or evaluation of existing cowpea varieties for high leaf production, promote utilization and benefits and recommend to communities for upscaling production.

2.3 Cowpea leaf productionin Kenya

Cowpea is the most important traditional vegetable in Kenya as its grains and leaves contribute significantly to food and nutritional security and household incomes. In 2014, Cowpea was produced on 24,431 ha, yielding 65,096 tons worth Ksh 812 million (Anon, 2014). Cowpea leaves contain enough recommended daily allowances for vitamins (especially pro-vitamin A and C), minerals (more than 30% Fe and Ca) and 40% proteins required for proper growth and health of young children and lactating mothers. In addition they contain phytochemicals which are not present in exotic vegetables, which help to protect against non-communicable diseases such as diabetes and cancer (Abukutsa, 2007). Cowpea leaf production is achieved by uprooting the entire plant at 3-5 true leaf stage when leaves are still young and less fibrous or sequential harvesting done at pre-determined intervals where leaves are handpicked (Saidi *et al*., 2010). Yields range from 240kg/ha for grains and 400kg/ha for leaves to a potential of 3000kg/ha for grains and 4000kg/ha for leaves (Olal *et al*., 2015). Cowpea is known to be drought tolerant though in extreme environmental stresses, production is severely hampered. Those grown for grain production require high rainfall of above 1000mm per annum, with critical periods of high moisture requirement to be the time just before flowering (Olal *et al.*, 2015). Mechanisms of drought-tolerant in cowpea include development of deep hairy roots, stomatal closures, reduced plant growth rate and leaf area, hastened or delayed reproductive cycle Stunted growth affects leaf expansion which inhibits photosynthesis and biomass accumulation as was found by Nyoki and Ndakindemi (2006). This lowers cowpea leaf production, poor pod filling, low mass grains and low seed weight. Since cowpea is a dependable crop to farming communtities in the marginal areas and is a potential food and nutritional security crop, there's need to develop mechanisms to enhance production in these marginal areas where there's unreliable little rainfall or drought to ensure food and nutritional security to these communities sustainably.

2.4 Nodulation in Cowpea

Cowpeahas been known to do well in arid and semi-arid areas where there's little or no rainfall and the soils are low in nitrogen & phosphorus (Nyoki and Ndakindemi, 2006). Cowpea has been credited with boosting soil fertility through nitrogen fixation via nodulation. Nodulation is an activity carried out in the roots of legumes in a symbiotic relationship with nitrogen fixing bacteria in soils and is the process of converting stable atmospheric nitrogen into organic products such nitrates, hence requiring no addition of inorganic nitrogenous fertilizers (Ferguson and Matthesius, 2014). Many factors that influence plant growth such as soil moisture content, soil pH, extremes of temperatures, acidic soils, excess availability of nitrates or ammonium, soils of low nutrient status, soils of low water holding capacity and low availability of phosphorusdirectly affect rhizobial establishment and subsequently nodulation (Zahran, 1999; Bonilla and Bolanos, 2009; Ferguson *et al*., 2013). Legume plants carrying out nitrogen fixation take up more cations than anions and release hydrogen ions in the rhizosphere, hence the more nitrogen is fixed the more acidic the rhizosphere becomes leading to phosphorus being complexed creating a 'deficiency' (Nkaa *et al*., 2014). For effective nodulation for efficient nitrogen fixation by the *Rhizobium* bacteria, soil moisture, nitratesand phosphates are required in sufficient amounts since nitrogen fixation is an energy expensive reaction (Gachimbi *et al*., 2003).Biological nitrogen fixation occurs well in soils with low N and P but not when N is below 0.15% and P is below 7mg/kg (Karikari *et al*., 2015). Over application of nitrogen above 0.15% leads to more vegetative growth, delayed maturity, reduced seed yield and suppressed nitrogen fixation (Ferguson *et al*., 2013). In addition, nodules have been found to be strong sinks for phosphorus and therefore nodulation and nitrogen fixation are strongly influenced by the availability of phosphorus (Bonilla and Bolanos, 2009; Ferguson and Matthesius, 2014). Studies carried out in Siakago and Gachoka in Mbeere districts showed that treating legumes with *Rhizobia* at the rate of 0.17kg/ha and application of Triple super phosphate at the rate of 104kg/ha greatly enhanced plant vigor, yields and leaf color of cowpea as a result of high rate of nitrogen fixation due to good nodulation as compared to legumes which were not treated with *Rhizobia* or with triple super phosphate (Nyoki and Ndakidemi, 2014). In very impoverished soils found to be low in nitrogen and phosphorus, starter nitrogen of 15kg/ha and 30kg/ha phosphorus is advised for proper root nodulation in cowpea (Karanja *et al*., 2006; Nkaa *et al*., 2014). Bio-stimulators have been found to mitigate the negative effects of drought through reinforcing plant processes or boosting growth both in above- and below-ground parts.Since factors affecting plant growth negatively are the same that affect nodulation negatively, it is imperative that mitigating these factors will lead to enhamced crop performance and equally nodulation will improve. It is expected therefore that bio-stimulators willmitigate the negative effects of abiotic stress thus increasing nodules, improve nitrogen fixation in the soils leading to more production of grains and leaves of cowpea (Karikari *et al*., 2015).

2.5 Definition and origin of bio-stimulators

Bio-stimulators are natural substances derived from plants and animals that stimulate plant processes at very low concentrations when applied to the plants but do not interfere with the natural pathways of plant processes and are independent of the crop's nutrient content (Khan *et al*., 2009; Anon, 2013). They contain amino acids, low molecular weight polypeptides, vitamins, enzymes, hormones (cytokinins, auxins and gibberellins), sugars, glycine betaines, polyphenols and pigments (Thirumaran *et al*., 2009). Majority of bio-stimulators that have been commercialized include seaweed extracts (SWE) from *Ascophyllum nodosum, Durvillaea antarctica, Durvillaea potatorum, Macrocystis pyrifera,* and *Ecklonia maxima* (Khan *et al*., 2009), humic substances commercialized as salts of humic acids (potassium, sodium and ammonium humates) or foliar spray preparations of humic acids (Pena –Mendez *et al*., 2005) and bio-fertilizers which include beneficial fungi (for example *Trichoderma*) and beneficial bacteria (*Rhizobium*), protein hydrolysates and amino acids, chitosan and other biopolymers and inorganic compounds/mineral elements, beneficial fungi and bacteria (Prakash *et al*., 2011; Du Jardin, 2015). Marketing of bio-stimulators has been projected to reach $2,241million globally by 2018 with an estimated 12.5% annual growth rate from 2013 to 2018 (Anon, 2013).Some commercial products available in market include Maxicrop, Algifert, Goemar, Kelpak 66, Sea Spray, Seasol, SM3, Cytex and Seacrop, humates, humic acids, Biofix (Gawronska *et al*.,2008; Ramya *et al*., 2011).

2.5.1 History of seaweed extracts (SWEs)

Seaweeds form an integral part of coastal marine ecosystem comprising macroscopic, multi-cellular marine algae (Ramya *et al*., 2011). There are about 9,000 species of seaweed macro-algae broadly classified into three main groups based on their pigmentation; *Phaeophyceae* (brown), *Rhodophyceae* (red), and *Chlorophyceae* (green)(Anderson, 2009; Khan *et al*., 2009). Red algae are the most abundant group of seaweeds being approximately 4000 species in number and commonly used in agriculture followed by brown seaweeds comprising about 2,000 species (McHugh, 2003). Majority of the commercially available seaweed fertilizers are made from brown algae, *Ascophyllum nodosum*, the only species in the family *Phaeophyceae* (Anderson, 2009; Craigie, 2011). Throughout centuries seaweeds have been used for domestic purposes (fuels, animal feed, human food, medicine, fertilizers) and industrial use (production of soda, iodine, alginates and carrageenans). Seaweed as fertilizer or manure enriching poor soils with minerals and growth hormones and in particular seaweed manure was important in areas with poor soils in Britain, France, Spain, Japan and China and is an ancient practice with the Romans (Khan *et al*., 2009; Thirumaran *et al*., 2009).

Global seaweeds production in 2013 was estimated at 26,978 tonnes valued at approximately USD 6 billion, with China leading with 50% of the total production, followed by Indonesia (35%), Phillipines (6%), Republic of Korea (4%) and the rest of the world making up the 5% (FAO, 2015). Seaweed is harvested from the wild sea along coastlines and in aquaculture from inland or off- shore farms (Amosu *et al*., 2013). Wild harvesting from the coastline has been estimated to be over 1 million tonnes globally (FAO, 2015). In Africa, seaweed cultivation has not been fully exploited despite African continent being the second largest after Asia with a coastline streatching to over 30,000km and rich seaweed diversity due to underdeveloped markets (Amosu *et al*., 2013). Africa produced 138,989 tonnes of seaweed in 2010 with Tanzania, Madagascar, South Africa, Mozambique and Namibia as the leading producers respectively (FAO, 2012). 29 countries spread in the north, south, east and west of Africa including islands cultivate seaweeds. In North Africa, Morocco leads in the number of species cultivated, followed by Libya, Tunisia, Western Sahara and Sudan with 178, 87, 81 and 18 speciesrepectively (Amosu *et al*., 2013). Morocco has a well established seaweed industry, growing *Gelidium species* for agar extraction because it is very near to Europe which provides a ready market (McHugh, 2003). In West Africa, 112 to 241 species have been identified for commercial cultivation with Senegal having the highest number of 241. In East Africa, seaweeds grow along the coastline from Somalia (403 species) to Mozambique (243 species) and also along the coastline of Madagascar (207 species) with cultivation concentrated in Tanzania (FAO, 2012). Species cultivated include *Euchema denticulatum* and *Kappaphycus alvarenzii* which are imports from the Phillipines for production of carrageenans (FAO, 2012). Cultivation of seaweed has exponentially increased in South Africa with S. Africa leading in production by 2012 cultivating 900 species utilized mainly in feed formulations. Significant seaweed industries exist in S. Africa and Namibia for production of agar from *Gracilaria* and *Gelidium* spp and Kelp (*Ecklonia* and *Laminaria*) for alginate production for Abalone industry. Harvesting *Ecklonia maxima* and *Laminaria pallida* began in 1940s although commercial production began in 1950s to supply agar to Japan when their sources failed (Amosu *et al*., 2013). From 1950s when commercial seweed production began in South Africa, only 6 seaweed genera have been harvested and exported for manufacture in the phycocolloid industry which includes *Ecklonia, Laminaria, Gracilaria, Gelidium and Poyphra*. Kelp has also been harvested from 1975 to make Kelpak® and AfriKelp® which are plant growth stimulants (FAO, 2012). Powdered Kelp has been exported to Japan to make fish feeds. Kelp harvested as fresh feed is used to culture Abalone in S. Africa. Other species in commercial production include *Gelidium pristiodes, G. pteridofolium* and *G. abbottiorum* which have been exported for agar production. One of the earliest patents was applied for by Plant Productivity Ltd, a British company, in 1949. Today there are several products and brands available, such as Maxicrop (United Kingdom), Goëmill (France), Algifert (Norway), Kelpak 66 (South Africa) and Seasol (Australia) (McHugh, 2003; Thirumaran *et al*., 2009).

2.5.2 Benefits and Uses of seaweed extracts

Seaweed extract is a sustainable resource, natural, edible, biodegradable, non-calorific and not genetically modified (McHugh, 2003; Khan *et al*., 2009) bio-chemical.Currently, more than 70 per cent of total seaweed produced is consumed directly, either dried or fresh in form of sushi, salads, soups, desserts and condiments and the remaining 20 per cent is utilized in phycocolloids extraction for use in food, industrial, cosmetic, and medical industry (McHugh, 2003)and in animal feed additive, fertilizer, water purifier, probiotics in aquaculture and for biofuel (Kim *et al*., 2014). Carrageenan and agar are extracted from red seaweedswhile alginates and fucoidans are extracted from brown seaweeds, generally from kelp species. Industrial use of seaweed is expanding with the kelp species *Saccharina lattisima* being considered for bioethanol production (Adams *et al*., 2009).Seaweed products are sold in concentrated form, are easy to transport and apply, are dilute, and mode of action is more rapid.Seaweeds utilized in agriculture have been estimated at 1% of the current seaweed industry and the potential has increased particularly after research work has been done over the years on the positive effects on plant growth (Thirumaran *et al*., 2009). Seaweeds have been applied to soils as manure or soil conditioners and greatly improved the growth, health and yields of crops. It is believed that seaweeds provide essential nutrients, improved soil texture or water holding capacity of the soil (Craigie, 2011).

2.5.3 Composition of seaweed extracts (SWEs)

Phyto-hormones

Cytokinins are a class of plant hormones or phyto-hormones that trigger cell division in shoots and roots of plants (Craigie, 2011). They promote seed germination, cell growth and differentiation, cause apical dominance, axillary & shoot initiation and growth, nutrient uptake, influences sink-source relationship, bud development, leaf senescence as well as plant interaction with biotic and abiotic factors (Khan *et al*., 2009). The cytokinins present in seaweed formulations include trans-zeatin, trans-zeatin riboside, and di-hydro derivatives of these two forms with the pre-dominant types being zeatin (Z) iso-pentenyl (IP), and conjugates of cytokinins (Chojnaka *et al*., 2012). In addition, there are aromatic cytokinins BAP (benzyl amino purine) and topolin (6-[3-hydroxybenzyl-amino] purine) derivatives (Gawronska*et al*., 2008). Auxins are naturally occurring plant hormones or phyto-hormones that stimulate different behaviors and growth processes in plants in response to light or gravity stimuli (Zhao, 2010). Auxins are produced in apical buds and transported down the shoots preventing formation of axillary buds, promotes shoot growth but restricting lateral branching, enhance initiation of adventitious roots, promotion of uniform flowering and fruit set while preventing premature fruit drop (Khan *et al*, 2009; Zhao, 2010). Naturally occurring auxins in plants include 4-chloroindole-3-acetic acid, phenyl acetic acid, indole-3-butyric acid, and indole-3-propionic acid with the most important group of auxins in plants being indole-3-acetic acid (IAA). An *Ascophyllum nodosum* extract had as high as 50 mg IAA (indole acetic acid) per gram of dry extract. Khan *et al*. (2009) found four amino acids and three conjugates of IAA in the extracts of two seaweeds, *Ecklonia maxima* and *Macrocystis pyrifera*.

Vitamins

Vitamins are biochemical compounds that are essential in plant processes which act as intermediates or catalysts (Morales-Payan., 2011). SWEs have been shown to contain vitamins A, B, C, and E6 and vitamin B12 which is normally found only in animals (Thirumaran *et al*., 2009). Thiamin (Vitamin A) serves as a factor in enzymatic reactions including pentose phosphate pathway, glycolysis, tri-carboxylic acid cycle, pyruvate dehydrogenase complex, trans-ketolase, and pyruvate decarboxylase (Goyer, 2010). Thiamin is associated with cytokinins present in SWEs and induces callus growth and rooting hence the improved effect on root growth (Abrahamian and Kanthrajah, 2011).

Glycine betains (GB)

Seaweed extracts (SWEs) have been found to contain various classes of betains such as glycinebetaine, β-alaninebetaine, γ-aminobutyric acid betaine, laminine, prolinebetaine, trans-4-hydroxyprolinebetaine, homarine and δ-aminovaleric acid betaines isolated using thin layer chromatography and nuclear magnetic resonance (NMR) techniques (Shawna *et al*., 2010; Khadouri, 2015). Betaines are organic amphoteric quartenary amines of low molecular mass or osmolytes synthesized or absorbed externally by cells to safeguard the plant against abiotic stress such as frost, soil acidity, ultra violet radiations, heavy metals absorption, toxicity from nutrients or salts, osmotic stress, drought, salinity or extremes of temperatures through restricting water loss from cells (Craigie, 2011). Glycine betaines are synthesized in chloroplast from serine tocholine through ethanolamine, and betaine aldehyde. Choline is converted to betaine aldehyde, by choline mono-oxygenase, which is then converted to glycine betains by betaine aldehyde dehydrogenase (BADH) (Ashraf and Foolad 2007). Glycine betaines are extremely soluble in water and serve as compatible solute either by being prevented from bonding with a protein so that layers of water within the cell are maintained around the surface of the protein or the hydrophobic portion of GB binds to the hydrophobic domains of the protein, from which bound water is readily released when there is a water deficit, hence maintaining the osmotic pressure. (Khadouri, 2015). GB allows the hydrophobic domains of the protein to become more accessible to water, preventing the protein from drying out hence altering the structures of proteins. (Fan *et al*., 2011).

Polysaccharides

Seaweed extracts (SWEs) have been found to contain large amounts of insoluble carbohydrates/polysaccharides which act as soil conditioners. Seaweeds, particularly the red and brown algae, are a source of unusual and complex polysaccharides which are not present in terrestrial plants (Chojnaka *et al*., 2012). For example, the brown seaweeds *Ascophyllum nodosum, Fucus vesiculosus,* and *Saccharina longicruris* contain the polysaccharides laminarans, fucoidans, complex mucilages and alginates (Khan *et al*., 2009). Of these three polysaccharides, laminaran and fucoidans exhibit a wide range of antiviral and antibacterial responses (Rioux *et al*., 2007). Alginates have been found to promote growth of symbiotic fungi in soils and have thickening, stabilizing colloidal properties. Alginic acid from alginates undergoes degradation to produce alginate oligosaccharides which stimulates hyphal growth, elongation and colonization of arbuscular mycorrhizal fungi (Kuwada *et al*., 2006). Alginates have also been found as chelating agent where they facilitate easy entry of ionic compounds into the plant but can also be used to rid soils of heavy metals (Khan *et al*., 2009). Alginates occur in cell walls as mixed salts of major cations such as Na, Ca, Mg, and K which combine with metallic ions in the soils to form high molecular weight complexes that absorb and retain moisture hence improving the soil structure and soil moisture content (Khan *et al*., 2009).Mannitol is the major chelating agent in kelp (a group of large sea algae) and has the capacity to naturally chelate all the cations present in seaweed (Craigie, 2011). Galactans, agars and carageenans are found in cell walls of red algae and have been found to exhibit anti-coagulating and antiviral properties as well as act as natural soil chelators and improving water holding capacity in addition to root elongation (Chojnaka *et al*., 2012).

Minerals

Seaweed extracts (SWEs) derived from algae are a rich source of minerals containing up to 40% of the dry matter of the algae (Chojnaka *et al*., 2012). Algae accumulate metal ions in their fronds as carbonate salts from sea water which is usually salty. Seaweed extracts (SWEs) have macro and micro-nutrients available although the quantities may not be similar to inorganic fertilizers (Chojnaka *et al*., 2012). Macro nutrients available include nitrogen, phosphorus, potassium, calcium, magnesium and sulphur while micronutrients are mainly iron, manganese, molybdenum, copper, zinc, boron and cobalt (Du Jardin, 2015). Algae were reported to contain 2.7g/l of potassium, and 0.2g/l of magnesium and calcium in *Sargassum ringgoldianum* and 1.2g/l of sodium in *Codium fragile*. Higher levels of magnesium and calcium of 581.2 and 460.1mg/l respectively were detected in *Kappaphycus alvazzeri* (Chojnaka *et al*., 2012). Minerals in SWEs have been found to be many times more plant-available in the chelated form than in the ionic form.

2.5.4 Mode of action of seaweed extracts (SWEs)

Abiotic stressessuch as drought lead to morphological and biochemical changes to help the plants to survivefor example stomatal closures, decreased number of stomata, formation of thick leaf cell walls, reduced leaf size, rolling of leaves, increased root mass, production of organic acids (proline,aspartic acid and glutamic acid), glycine betaines and sugars, oxidative reactions which produce reactive oxygen species such as superoxide and hydrogen peroxide(Anjum *et al*., 2011). Stomatal closures lead to reduced moisture loss and restricts gaseous exchange resulting to low photosynthesis rates, low biomass accumulation causing reduced growth rates while accumulation of reactive oxygen species (ROS)destroy DNA, lipids, carbohydrates and proteins which are the building blocks of organic substances and their derivatives in plants leading to early plant senescence (Khan *et al*., 2009). Plant cells accumulate cellular concentration of osmotically active compounds (compatible solutes or GBs) which serve to stabilize proteins, protein complexes or membranes which alleviate inhibitory effects of high ion concentrations on enzyme activity in abiotic stresses (Giri,2011).These compatible solutes work to prevent breakdown or denaturing of protein compounds, reduce water loss from cells hence maintaining cell integrity and protect break down of photosynthetic apparatus thus plant is able to continue metabolic processes, though at a lower rate leading to low biomass accumulation (Khadouri, 2015). Seaweed extracts (SWEs) contain cytokinins which get mobilized from the roots to the developing plant part or improve the amount or synthesis of endogenous cytokinins which protects the pigments such as chlorophyll from degradation and restricts water loss. They also mitigate stress-induced free radicals by direct scavenging of reactive oxygen species (ROS) and prevent their formation through inhibiting xanthine oxidation (Khan *et al*., 2009). This leads to lengthened plant life in field conditions because of prolonged photosynthesis process taking placeleading to accumulation of biomass in crops (Craigie, 2011). Glycine betaines in SWEs work as osmolytes preventing water loss,aid in maintaining cell integrity and improving growth and development of plants, retain leaf chlorophyll content and improve plant's resistance to frost, protect lipids, proteins, nucleic acids and other macro molecules from disintegration during abiotic stresses (Anderson, 2009;Fan *et al*., 2011; Giri, 2011). Polysaccharides present in SWEs applied to soils have been found to enhance the water retentive properties of the soil during drought besides helping to bind soil particles together through gel formation, fixation and exchange of cations, fixation of heavy metals thus playing a crucial role in soil remediation, enhancing growth of soil microflora (Du Jardin, 2015). They also improve soil aeration and structure, especially in clay soils hence increasing soil moisture retention properties and promoting the growth of beneficial soil microbes while improving proper root growth (Khan *et al*., 2009; Craigie, 2011). Studies done showed that drought-stressed plants treated with a combination of humic acid and seaweed extracts had root mass enhanced by 21–68%, foliar tocopherol by 110%, and endogenous zeatin riboside by 38% (Thirumaran *et al*., 2009; Fan *et al*., 2011).

Seaweed extracts (SWEs) have also been shown to enhance defense mechanisms against pests and diseases (Chojnacka *et al*., 2012). Seaweed extracts are important sources of plant defense elicitors such as polysaccharides, peptides, proteins and lipids found mostly in cell walls of attacking pathogens. In addition, SWEs enhances quorum sensing in plants (a communication mechanism used by bacterial populations that are dependent on cell density which triggers and controls gene expression that regulates various physiological functions and responses (Koh *et al*., 2013). According to Grimmer (2011), a seaweed extract, Kelpak® was applied to crops infested with nematodes where the SWEs did not control the nematodes but rather induced new root growth to compensate for the loss of root mass caused by the root knot nematodes.Application of SWEs to a cabbage crop led to stimulated plant growth and activity of microbes antagonistic to *Pythium ultimum* that causes damping-off disease. Aphids and sap feeding insects generally avoided plants treated with SWEs according to Craigie (2011). Hydrolyzed SWEs were sprayed onto apple trees and they reduced red spider mite (*Tetranychus urtica*) populations significantly to a level of control similar to that of acaricides (Khan *et al*., 2009). It has been reported in Craigie (2011) that there was a significant reduction in black bean aphid (*Aphis fabae*) infestations on broad bean leaves sprayed with Maxicrop® compared to water sprayed control.

2.6 Composition of humic substances

Humic substances are organic compounds produced by microbials as a result of decaying material of plant or animal origin and are made up of proteins, carbohydrates, portions of lignin, suberins, cutins and cellulose (David *et al.*, 2014). They are naturally present in soil organic matter, humus, thus contributes to soil chemical and physical quality hence reffered to as soil humic acids (Van tonder *et al.*, 2008). Humic substances consist of three main fractions; humic acids, fulvic acids and the natural salts of these acids (humates), and sponge-like substances called humins. They are found in large quantities in brown coal, peat, sapropel and other organic matter (Petrus *et al.*, 2010). Humic acids is the brown black polymeric alkali soluble acids found in soils, plants, sea grasses, fungi, sediments, sewage, manure, compost, peat, carbonaceous shales, brown coal, terrestrial and marine waters (Susic, 2008).Humic acids is not soluble in water under acidic conditions (pH < 2), but is soluble at higher pH values. Fulvic acid, ranges from light yellow to yellow-brown in color and is soluble in water under all pH conditions while humins are black in color, not soluble in water at any pH or in any alkali solution (Petrus *et al.*, 2010). Fulvic acids dominate forest soils, sediments and aquatic ecosystems whereas humic acids are mainly found in grassland soils (Van tonder *et al.*, 2008). Humic acids are reported to be high molecular weight substances while fulvic acids are humic substances of low molecular weightand higher oxygen content found to be very beneficial to above and below ground growth of plants since they increase soil fertility (Susic, 2008). Most humic substances are salts of natural humic acids with a hydrogen ion of carboxyl and hydroxyl groups exchanged for a metal such as sodium humates, potassium humates or ammonium humates (Van tonder *et al.*, 2008).For commercial purposes, humic acids are extracted from leonardite, an oxidized form of lignite (Craigie, 2011). Leonardite, named after Dr. A.G. Leonard, first director of the North Dakota Geological Survey, in recognition of his work on these deposits, is a dark coloured ultra-fine powder, colloid shaped granules and shiny, oxidized product of lignite (Susic, 2008). Leonardite possesses high humic substance content (>60%) as a result of being highly decomposed by micro-organisms therefore associated with near-surface lignite (Van tonder *et al*., 2008). Leonardite is derived from coal originating from plant matter and may be applied directly on to the land as humic acid or as humates. Leonardite has been found to condition the soil workability and therefore increases soil aeration, capillary and non-capillary space, cation exchange capacity and improves retention of applied inorganic fertilizers (Susic, 2008). This enhances soil microbial activities, retains carbon in the soils, reduces uptake by plants of metals in contaminated ground and may be applied in compost in case of contamination to prevent uptake of toxic metals by plants. (Van tonder *et al*., 2008). Demand for humic acids in agriculture and the need to conserve the natural resurce, coal, led to industrial manufacturing of synthetic humic acids refferd to as commercial humic acids. Commercial humic acids are not similar to soil humic acids because they do not contain biological properties such as proteins and polysaccharides but have some fulvic acids (Susic, 2008). They also have higher carbon content compared to soil humic acids which indicates that they will be less soluble and are believed to accomplish the normal functions of organic matter and thus reducing the bulk application of the organic matter (Susic, 2008; Petrus *et al*., 2010). Humates have been commercialized as Earthlee®, Black magic® (organic ultra-concentrated humate powder), Agrolog® (humic acid in organic matter), Humistar® (humic and fulvic acids), Humical® (humic acids, fulvic acids, Calcium oxide with EDTA) among others.The global market for humic substances was valued at USD 325 million with the projection of USD 674 million by 2020 (Anon, 2015).The largest market share is Europe (Spain, Italy, Germany, France, UK) who were early adopters of organic farming while biggest manufacturer is China (Anon, 2015).

2.6.1 Role of humates in plant growth

Humates improve soil properties making them friable, buffers soil pH and allows the soil to swell with moisture, complexes with trace elements making them more available to plants, and releases bound nutrients such as phosphates from clay and also form complexes with iron and aluminium which, when in excessive amounts (Susic, 2008). Humates combine with large quantities of carbon which promote healthy soil ecosystem in which beneficial soil microorganisms thrive in addition to providing the indigenous microbes with carbon source (Gawronska *et al*., 2008). Soil microbes solubilize vital nutrients such as phosphorus which are then adsorbed on humic acids fractions making them available to plants (Prakash, 2011). Humic acids in humates interacts with calcium, magnesium, aluminum and iron forming organic mineral bridges binding soil particles into certain structures able to resist soil, water and wind erosion (Susic, 2008). They also form insoluble substances with heavy metals thus creating a barrier to their penetration into plant cells and later into humans and animal bodies which is a health hazard (Susic, 2008).

Humic acids and fulvic acids applied to clay soils as humates break up clays and compacted soils enhancing water penetration and better root growth and development (Halpern *et al*., 2015). In sandy soils, they add essential organic material, enhance water retention and prevent leaching out of nutrients besides enhancing uptake of micronutrients thus improving nutrient uptake promoting plant growth. Humic acids improves accessibility and availability of nutrients, promotes gaseous exchange of carbon and oxygen in the rhizosphere and atmosphere (Calvo *et al*., 2014), increase permeability of the membranes for ease of nutrient uptake such as nitrates, maintenance of membrane permeability and enhanced anti-oxidative activities that would otherwise accelerate plant senescence under drought stress conditions in addition to promoting seed germination and growth of soil microbes (El-Nemr *et al*., 2012). Humic acids also improve nodulation through availing the element P through promoting soil microbial activity where P is solubilized and adsorbed on humic fractions making them available to plants. Release of protons under P deficiency facilitates acquisition of P from the rhizosphere especially in calcareous soils, neutral or acid soils. Humic acids were found by Halpern *et al*. (2015) to increase the development of root hairs. Phosphorus availability has been enhanced also through humic acid interaction with macro and micro elements forming organic metal-humic bridges and through soil buffering (Halpern *et al*., 2015). Regular use of humic acids is believed to reduce fertilizer use in the long run due to buildup of soil structure and fertility and enhanced plants' ability to make better use of the fertilizer or can also be entirely eliminated if sufficient organic matter is present in the soil (Van tonder *et al*., 2008). Humic acids are reported be effective in converting iron into available forms hence protecting plants from chlorosis even in the presence of high concentration of phosphate ion (Du Jardin, 2015). Grapes increased uptake of Fe and P (Sanchez-Sanchez *et al*., 2006) and pepper, pear and cucumber also were reported to have increased uptake of N, P, K, Ca and Mg after application of humic acids infield conditions (Cimrin *et al*., 2010; El-Nemr *et al*., 2012). Further studies done showed that application of humates to crops led to increased yields of grapesby increase 25% and that of cotton and corn by 11.2 % (Motier, 2012).Fulvic acidsalso have been reported to improve iron uptake in calcareous soils in rice (Calvo *et al*., 2014), in lemon and in maize (Anjum *et al*., 2011).

2.7 Bio-stimulators in Kenya

In Kenya, bio-stimulators have been used widely in agriculture with the sole purpose of increasing crop yields in quantities and quality sustainably. Majority of the bio-stimulators that have been used include bio-pesticides and bio-fertilizers which have been legally released through Pest Control and Produce Board (PCPB) of Kenya and used in crop protection and enhancing soil fertility (Anon, 2016b). Bio-pesticides have been defined as bio-chemicals extracted from plants, semio-chemicals, microbials or macrobials/natural enemies used to control pests, do not persist in the environment and with little or no residue effect hence safe to even waterways (Kimani, 2014). Use of bio-stimulators in Kenya has been estimated to be below 2% and currently it's concentrated mainly in large scale farms (Anon, 2016a). Currenly there are 52 products and 140 agents and distributors in the country among them Kenya Biologics Limited, Dudutech®, Green Life®, Koppert Biological Systems (K) Limited, Organix (K) Limited and chemical companies such as Osho chemical Company (Anon, 2016a).Some of the bio-stimulators used in Kenya incude bio-fungicides (Real *Bacillus subtilis,* Real Trichoderma®, Campaign®, Achieve®, Trianum® among others (www.icipe.org) and bio-fertilizers include Biofix® (www.mea.co.ke), Plantone® and Wokozim® (www.oshochem.com), Achook®, Nhance® (formerly Kelpak) and Earthlee®. Kelpak® (*Ecklonia maxima*) [11mg of auxins and 0.031mg of cytokinins] (www.organix-agro.com)has been used in production of cereals and vegetables in Kenya although scientific data that is available shows only trials done to produce seed potato mini-tubers in glasshouses in KARI Tigoni station and ware potato in farmers' fields in Limuru (KARI, 2005). In mini tuber production, 3ml and 4ml /l of Kelpak wereapplied as soil drench in *in-vitro* plantlets transplanted in potsto produce miti-tubers, followed by foliar sprays every 2 weeks until flowering. It was found out that Kelpak reduced transplant shock and increased mini-tuber production by 6% when sprayed with 4ml/l. In Potato field production, Kelpak® was sprayed 30 days after crop emergence followed by a second spray 15 days later just before flowering of the crop (KARI, 2005). Observations done showed that plots treated with Kelpak had more vigorous growth and remained green for an additional ten days compared to plots not treated with Kelpak. Potassium humates and Kelpak were further evaluated in KARI Tigoni during 2009-10 season. The treatments consisted of DAP (18:46:0) at 500 kg ha^{-1}; Kelpak (11mg/litre of auxins and 31µg/litre of cytokinins) at 5 ml^{-1}, *Earthlee®* (80% humate powder) at 200 kg ha^{-1}, DAP (18:46:0)at 500kg ha^{-1} plus *Earthlee®* (80% humate powder), DAP (18:46:0)at 500kg ha^{-1} plus Kelpak (11mg/litre of auxins and 31µg/litre of cytokinins) at 5ml l^{-1};and DAP (18:46:0)at 500kg ha^{-1} plus

Kelpak (11mg/litre of auxins and 31µg/litre of cytokinins)at 5 ml l^{-1}plus *Earthlee*® (80% humate powder) at 200kg ha^{-1} and zero fertilizer (control). Kelpak was applied by dipping tubers into the Kelpak solution of 5ml l^{-1}at planting followed by three subsequent foliar fertilizers applied every two weeks starting at emergence until flowering while *Earthlee*®was applied by coating on DAP before planting. DAP with Kelpak produced 15% more marketable tubers compared to DAP alone and 95% more than Control (KARI, 2005; Oyoo *et al*., 2010). On the other hand, biofix is the oldest commercial microbial inoculant developed to improve biological nutrient fixation in legumes in boosting soil fertility in Kenya (Wafula, 2013). Biofix was inoculated on soybean and increased yields by between 15-30% (Majengo *et al*., 2016)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experimental site

The study was conducted in Katumani, Machakos County and at Jomo Kenyatta University of Agriculture and Technology, Juja in Kiambu County between May and August, 2013and October to December, 2014. JKUAT lies at an altitude of 1525m above sea level and latitude of 1º 10' 48' S, long. 37º 07' 12' E. Rainfall amount in this area ranges from 600-800 mm annually with average temperatures of 25ºC. The rainfall is also bimodal falling between March-June and October-December. The soils in Juja in the experimental site were sandy clay loams with more clay content, dark in colour similar to black cotton soil. The soils in the area Katumani lies at an altitude of 1575 m above sea level and latitude of 01º 35' S and 37º 14' E in agro-ecological zone IV/V. Rainfall amount in the area ranges from 500 - 700 mm per year with mean maximum and minimum temperatures of 24.7ºC and 13.9ºC, respectively. Rainfall is bimodal falling between March to July and October to February. The area's soil types are sandy clay loams classified as chromic luvisols (Jaetzold *et al*., 2006).

3.2 Planting materials

Four dual purpose cowpea varieties were purchased from Kenya Agricultural and Livestock Research Organization (former Kenya Agricultural Research Institute, KARI) Katumani Seed Unit

3.3 Source of bio-stimulators

Bio stimulators which consisted of Kelpak® (11mg of auxins and 0.031mg of cytokinins) and Earthlee® (80% potassium humates powder) were purchased from Organix Kenya Limited. Rhizobium strains commercially packed as Biofix® specific to cowpea were purchased from Mea Limited.

3.4 Experimental design

The treatments were designed in factorial structure laid out in randomized complete block design andreplicated thrice. The layout was a combination of fourcowpea varieties, planted in 2 sites and 9 levels of bio-stimulators giving a total of 36 treatments for each replicate (Table 3.1).

Table 3.1: Sites, varieties and treatments

Sites
1. Juja
2. Katumani
Cowpea varieties
1. K80
2. M66
3. KVU 27-1
4. Kenya Kunde
Bio-stimulator levels
1. Sole Seaweed extract (SWE) basal application
2. Sole Seaweed extract (SWE) foliar spray
3. Sole Biofix
4. Sole humates
5. Humates+ SWE basal application
6. Humates + SWE foliar spray
7. Humates + SWE basal application + SWE foliar spray
8. SWE basal application + SWE foliar spray
9. Control

3.5 Land preparation, treatment application and crop management

The land was thoroughly ploughed and harrowed with a tractor in Katumani to a fine tilth while in Juja it was partly prepared using a tractor and partly manually using hoes. Two cowpea seeds were sown per hill at the spacing of 60cm by 20cm. Weeding was done thrice in Katumani and Juja. Common pests were black aphids, caterpillars and birds in Katumani and only aphids in Juja. Pests were controlled by spraying Fastac® (alpha-cypermethrin) and Cyclone® (cypermethrin 10%+chlorpyriphos 35%) insecticides alternatively while birds were physically chased away (Karanja *et al.*, 2006). Bio-stimulator basal treatments were applied in the holes during planting while foliar sprays which were done weekly at seedling stage.

3.6 Data collection

Each plot had five rows which were 2.5m long. The two outer rows were regarded as guard rows hence discarded. Ten plants were randomly selected within the inner 3 rows, tagged and used to measure different parameters.

3.6.1 Plant growth

Data was obtained for days to emergence by recording the date of 50% emergence in the field, rate of emergence by physically counting number of plants in every plots that had emerged two weeks after planting, divided by the total number of seeds sown and multiplied by 100 and survival rate by physically counting number of plants in every plot two weeks after planting.

Plant height, stem thickness and chlorophyll levels

Plant height was taken by measuring the whole plant from the ground level to the tip using a meter rule. Stem thickness was measured every week using a veneer calipers on the tagged plants. Chlorophyll levels in the field were taken using the SPAD 502 Plus Chlorophyll meter, sincethe readings taken have been found to correspond to field chlorophyll levels at thatparticular time. 10 samples of the readings were taken from each plot and chlorophyll levels determined for each plot by obtaining the average of the 10 samples.

3.6.2 Root length and nodulation

Root length

Root data was taken from week 5 to week 8. Five plants sampled in each plot every week were dug up for destructive sampling of the root length. The plant that was sampled was dug upwithin 5cm radius together with the roots. The plant was placed on a clean surface where excess soil was carefully shaken off the rootsbecause it was manily of sandy nature and other plant debris or old roots were removed. The root length was taken by measuring from the ground level on the plant to the tip of the root using a metre rule. Measurements were recorded in centimetres (cm).

Nodulation

Nodulation in legumes has been found to begin 28 days from plant emergence (Ramya, 2011). Data for root nodulation was taken 35, 42 and 56 days from plant emergence, corresponding to weeks 5, 6 and 8. The plants which were uprooted to measure root length were also used to count the number of nodules formed.

3.6.3 Production of leaves, leaf area and leaf weight

Number of leaves on each plant was physically counted weekly and recorded from week 3 to 8, which coincides with the shift from vegetative to reproductive phase. Counting was done on thrity plants which were sampled from the three inner rows, ten from each row and tagged. To obtain the leaf weight, leaves were harvested in every plot 3 weeks from planting. At this stage, plants had 2 to 3 trifoliate leaves. The first and second trifoliate leaves were harvested. The harvested leaves were bagged in self-sealing polythene bags and stored in cool boxes to remove field heat and leaves from every plot were weighed. Leaves at this stage are what growers harvest for vegetable use (Saidi *et al*., 2010). The leaf area of the harvested leaves was measured by a leaf area meter (model 3100 LICOR Lincoln Nebraska. USA). The total area was then divided by ten to obtain individual leaf area in square centimetres.

3.6.4 Production of cowpea seeds

Data on days to flowering and pod formation were done when 50% of the plant population had flowered and podded. Number of pods per plant was counted physically, length of the pods was obtained by measuring physically from the tip to the peduncle using a meter rule every week for three weeks from the ten plants sampled randomly and tagged within the plot and the data recorded for every plot. The mean of the data from ten plants obtained was taken to be the number of pods and length of pods (cm) per plot. All the pods were harvested from each treatment when physiologically mature and foliage is drying. The number of seeds was obtained by splitting the pods and counting all the seeds found for every plot. The average number of seeds per pod was obtained by getting the mean. The total weight of seed was determined by counting 100 seeds per sample from the tagged plants, weighed and recorded for every treatment. The meanwas obtained from the average of the 100 seed weight samples.

3.7 Data analysis

Collected data was entered into Microsoft excel spreadsheet and organized for analysis. Data was analyzed using GenStat statistical package 14th editionwhere analysis of variance was determined for all the parameters (Genstat, 2012). Fisher's protected Least Significant Difference (LSD) test at 95% confidence interval was done for separation of means for treatment means that showed significant differences.

CHAPTER FOUR

RESULTS

4.1 Performance of sites

There were significant differences between sites in days to emergence, rate of emergence, survival rate and chlorophyll levels (Table 4.1) and plant height (Figure 4.1) but not in leaf area, root length or stem thickness (Table 4.1; Figure 4.2) at $p \leq 0.05$. This could be due to differences in weather conditions and soils in the sites.

4.2 Performance of bio-stimulators

Bio-stimulators were significantly different in rate of emergence, days to emergence, survival rate, and leaf area but not in chlorophyll levels, leaf weight, plant height or stem thickness at $p \leq 0.05$ (Table 4.2, Figure 4.1 and 4.2).

4.3 Performance of Varieties

Varieties were significantly different in days to emergence, rate of emergence, survival rate and leaf area but not in chlorophyll levels and leaf weight at $p \leq 0.05$ (Table 4.1).

4.4 Contrasts in bio-stimulators between sites

Contrasts between treatments showed bio-stimulators to be significantly different from control between Juja and Katumani in days to emergence, rate of emergence, survival rate, root length, number of nodules formed and number of leaves produced at$p \leq 0.05$ (Appendix 2 and 3). Contrasts between humates and SWE basal application showed significance in rate of emergence, days to emergence, survival rate, number of nodules formed and number of leaves. Contrast between humates and biofix performed differently between sites in rate of emergence, survival rate and number of leaves formed (Appendix 4 and 5). Additional SWE foliar spray in the treatment of SWE basal application with foliar spraydid not have significant impact compared to when the foliar spray is applied in combination withhumates. (Appendix 5)

4.5 Plant growth

Earliest emergence was in Katumani while highest rate of emergence, survival rate and chlorophyll levelswere in Juja (Table 4.1). Humates+SWE basal application recorded the earliest emergence of four days followed by humates+SWE basal application+SWE foliar, SWE basal application+SWE foliar and SWE foliar of five days (Table 4.1). SWE basal application+SWE foliar had the highest rate of emergence (57%) and survival rate (66 plants).The highest cholorophyll levels was observed in SWE basal application (Table 4.1).K80 had the highest rate of emergence, survival rates and chlorophyll levels while KVU 27-1 was the earliest to emerge in six days (Table 4.1).

4.5.1 Effect of bio-stimulators on plant height

Plant height was significantly different between sites from week 3 to 8 at $p<0.05$ (Figure 4.1). Plant height was longest in Juja from week three to eight. Katumani had longest plants in the second week (Figure 4.1)

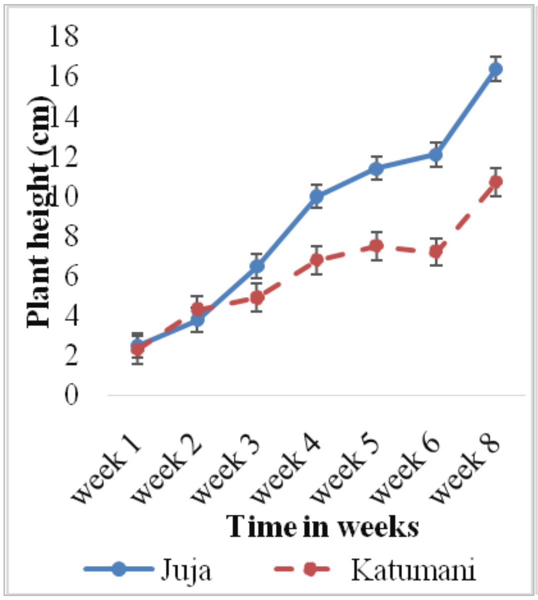
4.5.2 Effect of bio-stimulators on stem thickness

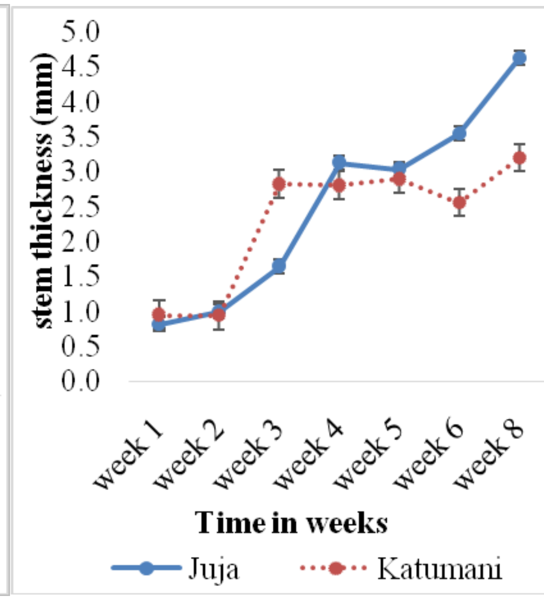
Stem thickness was not significantly different between Juja and Katumaniat $p\leq0.05$ (Figure 4.1). From week two to week three, stems were thicker in Katumani while in Juja, they were thicker from week 6 to 8 (Figure 4.1).

Table 4.1: Performance of different parameters in sites, biostimulators and varieties

Sites	**Days to emergence**	**Rate of emergence**	**Survival rate**	**Chlorophyll levels**
Juja	8^{a}	60^{a}	70.4^{a}	54.4^{a}
Katumani	5^{b}	29.2^{b}	34.4^{b}	48.9^{b}
Mean	**6**	**45**	**52.4**	**51.6**
LSD	0.8	4.9	6.1	2.7
P	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$
Bio-stimulators				
Biofix	10^{c}	32^{d}	37^{d}	48.6^{c}
Control	9^{bc}	43^{bcd}	51^{bc}	52.9^{ab}
Humates	7^{b}	41^{bcd}	49^{bcd}	47.8^{bc}
Humates+SWE basal application	$\mathbf{4^{a}}$	48^{abc}	56^{abc}	51.7^{abc}
Humates+SWE basal application+SWE foliar	5^{a}	48^{abc}	54^{abc}	52.9^{ab}
Humates+ SWE foliar	8^{b}	39^{cd}	47^{cd}	51.8^{abc}
SWE basal application	5^{a}	52^{ab}	62^{ab}	$\mathbf{54.7^{a}}$
SWE basal application+ SWE foliar	5^{a}	$\mathbf{57^{a}}$	$\mathbf{66^{a}}$	54.3^{a}
SWE foliar	8^{b}	43^{bcd}	51^{bc}	49.9^{abc}
LSD	2	10.6	13	5.6
P	$<.001^{***}$	$<.001^{***}$	0.002^{***}	0.19^{ns}
Varieties				
K80	6^{a}	$\mathbf{50.7^{a}}$	$\mathbf{59.3^{a}}$	$\mathbf{55.2^{a}}$
Kenya Kunde	6^{a}	38.4^{b}	44.0^{c}	52.2^{c}
KVU 27-1	$\mathbf{6^{a}}$	44.2^{ab}	51.6^{b}	52.0^{d}
M66	7^{b}	47.2^{a}	55.1^{b}	54.5^{b}
LSD	1	7.1	3.1	3.8
P	0.05^{*}	0.001^{***}	0.01^{*}	0.15^{ns}
Mean	**6**	**45**	**52**	**53.5**

*** - highly significant, *- significant, NS- not significant at p≤0.05; Means followed by the same letter are not significantly differentat p<0.05*



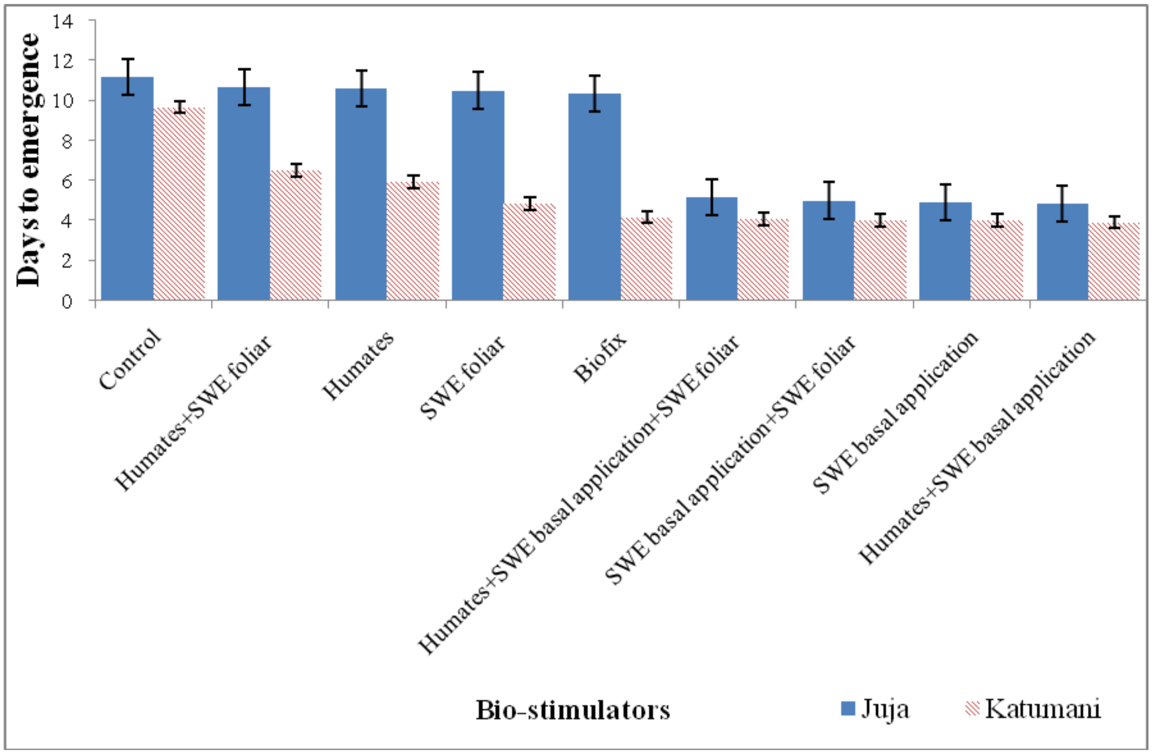


Error bars signify SE of means at p≤0.05 *Error bars signify SE of means at p≤0.05*

Figure 4.1: Plant height (left) and stem thickness (right) in Juja and Katumani over time

4.5.3 Effect of bio-stimulators on days toemergencein Juja and Katumani

Emergence was earliest in Katumani at 4 days while in Juja at 5 days. Treatments that recorded earliest germination were humates, SWE basal application, humates + SWE basal application, humates + SWE basal application + SWE foliar spray and in SWE basal application + SWE foliar spray (Katumani – four days; Juja – five days) . Between the two sites, longest days to emergence was in control in nine days in Katumani site and 11 days in Juja (Figure 4.2)



Error bars signify SE of means at $p \leq 0.05$

Figure 4.2: Effect of biostimulators on days to emergence in Juja and Katumani

4.5.4 Effect of bio-stimulators on rate of emergence in Juja and Katumani

Juja had the highest rate of emergence of 61%, while Katumani had 29%. Highest rate of emergence was 67% in humatesin Juja, compared to 59% in control while in Katumani it was 60 % in SWE basal application+SWE foliar compared to control with 27%. The lowest germination rate in Juja was recorded in SWE basal+SWE foliar spray with 51% which was higher than in biofix in Katumani by 94% (Table 4.2)

4.5.5 Effect of bio-stimulators on survival rate in Juja and Katumani

Survival rate was highest in Juja with an average of 70 plants and Katumani with 34. Humates had 81 plants in Juja andin Katumani, SWE basal application+SWE foliar had 72plants (Table 4.3). The lowest number of surviving plantsbetween the sites and among bio-stimulators was in biofix with only 4 plants in Katumani compared to control in the same site with 32 plants. In Juja the lowest number of surviving plants was in SWE basal application+SWE foliar with 39 plants (Table 4.3)

4.5.6 Effect of bio-stimulators on chlorophylly levels in Juja and Katumani

The highest chlorophyll levels were recorded in Juja with 54.4 while Katumani with 48.6. In addition, Juja had the highest chlorophyll levels in humates+SWEfoliar with 56.6while Katumnai had 53.5 in SWE basal application+SWE foliar (Table 4.3). Biofix had the lowest chlorophyll levels between the two sites of 32.1, lower than control which had 54.9 and 50.8 in Juja and Katumani respectively (Table 4.3)

Table 4.2: Means of different parameters between bio-stimulatorsin Juja and Katumani

	rate of emergence		**survival rate**		**chlorophyll levels**	
Bio-stimulators/ Sites	**Juja**	**Katumani**	**Juja**	**Katumani**	**Juja**	**Katumani**
Biofix	62^{ab}	3^{d}	73^{ab}	4^{d}	53.8^{ab}	43.5^{bcd}
Control	59^{ab}	27^{bcd}	71^{ab}	32^{bcd}	54.9^{ab}	50.8^{abc}
Humates	$\mathbf{67^{a}}$	15^{d}	$\mathbf{81^{a}}$	17^{d}	54.0^{ab}	41.6^{d}
Humates+ SWE basal application	60^{ab}	37^{bc}	70^{ab}	43^{bc}	52.2^{c}	51.3^{ab}
Humates+SWE basal application+SWE foliar	56^{ab}	40^{bc}	61^{b}	47^{bc}	54.1^{ab}	51.7^{a}
Humates+ SWE foliar	64^{a}	15^{d}	76^{ab}	17^{d}	$\mathbf{56.6^{a}}$	46.9^{abcd}
SWE basal application	61^{ab}	44^{ab}	72^{ab}	52^{b}	55.3^{ab}	54.1^{a}
SWE basal application+SWE foliar	51^{b}	60^{a}	60^{b}	72^{a}	55.1^{ab}	53.5^{a}
SWE foliar	63^{a}	23^{cd}	74^{ab}	27^{cd}	53.6^{ab}	43.3^{cd}
Mean	**61**	**29**	**70**	**34**	**54.4**	**48.9**
P	0.42	<.001	0.24	<.001	0.12	0.24
LSD	11.6	17.1	18.8	20.0	2.8	7.9

Means followed bythe same letter are not siginificant at p≤0.05

4.5.7 Effect of bio-stimulators on plant height in Juja and Katumani

Tallest plants from week 3 to 8 of 7.2,10, 11.4, 12.1 and 16.4 cm were observed in Juja while Katumani had the tallest plants only in week 2 of 4.3cm, 13% taller than the tallest plant in Juja (Table 4.3). Treatments with the tallest plants were humates in Juja with 4.2, 7.6, 11.6, 12.9, 13.6 and 18.9cm compared to control with 3.7, 5.9, 9.4, 10.4, 11.2 and 15.7cm (Table 4.3). Katumani had tallest plants in SWE basal application+SWE foliar with 5.1, 6.0, 8.5, 9.0, 9.1 and 13.2 cm while control had 3.7, 4.9, 6.0, 7.7, 8.8 and 10.1 (Table 4.3).

4.6 Root length and nodulation

4.6.1 Effect of bio-stimulators on root length in Juja and Katumani

Root length was not significantly different between sites, biostimulators or varieties at $p \leq 0.05$ neither were there interactions between biostimulators and sites, bio-stimulators and varieties or between sites, varieties and bio-stimulators. Longest roots were observed in Katumani in week 5 with 6.4cm while Juja recorded longest roots in week 6 and 8 with 7.8 and 11.2 cm respectively (Table 4.4). Longest roots in Juja were in humates+SWE foliar, SWE basal application, SWE basal application+SWE foliar and control in week 5 (6.6cm), biofix in week 6 (8.8cm) and 8 (11.8 cm) respectively (Table 4.4). In Katumani, humates+SWE basal application, humates+SWE basal application+SWE foliar and SWE basal application+SWE foliar had the longest roots of 7.4, 8.4 and 9.4 cm in weeks 5, 6 and 8 respectively.

Table 4.3: Means of plant height between bio-stimulators in Juja and Katumani

	week 1		week 2		week 3		week 4		week 5		week 6		week 8	
Bio-stimulators	**Juja**	**Katumani**	**Juja**	**Katumani**	**Juja**	**Katumani**	**Juja**	**Katumani**	**Juja**	**Katumani**	**Juja**	**Katumani**	**Juja**	**Katumani**
Humates	2.5	2.2	4.2^{a}	4^{ab}	7.6^{a}	4.4^{bc}	11.6^{a}	6.9^{abc}	12.9^{a}	8.6^{ab}	13.6^{a}	8.1	18.9^{a}	10.7^{ab}
Humates+SWE basal application	2.5	2.2	3.7^{b}	4.4^{ab}	6.5^{c}	4.9^{bc}	9.5^{b}	6.6^{bc}	11.7^{ab}	7.9^{ab}	11.7^{ab}	9.0	15.3^{b}	11.3^{ab}
Humates+SWE basal application+SWE foliar	2.5	2.4	3.9^{ab}	4.7^{ab}	6.5^{c}	5.0^{ab}	9.9^{ab}	7.5^{abc}	10.7^{b}	8.0^{ab}	12.2^{ab}	8.5	16.8^{ab}	11.4^{ab}
Humates+SWE foliar	2.5	2.2	4.0^{ab}	4.5^{ab}	6.7^{bc}	4.9^{bc}	10.9^{ab}	6.7^{abc}	12.5^{ab}	9.6^{a}	12.2^{ab}	9.7	16.5^{ab}	12.0^{ab}
SWE basal application	2.5	2.4	3.9^{ab}	4.9^{ab}	6.9^{b}	5.3^{ab}	10.3^{ab}	7.9^{ab}	11.2^{ab}	7.9^{ab}	12.6^{ab}	8.9	17.1^{ab}	12.6^{ab}
SWE basal+SWE foliar	2.5	2.4	3.7^{b}	5.1^{a}	6.7^{b}	6.0^{a}	10.0^{ab}	8.5^{a}	11.7^{ab}	9.0^{ab}	12.0^{ab}	9.1	16.7^{ab}	13.2^{a}
SWE foliar	2.5	2.3	3.7^{b}	4.7^{ab}	5.6^{d}	5.1^{ab}	9.4^{b}	7.1^{abc}	11.2^{ab}	8.2^{ab}	11.9^{ab}	8.1	16.2^{ab}	12.3^{ab}
Biofix	2.5	2.0	3.7^{b}	3.2^{b}	5.93^{d}	4.0^{c}	9.2^{b}	4.5^{d}	10.4^{b}	6.2^{c}	11.1^{b}	8.2	14.8^{b}	10.1^{b}
Control	2.5	2.1	3.7^{b}	3.7^{b}	5.9^{d}	4.9^{bc}	9.4^{b}	6.0^{cd}	10.4^{b}	7.9^{ab}	11.2^{b}	8.8	15.7^{b}	10.1^{b}
Mean	**2.5**	**2.2**	**3.8**	**4.4**	**7.2**	**4.9**	**10.0**	**6.9**	**11.4**	**8.1**	**12.1**	**8.7**	**16.4**	**11.5**
P	0.66^{ns}	0.53^{ns}	0.53^{ns}	0.02*	0.31^{ns}	0.04*	0.28^{ns}	0.003**	0.34^{ns}	0.01*	0.55^{ns}	0.94^{ns}	0.31^{ns}	0.38^{ns}
LSD	0.03	0.5	0.5	1.1	1.6	1	1.97	1.8	2.3	1.6	2.3	2.5	3	2.9

*Means ** - highly significant, *- significant, NS- not significant at p≤0.05; SE separation of means at p<0.05*

Table 4.4: Root length from week 5 to 8 between bio-stimulators in Juja and Katumani

	week 5		week 6		week 8	
	Juja	Katumani	Juja	Katumani	Juja	Katumani
Humates	6.2	5.7^{ab}	8.3^{ab}	7.1	11.4	7.8
Humates+SWE basal application	5.4	6.7^{ab}	7.6^{ab}	8.4	11.7	8.9
Humates+SWE basal application+SWE foliar	6.0	7.4^{a}	6.3^{b}	8.4	11	9.2
Humates+SWE foliar	6.6	4.7^{b}	8.5^{ab}	6.4	10.3	7.5
SWE basal application	6.6	7.3^{a}	7.6^{ab}	8.1	11.8	8.9
SWE basal application+SWE foliar	6.6	6.8^{ab}	8.4^{ab}	8.2	9.4	9.4
SWE foliar	5.8	6.2^{ab}	7.9^{ab}	7.5	11.6	9.1
Biofix	5.7	6.1^{ab}	8.8^{a}	6.9	11.8	6.5
Control	6.6	7^{a}	7.3^{ab}	8	12.1	7.5
Mean	**6.2**	**6.4**	**7.8**	**7.7**	**11.2**	**8.3**
P	0.47^{ns}	0.25^{ns}	0.57^{ns}	0.63^{ns}	0.51^{ns}	0.33^{ns}
LSD	1.3	2.2	2.3	2.3	3.2	2.6

*Means ** - highly significant, *- significant, NS- not significant at p≤0.05; Means followed by the same letter are not significantly different at p≤0.05*

4.6.2 Effect of bio-stimulators on nodule formation in Juja and Katumani

There were no interactions between bio-stimulators and sites, bio-stimulators and varieties or sites, varieties and biostimulators at p≤0.05. The highest number of nodules were recorded in Katumani in week 5 and Juja in week 6 and 8 (Table 4.5). Most nodules in Juja were in SWE basal application+SWE foliar in week 5 (8), humates+SWE basal application in week 6 (11) and control in week 8 (22). In Katumani, most nodules were in humates+SWE basal application+SWE foliar in week 5 (11), SWE basal application in week 6 (6) and humates in week 8 (11) (Table 4.5)

Table 4.5: Effect of bio-stimulators on number of nodules formed in Juja and Katumani

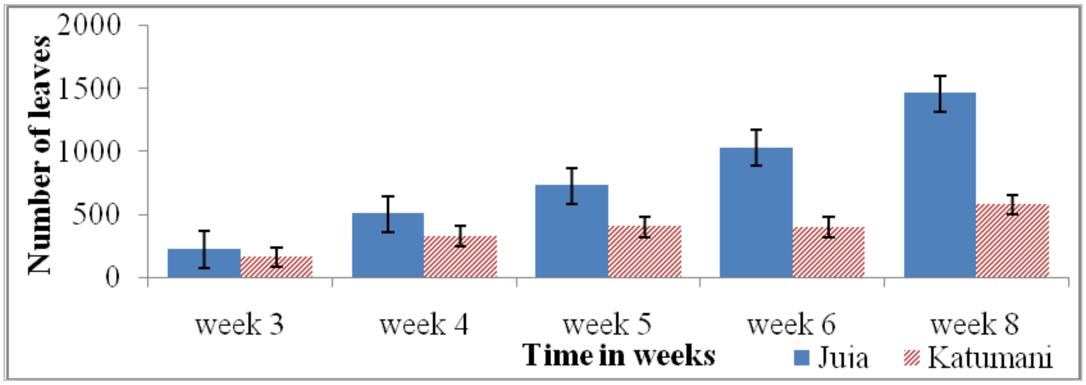
	week 5		week 6		week 8	
	Juja	Katumani	Juja	Katumani	Juja	Katumani
Humates	6	6^{abc}	9	2^{b}	21^{a}	11^{a}
Humates + SWE basal application	5	7^{abc}	11	3^{ab}	10^{d}	3^{cd}
Humates + SWE basal application + SWE foliar spray	6	11^{ab}	8	3^{ab}	18^{abc}	2^{d}
Humates + SWE foliar	4	6^{abc}	9	1^{b}	19^{ab}	4^{cd}
SWE basal application	6	9^{ab}	9	6^{a}	17^{abcd}	2^{d}
SWE basal application + SWE foliar	8	12^{a}	9	4^{ab}	8^{d}	3^{cd}
SWE foliar	5	5^{bc}	9	2^{b}	12^{bcd}	6^{bcd}
Biofix	4	2^{c}	9	2^{b}	11^{cd}	7^{abc}
Control	5	7^{abc}	8	3^{ab}	22^{a}	10^{ab}
Mean	**5**	**7**	**9**	**3**	**15**	**5**
P	0.77^{ns}	0.02^{*}	0.99^{ns}	0.01^{*}	$<.001^{***}$	0.76^{ns}
LSD	4	6	5	3	7	4

*Means ** - highly significant, *- significant, NS- not significant at p≤0.05; Means followed by the same letter are not significantly different at p≤0.05*

4.7 Production of leaves, leaf area and leaf weight

4.7.1 Production of leaves

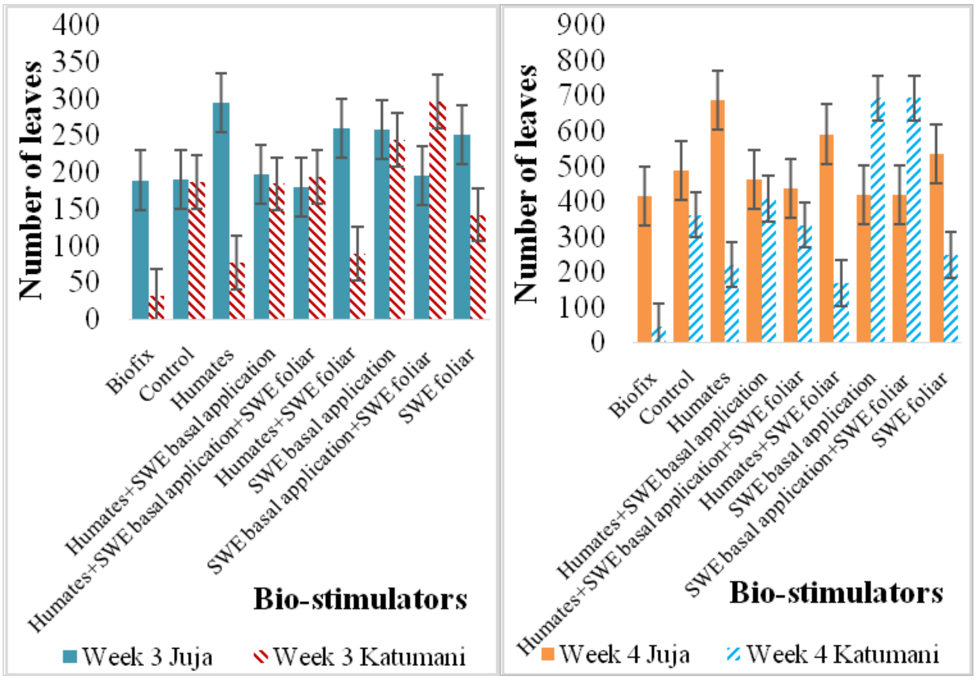
Production of leaves was significantly different between sites from week 3 to 8 at p≤0.05 (Figure 4.4). Highest number of leaves was produced in Juja site from week 3 to 8.



Error bars signify SE of means at p≤0.05

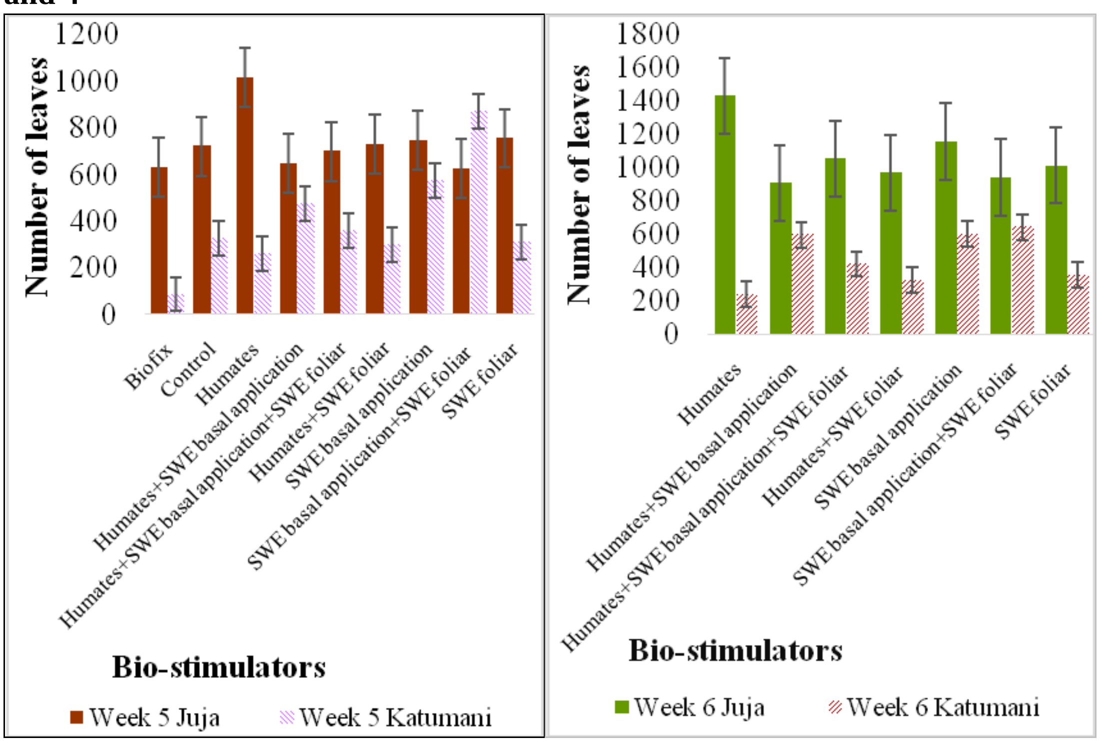
Figure 4.3: Production of leaves between Juja and Katumani from week 3 to 8

Leaf production between bio-stimulators was significantly different from week 3 to 8 at p≤0.05 (Figures 4.4 a, b & c). Highest number of leaves was produced Katumani in weeks 3 and 4 with 296 and 693 leaves in SWE basal application+SWE foliar (Figure 4a). In Juja, most number of leaves were produced in humates from week 5 to 8 with 1016, 1427 and 2101 leaves (Figures 4b & c). Control in Katumani had more leaves produced than in Juja in week 3, although highest number of leaves was produced in Juja in the rest of the weeks.

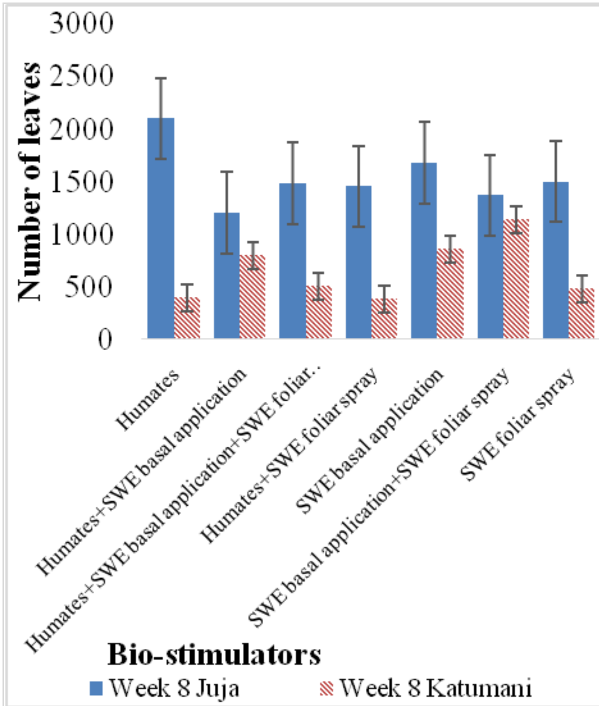


Error bars signify SE of means at p≤0.05

Figure 4.4 I: Effect of bio-stimulators on number of leaves produced for week 3 and 4



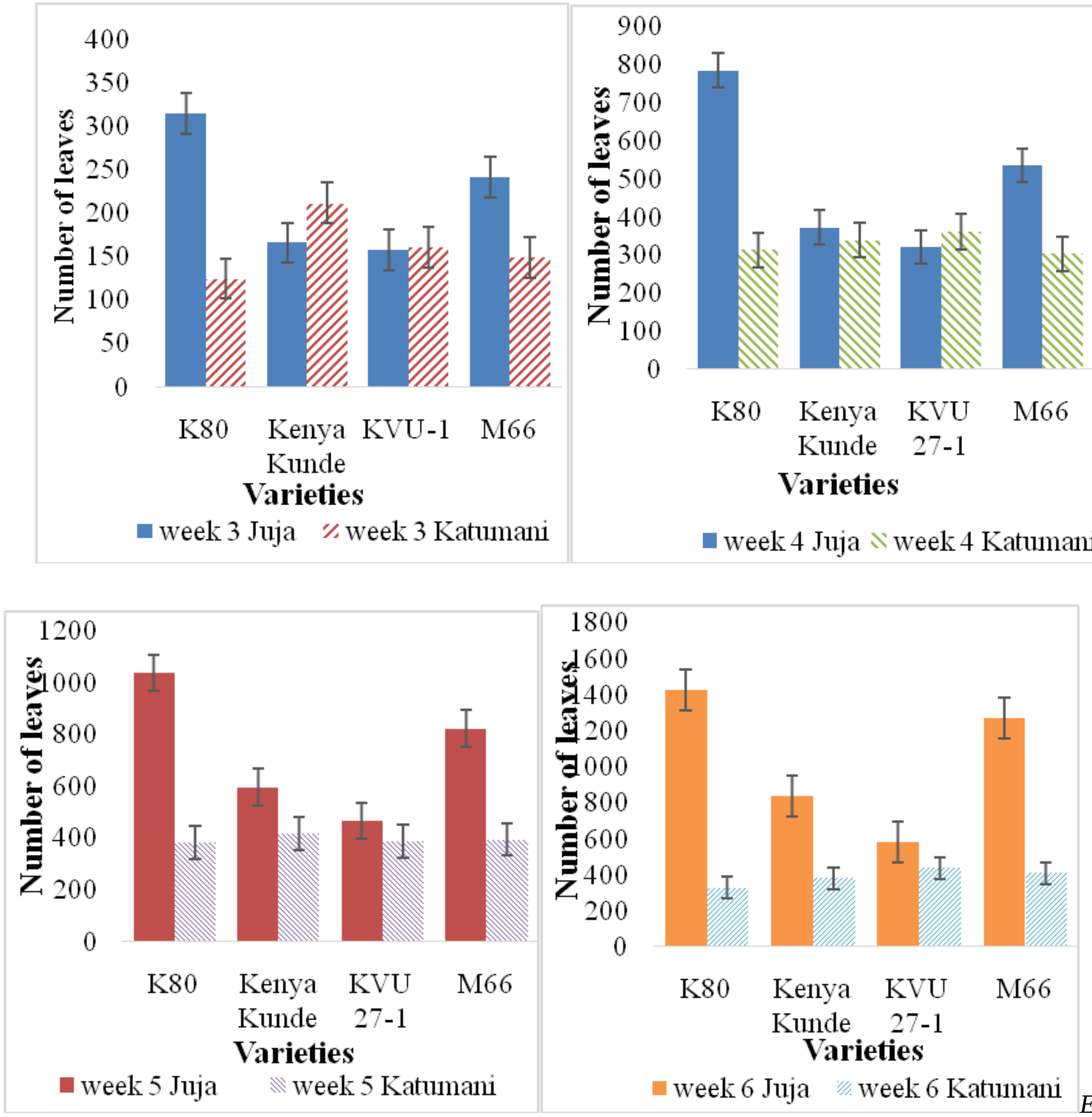
Error bars signify SE of means at p≤0.05



Error bars signify SE of means at p≤0.05

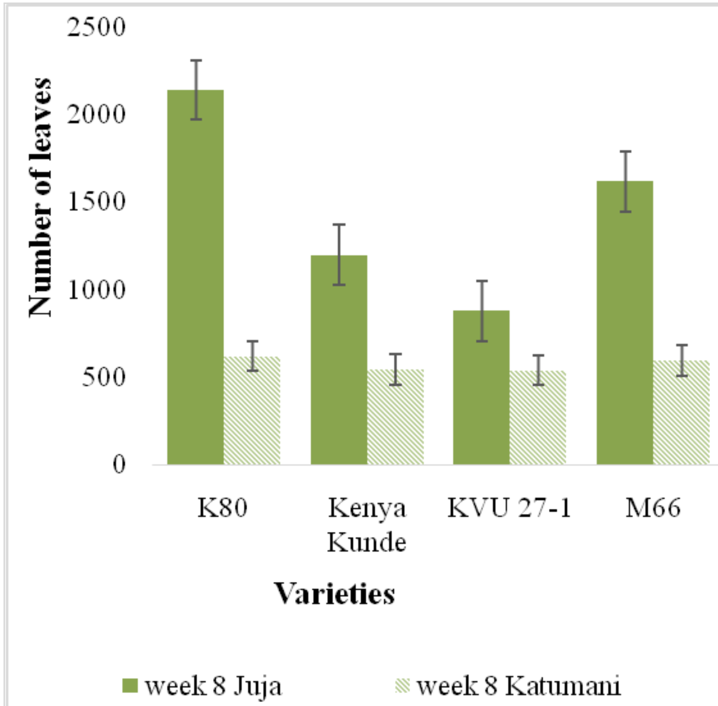
Figure 4.4 II: Effect of bio-stiulators on number of leaves produced from week5 to 8

Varieties were significantly differently from week 4 to 8 at p≤0.05 (Figures 4.5i and ii). There was no interaction between sites, varieties and bio-stimulators. K80 produced the highest number of leaves from week 3 to 8 in Juja (315, 784, 1036, 1424 and 2139) while in Katumani, Kenya Kunde produced the highest number of leaves in weeks 3 and 5 (211,417), KVU 27-1 in weeks 4 and 6 (361, 436) and K80 in week 8 with 618 (Figures 4.5i and ii)



Error bars signify SE of means at p≤0.05

Fig 4.5i: Number of leaves produced in varieties from week 3 to week 6



Error bars signify SE of means at p≤0.05

Fig 4.5ii: Number of leaves produced in varieties in week 8

4.7.2 Leaf area and leaf weight

Weight of leaves was significantly different between Juja and Katumani at p≤0.05 but not in leaf area. Katumani had the highest leaf weight of 2.2g while Juja had the highest leaf area of 39.2cm^2. humates had the highest leaf weight and leaf area of 2.3g and 46 cm^2 respectively.

Table 4.6: Performance of leaf weight and leaf area in sites, biostimulators and varieties

Sites	Leaf weight g	Leaf area cm^2
Juja	1.6^{a}	39.2^{a}
Katumani	2.2^{b}	34.5^{a}
Mean	**1.9**	**36.8**
LSD	0.2	5.1
P	<.001***	0.07 ^{ns}
Bio-stimulators		
Biofix	1.7^{b}	28.1^{b}
Control	1.7^{b}	31.8^{b}
Humates	**2.3^{a}**	**46.0^{a}**
Humates+SWE basal application	1.9^{ab}	29.7^{b}
Humates+SWE basal application+SWE foliar	1.8^{ab}	37.2^{ab}
Humates+ SWE foliar	2.0^{ab}	45.7^{a}
SWE basal application	1.9^{ab}	35.2^{ab}
SWE basal application+ SWE foliar	2.0^{ab}	38.8^{ab}
SWE foliar	1.9^{ab}	38.9^{ab}
LSD	0.5	11.3
P	0.38^{ns}	0.01^{*}
Varieties		
K80	**1.5^{a}**	**45.0^{a}**
Kenya Kunde	1.3^{ab}	33.9^{b}
KVU 27-1	1.2^{b}	27.7^{b}
M66	1.4^{ab}	40.9^{ab}
LSD	0.3	7.5
P	0.19 ^{ns}	<.001***
Mean	**1.3**	**36.8**

*Means ** - highly significant, *- significant, NS- not significant at p≤0.05; Means followed by the same letter are not significantly different at p≤0.05*

4.7.2.1 Effect of bio-stimulators on leaf weight in Juja and Katumani

The treatment with the highest leaf weight between Juja and Katumani was SWE basal application+SWE foliar spray in Katumani with 2.5g (Table 4.3). In Juja, humates had the highest leaf weight of 2.1g in humates with the least weight recorded in biofix of 1.3g which was lower than leaf weight recorded in control (1.9g) in Katumani (Table 4.3)

4.7.2.2 Effect of bio-stimulators on leaf area in Juja and Katumani

The largest leaves were in Juja in humates+SWE foliar spray (50.7cm^2) while in Katumani it was in humates with 42.6cm^2 (Table 4.3). Control had the lowest leaf area in Juja of 34.4cm^2 while in Katumani, biofix and humates+SWE basal application had the least leaf areas of 24.2 and 25.8cm^2 respectively, lower than control which had 29cm^2 (Table 4.3).

Table 4.7: Effect of bio-stimulators on leaf area and leaf weight in Juja and Katumani

	leaf area cm^2		**leaf weight g**	
Bio-stimulators/ Sites	**Juja**	**Katumani**	**Juja**	**Katumani**
Biofix	32.1^{c}	24.2^{c}	1.3^{c}	2.0^{a}
Control	34.4^{bc}	29.2^{bc}	1.5^{abc}	1.9^{a}
Humates	49.4^{ab}	42.6^{a}	2.1^{a}	2.4^{a}
Humates+ SWE basal application	33.7^{c}	25.8^{bc}	1.4^{bc}	2.4^{a}
Humates+SWE basal application+SWE foliar	40.0^{abc}	34.4^{abc}	1.5^{abc}	2.1^{a}
Humates+ SWE foliar	**50.7^{a}**	40.6^{ab}	2.0^{ab}	2.1^{a}
SWE basal application	36.7^{abc}	33.8^{abc}	1.4^{bc}	2.4^{a}
SWE basal application+SWE foliar	35.8^{abc}	41.9^{a}	1.5^{abc}	**2.5^{a}**
SWE foliar	39.9^{abc}	37.9^{abc}	1.7^{abc}	2.1^{a}
Mean	**34.5**	**29.2**	**1.6**	**2.1**
P	0.14	0.16	0.06	0.71
LSD	15.02	15.8	0.6	0.8

*Means ** - highly significant, *- significant, NS- not significant at p≤0.05; Means followed by the same letter are not significantly different at p≤0.05*

4.8 Production of cowpea seed

Cowpea seed production was significantly different between bio-stimulators in days to pod formation, rate of emergence, survival rate, number of pods, length of pods, number of seeds per pod and total 100 seed weight but not in number of pods formed at P≤0.05. There were significant differences in varieties in days to flowering, days to pod formation and number of pods formed and there were interactionsin days to pod formationbetween bio-stimulators and varietiesat p≤0.05 (Table 4.5). SWE basal application had the highest rate of emergence, earliest flowering and pod formation, highest number of pods, longest pods and highest total seed weight whereas humates influenced early flowering and highest number of seeds produced per pod (Table 4.5).

Bio-stimulators influenced length of pods, weight of pods, number of seeds formed and days to pod formation. Seaweed extracts (SWEs) produced longer pods of 13.5cm, higher number of pods formed (198) and higher weight of seeds produced (445kg/ha) though not significantly different from control (Table 4.5). K80 had the highest rate of emergence of 61.5% and number of pods (160). Kenya Karibu flowered and formed pods the earliest in 63 and 64 days respectively and KVU 27-1 had the longest pods of 14.3 cm and highest number of seeds/pods of 13. M66 had the highest total weight of seed of 355.7kg/ha (Table 4.5).

Table 4.8: Effect of bio-stimulators on cowpea seed production

Bio-stimulators/ Parameters	**Rate of emergence %**	**Days to flowering**	**Days to podding**	**Number of pods**	**Length of pods cm**	**Number of seeds/ pod**	**Total weight of seed kg/ha**
SWE basal application	**69.8**^{a}	**63**^{a}	**66**^{c}	**198**^{a}	**13.5**^{a}	13^{b}	**445**^{a}
Humates	67.3^{a}	**63**^{a}	67^{b}	181^{a}	13.4^{ab}	**14**^{a}	425^{a}
Control	62.5^{a}	64^{a}	67^{b}	162^{a}	12.6^{b}	12^{c}	229^{b}
Biofix	33.3^{b}	66^{a}	69^{a}	26^{b}	10.6^{c}	10^{d}	126^{c}
P	<.001***	0.05*	<.001***	<.001***	<.001***	<.001***	<.001***
Varieties							
K80	**61.5**^{a}	65^{b}	68^{b}	**160**^{a}	12.1^{b}	12^{b}	281.7^{a}
Kenya Kunde	51.7^{b}	**63**^{a}	**64**^{a}	156^{a}	10.6^{c}	12^{b}	276.7^{a}
KVU 27-1	58.7^{a}	65^{b}	68^{b}	120^{b}	**14.3**^{a}	**13**^{a}	312.5^{a}
M66	61.0^{a}	66^{b}	69^{c}	131^{a}	13.0^{b}	13^{a}	**355.7**^{a}
P	0.14^{ns}	0.01*	<.001***	0.14^{ns}	<.001***	0.03*	
Mean	**58.2**	**66**	**67**	**142**	**12.5**	**12**	**306**
LSD	9.3	2	1	40	1.0	1	81.8

**** - highly significant, *- significant, NS- not significant at p≤0.05; Means followed by the same letter are not significantly different at p≤0.05*

CHAPTER FIVE

DISCUSSION

The results described in this study show that bio-stimulators which were seaweed extracts (SWEs) of *Ecklonia maxima* and potassium humates enhanced cowpea growth and seed production.

5.1 Effect of bio-stimulators on plant growth

Bio-stimulators enhanced cowpea growth and development singly and in combination, in terms of early germination, better crop establishment/survival rate, plant height, number of leaves formed, and nodule formation compared to control both in Juja and Katumani. Seaweed extracts applied singly caused early emergence, high emergence rate and high number of nodules formed in Katumani and in Juja, early days to emergence and days to podding, high number of pods formed and total weight of seeds. In addition, seaweed extracts applied applied basally caused early emergence than seaweed foliar application.These findings agree with Sivasankari *et al*. (2006), Craigie (2011) and Zodape *et al*. (2011) who obtained better shoot length and higher total biomass when SWEs of *Sargassum wightii* and *Caulerpa chemnitzia* were applied to *Vigna sinensis.* Seaweed extracts (SWEs) contain phyto-hormones (cytokinins and auxins), macro nutrients, micronutrients, plant growth promoting substances, polyphenols, organic acids, amino acids and vitamins whichpromote plant growth and development.Cytokinins and auxins present promoted emergence through cell division, growth and expansion and stimulated root growth enhancing shoot:root ratio and biomass accumulation, improved water and nutrient uptake efficiency leading to early emergence and stronger seedlings (Khan *et al*., 2009). Gadimov *et al*. (2007) also found out that there was high concentration of soluble potash present in SWEs which caused early and increased germination rate of between 37 to 64% in Okra. On the other hand, humates applied singly enhanced crop establishment through high emergence rate and survival rate, improved cowpea leaf production, days to flowering and number of seeds formed per pod in Juja whereas in Katumani, it improved leaf expansion leading to higher leaf area probably due to phyto-hormones adsorbed on humic acids in potassium humates as was found out by Calvo *et al*.(2014). SWEs basal application+SWE foliar spray caused early emergence, better crop establishment resulting to high rate of emergence and survival rate, enhanced chlorophyll levels and leaf weight in Katumani. Seaweed extracts as foliar sprays enhanced crop growth since they have been found to be effectively absorbed in plants and nutrients and are directly and quickly incorporated into the plant metabolism as was observed by Mancuso *etal*. (2006) and Ramya *et al*. (2011).

5.2 Root length and nodule formation

Bio-stimulators enhanced root length both in Juja and Katumani. Seaweed extracts both as basal application and foliar sprays and humates combined with SWEs extracts enhanced root length in Juja and Katumani. Application of SWEs and humic acids could have increased endogenous cytokinin and auxin levels leading to more root formation (Khan *et al*., 2009; Chojnaka *et al*., 2012), enhanced chlorophyll levels and more nodules produced in both sites. Adsorption of phyto-hormones on humic fractions could also have triggered the combined effect of SWEs and humates leading to improved growth (Van tonder *et al*., 2008; Thirumaran *et al*., 2009; Fan *et al*., 2011). Biofix enhanced nodulation in Katumani in week 6, showing that microbial organisms had established well and nodulation was taking place. Nevertheless, increase in nodulation in Katumani in humates+SWEs in week 5, 6& 8 did not translate into more cowpea leaf production probably because the nodules formed were not actively nitrogen fixing probably due to the prevailing drought conditions. Bonilla and Bulanos (2010) found out that high temperature and moisture deficiency are the most limiting factors to legume nodulation and optimal functioning of nodules. In addition, marginal areas with low rainfall, extremes of temperatures, acidic soils, soils low in N and P, soils with poor water holding capacity or low moisture content inhibit rhizobia establishment and subsequent nodulation due to poor quality of nodules formed (Tahir *et al*., 2011). Weather data for Juja and Katumani showed that only 0.7mm of rainfall was received in Katumani with temperature of 25^{o} C and 332 mm in Juja (18^{o}C) during crop growth.

For optimal growth, cowpea requires approximately 340mm of rainfall and temperaures above 18^{o} C to grow well and form active nodules (Appendix 1) (DeTar, 2009).

5.3 Production of cowpea leaves

Bio-stimulators which were humates improved cowpea leaf production in Juja and SWE basal application+SWE foliar spray in Katumani, number of leaves produced, leaf weight and leaf area. Comparison between Juja and Katumani showed that number of leaves were higher in Juja than in Katumani from week 3 to 8. This could be as a result of low moisture content available to support production of more leaves or low N and P available in the soils. Plants growing in moisture deficient environments divert food reserves to develop thick stems as a mitigation measure against moisture loss, leading to low biomass accumulation**.** In addition, arid and semi- arid soils have been found to be low in N and P, the key elements that are the building blocks of plant food, so coupled with low soil moisture, this could have led to fewer leaves produced as a mitigation measure against moisture loss by plants (Ola *et al*., 2015). Leaf weight in Katumani was higher than in Juja and this could be attributed to accumulation of tissues in order to mitigate the water loss condition as compared to Juja.

5.4 Production of cowpea seed

In seed production, bio-stimulators enhanced days to flowering and podding, number of pods, length of pods, number of seeds/pod and total weight of seeds. Humates increased number of seeds per pod and number of pods formed besides triggering early flowering. Since soils in Juja have a clay characteristic (Appendix 2), humates could have broken up the compacted soils leading to enhanced water penetration and better root growth or could have added essential organic matter preventing leaching of nutrients besides releasing phosphorus from clay which is important element in seed formation, making it available for plant uptake as was found out by Susic (2008) and Pena- Mendez (2005). Similar observations done by Van tonder *et al*. (2008) showed that application of granules of humates to the soil surface resulted into rapid movement up to a distance of 12 inches into the soil, causing direct effect on roots through alteration of the integrity of the membranes or plant energy metabolism by the hydroxyl and carboxyl groups present within the humic substances leading to improved rooting and better plant growth. Humates triggered greater root mass as a result of direct contact with the roots and initiated formation of hypocotyl segments of legumes, improved root growth in early stages in Okra and in cucumber production in Egypt (Mora *et al*., 2010; Craigie, 2011; David *et al*., 2014). Humic acids possess contain bio-polymers which bind various organic molecules such as carbohydrates, lipids and proteins and chelate them for plant utilization, besides enhancing water retention in soils. Seaweed extracts on the hand caused earliest flowering and pod formation, produced high nmber of pods and longer pods and higher weight of seed, agreeing with Zodape *et al*. (2011) who found out that application of SWEs on mung bean significantly increased the seed yield, pod weight, number of pods, number of seeds per pod and weight of seeds in wheat. In addition, studies done by Haghighi *et al*. (2011).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Bio-stimulators caused early emergence, high plant survival rate, improved root length and nodulation both in Juja and Katumani. Bio-stimulators also contributed to high production of cowpea leaves and increased coweapea seed production. Humates produced the highest number of leaves and improved seed production in cowpea varieties in Juja and SWE basal application with foliar spray in Katumani. Humates enhanced flowering and increased number of seeds per pods while SWE basal application enhanced flowering and pod formation, increased number of pods, length of pods and weight of seeds.

6.2 Recommendation

Bio-stimulators under investigation, humates and SWEs of *Ecklonia maxima* should be adopted for cowpea leaf production in marginal areas and during seasons of low rainfall. Further evaluation onuse of humates and SWE with inorganic and/or organic fertilizers on cowpea production should be carried out. In addition, nutritional quality of cowpea leaves produced should be evaluated to establish the effect of bio-stimulators. There’s also need to determine the minimum water requirement that bio-stimulators would optimally influence cowpea production and the quality of the nodules produced.

REFERENCES

Abrahamian, P., & Kantharajah, A. (2011). Effect of vitamins on in vitro organogenesis of plant. *American Journal of Plant Sciences*, *2*, 669.

Abukutsa, M.O., (2007). The diversity of cultivated African leafy vegetables in three communities in western Kenya. *African Journal of Food, Agricultural, Nutrition and Development*, *7*, 1-15.

Adams, J., Gallagher, J., Donnison, I. (2009). Fermentation study on Saccharina lattisima for bioethanol production considering variable pre-treatments. *Journal of Applied Phycology*, *21*, 569-574.

Amosu, A.O., Maneveldt, G.W., Robert, J., and Bolton, J.J. (2013). South Africa Seweed Aquaculture: A sustainable development example for other African coastal countires. *African Journal of Agricultural Research*, *8*, 5268-5279

Anderson, G. (2009). Seaweed extract shows improved fruit quality at McLaren Vale vineyard trial. *Aust. NZ Grapegrow*. Winemaker, *548*, 17-22.

Anjum, S. A., Wang, L., Farooq, M., Xue, L., & Ali, S. (2011). Fulvic Acid Application Improves the Maize Performance under Well-watered and drought conditions. *Journal of Agronomy and Crop Science*, *197*, 409-417

Anon. (2011). *Production Guidelines for Cowpeas*. Department of Agriculture, Foestry and Fisheries. Directorate Plant Production. Republic of South Africa.

Anon. (2013). *Biostimulants market – By Active Ingredients, Applications, Crop Types & Geography—Global Trends & Forecasts to 2018*. Markets and markets. http://www. Retrieved from markets and markets.com/Market-Reports/biostimulant- market-1081.html

Anon. (2014).*Horticulture Validation report*. Report made in partnership with Horticultural Crops Development Authority (HCDA), Ministry of Agriculture and USAID

Anon. (2015). *Global humic acid market size, share, development, growth and demand forecast to 2020*.Industry Insights by application, Crop type. Report Buyer. Report ID 3605411.

Anon, (2016a). *European Biostimulant Industry Council [EBIC] (2016)*.Retrieved from http://www.biostimulants.eu/

Anon. (2016b). *Bio-pesticides to the aid of smallholder farmers*. Kenya Markets Trusts. Retrieved from**www.kenyamarkets.org**.

Ashraf, M., & Foolad, M. (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. *Environmental and Experimental Botany*, *59*, 206-216.

Bonilla, I., & Bolaños, L. (2009). Mineral nutrition for legume-rhizobia symbiosis: B, Ca, N, P, S, K, Fe, Mo, Co, and Ni: A review. In *Organic Farming, Pest Control and Remediation of Soil Pollutants*, 253-274. Springer Netherlands.

Biamah, E.K., Sterk, G. and Stroosnijder, L. (2003). Tillage and Farmyard manure effects on crusting and compaction of soils at Katumani, semi-arid Kenya In: Tullberg, J and Hoogmoed, W (Eds.) *Soil management for sustainability*. Proceedings of the 16th International Soil Tillage Research Organization conferenceheld in Brisbane, Australia from 13 to 18th July.

Balume, I.K., Keya, O., Karanja, N.K., and Woomer, P.L. (2015) Shelf life of legume innoculants in different carrier materials available in East Africa. *African Crop Science Journal*, *23*,379-385

Calvo, P., Nelson, L., & Kloepper, J. W. (2014). Agricultural uses of plant biostimulants. *Plant and Soil*, *383*, 3-41.

Chauvin, N.D., Mulangu, F., and Porto, G. (2012). Food Production and consumption trends in sub-saharan Africa: Prospects for the transformation of the Agricultural sector. Policy notes 2012-011. *United Nations Development Program (UNDP) Regional Bureau for Africa*. New York, NY

Chiulele, R. (2010). Breeding Cowpea (*Vignaunguiculata* (L.) Walp.) for Improved Drought Tolerance in Mozambique. Thesis. *University of Stellenbosch*, South Africa.

Chojnacka, Z., Saeid, A., Witkowska, Z., and Tuhy, L. (2012). Biologically Active Compunds in Seaweed Extracts-Prospects for the application. *The Open conference proceedings Journal*, *1*, 20-28.

Çimrin, K. M., Türkmen, Ö., Turan, M., & Tuncer, B. (2010). Phosphorus and humic acid application alleviate salinity stress of pepper seedling. *African Journal of Biotechnology*, *9*, 5845–5851

Craigie, J. S. (2011). Seaweed extract stimuli in plant science and Agriculture. *Journal of Applied Phycology*, *23*, 371-393.

David, J., Šmejkalová, D., Hudecová, Š., Zmeškal, O., von Wandruszka, R., Gregor, T., & Kučerík, J. (2014). The physico-chemical properties and biostimulative activities of humic substances regenerated from lignite. *SpringerPlus*, *3*, 1.

DeTar, W. R. (2009). Crop coefficients and water use for cowpea in the San Joaquin Valley of California. *Agricultural Water Management*, 96, 53-66.

Du Jardin, P. (2015). Plant biostimulants: Definition, concept, main categories and regulation. *Scientia Horticulturae*, *196*, 3-14.

Dugje, I.Y., Omoigui, L.O., Ekeleme, F., Kamara, A.Y., Ajeigbe, H. (2009). Farmers guide to Cowpea production in West Africa. *International Institute of Tropical Agriculture.*

El-Nemr, M. A., El-Desuki, M., El-Bassiony, A. M., & Fawzy, Z. F. (2012). Response of growth and yield of cucumber plants (Cucumis sativus L.) to different foliar applications of humic acid and bio-stimulators. *Aust. J. Basic Appl. Sci*, *6*, 630-637.

Fahad, S., Bajwa, A.A., Nazir, U., Anjum, A.S., Farooq, A., Zohaib, A., Sadia, S., Nasim, W., Adkins, S., Saud, S., Ihsan, Z.M., Alharby, H., Wu, C., Wang, D and Huang, J.(2017). Crop production under drought and Heat stress: Plant repsonses and management options. *Frontiers in Plant Science*, *8*, 1147

FAO (2012). *The State of World Fisheries and Aquaculture*. ISBN: 978- 92-5-107225-7. Retrieved from **ftp://ftp.fao.org/FI/brochure/SOFIA/2012/english_flyer.pdf**.

Fan, D., Hodges, D. M., Zhang, J., Kirby, C. W., Ji, X., Locke, S. J., ...& Prithiviraj, B. (2011). Commercial extract of the brown seaweed *Ascophyllum nodosum* enhances phenolic antioxidant content of spinach (Spinacia oleracea L.) which protects *Caenorhabditis elegans* against oxidative and thermal stress. *Food Chemistry*, *124*, 195-202.

Fatokun, C., Boukar, O. and Muranaka, S. (2012). Evaluation of Cowpea (*Vigna unguiculata* L. Walp.) germplasm lines for tolerance to drought. *Plant Genetic Resources: Characerization and Utilization*, *10*, 171 -176

FAO (2015). FAO *Global Aquaculture Production Database updated to 2013-Summary Information*. Retrieved on http://www.fao.org/3/a-i4899e.pdf

F.Y. Joosten., Y. Dijkxhoorn., Y. Sertse and R. Ruben (2015). *How does fruit and Vegetable sector contribute to food and nutritional security*. LEI Nota 2015-76. LEI Wageningen, UR, Wageningen.

Francisca I. Smith and Pablo Eyzaguirre (2007). *African Leafy Vegetables*: Their role in the World Health Organization's global Fruit and Vegetables Initiative.

Ferguson, B. J., & Mathesius, U. (2014). Phytohormone regulation of legume-rhizobia interactions. *Journal of chemical ecology*, *40*, 770-790.

Ferguson, B., Lin, M. H., & Gresshoff, P. M. (2013). Regulation of legume nodulation by acidic growth conditions. *Plant signaling & behavior*, *8*, e23426.

Gachimbi, L.N., Onduru, D.D., Muchena, F.N., Jager, A., Gachini, G.N., and Obanyi, S.N. (2003). *Impact of Rhizobium and Phosphate fertilizer in enhancing legume production in Mbeere district in Kenya using farmer field schools approach*. Retrieved from www.kari.org

Gadimov, A. G., Ahmedova, A. N., & Alieva, R. C. (2007). Simbiosis nodules bacteria *Rhizobiumleguminosarum* with Peas (*Pisumsativum*) nitrate reductase, salinification and potassium humus. Azerbaijan Natl. Acad. Sci. Baku, *Trans. Inst. Microbiol*, *4*, 158-163.

Galy, A.E., and Alkoaik, F.N. (2016) Extraction of Protein from common plant leaves for use as human food. *Journal of Applied Science*, *7*, 331-342

Gawrońska, H., Przybysz, A., Szalacha, E., & Słowiński, A. (2008). Physiological and molecular mode of action of Asahi SL biostimulator under optimal and stress conditions. *Biostimulators in Modern Agriculture*. General Aspects" (H. Gawronska, ed.). Wieś Jutra, Warsaw, 54-77.

GenStat, (2012).*GenStat for Windows*. Lawes Agricultural Trust, Rothamsted Experimental Station, Harpenden, UK

Giri, J. (2011). Glycinebetaine ad Abiotic stress tolerance in plants. *Plant Signalling and Behaviour*, *6*, 1746–1751.

Government of Kenya [GoK]. (2010). Kenya Agricultural Sector Development Strategy (ASDS), 2010 -2020. Retrieved from http://www.kilimo.go.ke/kilimo_docs/pdf/ASDS_Final.pdf.

Goyer, A. (2010). Thiamine in plants: aspects of its metabolism and functions. *Phytochemistry*, *71*, 1615-1624

Grimmer, L. (2011). Integrated Control Options for root knot nematodes. Part 2. *Kelpak*.Retrived from http://www.ezinearticle.com.

Haghighi, B. J., Alizadeh, O., & Firoozabadi, A. H. (2011). The role of plant growth promoting rhizobacteria (PGPR) in Sustainable Agriculture. *Advances in Environmental Biology*, *5*, 3079-3083.

Hallensleben, M., Polreich, S., Heller, J., & Maass, B. L. (2009). Assessment of the importance and utilization of cowpea (Vigna unguiculata L. Walp.) as leafy vegetable in small-scale farm households in Tanzania-East Africa.Proceedings of the Conference on international research on food security, natural resource management and rural development. University of Hamburg, Tropentag. October 6-8.

Halpern, M., Bar-Tal, A., Ofek, M., Minz, D., Muller, T., & Yermiyahu, U. (2015). Chapter Two-The Use of Biostimulants for Enhancing Nutrient Uptake. *Advances in Agronomy*, *130*, 141-174.

Jaetzold, R.S. H., Hornetz, B., Shisanya, C. (2006).*Farm Management Handbook of Kenya. Vol. II*. Natural Conditions and Farm Management Information. 2nd Edition. Part B. Central Kenya. Subpart B2. Ministry of Agriculture, Nairobi, Kenya.

Kamau, M., Mathenge, M., Githuku, J. and Olwande, J. (2010).*Food Security in Urban households: An Analysis of the prevalence and depth of hunger in Nairobi and its relationship to food expenditure.* Expanding Kenya's competitiveness Market access and Food security: Research findings and Policy Options. Nairobi, Kenya

Karanja, D.R., Githunguri, C.M., M'Ragwa, L., Mulwa, D. and Mwiti, S. (2006).*Variety, Characteristics and Production Guidelines of Traditional Food Crops.* KARI Katumani Research Centre.

KARI Tigoni. (2005). Annual Report. National Potato Research Centre, Tigoni. Kenya Agricultural Research Institute (KARI), 51-53

Karikari, B., Arkorful, E., and Addy, S. (2015). Growth, Nodulation and Yield Response of Cowpea to Phosphorus Fertilizer Application in Ghana. *Journal of Agronomy*, *14*, 234.

Kelleher, B. P .and A. J. Simpson. (2006). Humic substances in soils: are they really chemically distinct? *Environmental Science & Technology*, *40*, 4605 –4611

Khadouri, H.K. (2015). *Effects of Glycine betaine on Plant growth and performance of Alfalfa (Medicago sativa L.) and Cowpea (Vigna unguiculata L.Walp) within water deficit conditions*. Thesis. United Arab Emirates University. Scholarlworks@ UAEU

Khan, W., Rayirath, U. P., Subramanian, S., Jithesh, M. N., Rayorath, P., Hodges, D. M., and Prithiviraj, B. (2009). Seaweed extracts as biostimulants of plant growth and development. *Journal of Plant Growth Regulation*, *28*, 386-399.

Kim, J.K., Kraemer, G.P., Yarish, C. (2014). Field scale evaluation of seaweed aquaculture as a nutrient bioextraction strategy in Long Island Sound and the Bronx River Estuary. *Aquaculture, 433*, 148-156.

Kimani, V. (2014). *Bio-Pesticides development, use and regulation in Kenya*. Powerpoint Presentation at the Regional Experts Workshop on Development, regulation and Use of Bio-pesticides in East Africa, Nairobi, Kenya, 23-24 May 2014

Kimiywe, J., Waudo, J., Mbithe, D. and Maundu. P. (2007). Utilization of medicinal value of indigenous leafy vegetables consumed in urban and peri-urban Nairobi. *African Journal of Food and Agriculture, Nutrition and Development*, *7*, 15

Koh, C. L., Sam, C. K., Yin, W. F., Tan, L. Y., Krishnan, T., Chong, Y. M., & Chan, K. G. (2013). Plant-derived natural products as sources of anti-quorum sensing compounds. *Sensors*, *13*, 6217-6228.

Kuwada, K., Wamocho, L. S., Utamura, M., Matsushita, I., & Ishii, T. (2006). Effect of red and green algal extracts on hyphal growth of arbuscular mycorrhizal fungi, and on mycorrhizal development and growth of papaya and passionfruit. *Agronomy Journal*, *98*, 1340-1344.

Lobato, A. K. S., Costa, R. C. L., Neto, M. A. M., Oliveira Neto, C. F., Santos Filho, B. G., Alves, G. A. R., ... & Maleia, M. P. (2009). Consequences of the water deficit on nitrogen compounds in pepper (cv. *Vermelhogigante*) plants. *Res J Biol Sci*, *4*, 760-764.

Magdi, T.A., E.M. Selim and A.M. El-ghamry. (2011). Integrated effects of bio and mineral fertilizers and humic substances on growth yield and nutrient contents of fertigated cowpea (*Vigna unguiculata* L.). *Journal of agronomy*. *10*, 34-39.

Mahmoud, A. R., and Hafez, M. M. (2010). Increasing productivity of potato plants (*Solanumtuberosum*, l.) by using potassium fertilizer and humic acid application. *International Journal of Academic Research, 2*, 83-88.

Majengo, C.O., Okalebo, J.R., Lesueur, D., Pypers, P., Ng'etich, W., Mutegi, E., Mburu M.W. and Musyoki, M. (2011). Interaction between Nitrogen and Phosphorus Microbial Inoculants on Soybean Production in Bungoma, Kenya. *African Crop Science Conference Proceedings, 10*, 121 – 123

Mancuso, S., Azzarello, E., Mugnai, S., & Briand, X. (2006). Marine bioactive substances (IPA extract) improve foliar ion uptake and water stress tolerance in potted Vitis vinifera plants. *Advances in Horticultural Science*, 156-161.

Mazouk, A.H., Kassem, H. (2011). Improving yield, quality and shelf life of Thompson seedless grapevine by pre-harvest foliar application. *Scientia Horticulturae, 130*,425-430

McHugh, D. J. (2003). *A guide to the seaweed industry FAO Fisheries Technical Paper 441*. Food and Agriculture Organization of the United Nations, Rome.

Mora, V., Bacaicoa, E., Zamarreño, A. M., Aguirre, E., Garnica, M., Fuentes, M., & García-Mina, J. M. (2010). Action of humic acid on promotion of cucumber shoot growth involves nitrate-related changes associated with the root-to-shoot distribution of cytokinins, polyamines and mineral nutrients. *Journal of plant physiology*, *167*, 633-642.

Morales-Payan, J. P. (2011). Herbs and leaf crops: Cilantro, broadleaf cilantro and vegetable amaranth. *Soils, Plant Growth and Corp Production*, *3*, 1-28.

Mortier, V., Holsters, M., & Goormachtig, S. (2012). Never too many? How legumes control nodule numbers. *Plant, cell & Environment*, *35*, 245-258.

Mukhongo, R.W., Tumuhairwe, J.B., Ebanyat, P., AbdelGadir, A.H., Thuita, M. and Masso, C. (2016). Production and Use of Arbuscular Mycorrhizal Fungi Inoculum in Sub-Saharan Africa: Challenges and Ways of Improving. *International Journal of Soil Science*, *11: 108-122*

Ndiso, J, B., Chemining'wa, G.N., Olubayo, F.M. and Saha, H.M. (2016). Effect of Drought stress on Canopy temperature, growth and Yield performance of Cowpea varieties. *International Journal of Plant and Soil Science*, *9*,1-12.

Ngugi, I. K., Gitau, R., and Nyoro, J. (2007). *Access to high value markets by smallholder farmers of African indigenous vegetables in Kenya*. Regoverning Markets Innovative Practice Series, IIED, London.

Nkaa, F.A., O.W. Nwokeocha and O. Ihuoma (2014). Effect of phosphorus fertilizer on growth and yield of cowpea (*Vigna unguiculata*). *IOSR J. Pharm. Biol. Sci*., *9*, 74-82

Nyoki, D., and Ndakidemi, P. A. (2014). Effects of Bradyrhizobium japonicum inoculation and supplementation with phosphorus on macronutrients uptake in cowpea (*Vigna unguiculata* (L.) Walp). *American Journal of Plant Sciences*, *5*, 442-451

Ochieng, J., Afari-Sefa, V., Karanja, D., Rajendran, S., Silvest, S. and Kerry,R.(2016). *Promoting the consumption of traditional African vegetables and its effect on food and nutritional security in Tanzania*. Paper presented in 5th International conference of AAAE from 23rd to 26th September 2016 in Addis Ababa, Ethiopia.

Olal, D.A., Ochuodho, J.O., Omami, E.N. (2015).*Determining the Quantity of Cowpea (Vigna unguiculata) leaf yield under different manure application regimes and cropping systems in Western Kenya*. Thesis. University of Eldoret.

Oyoo, J., Nyongesa, M., Mbiyu, M., and Lungaho, C. (2010). Organic farming: effect of Kelpak and Earthlee on the yield of Irish potatoes. In Proceedings of the 12th Kari Biennial Scientific Conference “Transforming Agriculture for improved livelihoods through Agricultural Product Value Chains, 253-256

Peña-Méndez, E. M., Havel, J., & Patočka, J. (2005). Humic substances–compounds of still unknown structure: applications in agriculture, industry, environment, and biomedicine. *J. Appl. Biomed*, *3*, 13-24.

Petrus, A. C., Ahmed, O. H., Muhamad, A. M. N., Nasir, H. M., and Jiwan, M. (2010). Effect of KN-humates on dry matter production and nutrient use efficiency of maize in Sarawak, Malaysia. *The Scientific World Journal*, *10*, 1282-1292.

Pottorff, M., Ehlers, J. D., Fatokun, C., Roberts, P. A., & Close, T. J. (2012). Leaf morphology in Cowpea [*Vigna unguiculata* (L.) Walp]: QTL analysis, physical mapping and identifying a candidate gene using synteny with model legume species. *BMC genomics*, *13*, 234

Prakash, P., Samundeeswari, R., Vivek, C., & Chitra Devi, A. (2011). The influence of potassium humate on *Pleurotus florida*. *World Journal of Science and Technology*, *1*, 28-31.

Ramya, S. S., Nagaraj, S., & Vijayanand, N. (2011). Influence of Seaweed Liquid Extracts on Growth, Biochemical and Yield Characteristics of *Cyamopsis tetragonolaba* (L.) Taub. *Journal of Phytology*, *3*, 37-41.

Rioux, L.E., Turgeon, S.L. & Beaulieu, M. (2010). Structural characterization of laminaran and galactofucan extracted from the brown seaweed, *Saccharina longicruris*. *Phytochemistry*, *71*, 1586–1595.

Rothová, O. (2006). The effect of brassinosteroids on selected photosynthetic and morphological parameters of different genotypes of maize subjected to chilling conditions. (in Czechs). Proceedings of conference: Vlivabiotickych a biotickychstresorunavlastnostirostlin. *Agricultural University Praha*, 67-71.

Ruel, M.T., Minot, N. and Smith, L. (2005).*Patterns and determinants of fruit and vegetable consumption in sub Saharan Africa*: *A multi country comparison paper* presented in Joint FAO/WHO workshop on fruit and vegetable for health held from 1st to 3rd September 2004, Kobe Japan

Saidi, M., Itulya, F. M., Aguyoh, J. N., & Mshenga, P. M. (2010). Yields and profitability of a dual-purpose sole cowpea and cowpea-maize intercrop as influenced by cowpea leaf harvesting frequency. *Journal of Agricultural and Biological Science*, *5*, 65-71.

Sánchez-Sánchez, A., Sánchez-Andreu, J., Juárez, M., Jordá, J., & Bermúdez, D. (2006). Improvement of iron uptake in table grape by addition of humic substances. *Journal of Plant Nutrition, 29*, 259-272.

Schreinemachers, P., Simmons, E.B., Woperes, M.C.S. (2018). Tapping the economic and nutritional power of vegetables. Global Food Security, *16*, 36-45.

Sennhenn, A., Njarui, D.M.G., Maass, B.L., Whitbread, A.M. (2017). Exploring Niches for Short-season Grain legumes in Semi-arid Eastern Kenya-Copping with the impacts of climate variability. *Frontiers in Plant Science, 8*,699

Shawna, M.L., Hiltz, D., Ugarte, R., and Craft, C.A. (2010) Improved methods of analysis for betains in *Ascophylum nodosum* and its commercial seaweed extracts. *Journal of Apllied Phycology*, *22*, 489-494.

Sheahan, M. and Barrett, C.B. (2014). *Understanding the Agricultural Input Landscape in sub-Saharan Africa – Recent Plot, Household, and Community-Level Evidence*, World Bank Group, Africa region, Office of the Chief Economist

Singh, B. B., Ajeigbe, H. A., Tarawali, S. A., Fernandez-Rivera, S., & Abubakar, M. (2003). Improving the production and utilization of cowpea as food and fodder. *Field Crops Research*, *84*, 169-177.

Singh, R.P., Prasad, P.V. and Reddy, K.R. (2011). Impacts of high-temperature stress and Potential opportunities for breeding In: *Crop Adaptation to climate change* (eds. S.S. Yadah., R.J. Redden., J.L. Hatfield., H. Lotzencampen and A.E. Hall). John Wiley & Sons, Inc

Sithole, A., and Murewi, C.T.F. (2009). Climate variability and change over Southern Africa: Impacts and challenges. *African Journal of Ecology*, *47*, 17-20

Sivasankari, S., Venkatesalu, V., Anantharaj, M.,and Chandrasekaran, M. (2006). Effect of Seaweed extracts on growth and biochemical constituent of *Vignasinensis*. *Bioresource Technology*, *97*, 1745-1751

Smith, I.F., and Eyzaguirre. (2007). African leafy vegetables: Their role in World Health Organization's globalfruit and vegetable initiatiative. *African Journal of Food, Agriculture, Nutrition and Development*, *7*, 1 - 17

Susic, M. (2008). Humic acid.Ahistory of Humic acidResearch. More than two centuries of Humic acid Research- Whyso long? Wordpress

Tahir, M. M., Khurshid, M., Khan, M. Z., Abbasi, M. K., & Kazmi, M. H. (2011). Lignite-derived humic acid effect on growth of wheat plants in different soils. *Pedosphere*, *21*, 124-131.

Takim, F.O. and Uddin II, R.O (2010). Effect of weed removal on Insect populations and yield of cowpea (*Vigna unguiculata* L. Walp). *Australia Journal of Agricultural Engineering*, *1*, 194-199

Thirumaran, G., Arumugam, M., Arumugam, R., & Anantharaman, P. (2009). Effect of seaweed liquid fertilizer on growth and pigment concentration of *Abelmoschusesculentus* (I) Medikus. *American-Eurasian Journal of Agronomy*, *2*, 57-66.

Van Tonder, J. T. (2008). Effect of *potassium humate on soil properties and growth of wheat*.Thesis. University of Pretoria.

Van oosten, M., Pepe, O., De Pascale, S., Silleti, S., and Maggio,.O. (2017). The role of bio-stimulators and bio-effectors as alleviators of abiotic stress in crop plants. *Chemical and Biological Technologies in Agriculture*, *4*, 5

Wafulah, T.N. (2013). *Supporting the soybean industry by provision of quality and affordable inputs*. World Soybean Research Conference 13. Durban, South Africa.

Wang, X., & Hargrove, M. S. (2013). Nitric oxide in plants: the roles of ascorbate and hemoglobin. *PloS one*, *8*, e82611.

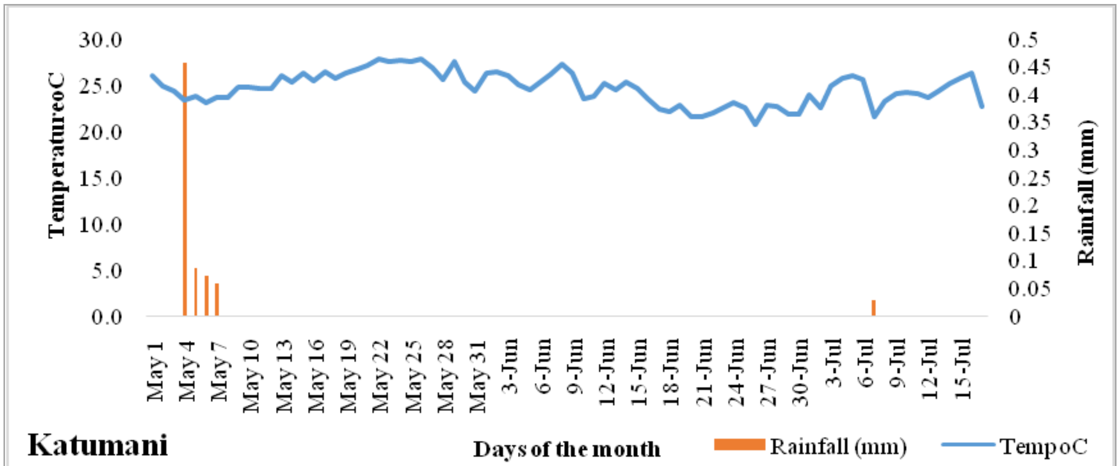
Zahran, H. H. (1999). Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. *Microbiology and molecular biology reviews*, *63*, 968-989.

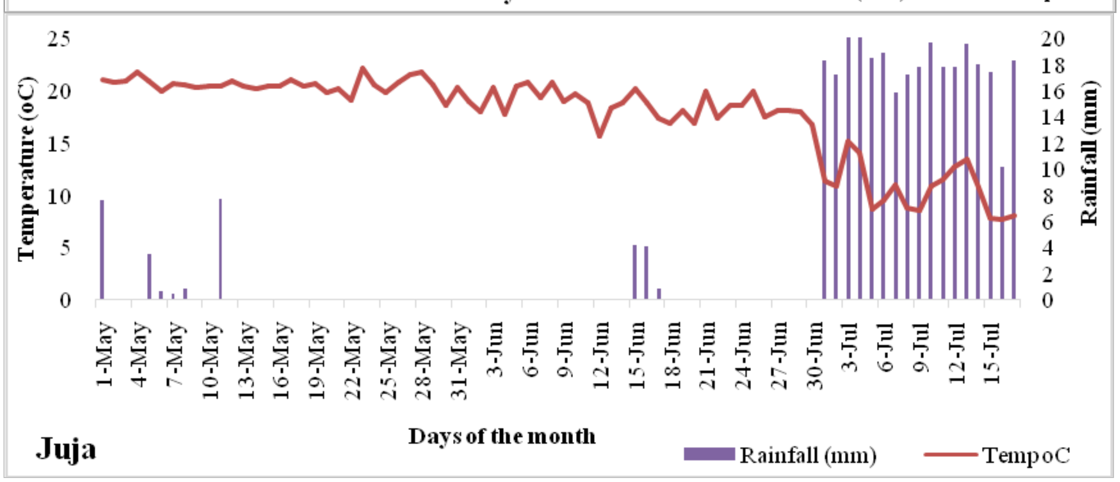
Zhao, Z., Andersen, S. U., Ljung, K., Dolezal, K., Miotk, A., Schultheiss, S. J., & Lohmann, J. U. (2010). Hormonal control of the shoot stem-cell niche. *Nature*, *465*, 1089-1092.

Zodape, S. T., Gupta, A., Bhandari, S. C., Rawat, U. S., Chaudhary, D. R., Eswaran, K., & Chikara, J. (2011). Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato (*Lycopersicon esculentum* Mill.). *J Sci Ind Res*, *70*, 215-219.

APPENDICES

Appendix 1: Weather data for Katumani and Juja





Appendix 2: Soil Analysis report for field A, Jomo Kenyatta University of Agriculture and Technology

Soil Analysis for Field A, Jomo Kenyatta University of Agriculture and Technolog			
Year- 2013			
Item description	**Actual**	**Optimal**	**remarks**
Soil pH	6.4	5.5 to 7	Adequate
Electro-conductivity	0.08	<0.8 ds/m	Adequate
N %	0.17	>0.25%	below range
K %	1.64	0-2%	Adequate
P %	109mg/kg	100-200mg/kg	Adequate
Ca %	9.34%	4-11%	Adequate
Mg %	4.79%	1-4%	Adequate
Bulk density	1.1g/cm3	1 for clay soils	Dominant soils are clay
Moisture content	5.47	4 to 10	Adequate
Total carbon	2.23%	1-3%	Adequate
C:N ratio	13.10%	10 to 20%	Adequate
Particle size	Sandy clay	Sandy content was 48.31%	Sandy- Clay soils
		Clay content was 37.695	
		Silt content was 1.4 %	

Appendix 3: Contrasting Control versus single bio-stimulators and Anova tables

Contrasts	Control	Humates	SWE basal	Biofix	SWE foliar
1	1	-1	0	0	0
2	1	0	-1	0	0
3	1	0	0	-1	0
4	1	0	0	0	-1

Rate of emergence					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	52812.5	52812.5	153	<.001
Treatment	8	10275.9	1284.5	3.7	<.001
Contrast 1	1	1319.5	1319.5	3.8	0.053
Contrast 2	1	47	47	0.1	0.713
Contrast 3	1	1000.7	1000.7	2.9	0.091
Contrast 4	1	0.2	0.2	0	0.979
Variety	3	5133.7	1711.2	5	0.003
Site.Treatment	8	21772.2	2721.5	7.9	<.001
Site.Contrast 1	1	2045.3	2045.3	5.9	0.016
Site.Contrast 2	1	1126.2	1126.2	3.3	0.073
Site.Contrast 3	1	826.4	826.4	2.4	0.124
Site.Contrast 4	1	168.8	168.8	0.5	0.486
Site.Variety	3	6859.2	2286.4	6.6	<.001
Treatment.Variety	24	6929	288.7	0.8	0.688
Contrast 1.Variety	3	126.7	42.2	0.1	0.947
Contrast 2.Variety	3	586.3	195.4	0.6	0.639
Contrast 3.Variety	3	240.9	80.3	0.2	0.874
Contrast 4.Variety	3	502.9	167.6	0.5	0.694
Site.Treatment.Variety	24	7049.8	293.7	0.9	0.669
Site.Contrast 1.Variety	3	505.9	168.6	0.5	0.691
Site.Contrast 2.Variety	3	474.2	158.1	0.5	0.713
Site.Contrast 3.Variety	3	992.1	330.7	1	0.415
Site.Contrast 4.Variety	3	817.5	272.5	0.8	0.503
Residual	144	49811.6	345.9		
Total	215	160644			

Days_to_emergence					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	453.56	454	49	<.001
Treatment	8	934.333	117	13	<.001
Contrast 1	1	16.333	16	1.8	0.187
Contrast 2	1	25.521	26	2.8	0.1
Contrast 3	1	229.688	230	25	<.001
Contrast 4	1	16.333	16	1.8	0.187
Variety	3	75.495	25	2.7	0.047
Site.Treatment	8	278.148	35	3.7	<.001
Site.Contrast 1	1	48	48	5.2	0.024
Site.Contrast 2	1	9.188	9.2	1	0.322
Site.Contrast 3	1	42.188	42	4.5	0.035
Site.Contrast 4	1	3	3	0.3	0.571
Site.Variety	3	38.199	13	1.4	0.254
Treatment.Variety	24	132.63	5.5	0.6	0.931
Contrast 1.Variety	3	14.5	4.8	0.5	0.669
Contrast 2.Variety	3	19.896	6.6	0.7	0.545
Contrast 3.Variety	3	15.562	5.2	0.6	0.643
Contrast 4.Variety	3	12.167	4.1	0.4	0.727
Site.Treatment.Variety	24	191.259	8	0.9	0.657
Site.Contrast 1.Variety	3	27.833	9.3	1	0.395
Site.Contrast 2.Variety	3	28.562	9.5	1	0.383
Site.Contrast 3.Variety	3	26.729	8.9	1	0.414
Site.Contrast 4.Variety	3	22.833	7.6	0.8	0.485
Residual	144	1337.333	9.3		
Total	215	3440.958			

Chlorophyll					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	1653.66	1653.7	17	<.001
Treatment	8	1119.63	139.95	1.44	0.186
Contrast 1	1	217.32	217.32	2.23	0.138
Contrast 2	1	310.66	310.66	3.19	0.076
Contrast 3	1	40.44	40.44	0.41	0.52
Contrast 4	1	103.69	103.69	1.06	0.304
Variety	3	528.56	176.19	1.81	0.148
Site.Treatment	8	958.6	119.82	1.23	0.286
Site.Contrast 1	1	116.98	116.98	1.2	0.275
Site.Contrast 2	1	212.16	212.16	2.18	0.142
Site.Contrast 3	1	23.6	23.6	0.24	0.623
Site.Contrast 4	1	31.93	31.93	0.33	0.568
Site.Variety	3	574.55	191.52	1.97	0.122
Treatment.Variety	24	5683.77	236.82	2.43	<.001
Contrast 1.Variety	3	1275.29	425.1	4.36	0.006
Contrast 2.Variety	3	685.11	228.37	2.34	0.076
Contrast 3.Variety	3	311.92	103.97	1.07	0.365
Contrast 4.Variety	3	768.81	256.27	2.63	0.052
Site.Treatment.Variety	24	4926.85	205.29	2.11	0.004
Site.Contrast 1.Variety	3	985.04	328.35	3.37	0.02
Site.Contrast 2.Variety	3	498.8	166.27	1.71	0.168
Site.Contrast 3.Variety	3	270.59	90.2	0.93	0.43
Site.Contrast 4.Variety	3	567.07	189.02	1.94	0.126
Residual	144	14033.1	97.45		
Total	215	29478.7			

leaf_area_cm2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	1193	1193	3.1	0.082
Treatment	8	7797	975	2.5	0.014
Contrast 1	1	157.9	158	0.4	0.525
Contrast 2	1	2432	2432	6.3	0.014
Contrast 3	1	144	144	0.4	0.544
Contrast 4	1	609.1	609	1.6	0.213
Variety	3	9108	3036	7.8	<.001
Site.Treatment	8	1096	137	0.4	0.944
Site.Contrast 1	1	21	21	0.1	0.816
Site.Contrast 2	1	8.2	8.2	0	0.885
Site.Contrast 3	1	16.3	16.3	0	0.838
Site.Contrast 4	1	30.2	30.2	0.1	0.781
Site.Variety	3	294.7	98.2	0.3	0.859
Treatment.Variety	24	6481	270	0.7	0.851
Contrast 1.Variety	3	308.4	103	0.3	0.851
Contrast 2.Variety	3	738.7	246	0.6	0.595
Contrast 3.Variety	3	277.4	92.5	0.2	0.87
Contrast 4.Variety	3	485.5	162	0.4	0.742
Site.Treatment.Variety	24	2937	122	0.3	0.999
Site.Contrast 1.Variety	3	285	95	0.2	0.865
Site.Contrast 2.Variety	3	436.8	146	0.4	0.772
Site.Contrast 3.Variety	3	151.5	50.5	0.1	0.942
Site.Contrast 4.Variety	3	19.1	6.4	0	0.997
Residual	144	56024	389		
Total	215	84929			

Leaf_weight_g					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	20.1	20.1	24.8	<.001
Treatment	8	7.05	0.88	1.09	0.38
Contrast 1	1	0	0	0	0.95
Contrast 2	1	4.62	4.62	5.7	0.02
Contrast 3	1	0.69	0.69	0.85	0.36
Contrast 4	1	0.59	0.59	0.73	0.4
Variety	3	3.88	1.29	1.59	0.19
Site.Treatment	8	5.46	0.68	0.84	0.57
Site.Contrast 1	1	0.35	0.35	0.43	0.51
Site.Contrast 2	1	0.01	0.01	0.02	0.89
Site.Contrast 3	1	0.99	0.99	1.22	0.27
Site.Contrast 4	1	0.01	0.01	0.01	0.94
Site.Variety	3	3.77	1.26	1.55	0.2
Treatment.Variety	24	14.8	0.62	0.76	0.78
Contrast 1.Variety	3	0.29	0.1	0.12	0.95
Contrast 2.Variety	3	1.43	0.48	0.59	0.62
Contrast 3.Variety	3	2.75	0.92	1.13	0.34
Contrast 4.Variety	3	0.41	0.14	0.17	0.92
Site.Treatment.Variety	24	17.1	0.71	0.88	0.63
Site.Contrast 1.Variety	3	0.47	0.16	0.19	0.9
Site.Contrast 2.Variety	3	0.5	0.17	0.2	0.89
Site.Contrast 3.Variety	3	2.34	0.78	0.96	0.41
Site.Contrast 4.Variety	3	2.98	0.99	1.22	0.3
Residual	144	117	0.81		
Total	215	189			

Survival rate					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	69948	69948	129	<.001
Treatment	8	13915	1739	3.2	0.002
Contrast 1	1	2523	2523	4.65	0.033
Contrast 2	1	88	88	0.16	0.688
Contrast 3	1	1271	1271	2.34	0.128
Contrast 4	1	8.3	8.3	0.02	0.902
Variety	3	6926.1	2309	4.25	0.007
Site.Treatment	8	33478	4185	7.71	<.001
Site.Contrast 1	1	2160.1	2160	3.98	0.048
Site.Contrast 2	1	1716	1716	3.16	0.078
Site.Contrast 3	1	1210	1210	2.23	0.138
Site.Contrast 4	1	161.3	161.3	0.3	0.586
Site.Variety	3	12510	4170	7.68	<.001
Treatment.Variety	24	10315	429.8	0.79	0.742
Contrast 1.Variety	3	231.3	77.1	0.14	0.935
Contrast 2.Variety	3	970.4	323.5	0.6	0.619
Contrast 3.Variety	3	320.2	106.7	0.2	0.899
Contrast 4.Variety	3	880.5	293.5	0.54	0.655
Site.Treatment.Variety	24	9857.9	410.7	0.76	0.784
Site.Contrast 1.Variety	3	392.2	130.7	0.24	0.868
Site.Contrast 2.Variety	3	795.1	265	0.49	0.691
Site.Contrast 3.Variety	3	1548.6	516.2	0.95	0.418
Site.Contrast 4.Variety	3	981.2	327.1	0.6	0.614
Residual	144	78163	542.8		
Total	215	235113			

Plant height cm week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	3.2825	3.283	20.6	<.001
Treatment	8	1.1618	0.145	0.91	0.509
Contrast 1	1	0.0792	0.079	0.5	0.482
Contrast 2	1	0.0164	0.016	0.1	0.749
Contrast 3	1	0.293	0.293	1.84	0.177
Contrast 4	1	0.1212	0.121	0.76	0.385
Variety	3	0.4048	0.135	0.85	0.471
Site.Treatment	8	1.164	0.146	0.91	0.508
Site.Contrast 1	1	0.0581	0.058	0.36	0.547
Site.Contrast 2	1	0.0092	0.009	0.06	0.81
Site.Contrast 3	1	0.3024	0.302	1.9	0.171
Site.Contrast 4	1	0.1791	0.179	1.12	0.291
Site.Variety	3	0.392	0.131	0.82	0.485
Treatment.Variety	24	3.8514	0.161	1.01	0.462
Contrast 1.Variety	3	0.4831	0.161	1.01	0.39
Contrast 2.Variety	3	1.0226	0.341	2.14	0.098
Contrast 3.Variety	3	0.306	0.102	0.64	0.591
Contrast 4.Variety	3	0.3563	0.119	0.74	0.527
Site.Treatment.Variety	24	3.6249	0.151	0.95	0.539
Site.Contrast 1.Variety	3	0.5249	0.175	1.1	0.352
Site.Contrast 2.Variety	3	0.9906	0.33	2.07	0.107
Site.Contrast 3.Variety	3	0.3242	0.108	0.68	0.567
Site.Contrast 4.Variety	3	0.3228	0.108	0.68	0.569
Residual	144	22.9569	0.159		
Total	215	36.8382			

Plant height cm week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	15.79	15.79	14.2	<.001
Treatment	8	20.23	2.529	2.28	0.03
Contrast 1	1	0.954	0.954	0.86	0.36
Contrast 2	1	1.842	1.842	1.66	0.2
Contrast 3	1	6.044	6.044	5.44	0.02
Contrast 4	1	3.004	3.004	2.71	0.1
Variety	3	1.358	0.453	0.41	0.75
Site.Treatment	8	18.09	2.261	2.04	0.05
Site.Contrast 1	1	0.567	0.567	0.51	0.48
Site.Contrast 2	1	0.047	0.047	0.04	0.84
Site.Contrast 3	1	3.169	3.169	2.85	0.09
Site.Contrast 4	1	3.418	3.418	3.08	0.08
Site.Variety	3	0.905	0.302	0.27	0.85
Treatment.Variety	24	29.8	1.241	1.12	0.33
Contrast 1.Variety	3	5.885	1.962	1.77	0.16
Contrast 2.Variety	3	12.99	4.329	3.9	0.01
Contrast 3.Variety	3	3.008	1.003	0.9	0.44
Contrast 4.Variety	3	3.753	1.251	1.13	0.34
Site.Treatment.Variety	24	25.76	1.073	0.97	0.51
Site.Contrast 1.Variety	3	6.155	2.052	1.85	0.14
Site.Contrast 2.Variety	3	8.117	2.706	2.44	0.07
Site.Contrast 3.Variety	3	5.936	1.979	1.78	0.15
Site.Contrast 4.Variety	3	4.226	1.409	1.27	0.29
Residual	144	159.9	1.11		
Total	215	271.8			

plant height cm week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	127	127	42	<.001
Treatment	8	33	4.1	1.3	0.226
Contrast 1	1	2.3	2.3	0.7	0.39
Contrast 2	1	4.3	4.3	1.4	0.236
Contrast 3	1	5.3	5.3	1.7	0.19
Contrast 4	1	0	0	0	0.903
Variety	3	8.1	2.7	0.9	0.447
Site.Treatment	8	31	3.9	1.3	0.261
Site.Contrast 1	1	2.6	2.6	0.9	0.353
Site.Contrast 2	1	15	15	4.9	0.028
Site.Contrast 3	1	1.1	1.1	0.4	0.55
Site.Contrast 4	1	0.7	0.7	0.2	0.625
Site.Variety	3	32	11	3.5	0.018
Treatment.Variety	24	71	2.9	1	0.504
Contrast 1.Variety	3	6.8	2.3	0.8	0.526
Contrast 2.Variety	3	5.1	1.7	0.6	0.638
Contrast 3.Variety	3	2.4	0.8	0.3	0.855
Contrast 4.Variety	3	8.9	3	1	0.402
Site.Treatment.Variety	24	67	2.8	0.9	0.57
Site.Contrast 1.Variety	3	1	0.3	0.1	0.954
Site.Contrast 2.Variety	3	5.5	1.8	0.6	0.611
Site.Contrast 3.Variety	3	9.5	3.2	1	0.375
Site.Contrast 4.Variety	3	7.3	2.5	0.8	0.491
Residual	144	436	3		
Total	215	804			

Plant height cm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	543	543	99	<.001
Treatment	8	128	16	2.9	0.005
Contrast 1	1	8.75	8.7	1.6	0.208
Contrast 2	1	29.8	30	5.5	0.021
Contrast 3	1	24.1	24	4.4	0.038
Contrast 4	1	3.8	3.8	0.7	0.406
Variety	3	18.4	6.1	1.1	0.343
Site.Treatment	8	59.2	7.4	1.4	0.222
Site.Contrast 1	1	4.94	4.9	0.9	0.344
Site.Contrast 2	1	3.86	3.9	0.7	0.402
Site.Contrast 3	1	2.75	2.7	0.5	0.48
Site.Contrast 4	1	3.94	3.9	0.7	0.398
Site.Variety	3	26.5	8.8	1.6	0.188
Treatment.Variety	24	137	5.7	1.1	0.412
Contrast 1.Variety	3	3.4	1.1	0.2	0.891
Contrast 2.Variety	3	27.6	9.2	1.7	0.174
Contrast 3.Variety	3	14.1	4.7	0.9	0.465
Contrast 4.Variety	3	2.38	0.8	0.1	0.933
Site.Treatment.Variety	24	78.1	3.3	0.6	0.931
Site.Contrast 1.Variety	3	1.12	0.4	0.1	0.977
Site.Contrast 2.Variety	3	8.39	2.8	0.5	0.675
Site.Contrast 3.Variety	3	12.6	4.2	0.8	0.514
Site.Contrast 4.Variety	3	2.56	0.9	0.2	0.926
Residual	144	787	5.5		
Total	215	1778			

Plant height cm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	572	572	82	<.001
Treatment	8	134	16.8	2.4	0.02
Contrast 1	1	8.39	8.39	1.2	0.27
Contrast 2	1	30.6	30.6	4.4	0.04
Contrast 3	1	2.01	2.01	0.3	0.59
Contrast 4	1	3.9	3.9	0.6	0.46
Variety	3	33.8	11.3	1.6	0.19
Site.Treatment	8	20.9	2.61	0.4	0.93
Site.Contrast 1	1	7.72	7.72	1.1	0.29
Site.Contrast 2	1	8.92	8.92	1.3	0.26
Site.Contrast 3	1	1.26	1.26	0.2	0.67
Site.Contrast 4	1	0.43	0.43	0.1	0.81
Site.Variety	3	6.99	2.33	0.3	0.8
Treatment.Variety	24	146	6.1	0.9	0.63
Contrast 1.Variety	3	5.35	1.78	0.3	0.86
Contrast 2.Variety	3	19.7	6.57	0.9	0.42
Contrast 3.Variety	3	2.02	0.67	0.1	0.96
Contrast 4.Variety	3	6.61	2.2	0.3	0.81
Site.Treatment.Variety	24	107	4.46	0.6	0.9
Site.Contrast 1.Variety	3	11.8	3.93	0.6	0.64
Site.Contrast 2.Variety	3	7.96	2.66	0.4	0.77
Site.Contrast 3.Variety	3	3.48	1.16	0.2	0.92
Site.Contrast 4.Variety	3	0.76	0.25	0	0.99
Residual	144	1002	6.96		
Total	215	2024			

Plant height cm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	612.51	612.5	67.2	<.001
Treatment	8	34.434	4.304	0.47	0.87
Contrast 1	1	1.411	1.411	0.15	0.7
Contrast 2	1	8.224	8.224	0.9	0.34
Contrast 3	1	5.829	5.829	0.64	0.43
Contrast 4	1	0.003	0.003	0	0.99
Variety	3	35.3	11.77	1.29	0.28
Site.Treatment	8	46.198	5.775	0.63	0.75
Site.Contrast 1	1	0.795	0.795	0.09	0.77
Site.Contrast 2	1	29.947	29.95	3.29	0.07
Site.Contrast 3	1	5.536	5.536	0.61	0.44
Site.Contrast 4	1	6.178	6.178	0.68	0.41
Site.Variety	3	24.406	8.135	0.89	0.45
Treatment.Variety	24	129.51	5.396	0.59	0.93
Contrast 1.Variety	3	3.28	1.093	0.12	0.95
Contrast 2.Variety	3	6.644	2.215	0.24	0.87
Contrast 3.Variety	3	3.364	1.121	0.12	0.95
Contrast 4.Variety	3	36.18	12.06	1.32	0.27
Site.Treatment.Variety	24	206.03	8.585	0.94	0.55
Site.Contrast 1.Variety	3	9.118	3.039	0.33	0.8
Site.Contrast 2.Variety	3	21.073	7.024	0.77	0.51
Site.Contrast 3.Variety	3	22.229	7.41	0.81	0.49
Site.Contrast 4.Variety	3	7.974	2.658	0.29	0.83
Residual	144	1311.7	9.109		
Total	215	2400.1			

Plant height cm week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	152.67	19.08	1.19	0.312
Contrast 1	1	67.19	67.19	4.17	0.043
Contrast 2	1	28.67	28.67	1.78	0.184
Contrast 3	1	4.29	4.29	0.27	0.606
Contrast 4	1	4.45	4.45	0.28	0.6
Contrast 5	1	0.11	0.11	0.01	0.933
Site	1	1289.49	1289.49	80.1	<.001
Variety	3	111.54	37.18	2.31	0.079
Treatment.Site	8	91.68	11.46	0.71	0.681
Contrast 1.Site	1	0.07	0.07	0	0.949
Contrast 2.Site	1	1.17	1.17	0.07	0.788
Contrast 3.Site	1	0.93	0.93	0.06	0.81
Contrast 4.Site	1	0.88	0.88	0.05	0.816
Contrast 5.Site	1	3.45	3.45	0.21	0.644
Treatment.Variety	24	480	20	1.24	0.216
Contrast 1.Variety	3	42.04	14.01	0.87	0.458
Contrast 2.Variety	3	20.51	6.84	0.42	0.736
Contrast 3.Variety	3	16.82	5.61	0.35	0.79
Contrast 4.Variety	3	29.68	9.89	0.61	0.607
Contrast 5.Variety	3	28.86	9.62	0.6	0.618
Site.Variety	3	39.85	13.28	0.83	0.482
Treatment.Site.Variety	24	175.63	7.32	0.45	0.987
Contrast 1.Site.Variety	3	11.25	3.75	0.23	0.873
Contrast 2.Site.Variety	3	26.9	8.97	0.56	0.644
Contrast 3.Site.Variety	3	17.11	5.7	0.35	0.786
Contrast 4.Site.Variety	3	6.55	2.18	0.14	0.939
Contrast 5.Site.Variety	3	22.75	7.58	0.47	0.703
Residual	144	2318.23	16.1		
Total	215	4659.09			

Shoot girth mm week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	0.81	0.81	27.2	<.001
Treatment	8	0.18	0.022	0.75	0.648
Contrast 1	1	0	0.002	0.08	0.779
Contrast 2	1	0.01	0.005	0.18	0.676
Contrast 3	1	0.04	0.039	1.3	0.255
Contrast 4	1	0.03	0.031	1.03	0.311
Variety	3	0.13	0.044	1.47	0.224
Site.Treatment	8	0.19	0.024	0.81	0.593
Site.Contrast 1	1	0.06	0.058	1.94	0.166
Site.Contrast 2	1	0.01	0.005	0.18	0.676
Site.Contrast 3	1	0.01	0.008	0.28	0.596
Site.Contrast 4	1	0.01	0.013	0.43	0.512
Site.Variety	3	0.06	0.021	0.72	0.544
Treatment.Variety	24	0.62	0.026	0.87	0.645
Contrast 1.Variety	3	0.07	0.022	0.73	0.537
Contrast 2.Variety	3	0.21	0.071	2.39	0.071
Contrast 3.Variety	3	0.05	0.017	0.56	0.644
Contrast 4.Variety	3	0.07	0.024	0.81	0.491
Site.Treatment.Variety	24	0.58	0.024	0.81	0.725
Site.Contrast 1.Variety	3	0.06	0.021	0.72	0.54
Site.Contrast 2.Variety	3	0.13	0.043	1.46	0.228
Site.Contrast 3.Variety	3	0.08	0.027	0.9	0.444
Site.Contrast 4.Variety	3	0.06	0.019	0.64	0.593
Residual	144	4.28	0.03		
Total	215	6.86			

Shoot girth mm week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	0.03	0.02952	0.98	0.323
Treatment	8	0.28	0.03534	1.18	0.316
Contrast 1	1	0.04	0.03987	1.33	0.251
Contrast 2	1	0	0.00008	0	0.959
Contrast 3	1	0.03	0.02567	0.86	0.356
Contrast 4	1	0.02	0.02046	0.68	0.41
Variety	3	0.04	0.01248	0.42	0.742
Site.Treatment	8	0.24	0.03033	1.01	0.43
Site.Contrast 1	1	0.02	0.02445	0.82	0.368
Site.Contrast 2	1	0	0.00008	0	0.959
Site.Contrast 3	1	0.03	0.02567	0.86	0.356
Site.Contrast 4	1	0.02	0.02046	0.68	0.41
Site.Variety	3	0.04	0.01184	0.39	0.757
Treatment.Variety	24	0.45	0.01895	0.63	0.905
Contrast 1.Variety	3	0.04	0.01477	0.49	0.688
Contrast 2.Variety	3	0.11	0.038	1.27	0.288
Contrast 3.Variety	3	0.02	0.00575	0.19	0.902
Contrast 4.Variety	3	0.03	0.011	0.37	0.777
Site.Treatment.Variety	24	0.41	0.01696	0.57	0.948
Site.Contrast 1.Variety	3	0.04	0.01408	0.47	0.704
Site.Contrast 2.Variety	3	0.11	0.038	1.27	0.288
Site.Contrast 3.Variety	3	0.02	0.00575	0.19	0.902
Site.Contrast 4.Variety	3	0.03	0.011	0.37	0.777
Residual	144	4.32	0.02997		
Total	215	5.81			

Variate: shoot girth 3 mm					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	74.6315	74.632	163	<.001
Treatment	8	4.9923	0.624	1.36	0.218
Contrast 1	1	0.2259	0.2259	0.49	0.484
Contrast 2	1	0.1651	0.1651	0.36	0.549
Contrast 3	1	0.4706	0.4706	1.03	0.313
Contrast 4	1	0.2508	0.2508	0.55	0.461
Variety	3	1.2434	0.4145	0.9	0.441
Site.Treatment	8	2.9407	0.3676	0.8	0.602
Site.Contrast 1	1	0.1863	0.1863	0.41	0.525
Site.Contrast 2	1	0.0005	0.0005	0	0.973
Site.Contrast 3	1	0.1478	0.1478	0.32	0.571
Site.Contrast 4	1	0.0902	0.0902	0.2	0.658
Site.Variety	3	0.9001	0.3	0.65	0.581
Treatment.Variety	24	7.8005	0.325	0.71	0.836
Contrast 1.Variety	3	0.48	0.16	0.35	0.79
Contrast 2.Variety	3	0.5666	0.1889	0.41	0.744
Contrast 3.Variety	3	0.1154	0.0385	0.08	0.969
Contrast 4.Variety	3	0.6744	0.2248	0.49	0.689
Site.Treatment.Variety	24	6.331	0.2638	0.58	0.943
Site.Contrast 1.Variety	3	1.2447	0.4149	0.91	0.44
Site.Contrast 2.Variety	3	0.3821	0.1274	0.28	0.841
Site.Contrast 3.Variety	3	1.7046	0.5682	1.24	0.298
Site.Contrast 4.Variety	3	0.8935	0.2978	0.65	0.584
Residual	144	65.985	0.4582		
Total	215	164.825			

Shoot girth mm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	1.7253	1.725	2.58	0.11
Treatment	8	15.712	1.964	2.94	0.004
Contrast 1	1	2.644	2.644	3.96	0.048
Contrast 2	1	0.1696	0.17	0.25	0.615
Contrast 3	1	1.961	1.961	2.94	0.089
Contrast 4	1	0.0016	0.002	0	0.961
Variety	3	1.27	0.423	0.63	0.594
Site.Treatment	8	12.92	1.615	2.42	0.018
Site.Contrast 1	1	0.0234	0.023	0.03	0.852
Site.Contrast 2	1	0.006	0.006	0.01	0.925
Site.Contrast 3	1	0.5175	0.518	0.78	0.38
Site.Contrast 4	1	2.8166	2.817	4.22	0.042
Site.Variety	3	1.5343	0.511	0.77	0.515
Treatment.Variety	24	23.883	0.995	1.49	0.079
Contrast 1.Variety	3	0.85	0.283	0.42	0.736
Contrast 2.Variety	3	2.2223	0.741	1.11	0.347
Contrast 3.Variety	3	0.1274	0.043	0.06	0.979
Contrast 4.Variety	3	1.6086	0.536	0.8	0.494
Site.Treatment.Variety	24	22.114	0.921	1.38	0.127
Site.Contrast 1.Variety	3	1.0448	0.348	0.52	0.668
Site.Contrast 2.Variety	3	4.3722	1.457	2.18	0.093
Site.Contrast 3.Variety	3	1.7163	0.572	0.86	0.465
Site.Contrast 4.Variety	3	2.5837	0.861	1.29	0.28
Residual	144	96.149	0.668		
Total	215	175.31			

Variate: shoot girth 5 mm					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	0.88	0.885	1.42	0.235
Treatment	8	8.62	1.077	1.73	0.096
Contrast 1	1	0.92	0.925	1.49	0.225
Contrast 2	1	0.92	0.921	1.48	0.225
Contrast 3	1	0.01	0.005	0.01	0.926
Contrast 4	1	0.12	0.118	0.19	0.663
Variety	3	1.32	0.441	0.71	0.547
Site.Treatment	8	4.36	0.545	0.88	0.538
Site.Contrast 1	1	0.99	0.987	1.59	0.21
Site.Contrast 2	1	0.06	0.058	0.09	0.76
Site.Contrast 3	1	0.28	0.283	0.46	0.501
Site.Contrast 4	1	0	0.001	0	0.962
Site.Variety	3	1.18	0.394	0.63	0.594
Treatment.Variety	24	15.7	0.653	1.05	0.409
Contrast 1.Variety	3	1.98	0.66	1.06	0.367
Contrast 2.Variety	3	0.21	0.069	0.11	0.953
Contrast 3.Variety	3	0.17	0.058	0.09	0.964
Contrast 4.Variety	3	0.89	0.295	0.48	0.7
Site.Treatment.Variety	24	11.6	0.485	0.78	0.756
Site.Contrast 1.Variety	3	1.83	0.611	0.98	0.403
Site.Contrast 2.Variety	3	1.18	0.394	0.63	0.595
Site.Contrast 3.Variety	3	0.81	0.27	0.43	0.729
Site.Contrast 4.Variety	3	0.25	0.082	0.13	0.941
Residual	144	89.5	0.622		
Total	215	133			

Shoot girth mm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	6.0261	6.03	9.19	0.003
Treatment	8	0.6791	0.08	0.13	0.998
Contrast 1	1	0.0027	0	0	0.949
Contrast 2	1	0.0035	0	0.01	0.942
Contrast 3	1	0.1083	0.11	0.17	0.685
Contrast 4	1	0.0156	0.02	0.02	0.878
Variety	3	0.5983	0.2	0.3	0.822
Site.Treatment	8	5.4639	0.68	1.04	0.408
Site.Contrast 1	1	0.0106	0.01	0.02	0.899
Site.Contrast 2	1	1.3814	1.38	2.11	0.149
Site.Contrast 3	1	0.0011	0	0	0.967
Site.Contrast 4	1	2.3339	2.33	3.56	0.061
Site.Variety	3	1.9646	0.65	1	0.396
Treatment.Variety	24	8.7302	0.36	0.55	0.954
Contrast 1.Variety	3	0.2495	0.08	0.13	0.944
Contrast 2.Variety	3	0.3101	0.1	0.16	0.925
Contrast 3.Variety	3	0.1574	0.05	0.08	0.971
Contrast 4.Variety	3	2.9341	0.98	1.49	0.22
Site.Treatment.Variety	24	18.039	0.75	1.15	0.303
Site.Contrast 1.Variety	3	0.2712	0.09	0.14	0.937
Site.Contrast 2.Variety	3	1.9592	0.65	1	0.397
Site.Contrast 3.Variety	3	0.6204	0.21	0.32	0.814
Site.Contrast 4.Variety	3	3.1432	1.05	1.6	0.193
Residual	144	94.453	0.66		
Total	215	135.95			

Variate: shoot girth8 mm					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	83	83	102	<.001
Treatment	8	8.2	1.02	1.26	0.266
Contrast 1	1	2.59	2.59	3.2	0.076
Contrast 2	1	0.05	0.05	0.06	0.811
Contrast 3	1	0.39	0.39	0.48	0.488
Contrast 4	1	0.13	0.13	0.16	0.694
Variety	3	6.28	2.09	2.58	0.056
Site.Treatment	8	8.03	1	1.24	0.281
Site.Contrast 1	1	0.9	0.9	1.11	0.295
Site.Contrast 2	1	1.56	1.56	1.93	0.167
Site.Contrast 3	1	0.38	0.38	0.47	0.494
Site.Contrast 4	1	0.91	0.91	1.12	0.291
Site.Variety	3	0.77	0.26	0.32	0.813
Treatment.Variety	24	19.9	0.83	1.02	0.44
Contrast 1.Variety	3	1.51	0.5	0.62	0.602
Contrast 2.Variety	3	3.82	1.27	1.57	0.199
Contrast 3.Variety	3	1.07	0.36	0.44	0.725
Contrast 4.Variety	3	1.52	0.51	0.62	0.6
Site.Treatment.Variety	24	22.1	0.92	1.13	0.314
Site.Contrast 1.Variety	3	2.53	0.84	1.04	0.377
Site.Contrast 2.Variety	3	2.6	0.87	1.07	0.364
Site.Contrast 3.Variety	3	3.45	1.15	1.42	0.24
Site.Contrast 4.Variety	3	2.46	0.82	1.01	0.39
Residual	144	117	0.81		
Total	215	265			

Root length cm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	3.59	3.586	0.73	0.395
Treatment	8	47.2	5.903	1.2	0.305
Contrast 1	1	10	10	2.03	0.157
Contrast 2	1	8.63	8.633	1.75	0.188
Contrast 3	1	0.27	0.272	0.06	0.815
Contrast 4	1	8.26	8.26	1.67	0.198
Variety	3	47	15.66	3.18	0.026
Site.Treatment	8	47.3	5.907	1.2	0.304
Site.Contrast 1	1	0.04	0.039	0.01	0.929
Site.Contrast 2	1	2.59	2.593	0.53	0.47
Site.Contrast 3	1	0.08	0.084	0.02	0.896
Site.Contrast 4	1	0.01	0.006	0	0.973
Site.Variety	3	23.3	7.779	1.58	0.197
Treatment.Variety	24	267	11.12	2.26	0.002
Contrast 1.Variety	3	19.1	6.367	1.29	0.28
Contrast 2.Variety	3	36	11.99	2.43	0.068
Contrast 3.Variety	3	10.5	3.507	0.71	0.547
Contrast 4.Variety	3	14.7	4.907	0.99	0.397
Site.Treatment.Variety	24	158	6.6	1.34	0.15
Site.Contrast 1.Variety	3	28.7	9.564	1.94	0.126
Site.Contrast 2.Variety	3	22	7.34	1.49	0.22
Site.Contrast 3.Variety	3	8.29	2.764	0.56	0.642
Site.Contrast 4.Variety	3	10.9	3.619	0.73	0.533
Residual	144	710	4.932		
Total	215	1304			

Root length cm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	1.67	1.67	0.19	0.66
Treatment	8	15.7	1.963	0.23	0.985
Contrast 1	1	0.64	0.642	0.07	0.785
Contrast 2	1	0.01	0.011	0	0.972
Contrast 3	1	0.6	0.595	0.07	0.793
Contrast 4	1	0.02	0.023	0	0.959
Variety	3	72.7	24.224	2.82	0.041
Site.Treatment	8	88.1	11.01	1.28	0.257
Site.Contrast 1	1	19.4	19.364	2.26	0.135
Site.Contrast 2	1	10.1	10.102	1.18	0.28
Site.Contrast 3	1	0.04	0.04	0	0.945
Site.Contrast 4	1	3.15	3.149	0.37	0.546
Site.Variety	3	2.36	0.788	0.09	0.964
Treatment.Variety	24	230	9.582	1.12	0.334
Contrast 1.Variety	3	15.9	5.283	0.62	0.606
Contrast 2.Variety	3	36	11.994	1.4	0.246
Contrast 3.Variety	3	5.82	1.94	0.23	0.878
Contrast 4.Variety	3	3.77	1.257	0.15	0.932
Site.Treatment.Variety	24	182	7.569	0.88	0.626
Site.Contrast 1.Variety	3	25.5	8.515	0.99	0.399
Site.Contrast 2.Variety	3	13.3	4.443	0.52	0.671
Site.Contrast 3.Variety	3	3.1	1.033	0.12	0.948
Site.Contrast 4.Variety	3	4.58	1.526	0.18	0.911
Residual	144	1236	8.586		
Total	215	1829			

No of nodules week 5

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Site	1		150.7	151	3.62	0.06
Treatment	8		861.6	108	2.59	0.01
Contrast 1	1		115.6	116	2.78	0.1
Contrast 2	1		0.19	0.19	0	0.95
Contrast 3	1		33.33	33.3	0.8	0.37
Contrast 4	1		15.19	15.2	0.36	0.55
Variety	3		317.2	106	2.54	0.06
Site.Treatment	8		549	68.6	1.65	0.12
Site.Contrast 1	1		138.4	138	3.32	0.07
Site.Contrast 2	1		17.52	17.5	0.42	0.52
Site.Contrast 3	1		14.08	14.1	0.34	0.56
Site.Contrast 4	1		22.69	22.7	0.54	0.46
Site.Variety	3		222.2	74.1	1.78	0.15
Treatment.Variety	24		1490	62.1	1.49	0.08
Contrast 1.Variety	3		22.64	7.55	0.18	0.91
Contrast 2.Variety	3		10.4	3.47	0.08	0.97
Contrast 3.Variety	3		36.83	12.3	0.29	0.83
Contrast 4.Variety	3		149.9	50	1.2	0.31
Site.Treatment.Variety	24		1656	69	1.66	0.04
Site.Contrast 1.Variety	3		124.1	41.4	0.99	0.4
Site.Contrast 2.Variety	3		102.7	34.2	0.82	0.48
Site.Contrast 3.Variety	3		14.42	4.81	0.12	0.95
Site.Contrast 4.Variety	3		224.4	74.8	1.8	0.15
Residual	140	-4	5831	41.7		
Total	211	-4	11066			

Root length cm week 8

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Site	1		457.72	458	37.24	<.001
Treatment	8		56.69	7.09	0.58	0.8
Contrast 1	1		5.43	5.43	0.44	0.51
Contrast 2	1		0.57	0.57	0.05	0.83
Contrast 3	1		3.93	3.93	0.32	0.57
Contrast 4	1		3.1	3.1	0.25	0.62
Variety	3		23.59	7.86	0.64	0.59
Site.Treatment	8		110.75	13.8	1.13	0.35
Site.Contrast 1	1		1.23	1.23	0.1	0.75
Site.Contrast 2	1		3.22	3.22	0.26	0.61
Site.Contrast 3	1		8.56	8.56	0.7	0.41
Site.Contrast 4	1		13.24	13.2	1.08	0.3
Site.Variety	3		41.16	13.7	1.12	0.35
Treatment.Variety	24		301	12.5	1.02	0.45
Contrast 1.Variety	3		11.15	3.72	0.3	0.82
Contrast 2.Variety	3		11.29	3.76	0.31	0.82
Contrast 3.Variety	3		5.41	1.8	0.15	0.93
Contrast 4.Variety	3		11.94	3.98	0.32	0.81
Site.Treatment.Variety	24		435.92	18.2	1.48	0.08
Site.Contrast 1.Variety	3		107.18	35.7	2.91	0.04
Site.Contrast 2.Variety	3		80.49	26.8	2.18	0.09
Site.Contrast 3.Variety	3		13.77	4.59	0.37	0.77
Site.Contrast 4.Variety	3		26.31	8.77	0.71	0.55
Residual	142	-2	1745.2	12.3		
Total	213	-2	3172			

No of nodules week 6

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	2347	2347	73.4	<.001
Treatment	8	227	28.32	0.89	0.53
Contrast 1	1	12	12	0.38	0.541
Contrast 2	1	0.75	0.75	0.02	0.878
Contrast 3	1	63	63.02	1.97	0.163
Contrast 4	1	0.08	0.08	0	0.959
Variety	3	113	37.81	1.18	0.319
Site.Treatment	8	176	22.02	0.69	0.701
Site.Contrast 1	1	36.8	36.75	1.15	0.285
Site.Contrast 2	1	14.1	14.08	0.44	0.508
Site.Contrast 3	1	22.7	22.69	0.71	0.401
Site.Contrast 4	1	8.33	8.33	0.26	0.61
Site.Variety	3	39.7	13.25	0.41	0.743
Treatment.Variety	24	621	25.89	0.81	0.72
Contrast 1.Variety	3	24.2	8.06	0.25	0.86
Contrast 2.Variety	3	7.42	2.47	0.08	0.972
Contrast 3.Variety	3	55.6	18.52	0.58	0.63
Contrast 4.Variety	3	63.6	21.19	0.66	0.576
Site.Treatment.Variety	24	671	27.97	0.87	0.636
Site.Contrast 1.Variety	3	32.4	10.81	0.34	0.798
Site.Contrast 2.Variety	3	17.4	5.81	0.18	0.909
Site.Contrast 3.Variety	3	77.2	25.74	0.81	0.493
Site.Contrast 4.Variety	3	14.7	4.89	0.15	0.928
Residual	144	4605	31.98		
Total	215	8800			

No of nodules week 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	6894.5	6895	111	<.001
Treatment	8	1192	149	2.4	0.019
Contrast 1	1	553.52	554	8.91	0.003
Contrast 2	1	25.52	25.5	0.41	0.523
Contrast 3	1	58.52	58.5	0.94	0.333
Contrast 4	1	229.69	230	3.7	0.056
Variety	3	672.94	224	3.61	0.015
Site.Treatment	8	1583.4	198	3.19	0.002
Site.Contrast 1	1	238.52	239	3.84	0.052
Site.Contrast 2	1	3.52	3.52	0.06	0.812
Site.Contrast 3	1	46.02	46	0.74	0.391
Site.Contrast 4	1	368.52	369	5.93	0.016
Site.Variety	3	500.51	167	2.69	0.049
Treatment.Variety	24	952.49	39.7	0.64	0.9
Contrast 1.Variety	3	365.56	122	1.96	0.122
Contrast 2.Variety	3	83.73	27.9	0.45	0.718
Contrast 3.Variety	3	24.9	8.3	0.13	0.94
Contrast 4.Variety	3	124.56	41.5	0.67	0.573
Site.Treatment.Variety	24	1188.4	49.5	0.8	0.736
Site.Contrast 1.Variety	3	133.56	44.5	0.72	0.544
Site.Contrast 2.Variety	3	148.73	49.6	0.8	0.497
Site.Contrast 3.Variety	3	310.73	104	1.67	0.177
Site.Contrast 4.Variety	3	71.06	23.7	0.38	0.767
Residual	144	8944.7	62.1		
Total	215	21929			

No of leaves week 3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	209271	209271	13.2	<.001
Treatment	8	331185	41398	2.62	0.01
Contrast 1	1	53132	53132	3.36	0.069
Contrast 2	1	1092	1092	0.07	0.793
Contrast 3	1	66070	66070	4.18	0.043
Contrast 4	1	4802	4802	0.3	0.582
Variety	3	78459	26153	1.65	0.18
Site.Treatment	8	552905	69113	4.37	<.001
Site.Contrast 1	1	51905	51905	3.28	0.072
Site.Contrast 2	1	109170	109170	6.91	0.01
Site.Contrast 3	1	476	476	0.03	0.862
Site.Contrast 4	1	20740	20740	1.31	0.254
Site.Variety	3	424803	141601	8.96	<.001
Treatment.Variety	24	276547	11523	0.73	0.815
Contrast 1.Variety	3	6885	2295	0.15	0.933
Contrast 2.Variety	3	49270	16423	1.04	0.377
Contrast 3.Variety	3	19502	6501	0.41	0.745
Contrast 4.Variety	3	31628	10543	0.67	0.574
Site.Treatment.Variety	24	319524	13314	0.84	0.678
Site.Contrast 1.Variety	3	32079	10693	0.68	0.568
Site.Contrast 2.Variety	3	50712	16904	1.07	0.364
Site.Contrast 3.Variety	3	53806	17935	1.13	0.337
Site.Contrast 4.Variety	3	39133	13044	0.83	0.482
Residual	144	2276272	15807		
Total	215	4468967			

No of leaves week 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	1634411	1634411	27	<.001
Treatment	8	1620685	202586	3.35	0.002
Contrast 1	1	274786	274786	4.54	0.035
Contrast 2	1	63117	63117	1.04	0.309
Contrast 3	1	195252	195252	3.23	0.075
Contrast 4	1	1242	1242	0.02	0.886
Variety	3	1450141	483380	7.98	<.001
Site.Treatment	8	2814338	351792	5.81	<.001
Site.Contrast 1	1	74852	74852	1.24	0.268
Site.Contrast 2	1	192755	192755	3.18	0.076
Site.Contrast 3	1	168917	168917	2.79	0.097
Site.Contrast 4	1	16577	16577	0.27	0.602
Site.Variety	3	2124577	708192	11.7	<.001
Treatment.Variety	24	1318345	54931	0.91	0.592
Contrast 1.Variety	3	27590	9197	0.15	0.928
Contrast 2.Variety	3	150675	50225	0.83	0.48
Contrast 3.Variety	3	74047	24682	0.41	0.748
Contrast 4.Variety	3	114091	38030	0.63	0.598
Site.Treatment.Variety	24	857525	35730	0.59	0.934
Site.Contrast 1.Variety	3	91062	30354	0.5	0.682
Site.Contrast 2.Variety	3	61978	20659	0.34	0.796
Site.Contrast 3.Variety	3	195081	65027	1.07	0.362
Site.Contrast 4.Variety	3	28078	9359	0.15	0.927
Residual	144	8717928	60541		
Total	215	20537950			

No of leaves week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	5803976	5803976	42.2	<.001
Treatment	8	2346658	293332	2.13	0.036
Contrast 1	1	330066	330066	2.4	0.124
Contrast 2	1	157370	157370	1.14	0.287
Contrast 3	1	222719	222719	1.62	0.205
Contrast 4	1	651	651	0	0.945
Variety	3	2403358	801119	5.82	<.001
Site.Treatment	8	3783673	472959	3.44	0.001
Site.Contrast 1	1	64679	64679	0.47	0.494
Site.Contrast 2	1	389880	389880	2.83	0.095
Site.Contrast 3	1	147190	147190	1.07	0.303
Site.Contrast 4	1	7782	7782	0.06	0.812
Site.Variety	3	2748993	916331	6.66	<.001
Treatment.Variety	24	2293986	95583	0.69	0.851
Contrast 1.Variety	3	159166	53055	0.39	0.764
Contrast 2.Variety	3	81329	27110	0.2	0.898
Contrast 3.Variety	3	373679	124560	0.9	0.44
Contrast 4.Variety	3	56790	18930	0.14	0.937
Site.Treatment.Variety	24	1338660	55778	0.41	0.994
Site.Contrast 1.Variety	3	226999	75666	0.55	0.649
Site.Contrast 2.Variety	3	80036	26679	0.19	0.9
Site.Contrast 3.Variety	3	260192	86731	0.63	0.597
Site.Contrast 4.Variety	3	35217	11739	0.09	0.968
Residual	144	19820944	137645		
Total	215	40540249			

No of leaves week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	21529031	21529031	95.2	<.001
Treatment	8	2361427	295178	1.31	0.245
Contrast 1	1	139321	139321	0.62	0.434
Contrast 2	1	501633	501633	2.22	0.139
Contrast 3	1	752000	752000	3.33	0.07
Contrast 4	1	34848	34848	0.15	0.695
Variety	3	5488588	1829529	8.09	<.001
Site.Treatment	8	3362331	420291	1.86	0.071
Site.Contrast 1	1	579016	579016	2.56	0.112
Site.Contrast 2	1	1776778	1776778	7.86	0.006
Site.Contrast 3	1	56850	56850	0.25	0.617
Site.Contrast 4	1	172250	172250	0.76	0.384
Site.Variety	3	6776589	2258863	9.99	<.001
Treatment.Variety	24	4112636	171360	0.76	0.783
Contrast 1.Variety	3	196773	65591	0.29	0.832
Contrast 2.Variety	3	562772	187591	0.83	0.48
Contrast 3.Variety	3	303252	101084	0.45	0.72
Contrast 4.Variety	3	427831	142610	0.63	0.596
Site.Treatment.Variety	24	2899557	120815	0.53	0.963
Site.Contrast 1.Variety	3	556835	185612	0.82	0.484
Site.Contrast 2.Variety	3	113941	37980	0.17	0.918
Site.Contrast 3.Variety	3	525641	175214	0.78	0.51
Site.Contrast 4.Variety	3	460089	153363	0.68	0.567
Residual	144	32555108	226077		
Total	215	79085267			

No of leaves week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Site	1	41725699	41725699	77.1	<.001
Treatment	8	8631049	1078881	1.99	0.051
Contrast 1	1	403978	403978	0.75	0.389
Contrast 2	1	2100714	2100714	3.88	0.051
Contrast 3	1	2216645	2216645	4.1	0.045
Contrast 4	1	303664	303664	0.56	0.455
Variety	3	13517195	4505732	8.33	<.001
Site.Treatment	8	7978148	997268	1.84	0.074
Site.Contrast 1	1	180086	180086	0.33	0.565
Site.Contrast 2	1	2870248	2870248	5.3	0.023
Site.Contrast 3	1	37136	37136	0.07	0.794
Site.Contrast 4	1	255495	255495	0.47	0.493
Site.Variety	3	10758082	3586027	6.63	<.001
Treatment.Variety	24	11125563	463565	0.86	0.659
Contrast 1.Variety	3	867134	289045	0.53	0.66
Contrast 2.Variety	3	788472	262824	0.49	0.693
Contrast 3.Variety	3	486328	162109	0.3	0.826
Contrast 4.Variety	3	1072493	357498	0.66	0.578
Site.Treatment.Variety	24	7146265	297761	0.55	0.956
Site.Contrast 1.Variety	3	942031	314010	0.58	0.629
Site.Contrast 2.Variety	3	360030	120010	0.22	0.881
Site.Contrast 3.Variety	3	1270868	423623	0.78	0.505
Site.Contrast 4.Variety	3	880539	293513	0.54	0.654
Residual	144	77928671	541171		
Total	215	178810673			

Appendix 4: Contrasting Control versus combined bio-stimulators (Set 2)

Contrasts	Control	Humates+ SWE basal application	Humates + SWE basal application + SWE foliar spray	SWE basal application + SWE foliar	Humates+ SWE foliar
1	1	-1	0	0	0
2	1	0	-1	0	0
3	1	0	0	-1	0
4	1	0	0	0	-1

Emergence rate %					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	10276	1284.5	3.71	<.001
Contrast 1	1	370.4	370.4	1.07	0.303
Contrast 2	1	304.2	304.2	0.88	0.35
Contrast 3	1	175.1	175.1	0.51	0.478
Contrast 4	1	2314.8	2314.8	6.69	0.011
Variety	3	5133.7	1711.2	4.95	0.003
Site	1	52813	52813	153	<.001
Treatment.Variety	24	6929	288.7	0.83	0.688
Contrast 1.Variety	3	2316.3	772.1	2.23	0.087
Contrast 2.Variety	3	648.1	216	0.62	0.6
Contrast 3.Variety	3	254.3	84.8	0.25	0.865
Contrast 4.Variety	3	258.2	86.1	0.25	0.862
Treatment.Site	8	21772	2721.5	7.87	<.001
Contrast 1.Site	1	267.6	267.6	0.77	0.381
Contrast 2.Site	1	926.1	926.1	2.68	0.104
Contrast 3.Site	1	765.3	765.3	2.21	0.139
Contrast 4.Site	1	4833.4	4833.4	14	<.001
Variety.Site	3	6859.2	2286.4	6.61	<.001
Treatment.Variety.Site	24	7049.8	293.7	0.85	0.669
Contrast 1.Variety.Site	3	1620	540	1.56	0.201
Contrast 2.Variety.Site	3	816.3	272.1	0.79	0.503
Contrast 3.Variety.Site	3	50.6	16.9	0.05	0.986
Contrast 4.Variety.Site	3	1083.9	361.3	1.04	0.375
Residual	144	49812	345.9		
Total	215	160644			

Days to emergence					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	934.33	116.79	12.6	<.001
Contrast 1	1	238.52	238.52	25.7	<.001
Contrast 2	1	216.75	216.75	23.3	<.001
Contrast 3	1	3.521	3.521	0.38	0.54
Contrast 4	1	221.02	221.02	23.8	<.001
Variety	3	75.495	25.165	2.71	0.05
Site	1	453.56	453.56	48.8	<.001
Treatment.Variety	24	132.63	5.526	0.6	0.93
Contrast 1.Variety	3	26.062	8.687	0.94	0.43
Contrast 2.Variety	3	14.417	4.806	0.52	0.67
Contrast 3.Variety	3	8.396	2.799	0.3	0.82
Contrast 4.Variety	3	24.729	8.243	0.89	0.45
Treatment.Site	8	278.15	34.769	3.74	<.001
Contrast 1.Site	1	42.188	42.188	4.54	0.04
Contrast 2.Site	1	36.75	36.75	3.96	0.05
Contrast 3.Site	1	0.021	0.021	0	0.96
Contrast 4.Site	1	42.188	42.188	4.54	0.04
Variety.Site	3	38.199	12.733	1.37	0.25
Treatment.Variety.Site	24	191.26	7.969	0.86	0.66
Contrast 1.Variety.Site	3	19.396	6.465	0.7	0.56
Contrast 2.Variety.Site	3	34.75	11.583	1.25	0.3
Contrast 3.Variety.Site	3	3.563	1.188	0.13	0.94
Contrast 4.Variety.Site	3	22.896	7.632	0.82	0.48
Residual	144	1337.3	9.287		
Total	215	3441			

Chlorophyll					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1119.63	140	1.44	0.186
Contrast 1	1	15.72	15.7	0.16	0.689
Contrast 2	1	0	0	0	0.994
Contrast 3	1	14.85	14.9	0.15	0.697
Contrast 4	1	25.33	25.3	0.26	0.611
Variety	3	528.56	176	1.81	0.148
Site	1	1653.66	1654	17	<.001
Treatment.Variety	24	5683.77	237	2.43	<.001
Contrast 1.Variety	3	422.82	141	1.45	0.232
Contrast 2.Variety	3	176.61	58.9	0.6	0.613
Contrast 3.Variety	3	689.15	230	2.36	0.074
Contrast 4.Variety	3	209.37	69.8	0.72	0.544
Treatment.Site	8	958.6	120	1.23	0.286
Contrast 1.Site	1	31.26	31.3	0.32	0.572
Contrast 2.Site	1	9.09	9.09	0.09	0.761
Contrast 3.Site	1	93.8	93.8	0.96	0.328
Contrast 4.Site	1	18.83	18.8	0.19	0.661
Variety.Site	3	574.55	192	1.97	0.122
Treatment.Variety.Site	24	4926.85	205	2.11	0.004
Contrast 1.Variety.Site	3	670.14	223	2.29	0.081
Contrast 2.Variety.Site	3	131.04	43.7	0.45	0.719
Contrast 3.Variety.Site	3	779.76	260	2.67	0.05
Contrast 4.Variety.Site	3	141.73	47.2	0.48	0.693
Residual	144	14033.1	97.5		
Total	215	29478.7			

Survival rate					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	13914.5	1739	3.2	0.002
Contrast 1	1	261.3	261.3	0.48	0.489
Contrast 2	1	85.3	85.3	0.16	0.692
Contrast 3	1	261.3	261.3	0.48	0.489
Contrast 4	1	2581.3	2581	4.76	0.031
Variety	3	6926.1	2309	4.25	0.007
Site	1	69948	69948	129	<.001
Treatment.Variety	24	10315.4	429.8	0.79	0.742
Contrast 1.Variety	3	3000.8	1000	1.84	0.142
Contrast 2.Variety	3	858.5	286.2	0.53	0.664
Contrast 3.Variety	3	339.2	113.1	0.21	0.891
Contrast 4.Variety	3	377.5	125.8	0.23	0.874
Treatment.Site	8	33478	4185	7.71	<.001
Contrast 1.Site	1	481.3	481.3	0.89	0.348
Contrast 2.Site	1	2054.1	2054	3.78	0.054
Contrast 3.Site	1	1121.3	1121	2.07	0.153
Contrast 4.Site	1	8216.3	8216	15.1	<.001
Variety.Site	3	12510	4170	7.68	<.001
Treatment.Variety.Site	24	9857.9	410.7	0.76	0.784
Contrast 1.Variety.Site	3	2355.5	785.2	1.45	0.232
Contrast 2.Variety.Site	3	1568.7	522.9	0.96	0.412
Contrast 3.Variety.Site	3	74.2	24.7	0.05	0.987
Contrast 4.Variety.Site	3	1838.5	612.8	1.13	0.339
Residual	144	78163.3	542.8		
Total	215	235113			

Plant height cm week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1.1618	0.1452	0.91	0.509
Contrast 1	1	0.0243	0.0243	0.15	0.697
Contrast 2	1	0.2248	0.2248	1.41	0.237
Contrast 3	1	0.0036	0.0036	0.02	0.881
Contrast 4	1	0.2153	0.2153	1.35	0.247
Variety	3	0.4048	0.1349	0.85	0.471
Site	1	3.2825	3.2825	20.6	<.001
Treatment.Variety	24	3.8514	0.1605	1.01	0.462
Contrast 1.Variety	3	1.1187	0.3729	2.34	0.076
Contrast 2.Variety	3	0.2992	0.0997	0.63	0.6
Contrast 3.Variety	3	0.0235	0.0078	0.05	0.986
Contrast 4.Variety	3	0.2806	0.0935	0.59	0.625
Treatment.Site	8	1.164	0.1455	0.91	0.508
Contrast 1.Site	1	0.0363	0.0363	0.23	0.634
Contrast 2.Site	1	0.2317	0.2317	1.45	0.23
Contrast 3.Site	1	0.0047	0.0047	0.03	0.864
Contrast 4.Site	1	0.2235	0.2235	1.4	0.238
Variety.Site	3	0.392	0.1307	0.82	0.485
Treatment.Variety.Site	24	3.6249	0.151	0.95	0.539
Contrast 1.Variety.Site	3	1.1089	0.3696	2.32	0.078
Contrast 2.Variety.Site	3	0.2961	0.0987	0.62	0.604
Contrast 3.Variety.Site	3	0.0266	0.0089	0.06	0.983
Contrast 4.Variety.Site	3	0.291	0.097	0.61	0.611
Residual	144	22.957	0.1594		
Total	215	36.838			

Plant height cm week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	20.231	2.529	2.28	0.03
Contrast 1	1	1.434	1.434	1.29	0.26
Contrast 2	1	4.104	4.104	3.7	0.06
Contrast 3	1	3	3	2.7	0.1
Contrast 4	1	5.26	5.26	4.74	0.03
Variety	3	1.358	0.453	0.41	0.75
Site	1	15.789	15.789	14.2	<.001
Treatment.Variety	24	29.796	1.241	1.12	0.33
Contrast 1.Variety	3	6.324	2.108	1.9	0.13
Contrast 2.Variety	3	9.971	3.324	2.99	0.03
Contrast 3.Variety	3	2.205	0.735	0.66	0.58
Contrast 4.Variety	3	6.015	2.005	1.81	0.15
Treatment.Site	8	18.085	2.261	2.04	0.05
Contrast 1.Site	1	1.724	1.724	1.55	0.22
Contrast 2.Site	1	1.974	1.974	1.78	0.18
Contrast 3.Site	1	0.827	0.827	0.74	0.39
Contrast 4.Site	1	5.664	5.664	5.1	0.03
Variety.Site	3	0.905	0.302	0.27	0.85
Treatment.Variety.Site	24	25.755	1.073	0.97	0.51
Contrast 1.Variety.Site	3	10.621	3.54	3.19	0.03
Contrast 2.Variety.Site	3	3.928	1.309	1.18	0.32
Contrast 3.Variety.Site	3	3.148	1.049	0.95	0.42
Contrast 4.Variety.Site	3	4.625	1.542	1.39	0.25
Residual	144	159.89	1.11		
Total	215	271.81			

Plant height cm week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	32.557	4.07	1.34	0.226
Contrast 1	1	1.111	1.11	0.37	0.546
Contrast 2	1	1.322	1.32	0.44	0.51
Contrast 3	1	1.792	1.79	0.59	0.443
Contrast 4	1	9.914	9.91	3.28	0.072
Variety	3	8.09	2.7	0.89	0.447
Site	1	126.889	127	41.9	<.001
Treatment.Variety	24	70.763	2.95	0.97	0.504
Contrast 1.Variety	3	5.341	1.78	0.59	0.624
Contrast 2.Variety	3	1.907	0.64	0.21	0.889
Contrast 3.Variety	3	6.756	2.25	0.74	0.528
Contrast 4.Variety	3	6.951	2.32	0.77	0.515
Treatment.Site	8	30.856	3.86	1.27	0.261
Contrast 1.Site	1	1.112	1.11	0.37	0.545
Contrast 2.Site	1	0.687	0.69	0.23	0.634
Contrast 3.Site	1	2.465	2.47	0.81	0.368
Contrast 4.Site	1	0.186	0.19	0.06	0.804
Variety.Site	3	31.632	10.5	3.48	0.018
Treatment.Variety.Site	24	67.107	2.8	0.92	0.57
Contrast 1.Variety.Site	3	11.963	3.99	1.32	0.271
Contrast 2.Variety.Site	3	5.405	1.8	0.6	0.619
Contrast 3.Variety.Site	3	7.86	2.62	0.87	0.461
Contrast 4.Variety.Site	3	17.79	5.93	1.96	0.123
Residual	144	435.865	3.03		
Total	215	803.76			

Plant height cm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	128.074	16.01	2.93	0.005
Contrast 1	1	1.233	1.233	0.23	0.636
Contrast 2	1	12.909	12.91	2.36	0.127
Contrast 3	1	13.377	13.38	2.45	0.12
Contrast 4	1	29.742	29.74	5.44	0.021
Variety	3	18.392	6.131	1.12	0.343
Site	1	542.647	542.6	99.3	<.001
Treatment.Variety	24	137.388	5.724	1.05	0.412
Contrast 1.Variety	3	11.236	3.745	0.69	0.563
Contrast 2.Variety	3	12.786	4.262	0.78	0.507
Contrast 3.Variety	3	8.52	2.84	0.52	0.67
Contrast 4.Variety	3	5.599	1.866	0.34	0.795
Treatment.Site	8	59.194	7.399	1.35	0.222
Contrast 1.Site	1	0.925	0.925	0.17	0.681
Contrast 2.Site	1	2.603	2.603	0.48	0.491
Contrast 3.Site	1	1.792	1.792	0.33	0.568
Contrast 4.Site	1	10.515	10.52	1.92	0.168
Variety.Site	3	26.537	8.846	1.62	0.188
Treatment.Variety.Site	24	78.12	3.255	0.6	0.931
Contrast 1.Variety.Site	3	19.88	6.627	1.21	0.308
Contrast 2.Variety.Site	3	14.81	4.937	0.9	0.441
Contrast 3.Variety.Site	3	14.334	4.778	0.87	0.456
Contrast 4.Variety.Site	3	10.192	3.397	0.62	0.602
Residual	144	787.293	5.467		
Total	215	1777.64			

Plant height cm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	134.43	16.8	2.41	0.018
Contrast 1	1	4.706	4.706	0.68	0.412
Contrast 2	1	0.504	0.504	0.07	0.788
Contrast 3	1	41.856	41.86	6.01	0.015
Contrast 4	1	18.069	18.07	2.6	0.109
Variety	3	33.752	11.25	1.62	0.188
Site	1	571.92	571.9	82.2	<.001
Treatment.Variety	24	146.37	6.099	0.88	0.633
Contrast 1.Variety	3	5.544	1.848	0.27	0.85
Contrast 2.Variety	3	16.424	5.475	0.79	0.503
Contrast 3.Variety	3	15.966	5.322	0.76	0.516
Contrast 4.Variety	3	3.897	1.299	0.19	0.905
Treatment.Site	8	20.896	2.612	0.38	0.932
Contrast 1.Site	1	4.322	4.322	0.62	0.432
Contrast 2.Site	1	0.05	0.05	0.01	0.932
Contrast 3.Site	1	0.279	0.279	0.04	0.842
Contrast 4.Site	1	0.079	0.079	0.01	0.915
Variety.Site	3	6.992	2.331	0.33	0.8
Treatment.Variety.Site	24	107.11	4.463	0.64	0.898
Contrast 1.Variety.Site	3	33.769	11.26	1.62	0.188
Contrast 2.Variety.Site	3	18.389	6.13	0.88	0.453
Contrast 3.Variety.Site	3	8.879	2.96	0.43	0.735
Contrast 4.Variety.Site	3	0.812	0.271	0.04	0.99
Residual	144	1002.3	6.961		
Total	215	2023.8			

Plant height cm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	34.43	4.3	0.47	0.874
Contrast 1	1	1.696	1.7	0.19	0.667
Contrast 2	1	1.557	1.56	0.17	0.68
Contrast 3	1	10.52	10.5	1.16	0.284
Contrast 4	1	2.188	2.19	0.24	0.625
Variety	3	35.3	11.8	1.29	0.28
Site	1	612.5	613	67.2	<.001
Treatment.Variety	24	129.5	5.4	0.59	0.933
Contrast 1.Variety	3	16.11	5.37	0.59	0.623
Contrast 2.Variety	3	1.141	0.38	0.04	0.989
Contrast 3.Variety	3	2.685	0.9	0.1	0.961
Contrast 4.Variety	3	13.72	4.57	0.5	0.681
Treatment.Site	8	46.2	5.78	0.63	0.748
Contrast 1.Site	1	0.23	0.23	0.03	0.874
Contrast 2.Site	1	5.187	5.19	0.57	0.452
Contrast 3.Site	1	0.071	0.07	0.01	0.93
Contrast 4.Site	1	1.129	1.13	0.12	0.725
Variety.Site	3	24.41	8.14	0.89	0.446
Treatment.Variety.Site	24	206	8.59	0.94	0.545
Contrast 1.Variety.Site	3	41.43	13.8	1.52	0.213
Contrast 2.Variety.Site	3	34.01	11.3	1.24	0.296
Contrast 3.Variety.Site	3	15.75	5.25	0.58	0.631
Contrast 4.Variety.Site	3	32.18	10.7	1.18	0.321
Residual	144	1312	9.11		
Total	215	2400			

Plant_height_cm week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	152.67	19.08	1.2	0.31
Contrast 1	1	1.67	1.67	0.1	0.75
Contrast 2	1	20.6	20.6	1.3	0.26
Contrast 3	1	20.4	20.4	1.3	0.26
Contrast 4	1	48.76	48.76	3	0.08
Variety	3	111.54	37.18	2.3	0.08
Site	1	1289.49	1289.5	80	<.001
Treatment.Variety	24	480	20	1.2	0.22
Contrast 1.Variety	3	70.41	23.47	1.5	0.23
Contrast 2.Variety	3	3.45	1.15	0.1	0.98
Contrast 3.Variety	3	32.85	10.95	0.7	0.57
Contrast 4.Variety	3	47.34	15.78	1	0.4
Treatment.Site	8	91.68	11.46	0.7	0.68
Contrast 1.Site	1	8.76	8.76	0.5	0.46
Contrast 2.Site	1	0.88	0.88	0.1	0.82
Contrast 3.Site	1	3.82	3.82	0.2	0.63
Contrast 4.Site	1	13.95	13.95	0.9	0.35
Variety.Site	3	39.85	13.28	0.8	0.48
Treatment.Variety.Site	24	175.63	7.32	0.5	0.99
Contrast 1.Variety.Site	3	67.26	22.42	1.4	0.25
Contrast 2.Variety.Site	3	50.53	16.84	1.1	0.37
Contrast 3.Variety.Site	3	31.13	10.38	0.6	0.59
Contrast 4.Variety.Site	3	42.45	14.15	0.9	0.45
Residual	144	2318.23	16.1		
Total	215	4659.09			

Stem thickness_mm week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.178	0.0223	0.75	0.65
Contrast 1	1	0	0	0	0.99
Contrast 2	1	0.054	0.0543	1.83	0.18
Contrast 3	1	1E-03	0.001	0.03	0.86
Contrast 4	1	0.039	0.0388	1.3	0.26
Variety	3	0.132	0.0439	1.47	0.22
Site	1	0.81	0.8102	27.2	<.001
Treatment.Variety	24	0.619	0.0258	0.87	0.65
Contrast 1.Variety	3	0.164	0.0548	1.84	0.14
Contrast 2.Variety	3	0.047	0.0156	0.53	0.67
Contrast 3.Variety	3	0.001	0.0004	0.01	1
Contrast 4.Variety	3	0.051	0.0169	0.57	0.64
Treatment.Site	8	0.193	0.0242	0.81	0.59
Contrast 1.Site	1	0	0	0	0.99
Contrast 2.Site	1	0.003	0.0031	0.1	0.75
Contrast 3.Site	1	1E-03	0.001	0.03	0.86
Contrast 4.Site	1	0.008	0.0084	0.28	0.6
Variety.Site	3	0.064	0.0213	0.72	0.54
Treatment.Variety.Site	24	0.575	0.024	0.81	0.73
Contrast 1.Variety.Site	3	0.169	0.0564	1.89	0.13
Contrast 2.Variety.Site	3	0.081	0.0272	0.91	0.44
Contrast 3.Variety.Site	3	0.001	0.0004	0.01	1
Contrast 4.Variety.Site	3	0.081	0.027	0.91	0.44
Residual	144	4.284	0.0298		
Total	215	6.855			

Stem thickness_mm week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.28	0.04	1.18	0.32
Contrast 1	1	0	0	0.08	0.78
Contrast 2	1	0.03	0.03	1.06	0.31
Contrast 3	1	0.04	0.04	1.26	0.26
Contrast 4	1	0.05	0.05	1.52	0.22
Variety	3	0.04	0.01	0.42	0.74
Site	1	0.03	0.03	0.98	0.32
Treatment.Variety	24	0.45	0.02	0.63	0.91
Contrast 1.Variety	3	0.07	0.02	0.73	0.54
Contrast 2.Variety	3	0.04	0.01	0.48	0.69
Contrast 3.Variety	3	0.05	0.02	0.59	0.62
Contrast 4.Variety	3	0.02	0.01	0.26	0.85
Treatment.Site	8	0.24	0.03	1.01	0.43
Contrast 1.Site	1	0	0	0.08	0.78
Contrast 2.Site	1	0.04	0.04	1.24	0.27
Contrast 3.Site	1	0.04	0.04	1.26	0.26
Contrast 4.Site	1	0.05	0.05	1.52	0.22
Variety.Site	3	0.04	0.01	0.39	0.76
Treatment.Variety.Site	24	0.41	0.02	0.57	0.95
Contrast 1.Variety.Site	3	0.07	0.02	0.73	0.54
Contrast 2.Variety.Site	3	0.04	0.01	0.43	0.73
Contrast 3.Variety.Site	3	0.05	0.02	0.59	0.62
Contrast 4.Variety.Site	3	0.02	0.01	0.26	0.85
Residual	144	4.32	0.03		
Total	215	5.81			

Stem thickness_mm week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	5	0.62	1.4	0.22
Contrast 1	1	0.1	0.14	0.3	0.58
Contrast 2	1	1	1.03	2.3	0.14
Contrast 3	1	0.8	0.83	1.8	0.18
Contrast 4	1	2	1.97	4.3	0.04
Variety	3	1.2	0.41	0.9	0.44
Site	1	75	74.6	163	<.001
Treatment.Variety	24	7.8	0.33	0.7	0.84
Contrast 1.Variety	3	1.7	0.56	1.2	0.3
Contrast 2.Variety	3	0.4	0.14	0.3	0.83
Contrast 3.Variety	3	0.4	0.14	0.3	0.82
Contrast 4.Variety	3	0.7	0.24	0.5	0.67
Treatment.Site	8	2.9	0.37	0.8	0.6
Contrast 1.Site	1	0	0.04	0.1	0.76
Contrast 2.Site	1	0	0.01	0	0.9
Contrast 3.Site	1	0	0.04	0.1	0.78
Contrast 4.Site	1	1.3	1.29	2.8	0.1
Variety.Site	3	0.9	0.3	0.7	0.58
Treatment.Variety.Site	24	6.3	0.26	0.6	0.94
Contrast 1.Variety.Site	3	1	0.35	0.8	0.52
Contrast 2.Variety.Site	3	0.5	0.15	0.3	0.8
Contrast 3.Variety.Site	3	0.2	0.08	0.2	0.92
Contrast 4.Variety.Site	3	0.2	0.06	0.1	0.95
Residual	144	66	0.46		
Total	215	165			

Stem thickness_mm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	15.7	1.96	2.94	0.004
Contrast 1	1	2.64	2.64	3.95	0.049
Contrast 2	1	0.51	0.51	0.76	0.386
Contrast 3	1	0.01	0.01	0.02	0.887
Contrast 4	1	1.28	1.28	1.92	0.168
Variety	3	1.27	0.42	0.63	0.594
Site	1	1.73	1.73	2.58	0.11
Treatment.Variety	24	23.9	1	1.49	0.079
Contrast 1.Variety	3	4.18	1.39	2.08	0.105
Contrast 2.Variety	3	0.59	0.2	0.3	0.829
Contrast 3.Variety	3	2.13	0.71	1.06	0.366
Contrast 4.Variety	3	0.96	0.32	0.48	0.697
Treatment.Site	8	12.9	1.62	2.42	0.018
Contrast 1.Site	1	3.69	3.69	5.53	0.02
Contrast 2.Site	1	0.93	0.93	1.39	0.24
Contrast 3.Site	1	0.15	0.15	0.23	0.631
Contrast 4.Site	1	3.14	3.14	4.71	0.032
Variety.Site	3	1.53	0.51	0.77	0.515
Treatment.Variety.Site	24	22.1	0.92	1.38	0.127
Contrast 1.Variety.Site	3	8.74	2.91	4.37	0.006
Contrast 2.Variety.Site	3	1.5	0.5	0.75	0.526
Contrast 3.Variety.Site	3	2.2	0.73	1.1	0.353
Contrast 4.Variety.Site	3	2.54	0.85	1.27	0.288
Residual	144	96.1	0.67		
Total	215	175			

Stem thickness_mm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.62	1.08	1.73	0.1
Contrast 1	1	0.01	0.01	0.01	0.93
Contrast 2	1	1.4	1.4	2.25	0.14
Contrast 3	1	2.1	2.1	3.37	0.07
Contrast 4	1	0.41	0.41	0.66	0.42
Variety	3	1.32	0.44	0.71	0.55
Site	1	0.88	0.88	1.42	0.24
Treatment.Variety	24	15.7	0.65	1.05	0.41
Contrast 1.Variety	3	1.06	0.35	0.57	0.64
Contrast 2.Variety	3	2.27	0.76	1.22	0.31
Contrast 3.Variety	3	2.09	0.7	1.12	0.34
Contrast 4.Variety	3	0.84	0.28	0.45	0.72
Treatment.Site	8	4.36	0.54	0.88	0.54
Contrast 1.Site	1	0.53	0.53	0.86	0.36
Contrast 2.Site	1	0.98	0.98	1.57	0.21
Contrast 3.Site	1	0.11	0.11	0.17	0.68
Contrast 4.Site	1	0.01	0.01	0.01	0.93
Variety.Site	3	1.18	0.39	0.63	0.59
Treatment.Variety.Site	24	11.6	0.49	0.78	0.76
Contrast 1.Variety.Site	3	1.86	0.62	1	0.4
Contrast 2.Variety.Site	3	3.56	1.19	1.91	0.13
Contrast 3.Variety.Site	3	2.08	0.69	1.12	0.35
Contrast 4.Variety.Site	3	0.52	0.17	0.28	0.84
Residual	144	89.5	0.62		
Total	215	133			

Stem thickness_mm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.68	0.0849	0.13	0.998
Contrast 1	1	0	0.0001	0	0.993
Contrast 2	1	0.08	0.0836	0.13	0.722
Contrast 3	1	0.25	0.249	0.38	0.539
Contrast 4	1	0.02	0.0152	0.02	0.879
Variety	3	0.6	0.1994	0.3	0.822
Site	1	6.03	6.0261	9.19	0.003
Treatment.Variety	24	8.73	0.3638	0.55	0.954
Contrast 1.Variety	3	1.71	0.5688	0.87	0.46
Contrast 2.Variety	3	0.7	0.2342	0.36	0.784
Contrast 3.Variety	3	0.27	0.0892	0.14	0.938
Contrast 4.Variety	3	0.15	0.0515	0.08	0.972
Treatment.Site	8	5.46	0.683	1.04	0.408
Contrast 1.Site	1	0.49	0.4905	0.75	0.389
Contrast 2.Site	1	0.04	0.0366	0.06	0.814
Contrast 3.Site	1	0.05	0.0473	0.07	0.789
Contrast 4.Site	1	0.84	0.8447	1.29	0.258
Variety.Site	3	1.96	0.6549	1	0.396
Treatment.Variety.Site	24	18	0.7516	1.15	0.303
Contrast 1.Variety.Site	3	1.01	0.3371	0.51	0.673
Contrast 2.Variety.Site	3	0.7	0.2339	0.36	0.784
Contrast 3.Variety.Site	3	0.47	0.1563	0.24	0.87
Contrast 4.Variety.Site	3	2.06	0.6851	1.04	0.375
Residual	144	94.5	0.6559		
Total	215	136			

Stem thickness_mm week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.1992	1.025	1.3	0.266
Contrast 1	1	0.0812	0.081	0.1	0.752
Contrast 2	1	0.4373	0.437	0.5	0.464
Contrast 3	1	0.0115	0.012	0	0.905
Contrast 4	1	0.6437	0.644	0.8	0.374
Variety	3	6.2783	2.093	2.6	0.056
Site	1	83.013	83.01	102	<.001
Treatment.Variety	24	19.922	0.83	1	0.44
Contrast 1.Variety	3	3.1711	1.057	1.3	0.275
Contrast 2.Variety	3	0.6504	0.217	0.3	0.849
Contrast 3.Variety	3	2.8014	0.934	1.2	0.33
Contrast 4.Variety	3	1.4706	0.49	0.6	0.613
Treatment.Site	8	8.028	1.004	1.2	0.281
Contrast 1.Site	1	0.0175	0.018	0	0.883
Contrast 2.Site	1	0	0	0	0.997
Contrast 3.Site	1	0.0091	0.009	0	0.916
Contrast 4.Site	1	0.2401	0.24	0.3	0.587
Variety.Site	3	0.771	0.257	0.3	0.813
Treatment.Variety.Site	24	22.07	0.92	1.1	0.314
Contrast 1.Variety.Site	3	4.6058	1.535	1.9	0.133
Contrast 2.Variety.Site	3	4.2901	1.43	1.8	0.157
Contrast 3.Variety.Site	3	5.4534	1.818	2.2	0.086
Contrast 4.Variety.Site	3	3.0826	1.028	1.3	0.288
Residual	144	116.68	0.81		
Total	215	264.96			

Root_length_cm_week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	47.221	5.903	1.2	0.305
Contrast 1	1	6.603	6.603	1.34	0.249
Contrast 2	1	0.043	0.043	0.01	0.926
Contrast 3	1	16.392	16.39	3.32	0.07
Contrast 4	1	0.042	0.042	0.01	0.927
Variety	3	46.985	15.66	3.18	0.026
Site	1	3.586	3.586	0.73	0.395
Treatment.Variety	24	266.97	11.12	2.26	0.002
Contrast 1.Variety	3	23.432	7.811	1.58	0.196
Contrast 2.Variety	3	11.346	3.782	0.77	0.514
Contrast 3.Variety	3	29.736	9.912	2.01	0.115
Contrast 4.Variety	3	3.55	1.183	0.24	0.868
Treatment.Site	8	47.254	5.907	1.2	0.304
Contrast 1.Site	1	2.266	2.266	0.46	0.499
Contrast 2.Site	1	2.723	2.723	0.55	0.459
Contrast 3.Site	1	16.705	16.71	3.39	0.068
Contrast 4.Site	1	0.165	0.165	0.03	0.855
Variety.Site	3	23.337	7.779	1.58	0.197
Treatment.Variety.Site	24	158.4	6.6	1.34	0.15
Contrast 1.Variety.Site	3	13.992	4.664	0.95	0.42
Contrast 2.Variety.Site	3	5.616	1.872	0.38	0.768
Contrast 3.Variety.Site	3	46.278	15.43	3.13	0.028
Contrast 4.Variety.Site	3	10.892	3.631	0.74	0.532
Residual	144	710.23	4.932		
Total	215	1304			

Root_length_cm_week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	15.707	1.963	0.23	0.99
Contrast 1	1	1.634	1.634	0.19	0.66
Contrast 2	1	1.114	1.114	0.13	0.72
Contrast 3	1	0.313	0.313	0.04	0.85
Contrast 4	1	5.078	5.078	0.59	0.44
Variety	3	72.672	24.224	2.82	0.04
Site	1	1.67	1.67	0.19	0.66
Treatment.Variety	24	229.96	9.582	1.12	0.33
Contrast 1.Variety	3	27.141	9.047	1.05	0.37
Contrast 2.Variety	3	12.191	4.064	0.47	0.7
Contrast 3.Variety	3	46.812	15.604	1.82	0.15
Contrast 4.Variety	3	10.637	3.546	0.41	0.74
Treatment.Site	8	88.084	11.01	1.28	0.26
Contrast 1.Site	1	0.1	0.1	0.01	0.91
Contrast 2.Site	1	5.895	5.895	0.69	0.41
Contrast 3.Site	1	21.885	21.885	2.55	0.11
Contrast 4.Site	1	1.862	1.862	0.22	0.64
Variety.Site	3	2.364	0.788	0.09	0.96
Treatment.Variety.Site	24	181.66	7.569	0.88	0.63
Contrast 1.Variety.Site	3	9.781	3.26	0.38	0.77
Contrast 2.Variety.Site	3	0.902	0.301	0.04	0.99
Contrast 3.Variety.Site	3	35.316	11.772	1.37	0.25
Contrast 4.Variety.Site	3	4.306	1.435	0.17	0.92
Residual	144	1236.4	8.586		
Total	215	1828.6			

Root_length_cm_week 8						
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Treatment	8		56.69	7.09	0.58	0.8
Contrast 1	1		2.62	2.62	0.21	0.65
Contrast 2	1		0.78	0.78	0.06	0.8
Contrast 3	1		10.34	10.3	0.84	0.36
Contrast 4	1		1.77	1.77	0.14	0.71
Variety	3		23.59	7.86	0.64	0.59
Site	1		457.7	458	37.2	<.001
Treatment.Variety	24		301	12.5	1.02	0.45
Contrast 1.Variety	3		45.95	15.3	1.25	0.3
Contrast 2.Variety	3		11.04	3.68	0.3	0.83
Contrast 3.Variety	3		118.1	39.4	3.2	0.03
Contrast 4.Variety	3		6.45	2.15	0.17	0.91
Treatment.Site	8		110.8	13.8	1.13	0.35
Contrast 1.Site	1		9.26	9.26	0.75	0.39
Contrast 2.Site	1		22.89	22.9	1.86	0.17
Contrast 3.Site	1		9.17	9.17	0.75	0.39
Contrast 4.Site	1		63.27	63.3	5.15	0.03
Variety.Site	3		41.16	13.7	1.12	0.35
Treatment.Variety.Site	24		435.9	18.2	1.48	0.08
Contrast 1.Variety.Site	3		41.85	14	1.14	0.34
Contrast 2.Variety.Site	3		28.78	9.59	0.78	0.51
Contrast 3.Variety.Site	3		57.67	19.2	1.56	0.2
Contrast 4.Variety.Site	3		32.34	10.8	0.88	0.46
Residual	142	-2	1745	12.3		
Total	213	-2	3172			

No_of_nodules week 5						
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Treatment	8		861.6	108	2.59	0.012
Contrast 1	1		6.83	6.83	0.16	0.686
Contrast 2	1		80.08	80.1	1.92	0.168
Contrast 3	1		17.52	17.5	0.42	0.518
Contrast 4	1		176.3	176	4.23	0.041
Variety	3		317.2	106	2.54	0.059
Site	1		150.7	151	3.62	0.059
Treatment.Variety	24		1490	62.1	1.49	0.08
Contrast 1.Variety	3		257.6	85.9	2.06	0.108
Contrast 2.Variety	3		74.42	24.8	0.6	0.619
Contrast 3.Variety	3		150.2	50.1	1.2	0.311
Contrast 4.Variety	3		354.5	118	2.84	0.04
Treatment.Site	8		549	68.6	1.65	0.117
Contrast 1.Site	1		6.68	6.68	0.16	0.69
Contrast 2.Site	1		56.33	56.3	1.35	0.247
Contrast 3.Site	1		1.69	1.69	0.04	0.841
Contrast 4.Site	1		18.75	18.8	0.45	0.503
Variety.Site	3		222.2	74.1	1.78	0.154
Treatment.Variety.Site	24		1656	69	1.66	0.038
Contrast 1.Variety.Site	3		678.2	226	5.43	0.001
Contrast 2.Variety.Site	3		223.8	74.6	1.79	0.152
Contrast 3.Variety.Site	3		312.1	104	2.5	0.062
Contrast 4.Variety.Site	3		280.8	93.6	2.25	0.086
Residual	140	-4	5831	41.7		
Total	211	-4	11066			

No of nodules week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	226.56	28.32	0.89	0.53
Contrast 1	1	36.75	36.75	1.15	0.285
Contrast 2	1	0.02	0.02	0	0.98
Contrast 3	1	2.08	2.08	0.07	0.799
Contrast 4	1	13.02	13.02	0.41	0.524
Variety	3	113.44	37.81	1.18	0.319
Site	1	2347	2347	73.4	<.001
Treatment.Variety	24	621.47	25.89	0.81	0.72
Contrast 1.Variety	3	45.42	15.14	0.47	0.701
Contrast 2.Variety	3	38.06	12.69	0.4	0.756
Contrast 3.Variety	3	32.25	10.75	0.34	0.799
Contrast 4.Variety	3	104.06	34.69	1.08	0.358
Treatment.Site	8	176.12	22.02	0.69	0.701
Contrast 1.Site	1	18.75	18.75	0.59	0.445
Contrast 2.Site	1	0.52	0.52	0.02	0.899
Contrast 3.Site	1	24.08	24.08	0.75	0.387
Contrast 4.Site	1	0.19	0.19	0.01	0.939
Variety.Site	3	39.74	13.25	0.41	0.743
Treatment.Variety.Site	24	671.18	27.97	0.87	0.636
Contrast 1.Variety.Site	3	28.42	9.47	0.3	0.828
Contrast 2.Variety.Site	3	83.56	27.85	0.87	0.458
Contrast 3.Variety.Site	3	62.92	20.97	0.66	0.581
Contrast 4.Variety.Site	3	96.23	32.08	1	0.393
Residual	144	4604.7	31.98		
Total	215	8800.2			

No of nodules week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1192.01	149	2.4	0.019
Contrast 1	1	487.69	487.69	7.85	0.006
Contrast 2	1	132.22	132.22	2.13	0.147
Contrast 3	1	65.33	65.33	1.05	0.307
Contrast 4	1	553.52	553.52	8.91	0.003
Variety	3	672.94	224.31	3.61	0.015
Site	1	6894.51	6894.51	111	<.001
Treatment.Variety	24	952.49	39.69	0.64	0.9
Contrast 1.Variety	3	124.4	41.47	0.67	0.573
Contrast 2.Variety	3	133.17	44.39	0.71	0.545
Contrast 3.Variety	3	176.17	58.72	0.95	0.421
Contrast 4.Variety	3	30.73	10.24	0.16	0.92
Treatment.Site	8	1583.36	197.92	3.19	0.002
Contrast 1.Site	1	325.52	325.52	5.24	0.024
Contrast 2.Site	1	15.95	15.95	0.26	0.613
Contrast 3.Site	1	10.08	10.08	0.16	0.688
Contrast 4.Site	1	713.02	713.02	11.5	<.001
Variety.Site	3	500.51	166.84	2.69	0.049
Treatment.Variety.Site	24	1188.42	49.52	0.8	0.736
Contrast 1.Variety.Site	3	405.23	135.08	2.17	0.094
Contrast 2.Variety.Site	3	156.45	52.15	0.84	0.474
Contrast 3.Variety.Site	3	184.42	61.47	0.99	0.4
Contrast 4.Variety.Site	3	301.23	100.41	1.62	0.188
Residual	144	8944.74	62.12		
Total	215	21928.97			

No_of_leaves week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	90718	11340	5.62	<.001
Contrast 1	1	8374	8374	4.15	0.043
Contrast 2	1	3536	3536	1.75	0.188
Contrast 3	1	3201	3201	1.59	0.21
Contrast 4	1	12740	12740	6.32	0.013
Variety	3	29752	9917	4.92	0.003
Site	1	15504	15504	7.69	0.006
Treatment.Variety	24	42636	1777	0.88	0.627
Contrast 1.Variety	3	9916	3305	1.64	0.183
Contrast 2.Variety	3	2844	948	0.47	0.704
Contrast 3.Variety	3	5231	1744	0.86	0.461
Contrast 4.Variety	3	1404	468	0.23	0.874
Treatment.Site	8	57070	7134	3.54	<.001
Contrast 1.Site	1	7	7	0	0.954
Contrast 2.Site	1	3136	3136	1.55	0.214
Contrast 3.Site	1	1496	1496	0.74	0.39
Contrast 4.Site	1	6864	6864	3.4	0.067
Variety.Site	3	22501	7500	3.72	0.013
Treatment.Variety.Site	24	65546	2731	1.35	0.141
Contrast 1.Variety.Site	3	14316	4772	2.37	0.073
Contrast 2.Variety.Site	3	7334	2445	1.21	0.308
Contrast 3.Variety.Site	3	1176	392	0.19	0.9
Contrast 4.Variety.Site	3	10815	3605	1.79	0.152
Residual	144	290443	2017		
Total	215	614170			

No_of_leaves week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	486354	60794	6.06	<.001
Contrast 1	1	20193	20193	2.01	0.16
Contrast 2	1	10133	10133	1.01	0.32
Contrast 3	1	6540	6540	0.65	0.42
Contrast 4	1	131639	131639	13.1	<.001
Variety	3	10938	3646	0.36	0.78
Site	1	25925	25925	2.59	0.11
Treatment.Variety	24	266498	11104	1.11	0.34
Contrast 1.Variety	3	90780	30260	3.02	0.03
Contrast 2.Variety	3	18705	6235	0.62	0.6
Contrast 3.Variety	3	5891	1964	0.2	0.9
Contrast 4.Variety	3	9413	3138	0.31	0.82
Treatment.Site	8	679312	84914	8.47	<.001
Contrast 1.Site	1	23608	23608	2.35	0.13
Contrast 2.Site	1	29870	29870	2.98	0.09
Contrast 3.Site	1	13342	13342	1.33	0.25
Contrast 4.Site	1	195802	195802	19.5	<.001
Variety.Site	3	72729	24243	2.42	0.07
Treatment.Variety.Site	24	239085	9962	0.99	0.48
Contrast 1.Variety.Site	3	74279	24760	2.47	0.06
Contrast 2.Variety.Site	3	27447	9149	0.91	0.44
Contrast 3.Variety.Site	3	2231	744	0.07	0.97
Contrast 4.Variety.Site	3	12406	4135	0.41	0.74
Residual	144	1443640	10025		
Total	215	3224481			

No_of_leaves week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	331185	41398	2.62	0.01
Contrast 1	1	2111	2111	0.13	0.72
Contrast 2	1	9359	9359	0.59	0.44
Contrast 3	1	47	47	0	0.96
Contrast 4	1	57186	57186	3.62	0.06
Variety	3	78459	26153	1.65	0.18
Site	1	209271	2E+05	13.2	<.001
Treatment.Variety	24	276547	11523	0.73	0.82
Contrast 1.Variety	3	83781	27927	1.77	0.16
Contrast 2.Variety	3	6979	2326	0.15	0.93
Contrast 3.Variety	3	19311	6437	0.41	0.75
Contrast 4.Variety	3	18877	6292	0.4	0.76
Treatment.Site	8	552905	69113	4.37	<.001
Contrast 1.Site	1	401	401	0.03	0.87
Contrast 2.Site	1	17502	17502	1.11	0.29
Contrast 3.Site	1	62024	62024	3.92	0.05
Contrast 4.Site	1	48655	48655	3.08	0.08
Variety.Site	3	424803	1E+05	8.96	<.001
Treatment.Variety.Site	24	319524	13314	0.84	0.68
Contrast 1.Variety.Site	3	101405	33802	2.14	0.1
Contrast 2.Variety.Site	3	20384	6795	0.43	0.73
Contrast 3.Variety.Site	3	19592	6531	0.41	0.74
Contrast 4.Variety.Site	3	33124	11041	0.7	0.55
Residual	144	2276272	15807		
Total	215	4468967			

No_of_leaves week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1620685	202586	3.4	0.002
Contrast 1	1	14156	14156	0.2	0.629
Contrast 2	1	24782	24782	0.4	0.523
Contrast 3	1	16	16	0	0.987
Contrast 4	1	367197	367197	6.1	0.015
Variety	3	1450141	483380	8	<.001
Site	1	1634411	1634411	27	<.001
Treatment.Variety	24	1318345	54931	0.9	0.592
Contrast 1.Variety	3	159191	53064	0.9	0.455
Contrast 2.Variety	3	9715	3238	0.1	0.984
Contrast 3.Variety	3	103840	34613	0.6	0.635
Contrast 4.Variety	3	28541	9514	0.2	0.925
Treatment.Site	8	2814338	351792	5.8	<.001
Contrast 1.Site	1	44213	44213	0.7	0.394
Contrast 2.Site	1	112610	112610	1.9	0.175
Contrast 3.Site	1	132868	132868	2.2	0.141
Contrast 4.Site	1	702973	702973	12	<.001
Variety.Site	3	2124577	708192	12	<.001
Treatment.Variety.Site	24	857525	35730	0.6	0.934
Contrast 1.Variety.Site	3	336795	112265	1.9	0.14
Contrast 2.Variety.Site	3	231980	77327	1.3	0.284
Contrast 3.Variety.Site	3	17399	5800	0.1	0.962
Contrast 4.Variety.Site	3	37385	12462	0.2	0.892
Residual	144	8717928	60541		
Total	215	20537950			

No_of_leaves week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2346658	293332	2.13	0.036
Contrast 1	1	1154	1154	0.01	0.927
Contrast 2	1	45950	45950	0.33	0.564
Contrast 3	1	1342	1342	0.01	0.921
Contrast 4	1	604395	604395	4.39	0.038
Variety	3	2403358	801119	5.82	<.001
Site	1	5803976	6E+06	42.2	<.001
Treatment.Variety	24	2293986	95583	0.69	0.851
Contrast 1.Variety	3	419411	139804	1.02	0.388
Contrast 2.Variety	3	56633	18878	0.14	0.938
Contrast 3.Variety	3	259076	86359	0.63	0.598
Contrast 4.Variety	3	95588	31863	0.23	0.874
Treatment.Site	8	3783673	472959	3.44	0.001
Contrast 1.Site	1	88278	88278	0.64	0.425
Contrast 2.Site	1	85830	85830	0.62	0.431
Contrast 3.Site	1	3212	3212	0.02	0.879
Contrast 4.Site	1	1229595	1E+06	8.93	0.003
Variety.Site	3	2748993	916331	6.66	<.001
Treatment.Variety.Site	24	1338660	55778	0.41	0.994
Contrast 1.Variety.Site	3	532742	177581	1.29	0.28
Contrast 2.Variety.Site	3	244429	81476	0.59	0.621
Contrast 3.Variety.Site	3	179668	59889	0.44	0.728
Contrast 4.Variety.Site	3	47713	15904	0.12	0.951
Residual	144	19820944	137645		
Total	215	40540249			

No_of_leaves week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2361427	295178	1.31	0.245
Contrast 1	1	46250	46250	0.2	0.652
Contrast 2	1	130894	130894	0.58	0.448
Contrast 3	1	3602	3602	0.02	0.9
Contrast 4	1	316575	316575	1.4	0.239
Variety	3	5488588	1829529	8.09	<.001
Site	1	21529031	21529031	95.2	<.001
Treatment.Variety	24	4112636	171360	0.76	0.783
Contrast 1.Variety	3	456807	152269	0.67	0.57
Contrast 2.Variety	3	16891	5630	0.02	0.995
Contrast 3.Variety	3	182832	60944	0.27	0.847
Contrast 4.Variety	3	222055	74018	0.33	0.806
Treatment.Site	8	3362331	420291	1.86	0.071
Contrast 1.Site	1	1038	1038	0	0.946
Contrast 2.Site	1	147128	147128	0.65	0.421
Contrast 3.Site	1	155643	155643	0.69	0.408
Contrast 4.Site	1	41800	41800	0.18	0.668
Variety.Site	3	6776589	2258863	9.99	<.001
Treatment.Variety.Site	24	2899557	120815	0.53	0.963
Contrast 1.Variety.Site	3	1248305	416102	1.84	0.142
Contrast 2.Variety.Site	3	260011	86670	0.38	0.765
Contrast 3.Variety.Site	3	395457	131819	0.58	0.627
Contrast 4.Variety.Site	3	480962	160321	0.71	0.548
Residual	144	32555108	226077		
Total	215	79085267			

No_of_leaves week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8631049	1078881	2	0.051
Contrast 1	1	152848	152848	0.3	0.596
Contrast 2	1	691178	691178	1.3	0.26
Contrast 3	1	97229	97229	0.2	0.672
Contrast 4	1	2162799	2162799	4	0.047
Variety	3	13517195	4505732	8.3	<.001
Site	1	41725699	4.2E+07	77	<.001
Treatment.Variety	24	11125563	463565	0.9	0.659
Contrast 1.Variety	3	1544817	514939	1	0.418
Contrast 2.Variety	3	255911	85304	0.2	0.925
Contrast 3.Variety	3	357178	119059	0.2	0.882
Contrast 4.Variety	3	1513887	504629	0.9	0.427
Treatment.Site	8	7978148	997268	1.8	0.074
Contrast 1.Site	1	132624	132624	0.3	0.621
Contrast 2.Site	1	26552	26552	0.1	0.825
Contrast 3.Site	1	351979	351979	0.7	0.421
Contrast 4.Site	1	745989	745989	1.4	0.242
Variety.Site	3	10758082	3586027	6.6	<.001
Treatment.Variety.Site	24	7146265	297761	0.6	0.956
Contrast 1.Variety.Site	3	2276848	758949	1.4	0.245
Contrast 2.Variety.Site	3	341379	113793	0.2	0.889
Contrast 3.Variety.Site	3	548147	182716	0.3	0.798
Contrast 4.Variety.Site	3	412898	137633	0.3	0.858
Residual	144	77928671	541171		
Total	215	178810673			

Appendix 5: Contrasting humates versus combined bio-stimulators (Set 3)

Contrasts	Humates	SWE basal application	Biofix	Humates+ SWE foliar	Humates+SWE basal application	Humates + SWE basal application +SWE foliar	SWE basal application + SWE foliar
1	1	-1	0	0	0	0	0
2	1	0	-1	0	0	0	0
3	1	0	0	-1	0	0	0
4	1	0	0	0	-1	0	0
5	1	0	0	0	0	-1	0
6	1	0	0	0	0	0	-1

Rate of emergence %					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	10276	1285	3.71	<.001
Contrast 1	1	681.3	681.3	1.97	0.163
Contrast 2	1	590.3	590.3	1.71	0.194
Contrast 3	1	40.6	40.6	0.12	0.732
Contrast 4	1	1481.5	1482	4.28	0.04
Contrast 5	1	3021.5	3022	8.73	0.004
Contrast 6	1	868.4	868.4	2.51	0.115
Variety	3	5133.7	1711	4.95	0.003
Site	1	52813	52813	153	<.001
Treatment.Variety	24	6929	288.7	0.83	0.688
Contrast 1.Variety	3	2808.1	936	2.71	0.048
Contrast 2.Variety	3	305.2	101.7	0.29	0.83
Contrast 3.Variety	3	1158.5	386.2	1.12	0.345
Contrast 4.Variety	3	89.2	29.7	0.09	0.968
Contrast 5.Variety	3	204	68	0.2	0.899
Contrast 6.Variety	3	736.8	245.6	0.71	0.548
Treatment.Site	8	21772	2722	7.87	<.001
Contrast 1.Site	1	2491.7	2492	7.2	0.008
Contrast 2.Site	1	4094.7	4095	11.8	<.001
Contrast 3.Site	1	34.7	34.7	0.1	0.752
Contrast 4.Site	1	3882	3882	11.2	0.001
Contrast 5.Site	1	10626	10626	30.7	<.001
Contrast 6.Site	1	136.1	136.1	0.39	0.531
Variety.Site	3	6859.2	2286	6.61	<.001
Treatment.Variety.Site	24	7049.8	293.7	0.85	0.669
Contrast 1.Variety.Site	3	1122.3	374.1	1.08	0.359
Contrast 2.Variety.Site	3	120.9	40.3	0.12	0.95
Contrast 3.Variety.Site	3	434.1	144.7	0.42	0.74
Contrast 4.Variety.Site	3	857.5	285.8	0.83	0.481
Contrast 5.Variety.Site	3	239.9	80	0.23	0.875
Residual	144	49812	345.9		
Total	215	160644			

Days_to_emergence					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	934.33	116.79	12.6	<.001
Contrast 1	1	108	108	11.6	<.001
Contrast 2	1	93.521	93.521	10.1	0.002
Contrast 3	1	10.083	10.083	1.09	0.299
Contrast 4	1	102.08	102.08	11	0.001
Contrast 5	1	96.333	96.333	10.4	0.002
Contrast 6	1	82.687	82.687	8.9	0.003
Variety	3	75.495	25.165	2.71	0.047
Site	1	453.56	453.56	48.8	<.001
Treatment.Variety	24	132.63	5.526	0.6	0.931
Contrast 1.Variety	3	2.833	0.944	0.1	0.959
Contrast 2.Variety	3	1.896	0.632	0.07	0.977
Contrast 3.Variety	3	5.417	1.806	0.19	0.9
Contrast 4.Variety	3	0.75	0.25	0.03	0.994
Contrast 5.Variety	3	1.833	0.611	0.07	0.978
Contrast 6.Variety	3	66.062	22.021	2.37	0.073
Treatment.Site	8	278.15	34.769	3.74	<.001
Contrast 1.Site	1	90.75	90.75	9.77	0.002
Contrast 2.Site	1	82.688	82.688	8.9	0.003
Contrast 3.Site	1	8.333	8.333	0.9	0.345
Contrast 4.Site	1	90.75	90.75	9.77	0.002
Contrast 5.Site	1	90.75	90.75	9.77	0.002
Contrast 6.Site	1	99.188	99.188	10.7	0.001
Variety.Site	3	38.199	12.733	1.37	0.254
Treatment.Variety.Site	24	191.26	7.969	0.86	0.657
Contrast 1.Variety.Site	3	2.417	0.806	0.09	0.967
Contrast 2.Variety.Site	3	2.729	0.91	0.1	0.961
Contrast 3.Variety.Site	3	14.833	4.944	0.53	0.661
Contrast 4.Variety.Site	3	2.417	0.806	0.09	0.967
Contrast 5.Variety.Site	3	0.417	0.139	0.01	0.997
Residual	144	1337.3	9.287		
Total	215	3441			

Survival rate					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	13915	1739	3.2	0.002
Contrast 1	1	652.7	652.7	1.2	0.275
Contrast 2	1	346.7	346.7	0.64	0.425
Contrast 3	1	46	46	0.08	0.771
Contrast 4	1	2028	2028	3.74	0.055
Contrast 5	1	3622.7	3623	6.67	0.011
Contrast 6	1	1668.5	1669	3.07	0.082
Variety	3	6926.1	2309	4.25	0.007
Site	1	69948	69948	129	<.001
Treatment.Variety	24	10315	429.8	0.79	0.742
Contrast 1.Variety	3	3950.7	1317	2.43	0.068
Contrast 2.Variety	3	661.7	220.6	0.41	0.749
Contrast 3.Variety	3	1723.7	574.6	1.06	0.369
Contrast 4.Variety	3	183	61	0.11	0.953
Contrast 5.Variety	3	563.7	187.9	0.35	0.792
Contrast 6.Variety	3	1317.7	439.2	0.81	0.491
Treatment.Site	8	33478	4185	7.71	<.001
Contrast 1.Site	1	4015	4015	7.4	0.007
Contrast 2.Site	1	7525	7525	13.9	<.001
Contrast 3.Site	1	63	63	0.12	0.734
Contrast 4.Site	1	5808	5808	10.7	0.001
Contrast 5.Site	1	17442	17442	32.1	<.001
Contrast 6.Site	1	25.5	25.5	0.05	0.829
Variety.Site	3	12510	4170	7.68	<.001
Treatment.Variety.Site	24	9857.9	410.7	0.76	0.784
Contrast 1.Variety.Site	3	1391.7	463.9	0.85	0.466
Contrast 2.Variety.Site	3	519.4	173.1	0.32	0.812
Contrast 3.Variety.Site	3	666.1	222	0.41	0.747
Contrast 4.Variety.Site	3	1433	477.7	0.88	0.453
Contrast 5.Variety.Site	3	609.6	203.2	0.37	0.772
Residual	144	78163	542.8		
Total	215	235113			

Leaf_area_cm^2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	7797	974.6	2.5	0.014
Contrast 1	1	3179	3179	8.17	0.005
Contrast 2	1	925.6	925.6	2.38	0.125
Contrast 3	1	1.3	1.3	0	0.954
Contrast 4	1	1392	1392	3.58	0.061
Contrast 5	1	616.2	616.2	1.58	0.21
Contrast 6	1	3829	3829	9.84	0.002
Variety	3	9108	3036	7.8	<.001
Site	1	1193	1193	3.07	0.082
Treatment.Variety	24	6481	270	0.69	0.851
Contrast 1.Variety	3	758.8	252.9	0.65	0.584
Contrast 2.Variety	3	658.8	219.6	0.56	0.639
Contrast 3.Variety	3	288	96	0.25	0.864
Contrast 4.Variety	3	409.8	136.6	0.35	0.788
Contrast 5.Variety	3	2264	754.6	1.94	0.126
Contrast 6.Variety	3	1438	479.2	1.23	0.3
Treatment.Site	8	1096	136.9	0.35	0.944
Contrast 1.Site	1	3.5	3.5	0.01	0.925
Contrast 2.Site	1	4.6	4.6	0.01	0.913
Contrast 3.Site	1	31.6	31.6	0.08	0.776
Contrast 4.Site	1	47.6	47.6	0.12	0.727
Contrast 5.Site	1	504.3	504.3	1.3	0.257
Contrast 6.Site	1	3	3	0.01	0.93
Variety.Site	3	294.7	98.2	0.25	0.859
Treatment.Variety.Site	24	2937	122.4	0.31	0.999
Contrast 1.Variety.Site	3	1527	509	1.31	0.274
Contrast 2.Variety.Site	3	410.7	136.9	0.35	0.788
Contrast 3.Variety.Site	3	462.2	154.1	0.4	0.756
Contrast 4.Variety.Site	3	679.3	226.4	0.58	0.628
Contrast 5.Variety.Site	3	80.7	26.9	0.07	0.976
Residual	144	56024	389.1		
Total	215	84929			

Leaf weight g					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	7.046	0.88	1.09	0.38
Contrast 1	1	1.704	1.7	2.1	0.15
Contrast 2	1	2.353	2.35	2.9	0.09
Contrast 3	1	0.84	0.84	1.04	0.31
Contrast 4	1	1.744	1.74	2.15	0.15
Contrast 5	1	1.016	1.02	1.25	0.27
Contrast 6	1	4.859	4.86	5.99	0.02
Variety	3	3.878	1.29	1.59	0.19
Site	1	20.11	20.1	24.8	<.001
Treatment.Variety	24	14.76	0.62	0.76	0.78
Contrast 1.Variety	3	3.193	1.06	1.31	0.27
Contrast 2.Variety	3	0.103	0.03	0.04	0.99
Contrast 3.Variety	3	2.945	0.98	1.21	0.31
Contrast 4.Variety	3	2.892	0.96	1.19	0.32
Contrast 5.Variety	3	3.583	1.19	1.47	0.22
Contrast 6.Variety	3	1.129	0.38	0.46	0.71
Treatment.Site	8	5.461	0.68	0.84	0.57
Contrast 1.Site	1	1.392	1.39	1.72	0.19
Contrast 2.Site	1	0.287	0.29	0.35	0.55
Contrast 3.Site	1	0.109	0.11	0.13	0.72
Contrast 4.Site	1	1.244	1.24	1.53	0.22
Contrast 5.Site	1	1.753	1.75	2.16	0.14
Contrast 6.Site	1	0.503	0.5	0.62	0.43
Variety.Site	3	3.773	1.26	1.55	0.2
Treatment.Variety.Site	24	17.09	0.71	0.88	0.63
Contrast 1.Variety.Site	3	6.429	2.14	2.64	0.05
Contrast 2.Variety.Site	3	2.543	0.85	1.05	0.37
Contrast 3.Variety.Site	3	6.567	2.19	2.7	0.05
Contrast 4.Variety.Site	3	4.485	1.5	1.84	0.14
Contrast 5.Variety.Site	3	1.528	0.51	0.63	0.6
Residual	144	116.8	0.81		
Total	215	188.9			

Plant height cm week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1.1618	0.145	0.91	0.509
Contrast 1	1	0.0008	8E-04	0	0.945
Contrast 2	1	0.1197	0.12	0.75	0.388
Contrast 3	1	0.0047	0.005	0.03	0.865
Contrast 4	1	0.1706	0.171	1.07	0.303
Contrast 5	1	0.1128	0.113	0.71	0.402
Contrast 6	1	0.1678	0.168	1.05	0.307
Variety	3	0.4048	0.135	0.85	0.471
Site	1	3.2825	3.283	20.6	<.001
Treatment.Variety	24	3.8514	0.161	1.01	0.462
Contrast 1.Variety	3	1.139	0.38	2.38	0.072
Contrast 2.Variety	3	0.5311	0.177	1.11	0.347
Contrast 3.Variety	3	1.1905	0.397	2.49	0.063
Contrast 4.Variety	3	0.4831	0.161	1.01	0.39
Contrast 5.Variety	3	0.4913	0.164	1.03	0.382
Contrast 6.Variety	3	1.557	0.519	3.26	0.024
Treatment.Site	8	1.164	0.146	0.91	0.508
Contrast 1.Site	1	0.0089	0.009	0.06	0.813
Contrast 2.Site	1	0.1485	0.149	0.93	0.336
Contrast 3.Site	1	0.0008	8E-04	0	0.945
Contrast 4.Site	1	0.206	0.206	1.29	0.258
Contrast 5.Site	1	0.1419	0.142	0.89	0.347
Contrast 6.Site	1	0.1136	0.114	0.71	0.4
Variety.Site	3	0.392	0.131	0.82	0.485
Treatment.Variety.Site	24	3.6249	0.151	0.95	0.539
Contrast 1.Variety.Site	3	1.1242	0.375	2.35	0.075
Contrast 2.Variety.Site	3	0.4814	0.161	1.01	0.392
Contrast 3.Variety.Site	3	1.1804	0.394	2.47	0.064
Contrast 4.Variety.Site	3	0.4392	0.146	0.92	0.434
Contrast 5.Variety.Site	3	0.4721	0.157	0.99	0.401
Residual	144	22.957	0.159		
Total	215	36.838			

Plant height cm week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	20.231	2.529	2.28	0.03
Contrast 1	1	0.026	0.026	0.02	0.88
Contrast 2	1	0.447	0.447	0.4	0.53
Contrast 3	1	0.14	0.14	0.13	0.72
Contrast 4	1	1.213	1.213	1.09	0.3
Contrast 5	1	0.876	0.876	0.79	0.38
Contrast 6	1	5.447	5.447	4.91	0.03
Variety	3	1.358	0.453	0.41	0.75
Site	1	15.789	15.789	14.2	<.001
Treatment.Variety	24	29.796	1.241	1.12	0.33
Contrast 1.Variety	3	5.546	1.849	1.67	0.18
Contrast 2.Variety	3	0.797	0.266	0.24	0.87
Contrast 3.Variety	3	5.707	1.902	1.71	0.17
Contrast 4.Variety	3	4.58	1.527	1.37	0.25
Contrast 5.Variety	3	2.991	0.997	0.9	0.44
Contrast 6.Variety	3	9.312	3.104	2.8	0.04
Treatment.Site	8	18.085	2.261	2.04	0.05
Contrast 1.Site	1	2.337	2.337	2.11	0.15
Contrast 2.Site	1	2.628	2.628	2.37	0.13
Contrast 3.Site	1	1.266	1.266	1.14	0.29
Contrast 4.Site	1	3.985	3.985	3.59	0.06
Contrast 5.Site	1	6.739	6.739	6.07	0.02
Contrast 6.Site	1	0.288	0.288	0.26	0.61
Variety.Site	3	0.905	0.302	0.27	0.85
Treatment.Variety.Site	24	25.755	1.073	0.97	0.51
Contrast 1.Variety.Site	3	6.96	2.32	2.09	0.1
Contrast 2.Variety.Site	3	1.573	0.524	0.47	0.7
Contrast 3.Variety.Site	3	2.76	0.92	0.83	0.48
Contrast 4.Variety.Site	3	1.783	0.594	0.54	0.66
Contrast 5.Variety.Site	3	1.674	0.558	0.5	0.68
Residual	144	159.887	1.11		
Total	215	271.806			

Plant height cm week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	32.557	4.07	1.34	0.226
Contrast 1	1	1.029	1.029	0.34	0.561
Contrast 2	1	0.843	0.843	0.28	0.598
Contrast 3	1	0.533	0.533	0.18	0.675
Contrast 4	1	0.05	0.05	0.02	0.898
Contrast 5	1	1.167	1.167	0.39	0.536
Contrast 6	1	12.737	12.737	4.21	0.042
Variety	3	8.09	2.697	0.89	0.447
Site	1	126.89	126.89	41.92	<.001
Treatment.Variety	24	70.763	2.948	0.97	0.504
Contrast 1.Variety	3	19.76	6.587	2.18	0.093
Contrast 2.Variety	3	1.053	0.351	0.12	0.951
Contrast 3.Variety	3	19.62	6.54	2.16	0.095
Contrast 4.Variety	3	13.449	4.483	1.48	0.222
Contrast 5.Variety	3	21.966	7.322	2.42	0.069
Contrast 6.Variety	3	18.511	6.17	2.04	0.111
Treatment.Site	8	30.856	3.857	1.27	0.261
Contrast 1.Site	1	7.909	7.909	2.61	0.108
Contrast 2.Site	1	9.228	9.228	3.05	0.083
Contrast 3.Site	1	5.275	5.275	1.74	0.189
Contrast 4.Site	1	7.971	7.971	2.63	0.107
Contrast 5.Site	1	18.475	18.475	6.1	0.015
Contrast 6.Site	1	5.046	5.046	1.67	0.199
Variety.Site	3	31.632	10.544	3.48	0.018
Treatment.Variety.Site	24	67.107	2.796	0.92	0.57
Contrast 1.Variety.Site	3	4.882	1.627	0.54	0.657
Contrast 2.Variety.Site	3	5.067	1.689	0.56	0.644
Contrast 3.Variety.Site	3	5.263	1.754	0.58	0.629
Contrast 4.Variety.Site	3	3.27	1.09	0.36	0.782
Contrast 5.Variety.Site	3	6.296	2.099	0.69	0.558
Residual	144	435.87	3.027		
Total	215	803.76			

Plant height cm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	128.074	16.009	2.93	0.005
Contrast 1	1	18.925	18.925	3.46	0.065
Contrast 2	1	3.489	3.489	0.64	0.426
Contrast 3	1	3.252	3.252	0.59	0.442
Contrast 4	1	0.307	0.307	0.06	0.813
Contrast 5	1	0	0	0	0.998
Contrast 6	1	70.871	70.871	13	<.001
Variety	3	18.392	6.131	1.12	0.343
Site	1	542.647	542.647	99.3	<.001
Treatment.Variety	24	137.388	5.724	1.05	0.412
Contrast 1.Variety	3	42.867	14.289	2.61	0.054
Contrast 2.Variety	3	4.192	1.397	0.26	0.857
Contrast 3.Variety	3	35.567	11.856	2.17	0.094
Contrast 4.Variety	3	4.707	1.569	0.29	0.835
Contrast 5.Variety	3	22.024	7.341	1.34	0.263
Contrast 6.Variety	3	47.011	15.67	2.87	0.039
Treatment.Site	8	59.194	7.399	1.35	0.222
Contrast 1.Site	1	8.569	8.569	1.57	0.213
Contrast 2.Site	1	12.809	12.809	2.34	0.128
Contrast 3.Site	1	0.393	0.393	0.07	0.789
Contrast 4.Site	1	13.124	13.124	2.4	0.124
Contrast 5.Site	1	27.126	27.126	4.96	0.027
Contrast 6.Site	1	0.066	0.066	0.01	0.913
Variety.Site	3	26.537	8.846	1.62	0.188
Treatment.Variety.Site	24	78.12	3.255	0.6	0.931
Contrast 1.Variety.Site	3	9.109	3.036	0.56	0.645
Contrast 2.Variety.Site	3	2.295	0.765	0.14	0.936
Contrast 3.Variety.Site	3	9.347	3.116	0.57	0.636
Contrast 4.Variety.Site	3	2.072	0.691	0.13	0.944
Contrast 5.Variety.Site	3	2.912	0.971	0.18	0.911
Residual	144	787.293	5.467		
Total	215	1777.64			

Plant height cm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	134.426	16.803	2.41	0.02
Contrast 1	1	11.288	11.288	1.62	0.21
Contrast 2	1	23.228	23.228	3.34	0.07
Contrast 3	1	0.884	0.884	0.13	0.72
Contrast 4	1	16.896	16.896	2.43	0.12
Contrast 5	1	1.634	1.634	0.23	0.63
Contrast 6	1	70.992	70.992	10.2	0
Variety	3	33.752	11.251	1.62	0.19
Site	1	571.92	571.92	82.2	<.001
Treatment.Variety	24	146.369	6.099	0.88	0.63
Contrast 1.Variety	3	43.182	14.394	2.07	0.11
Contrast 2.Variety	3	1.618	0.539	0.08	0.97
Contrast 3.Variety	3	27.536	9.179	1.32	0.27
Contrast 4.Variety	3	20.482	6.827	0.98	0.4
Contrast 5.Variety	3	32.161	10.72	1.54	0.21
Contrast 6.Variety	3	35.57	11.857	1.7	0.17
Treatment.Site	8	20.896	2.612	0.38	0.93
Contrast 1.Site	1	0.824	0.824	0.12	0.73
Contrast 2.Site	1	7.633	7.633	1.1	0.3
Contrast 3.Site	1	6.046	6.046	0.87	0.35
Contrast 4.Site	1	3.479	3.479	0.5	0.48
Contrast 5.Site	1	7.322	7.322	1.05	0.31
Contrast 6.Site	1	0.043	0.043	0.01	0.94
Variety.Site	3	6.992	2.331	0.33	0.8
Treatment.Variety.Site	24	107.107	4.463	0.64	0.9
Contrast 1.Variety.Site	3	32.465	10.822	1.55	0.2
Contrast 2.Variety.Site	3	14.092	4.697	0.67	0.57
Contrast 3.Variety.Site	3	21.485	7.162	1.03	0.38
Contrast 4.Variety.Site	3	3.775	1.258	0.18	0.91
Contrast 5.Variety.Site	3	5.798	1.933	0.28	0.84
Residual	144	1002.32	6.961		
Total	215	2023.78			

Plant_height_cm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	34.4	4.304	0.47	0.87
Contrast 1	1	2.45	2.451	0.27	0.61
Contrast 2	1	2.62	2.624	0.29	0.59
Contrast 3	1	0.14	0.142	0.02	0.9
Contrast 4	1	0.21	0.205	0.02	0.88
Contrast 5	1	1.93	1.928	0.21	0.65
Contrast 6	1	16.4	16.45	1.81	0.18
Variety	3	35.3	11.77	1.29	0.28
Site	1	613	612.5	67.2	<.001
Treatment.Variety	24	130	5.396	0.59	0.93
Contrast 1.Variety	3	38.6	12.86	1.41	0.24
Contrast 2.Variety	3	6.75	2.251	0.25	0.86
Contrast 3.Variety	3	13.1	4.383	0.48	0.7
Contrast 4.Variety	3	2.65	0.884	0.1	0.96
Contrast 5.Variety	3	30.2	10.06	1.1	0.35
Contrast 6.Variety	3	6.28	2.094	0.23	0.88
Treatment.Site	8	46.2	5.775	0.63	0.75
Contrast 1.Site	1	24.9	24.92	2.74	0.1
Contrast 2.Site	1	10.2	10.21	1.12	0.29
Contrast 3.Site	1	27.1	27.1	2.97	0.09
Contrast 4.Site	1	9.73	9.731	1.07	0.3
Contrast 5.Site	1	19.4	19.45	2.13	0.15
Contrast 6.Site	1	21	20.98	2.3	0.13
Variety.Site	3	24.4	8.135	0.89	0.45
Treatment.Variety.Site	24	206	8.585	0.94	0.55
Contrast 1.Variety.Site	3	60.7	20.23	2.22	0.09
Contrast 2.Variety.Site	3	15.3	5.111	0.56	0.64
Contrast 3.Variety.Site	3	35.4	11.79	1.29	0.28
Contrast 4.Variety.Site	3	18.8	6.264	0.69	0.56
Contrast 5.Variety.Site	3	36.9	12.29	1.35	0.26
Residual	144	1312	9.109		
Total	215	2400			

Plant_height_cm week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	152.7	19.08	1.19	0.31
Contrast 1	1	26.84	26.84	1.67	0.2
Contrast 2	1	3.74	3.74	0.23	0.63
Contrast 3	1	3.83	3.83	0.24	0.63
Contrast 4	1	0.03	0.03	0	0.97
Contrast 5	1	0.26	0.26	0.02	0.9
Contrast 6	1	64.37	64.37	4	0.05
Variety	3	111.5	37.18	2.31	0.08
Site	1	1289	1289	80.1	<.001
Treatment.Variety	24	480	20	1.24	0.22
Contrast 1.Variety	3	192.8	64.26	3.99	0.01
Contrast 2.Variety	3	22.68	7.56	0.47	0.7
Contrast 3.Variety	3	137.1	45.69	2.84	0.04
Contrast 4.Variety	3	88.66	29.55	1.84	0.14
Contrast 5.Variety	3	162.9	54.31	3.37	0.02
Contrast 6.Variety	3	240.5	80.15	4.98	0
Treatment.Site	8	91.68	11.46	0.71	0.68
Contrast 1.Site	1	53.66	53.66	3.33	0.07
Contrast 2.Site	1	28.15	28.15	1.75	0.19
Contrast 3.Site	1	39.92	39.92	2.48	0.12
Contrast 4.Site	1	38.96	38.96	2.42	0.12
Contrast 5.Site	1	65.62	65.62	4.08	0.05
Contrast 6.Site	1	35.83	35.83	2.23	0.14
Variety.Site	3	39.85	13.28	0.83	0.48
Treatment.Variety.Site	24	175.6	7.32	0.45	0.99
Contrast 1.Variety.Site	3	28.75	9.58	0.6	0.62
Contrast 2.Variety.Site	3	9.49	3.16	0.2	0.9
Contrast 3.Variety.Site	3	5.97	1.99	0.12	0.95
Contrast 4.Variety.Site	3	5.7	1.9	0.12	0.95
Contrast 5.Variety.Site	3	8.28	2.76	0.17	0.92
Residual	144	2318	16.1		
Total	215	4659			

Stem thickness week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.1783	0.022	0.75	0.65
Contrast 1	1	0.0049	0.005	0.17	0.69
Contrast 2	1	0.0259	0.026	0.87	0.35
Contrast 3	1	0.0017	0.002	0.06	0.81
Contrast 4	1	0.0156	0.016	0.52	0.47
Contrast 5	1	0.0156	0.016	0.52	0.47
Contrast 6	1	0.0146	0.015	0.49	0.49
Variety	3	0.1316	0.044	1.47	0.22
Site	1	0.8102	0.81	27.2	<.001
Treatment.Variety	24	0.6193	0.026	0.87	0.65
Contrast 1.Variety	3	0.1698	0.057	1.9	0.13
Contrast 2.Variety	3	0.0899	0.03	1.01	0.39
Contrast 3.Variety	3	0.2421	0.081	2.71	0.05
Contrast 4.Variety	3	0.1001	0.033	1.12	0.34
Contrast 5.Variety	3	0.0905	0.03	1.01	0.39
Contrast 6.Variety	3	0.2549	0.085	2.86	0.04
Treatment.Site	8	0.1933	0.024	0.81	0.59
Contrast 1.Site	1	0.0049	0.005	0.17	0.69
Contrast 2.Site	1	0.0163	0.016	0.55	0.46
Contrast 3.Site	1	0.0017	0.002	0.06	0.81
Contrast 4.Site	1	0.0269	0.027	0.9	0.34
Contrast 5.Site	1	0.0269	0.027	0.9	0.34
Contrast 6.Site	1	0.0282	0.028	0.95	0.33
Variety.Site	3	0.0639	0.021	0.72	0.54
Treatment.Variety.Site	24	0.5751	0.024	0.81	0.73
Contrast 1.Variety.Site	3	0.1746	0.058	1.96	0.12
Contrast 2.Variety.Site	3	0.0495	0.016	0.55	0.65
Contrast 3.Variety.Site	3	0.1087	0.036	1.22	0.31
Contrast 4.Variety.Site	3	0.0388	0.013	0.43	0.73
Contrast 5.Variety.Site	3	0.0459	0.015	0.51	0.67
Residual	144	4.2836	0.03		
Total	215	6.8552			

Stem thickness week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.283	0.04	1.18	0.32
Contrast 1	1	0.002	0	0.05	0.82
Contrast 2	1	0.029	0.03	0.95	0.33
Contrast 3	1	0.034	0.03	1.14	0.29
Contrast 4	1	0.023	0.02	0.76	0.38
Contrast 5	1	0.042	0.04	1.39	0.24
Contrast 6	1	0.044	0.04	1.45	0.23
Variety	3	0.037	0.01	0.42	0.74
Site	1	0.03	0.03	0.98	0.32
Treatment.Variety	24	0.455	0.02	0.63	0.91
Contrast 1.Variety	3	0.145	0.05	1.62	0.19
Contrast 2.Variety	3	0.042	0.01	0.47	0.7
Contrast 3.Variety	3	0.049	0.02	0.54	0.66
Contrast 4.Variety	3	0.054	0.02	0.61	0.61
Contrast 5.Variety	3	0.118	0.04	1.31	0.27
Contrast 6.Variety	3	0.206	0.07	2.29	0.08
Treatment.Site	8	0.243	0.03	1.01	0.43
Contrast 1.Site	1	0.002	0	0.05	0.82
Contrast 2.Site	1	0.034	0.03	1.12	0.29
Contrast 3.Site	1	0.034	0.03	1.14	0.29
Contrast 4.Site	1	0.023	0.02	0.76	0.38
Contrast 5.Site	1	0.042	0.04	1.39	0.24
Contrast 6.Site	1	0.027	0.03	0.91	0.34
Variety.Site	3	0.036	0.01	0.39	0.76
Treatment.Variety.Site	24	0.407	0.02	0.57	0.95
Contrast 1.Variety.Site	3	0.145	0.05	1.62	0.19
Contrast 2.Variety.Site	3	0.053	0.02	0.59	0.62
Contrast 3.Variety.Site	3	0.049	0.02	0.54	0.66
Contrast 4.Variety.Site	3	0.054	0.02	0.61	0.61
Contrast 5.Variety.Site	3	0.118	0.04	1.31	0.27
Residual	144	4.316	0.03		
Total	215	5.805			

Stem thickness week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	4.9923	0.624	1.36	0.22
Contrast 1	1	0.0008	0.0008	0	0.97
Contrast 2	1	0.3702	0.3702	0.81	0.37
Contrast 3	1	0.2567	0.2567	0.56	0.46
Contrast 4	1	0.0782	0.0782	0.17	0.68
Contrast 5	1	0.9911	0.9911	2.16	0.14
Contrast 6	1	0.7771	0.7771	1.7	0.2
Variety	3	1.2434	0.4145	0.9	0.44
Site	1	74.632	74.632	163	<.001
Treatment.Variety	24	7.8005	0.325	0.71	0.84
Contrast 1.Variety	3	4.0671	1.3557	2.96	0.03
Contrast 2.Variety	3	1.3847	0.4616	1.01	0.39
Contrast 3.Variety	3	1.5205	0.5068	1.11	0.35
Contrast 4.Variety	3	0.7215	0.2405	0.52	0.67
Contrast 5.Variety	3	1.8899	0.63	1.37	0.25
Contrast 6.Variety	3	1.281	0.427	0.93	0.43
Treatment.Site	8	2.9407	0.3676	0.8	0.6
Contrast 1.Site	1	0.0326	0.0326	0.07	0.79
Contrast 2.Site	1	0.0124	0.0124	0.03	0.87
Contrast 3.Site	1	0.0284	0.0284	0.06	0.8
Contrast 4.Site	1	0.1309	0.1309	0.29	0.59
Contrast 5.Site	1	1.236	1.236	2.7	0.1
Contrast 6.Site	1	0.2065	0.2065	0.45	0.5
Variety.Site	3	0.9001	0.3	0.65	0.58
Treatment.Variety.Site	24	6.331	0.2638	0.58	0.94
Contrast 1.Variety.Site	3	0.8147	0.2716	0.59	0.62
Contrast 2.Variety.Site	3	0.0625	0.0208	0.05	0.99
Contrast 3.Variety.Site	3	0.5288	0.1763	0.38	0.76
Contrast 4.Variety.Site	3	0.6036	0.2012	0.44	0.73
Contrast 5.Variety.Site	3	0.0862	0.0287	0.06	0.98
Residual	144	65.985	0.4582		
Total	215	164.82			

Stem thickness week 4					
Source of variation					
Treatment	8	15.71	1.96	2.94	0.004
Contrast 1	1	1.469	1.47	2.2	0.14
Contrast 2	1	0.09	0.09	0.13	0.715
Contrast 3	1	0.279	0.28	0.42	0.519
Contrast 4	1	0.977	0.98	1.46	0.228
Contrast 5	1	0.519	0.52	0.78	0.379
Contrast 6	1	4.153	4.15	6.22	0.014
Variety	3	1.27	0.42	0.63	0.594
Site	1	1.725	1.73	2.58	0.11
Treatment.Variety	24	23.88	1	1.49	0.079
Contrast 1.Variety	3	9.347	3.12	4.67	0.004
Contrast 2.Variety	3	1.336	0.45	0.67	0.574
Contrast 3.Variety	3	6.334	2.11	3.16	0.027
Contrast 4.Variety	3	1.294	0.43	0.65	0.587
Contrast 5.Variety	3	5.532	1.84	2.76	0.044
Contrast 6.Variety	3	4.071	1.36	2.03	0.112
Treatment.Site	8	12.92	1.62	2.42	0.018
Contrast 1.Site	1	3.399	3.4	5.09	0.026
Contrast 2.Site	1	0.786	0.79	1.18	0.28
Contrast 3.Site	1	0.221	0.22	0.33	0.566
Contrast 4.Site	1	0.412	0.41	0.62	0.433
Contrast 5.Site	1	2.876	2.88	4.31	0.04
Contrast 6.Site	1	0.053	0.05	0.08	0.779
Variety.Site	3	1.534	0.51	0.77	0.515
Treatment.Variety.Site	24	22.11	0.92	1.38	0.127
Contrast 1.Variety.Site	3	6.116	2.04	3.05	0.031
Contrast 2.Variety.Site	3	0.792	0.26	0.4	0.757
Contrast 3.Variety.Site	3	4.266	1.42	2.13	0.099
Contrast 4.Variety.Site	3	0.661	0.22	0.33	0.804
Contrast 5.Variety.Site	3	0.329	0.11	0.16	0.92
Residual	144	96.15	0.67		
Total	215	175.3			

Stem thickness week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.616	1.08	1.73	0.1
Contrast 1	1	0.79	0.79	1.27	0.26
Contrast 2	1	0.049	0.05	0.08	0.78
Contrast 3	1	0.238	0.24	0.38	0.54
Contrast 4	1	0.785	0.79	1.26	0.26
Contrast 5	1	0.103	0.1	0.17	0.68
Contrast 6	1	3.692	3.69	5.94	0.02
Variety	3	1.324	0.44	0.71	0.55
Site	1	0.885	0.88	1.42	0.24
Treatment.Variety	24	15.66	0.65	1.05	0.41
Contrast 1.Variety	3	1.688	0.56	0.91	0.44
Contrast 2.Variety	3	2.259	0.75	1.21	0.31
Contrast 3.Variety	3	2.598	0.87	1.39	0.25
Contrast 4.Variety	3	0.224	0.07	0.12	0.95
Contrast 5.Variety	3	1.089	0.36	0.58	0.63
Contrast 6.Variety	3	2.85	0.95	1.53	0.21
Treatment.Site	8	4.358	0.54	0.88	0.54
Contrast 1.Site	1	0.24	0.24	0.39	0.54
Contrast 2.Site	1	0.557	0.56	0.9	0.35
Contrast 3.Site	1	0.007	0.01	0.01	0.91
Contrast 4.Site	1	0.599	0.6	0.96	0.33
Contrast 5.Site	1	0.099	0.1	0.16	0.69
Contrast 6.Site	1	0.566	0.57	0.91	0.34
Variety.Site	3	1.182	0.39	0.63	0.59
Treatment.Variety.Site	24	11.65	0.49	0.78	0.76
Contrast 1.Variety.Site	3	1.544	0.51	0.83	0.48
Contrast 2.Variety.Site	3	4.274	1.42	2.29	0.08
Contrast 3.Variety.Site	3	1.471	0.49	0.79	0.5
Contrast 4.Variety.Site	3	0.759	0.25	0.41	0.75
Contrast 5.Variety.Site	3	0.768	0.26	0.41	0.75
Residual	144	89.5	0.62		
Total	215	133.2			

Stem thickness week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.679	0.085	0.13	0.998
Contrast 1	1	0.004	0.004	0.01	0.935
Contrast 2	1	0.121	0.121	0.18	0.668
Contrast 3	1	0.311	0.311	0.47	0.492
Contrast 4	1	0.15	0.15	0.23	0.633
Contrast 5	1	0.033	0.033	0.05	0.823
Contrast 6	1	0.012	0.012	0.02	0.892
Variety	3	0.598	0.199	0.3	0.822
Site	1	6.026	6.026	9.19	0.003
Treatment.Variety	24	8.73	0.364	0.55	0.954
Contrast 1.Variety	3	2.453	0.818	1.25	0.295
Contrast 2.Variety	3	1.739	0.58	0.88	0.451
Contrast 3.Variety	3	0.401	0.134	0.2	0.894
Contrast 4.Variety	3	0.841	0.281	0.43	0.734
Contrast 5.Variety	3	0.456	0.152	0.23	0.874
Contrast 6.Variety	3	0.757	0.252	0.38	0.764
Treatment.Site	8	5.464	0.683	1.04	0.408
Contrast 1.Site	1	0.226	0.226	0.34	0.558
Contrast 2.Site	1	0.968	0.968	1.48	0.226
Contrast 3.Site	1	0.917	0.917	1.4	0.239
Contrast 4.Site	1	1.305	1.305	1.99	0.161
Contrast 5.Site	1	0.066	0.066	0.1	0.752
Contrast 6.Site	1	1.635	1.635	2.49	0.117
Variety.Site	3	1.965	0.655	1	0.396
Treatment.Variety.Site	24	18.04	0.752	1.15	0.303
Contrast 1.Variety.Site	3	4.233	1.411	2.15	0.096
Contrast 2.Variety.Site	3	0.581	0.194	0.3	0.829
Contrast 3.Variety.Site	3	2.725	0.908	1.38	0.25
Contrast 4.Variety.Site	3	1.365	0.455	0.69	0.557
Contrast 5.Variety.Site	3	2.809	0.936	1.43	0.237
Residual	144	94.45	0.656		
Total	215	136			

Stem thickness week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.2	1.02	1.26	0.27
Contrast 1	1	0	0	0.01	0.94
Contrast 2	1	0.2	0.2	0.25	0.62
Contrast 3	1	0.01	0.01	0.01	0.9
Contrast 4	1	0.17	0.17	0.21	0.65
Contrast 5	1	0.34	0.34	0.42	0.52
Contrast 6	1	3.33	3.33	4.11	0.04
Variety	3	6.28	2.09	2.58	0.06
Site	1	83	83	102	<.001
Treatment.Variety	24	19.9	0.83	1.02	0.44
Contrast 1.Variety	3	6.47	2.16	2.66	0.05
Contrast 2.Variety	3	1.66	0.55	0.68	0.57
Contrast 3.Variety	3	7.21	2.4	2.97	0.03
Contrast 4.Variety	3	1.73	0.58	0.71	0.55
Contrast 5.Variety	3	6.8	2.27	2.8	0.04
Contrast 6.Variety	3	8.79	2.93	3.62	0.02
Treatment.Site	8	8.03	1	1.24	0.28
Contrast 1.Site	1	1.25	1.25	1.54	0.22
Contrast 2.Site	1	1.57	1.57	1.94	0.17
Contrast 3.Site	1	1.81	1.81	2.23	0.14
Contrast 4.Site	1	3.49	3.49	4.31	0.04
Contrast 5.Site	1	3.03	3.03	3.74	0.06
Contrast 6.Site	1	0.09	0.09	0.11	0.74
Variety.Site	3	0.77	0.26	0.32	0.81
Treatment.Variety.Site	24	22.1	0.92	1.13	0.31
Contrast 1.Variety.Site	3	0.85	0.28	0.35	0.79
Contrast 2.Variety.Site	3	0.96	0.32	0.39	0.76
Contrast 3.Variety.Site	3	1.89	0.63	0.78	0.51
Contrast 4.Variety.Site	3	0.32	0.11	0.13	0.94
Contrast 5.Variety.Site	3	0.09	0.03	0.04	0.99
Residual	144	117	0.81		
Total	215	265			

No_of_nodules week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	227	28.3	0.89	0.53
Contrast 1	1	48	48	1.5	0.22
Contrast 2	1	0.52	0.52	0.02	0.9
Contrast 3	1	0.33	0.33	0.01	0.92
Contrast 4	1	77.5	77.5	2.42	0.12
Contrast 5	1	20	20	0.63	0.43
Contrast 6	1	6.75	6.75	0.21	0.65
Variety	3	113	37.8	1.18	0.32
Site	1	2347	2347	73.4	<.001
Treatment.Variety	24	621	25.9	0.81	0.72
Contrast 1.Variety	3	70.3	23.4	0.73	0.53
Contrast 2.Variety	3	12.2	4.08	0.13	0.94
Contrast 3.Variety	3	22.8	7.61	0.24	0.87
Contrast 4.Variety	3	27.2	9.08	0.28	0.84
Contrast 5.Variety	3	98.2	32.7	1.02	0.38
Contrast 6.Variety	3	34.9	11.6	0.36	0.78
Treatment.Site	8	176	22	0.69	0.7
Contrast 1.Site	1	0.33	0.33	0.01	0.92
Contrast 2.Site	1	9.19	9.19	0.29	0.59
Contrast 3.Site	1	1.33	1.33	0.04	0.84
Contrast 4.Site	1	72.5	72.5	2.27	0.13
Contrast 5.Site	1	11	11	0.34	0.56
Contrast 6.Site	1	5.33	5.33	0.17	0.68
Variety.Site	3	39.7	13.3	0.41	0.74
Treatment.Variety.Site	24	671	28	0.87	0.64
Contrast 1.Variety.Site	3	30	10	0.31	0.82
Contrast 2.Variety.Site	3	119	39.5	1.24	0.3
Contrast 3.Variety.Site	3	92.2	30.7	0.96	0.41
Contrast 4.Variety.Site	3	106	35.3	1.1	0.35
Contrast 5.Variety.Site	3	177	58.9	1.84	0.14
Residual	144	4605	32		
Total	215	8800			

No_of_nodules week 5						
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Treatment	8		861.6	108	2.59	0.01
Contrast 1	1		9.28	9.28	0.22	0.64
Contrast 2	1		88.02	88	2.11	0.15
Contrast 3	1		14.08	14.1	0.34	0.56
Contrast 4	1		38.52	38.5	0.92	0.34
Contrast 5	1		188	188	4.51	0.04
Contrast 6	1		106.5	107	2.56	0.11
Variety	3		317.2	106	2.54	0.06
Site	1		150.7	151	3.62	0.06
Treatment.Variety	24		1490	62.1	1.49	0.08
Contrast 1.Variety	3		266.4	88.8	2.13	0.1
Contrast 2.Variety	3		86.56	28.9	0.69	0.56
Contrast 3.Variety	3		138.3	46.1	1.11	0.35
Contrast 4.Variety	3		57.73	19.2	0.46	0.71
Contrast 5.Variety	3		443.2	148	3.55	0.02
Contrast 6.Variety	3		56.6	18.9	0.45	0.72
Treatment.Site	8		549	68.6	1.65	0.12
Contrast 1.Site	1		45.83	45.8	1.1	0.3
Contrast 2.Site	1		136.7	137	3.28	0.07
Contrast 3.Site	1		8.33	8.33	0.2	0.66
Contrast 4.Site	1		63.02	63	1.51	0.22
Contrast 5.Site	1		72.52	72.5	1.74	0.19
Contrast 6.Site	1		57.42	57.4	1.38	0.24
Variety.Site	3		222.2	74.1	1.78	0.15
Treatment.Variety.Site	24		1656	69	1.66	0.04
Contrast 1.Variety.Site	3		282	94	2.26	0.08
Contrast 2.Variety.Site	3		169.6	56.5	1.36	0.26
Contrast 3.Variety.Site	3		142	47.3	1.14	0.34
Contrast 4.Variety.Site	3		47.56	15.9	0.38	0.77
Contrast 5.Variety.Site	3		47.06	15.7	0.38	0.77
Residual	140	-4	5831	41.7		
Total	211	-4	11066			

No_of_nodules week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1192	149	2.4	0.019
Contrast 1	1	290.08	290	4.67	0.032
Contrast 2	1	41.56	41.6	0.67	0.415
Contrast 3	1	9.19	9.19	0.15	0.701
Contrast 4	1	6.75	6.75	0.11	0.742
Contrast 5	1	341.33	341	5.5	0.02
Contrast 6	1	341.33	341	5.5	0.02
Variety	3	672.94	224	3.61	0.015
Site	1	6894.5	6895	111	<.001
Treatment.Variety	24	952.49	39.7	0.64	0.9
Contrast 1.Variety	3	49.42	16.5	0.27	0.85
Contrast 2.Variety	3	7.86	2.62	0.04	0.988
Contrast 3.Variety	3	58.23	19.4	0.31	0.816
Contrast 4.Variety	3	97.42	32.5	0.52	0.667
Contrast 5.Variety	3	18.83	6.28	0.1	0.959
Contrast 6.Variety	3	195.67	65.2	1.05	0.372
Treatment.Site	8	1583.4	198	3.19	0.002
Contrast 1.Site	1	396.75	397	6.39	0.013
Contrast 2.Site	1	34.45	34.5	0.55	0.458
Contrast 3.Site	1	25.52	25.5	0.41	0.523
Contrast 4.Site	1	75	75	1.21	0.274
Contrast 5.Site	1	816.75	817	13.2	<.001
Contrast 6.Site	1	300	300	4.83	0.03
Variety.Site	3	500.51	167	2.69	0.049
Treatment.Variety.Site	24	1188.4	49.5	0.8	0.736
Contrast 1.Variety.Site	3	285.75	95.3	1.53	0.208
Contrast 2.Variety.Site	3	20.19	6.73	0.11	0.955
Contrast 3.Variety.Site	3	74.9	25	0.4	0.752
Contrast 4.Variety.Site	3	190.5	63.5	1.02	0.385
Contrast 5.Variety.Site	3	159.42	53.1	0.86	0.466
Residual	144	8944.7	62.1		
Total	215	21929			

Number of leaves week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1620685	202586	3.35	0.002
Contrast 1	1	17490	17490	0.29	0.592
Contrast 2	1	8800	8800	0.15	0.704
Contrast 3	1	65140	65140	1.08	0.301
Contrast 4	1	36345	36345	0.6	0.44
Contrast 5	1	125838	125838	2.08	0.152
Contrast 6	1	601293	601293	9.93	0.002
Variety	3	1450141	483380	7.98	<.001
Site	1	1634411	1634411	27	<.001
Treatment.Variety	24	1318345	54931	0.91	0.592
Contrast 1.Variety	3	597141	199047	3.29	0.023
Contrast 2.Variety	3	178864	59621	0.98	0.402
Contrast 3.Variety	3	326428	108809	1.8	0.15
Contrast 4.Variety	3	154686	51562	0.85	0.468
Contrast 5.Variety	3	147590	49197	0.81	0.489
Contrast 6.Variety	3	272563	90854	1.5	0.217
Treatment.Site	8	2814338	351792	5.81	<.001
Contrast 1.Site	1	421602	421602	6.96	0.009
Contrast 2.Site	1	600025	600025	9.91	0.002
Contrast 3.Site	1	5554	5554	0.09	0.762
Contrast 4.Site	1	722558	722558	11.9	<.001
Contrast 5.Site	1	1631939	1631939	27	<.001
Contrast 6.Site	1	27373	27373	0.45	0.502
Variety.Site	3	2124577	708192	11.7	<.001
Treatment.Variety.Site	24	857525	35730	0.59	0.934
Contrast 1.Variety.Site	3	156032	52011	0.86	0.464
Contrast 2.Variety.Site	3	113475	37825	0.62	0.6
Contrast 3.Variety.Site	3	25688	8563	0.14	0.935
Contrast 4.Variety.Site	3	105635	35212	0.58	0.628
Contrast 5.Variety.Site	3	6130	2043	0.03	0.992
Residual	144	8717928	60541		
Total	215	2.1E+07			

Number of leaves week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	331185	41398	2.62	0.01
Contrast 1	1	167	167	0.01	0.918
Contrast 2	1	4057	4057	0.26	0.613
Contrast 3	1	1592	1592	0.1	0.751
Contrast 4	1	50176	50176	3.17	0.077
Contrast 5	1	42475	42475	2.69	0.103
Contrast 6	1	69455	69455	4.39	0.038
Variety	3	78459	26153	1.65	0.18
Site	1	209271	209271	13.2	<.001
Treatment.Variety	24	276547	11523	0.73	0.815
Contrast 1.Variety	3	141062	47021	2.97	0.034
Contrast 2.Variety	3	23729	7910	0.5	0.683
Contrast 3.Variety	3	62387	20796	1.32	0.272
Contrast 4.Variety	3	29194	9731	0.62	0.606
Contrast 5.Variety	3	50343	16781	1.06	0.367
Contrast 6.Variety	3	64887	21629	1.37	0.255
Treatment.Site	8	552905	69113	4.37	<.001
Contrast 1.Site	1	122797	122797	7.77	0.006
Contrast 2.Site	1	214096	214096	13.5	<.001
Contrast 3.Site	1	6620	6620	0.42	0.519
Contrast 4.Site	1	124065	124065	7.85	0.006
Contrast 5.Site	1	303588	303588	19.2	<.001
Contrast 6.Site	1	10523	10523	0.67	0.416
Variety.Site	3	424803	141601	8.96	<.001
Treatment.Variety.Site	24	319524	13314	0.84	0.678
Contrast 1.Variety.Site	3	10068	3356	0.21	0.888
Contrast 2.Variety.Site	3	7107	2369	0.15	0.93
Contrast 3.Variety.Site	3	16562	5521	0.35	0.79
Contrast 4.Variety.Site	3	62477	20826	1.32	0.271
Contrast 5.Variety.Site	3	44036	14679	0.93	0.429
Residual	144	2276272	15807		
Total	215	4468967			

Number of leaves week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2346658	293332	2.13	0.04
Contrast 1	1	131572	131572	0.96	0.33
Contrast 2	1	33247	33247	0.24	0.62
Contrast 3	1	187776	187776	1.36	0.25
Contrast 4	1	5660	5660	0.04	0.84
Contrast 5	1	144956	144956	1.05	0.31
Contrast 6	1	943253	943253	6.85	0.01
Variety	3	2403358	801119	5.82	<.001
Site	1	5803976	5803976	42.2	<.001
Treatment.Variety	24	2293986	95583	0.69	0.85
Contrast 1.Variety	3	714726	238242	1.73	0.16
Contrast 2.Variety	3	15206	5069	0.04	0.99
Contrast 3.Variety	3	331681	110560	0.8	0.49
Contrast 4.Variety	3	270169	90056	0.65	0.58
Contrast 5.Variety	3	230196	76732	0.56	0.64
Contrast 6.Variety	3	388005	129335	0.94	0.42
Treatment.Site	8	3783673	472959	3.44	0
Contrast 1.Site	1	849200	849200	6.17	0.01
Contrast 2.Site	1	841568	841568	6.11	0.02
Contrast 3.Site	1	322319	322319	2.34	0.13
Contrast 4.Site	1	1016180	1016180	7.38	0.01
Contrast 5.Site	1	3004240	3004240	21.8	<.001
Contrast 6.Site	1	136961	136961	1	0.32
Variety.Site	3	2748993	916331	6.66	<.001
Treatment.Variety.Site	24	1338660	55778	0.41	0.99
Contrast 1.Variety.Site	3	248518	82839	0.6	0.62
Contrast 2.Variety.Site	3	66791	22264	0.16	0.92
Contrast 3.Variety.Site	3	27319	9106	0.07	0.98
Contrast 4.Variety.Site	3	167976	55992	0.41	0.75
Contrast 5.Variety.Site	3	35297	11766	0.09	0.97
Residual	144	19820944	137645		
Total	215	40540249			

Number of leaves week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2361427	295178	1.31	0.245
Contrast 1	1	243249	243249	1.08	0.301
Contrast 2	1	120040	120040	0.53	0.467
Contrast 3	1	420220	420220	1.86	0.175
Contrast 4	1	25255	25255	0.11	0.739
Contrast 5	1	21202	21202	0.09	0.76
Contrast 6	1	1169682	1169682	5.17	0.024
Variety	3	5488588	1829529	8.09	<.001
Site	1	21529031	21529031	95.2	<.001
Treatment.Variety	24	4112636	171360	0.76	0.783
Contrast 1.Variety	3	1413087	471029	2.08	0.105
Contrast 2.Variety	3	697918	232639	1.03	0.382
Contrast 3.Variety	3	505076	168359	0.74	0.527
Contrast 4.Variety	3	231281	77094	0.34	0.796
Contrast 5.Variety	3	775274	258425	1.14	0.334
Contrast 6.Variety	3	651595	217198	0.96	0.413
Treatment.Site	8	3362331	420291	1.86	0.071
Contrast 1.Site	1	1691910	1691910	7.48	0.007
Contrast 2.Site	1	901334	901334	3.99	0.048
Contrast 3.Site	1	880674	880674	3.9	0.05
Contrast 4.Site	1	1197988	1197988	5.3	0.023
Contrast 5.Site	1	2363627	2363627	10.5	0.002
Contrast 6.Site	1	327215	327215	1.45	0.231
Variety.Site	3	6776589	2258863	9.99	<.001
Treatment.Variety.Site	24	2899557	120815	0.53	0.963
Contrast 1.Variety.Site	3	667233	222411	0.98	0.402
Contrast 2.Variety.Site	3	91413	30471	0.13	0.939
Contrast 3.Variety.Site	3	148272	49424	0.22	0.883
Contrast 4.Variety.Site	3	357264	119088	0.53	0.665
Contrast 5.Variety.Site	3	220005	73335	0.32	0.808
Residual	144	32555108	226077		
Total	215	79085267			

Number of leaves week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8631049	1078881	1.99	0.05
Contrast 1	1	1120267	1120267	2.07	0.15
Contrast 2	1	381940	381940	0.71	0.4
Contrast 3	1	1294063	1294063	2.39	0.12
Contrast 4	1	1557	1557	0	0.96
Contrast 5	1	452	452	0	0.98
Contrast 6	1	4347127	4347127	8.03	0.01
Variety	3	13517195	4505732	8.33	<.001
Site	1	41725699	41725699	77.1	<.001
Treatment.Variety	24	11125563	463565	0.86	0.66
Contrast 1.Variety	3	4050624	1350208	2.49	0.06
Contrast 2.Variety	3	181543	60514	0.11	0.95
Contrast 3.Variety	3	1237124	412375	0.76	0.52
Contrast 4.Variety	3	1249281	416427	0.77	0.51
Contrast 5.Variety	3	4192663	1397554	2.58	0.06
Contrast 6.Variety	3	2765291	921764	1.7	0.17
Treatment.Site	8	7978148	997268	1.84	0.07
Contrast 1.Site	1	4236832	4236832	7.83	0.01
Contrast 2.Site	1	2344677	2344677	4.33	0.04
Contrast 3.Site	1	1211986	1211986	2.24	0.14
Contrast 4.Site	1	2254419	2254419	4.17	0.04
Contrast 5.Site	1	6542786	6542786	12.1	<.001
Contrast 6.Site	1	1612432	1612432	2.98	0.09
Variety.Site	3	10758082	3586027	6.63	<.001
Treatment.Variety.Site	24	7146265	297761	0.55	0.96
Contrast 1.Variety.Site	3	1235870	411957	0.76	0.52
Contrast 2.Variety.Site	3	387670	129223	0.24	0.87
Contrast 3.Variety.Site	3	598694	199565	0.37	0.78
Contrast 4.Variety.Site	3	2089525	696508	1.29	0.28
Contrast 5.Variety.Site	3	980119	326706	0.6	0.61
Residual	144	77928671	541171		
Total	215	178810673			

Appendix 6: Contrasting combined bio-stimulators versus biofix and SWE (Set 4)

Contrasts	Bio-stimulator	SWE foliar	Biofix	SWE basal application+ SWE foliar
1	Humates	-1	0	0
2	Humates+SWE basal application	0	0	-1
3	Humates +SWE foliar	0	-1	0
4	SWE basal application+SWE foliar	0	-1	0
5	Humates+SWE basal application+SWE foliar	0	-1	0
6	SWE basal application	0	-1	0

Rate of emergence %					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	10275.9	1284.5	3.71	<.001
Contrast 1	1	40.6	40.6	0.12	0.732
Contrast 2	1	833.3	833.3	2.41	0.123
Contrast 3	1	533.3	533.3	1.54	0.216
Contrast 4	1	7129.6	7129.6	20.61	<.001
Contrast 5	1	2890.7	2890.7	8.36	0.004
Contrast 6	1	4618.4	4618.4	13.35	<.001
Variety	3	5133.7	1711.2	4.95	0.003
Site	1	52812.5	52812.5	152.68	<.001
Treatment.Variety	24	6929	288.7	0.83	0.688
Contrast 1.Variety	3	1667.6	555.9	1.61	0.19
Contrast 2.Variety	3	1748.7	582.9	1.69	0.173
Contrast 3.Variety	3	240.4	80.1	0.23	0.874
Contrast 4.Variety	3	217.3	72.4	0.21	0.89
Contrast 5.Variety	3	443.2	147.7	0.43	0.734
Contrast 6.Variety	3	362.2	120.7	0.35	0.79
Treatment.Site	8	21772.2	2721.5	7.87	<.001
Contrast 1.Site	1	423	423	1.22	0.271
Contrast 2.Site	1	2826.4	2826.4	8.17	0.005
Contrast 3.Site	1	308.4	308.4	0.89	0.347
Contrast 4.Site	1	13167.1	13167.1	38.06	<.001
Contrast 5.Site	1	5723.9	5723.9	16.55	<.001
Contrast 6.Site	1	5472	5472	15.82	<.001
Variety.Site	3	6859.2	2286.4	6.61	<.001
Treatment.Variety.Site	24	7049.8	293.7	0.85	0.669
Contrast 1.Variety.Site	3	602.4	200.8	0.58	0.629
Contrast 2.Variety.Site	3	829.9	276.6	0.8	0.496
Contrast 3.Variety.Site	3	492.7	164.2	0.47	0.7
Contrast 4.Variety.Site	3	668.2	222.7	0.64	0.588
Contrast 5.Variety.Site	3	443.1	147.7	0.43	0.734
Residual	144	49811.6	345.9		
Total	215	160644			

Days to germination					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	934.33	116.8	13	<.001
Contrast 1	1	1.021	1.021	0.1	0.741
Contrast 2	1	0.333	0.333	0	0.85
Contrast 3	1	35.021	35.02	3.8	0.054
Contrast 4	1	357.52	357.5	39	<.001
Contrast 5	1	352.08	352.1	38	<.001
Contrast 6	1	368.52	368.5	40	<.001
Variety	3	75.495	25.17	2.7	0.047
Site	1	453.56	453.6	49	<.001
Treatment.Variety	24	132.63	5.526	0.6	0.931
Contrast 1.Variety	3	1.896	0.632	0.1	0.977
Contrast 2.Variety	3	0.167	0.056	0	0.999
Contrast 3.Variety	3	39.062	13.02	1.4	0.245
Contrast 4.Variety	3	72.062	24.02	2.6	0.055
Contrast 5.Variety	3	55.75	18.58	2	0.117
Contrast 6.Variety	3	56.062	18.69	2	0.115
Treatment.Site	8	278.15	34.77	3.7	<.001
Contrast 1.Site	1	1.688	1.688	0.2	0.671
Contrast 2.Site	1	0	0	0	1
Contrast 3.Site	1	50.021	50.02	5.4	0.022
Contrast 4.Site	1	0.187	0.187	0	0.887
Contrast 5.Site	1	0.75	0.75	0.1	0.777
Contrast 6.Site	1	0.187	0.187	0	0.887
Variety.Site	3	38.199	12.73	1.4	0.254
Treatment.Variety.Site	24	191.26	7.969	0.9	0.657
Contrast 1.Variety.Site	3	1.229	0.41	0	0.988
Contrast 2.Variety.Site	3	2.167	0.722	0.1	0.972
Contrast 3.Variety.Site	3	40.063	13.35	1.4	0.234
Contrast 4.Variety.Site	3	78.729	26.24	2.8	0.041
Contrast 5.Variety.Site	3	97.75	32.58	3.5	0.017
Residual	144	1337.3	9.287		
Total	215	3441			

Survival rate					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	13915	1739.3	3.2	0.002
Contrast 1	1	42.2	42.2	0.1	0.781
Contrast 2	1	1200	1200	2.2	0.139
Contrast 3	1	1160.3	1160.3	2.1	0.146
Contrast 4	1	10208	10208.3	19	<.001
Contrast 5	1	3536.3	3536.3	6.5	0.012
Contrast 6	1	7375.5	7375.5	14	<.001
Variety	3	6926.1	2308.7	4.3	0.007
Site	1	69948	69948	129	<.001
Treatment.Variety	24	10315	429.8	0.8	0.742
Contrast 1.Variety	3	2709.7	903.2	1.7	0.177
Contrast 2.Variety	3	2541.2	847.1	1.6	0.202
Contrast 3.Variety	3	790.8	263.6	0.5	0.693
Contrast 4.Variety	3	210.5	70.2	0.1	0.943
Contrast 5.Variety	3	480.2	160.1	0.3	0.829
Contrast 6.Variety	3	678.9	226.3	0.4	0.741
Treatment.Site	8	33478	4184.7	7.7	<.001
Contrast 1.Site	1	825	825	1.5	0.22
Contrast 2.Site	1	4720.3	4720.3	8.7	0.004
Contrast 3.Site	1	168.8	168.8	0.3	0.578
Contrast 4.Site	1	18802	18802.1	35	<.001
Contrast 5.Site	1	8427	8427	16	<.001
Contrast 6.Site	1	6603.5	6603.5	12	<.001
Variety.Site	3	12510	4170	7.7	<.001
Treatment.Variety.Site	24	9857.9	410.7	0.8	0.784
Contrast 1.Variety.Site	3	740.2	246.7	0.5	0.714
Contrast 2.Variety.Site	3	849.2	283.1	0.5	0.668
Contrast 3.Variety.Site	3	329.4	109.8	0.2	0.895
Contrast 4.Variety.Site	3	918.8	306.2	0.6	0.639
Contrast 5.Variety.Site	3	769.5	256.5	0.5	0.702
Residual	144	78163	542.8		
Total	215	235113			

Chlorophyll					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1119.63	139.95	1.44	0.186
Contrast 1	1	55.39	55.39	0.57	0.452
Contrast 2	1	80.95	80.95	0.83	0.364
Contrast 3	1	118.55	118.55	1.22	0.272
Contrast 4	1	391.02	391.02	4.01	0.047
Contrast 5	1	219.38	219.38	2.25	0.136
Contrast 6	1	445.24	445.24	4.57	0.034
Variety	3	528.56	176.19	1.81	0.148
Site	1	1653.66	1653.7	17	<.001
Treatment.Variety	24	5683.77	236.82	2.43	<.001
Contrast 1.Variety	3	2083.83	694.61	7.13	<.001
Contrast 2.Variety	3	296.72	98.91	1.01	0.388
Contrast 3.Variety	3	1231.19	410.4	4.21	0.007
Contrast 4.Variety	3	850.85	283.62	2.91	0.037
Contrast 5.Variety	3	560.16	186.72	1.92	0.13
Contrast 6.Variety	3	751.69	250.56	2.57	0.057
Treatment.Site	8	958.6	119.82	1.23	0.286
Contrast 1.Site	1	79.47	79.47	0.82	0.368
Contrast 2.Site	1	1.56	1.56	0.02	0.899
Contrast 3.Site	1	1.28	1.28	0.01	0.909
Contrast 4.Site	1	229.69	229.69	2.36	0.127
Contrast 5.Site	1	191.27	191.27	1.96	0.163
Contrast 6.Site	1	245.66	245.66	2.52	0.115
Variety.Site	3	574.55	191.52	1.97	0.122
Treatment.Variety.Site	24	4926.85	205.29	2.11	0.004
Contrast 1.Variety.Site	3	1487.98	495.99	5.09	0.002
Contrast 2.Variety.Site	3	277.7	92.57	0.95	0.418
Contrast 3.Variety.Site	3	1187.13	395.71	4.06	0.008
Contrast 4.Variety.Site	3	654.15	218.05	2.24	0.086
Contrast 5.Variety.Site	3	457.08	152.36	1.56	0.201
Residual	144	14033.1	97.45		
Total	215	29478.7			

Leaf area cm^2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	7797	974.6	2.5	0.014
Contrast 1	1	606.6	606.6	1.56	0.214
Contrast 2	1	996	996	2.56	0.112
Contrast 3	1	3687	3687	9.48	0.002
Contrast 4	1	1373	1373	3.53	0.062
Contrast 5	1	989.2	989.2	2.54	0.113
Contrast 6	1	603.4	603.4	1.55	0.215
Variety	3	9108	3036	7.8	<.001
Site	1	1193	1193	3.07	0.082
Treatment.Variety	24	6481	270	0.69	0.851
Contrast 1.Variety	3	2049	683	1.76	0.158
Contrast 2.Variety	3	2421	807	2.07	0.106
Contrast 3.Variety	3	991.1	330.4	0.85	0.469
Contrast 4.Variety	3	1259	419.5	1.08	0.36
Contrast 5.Variety	3	416.9	139	0.36	0.784
Contrast 6.Variety	3	551.4	183.8	0.47	0.702
Treatment.Site	8	1096	136.9	0.35	0.944
Contrast 1.Site	1	69.8	69.8	0.18	0.672
Contrast 2.Site	1	591.2	591.2	1.52	0.22
Contrast 3.Site	1	15.2	15.2	0.04	0.844
Contrast 4.Site	1	584.8	584.8	1.5	0.222
Contrast 5.Site	1	15	15	0.04	0.844
Contrast 6.Site	1	74.4	74.4	0.19	0.663
Variety.Site	3	294.7	98.2	0.25	0.859
Treatment.Variety.Site	24	2937	122.4	0.31	0.999
Contrast 1.Variety.Site	3	275.7	91.9	0.24	0.871
Contrast 2.Variety.Site	3	1171	390.4	1	0.393
Contrast 3.Variety.Site	3	223.5	74.5	0.19	0.902
Contrast 4.Variety.Site	3	362.8	120.9	0.31	0.818
Contrast 5.Variety.Site	3	212.6	70.9	0.18	0.908
Residual	144	56024	389.1		
Total	215	84929			

Leaf_weight_g					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	7.046	0.88	1.09	0.38
Contrast 1	1	1.909	1.91	2.35	0.13
Contrast 2	1	0.088	0.09	0.11	0.74
Contrast 3	1	1.659	1.66	2.05	0.16
Contrast 4	1	1.431	1.43	1.77	0.19
Contrast 5	1	0.45	0.45	0.55	0.46
Contrast 6	1	0.781	0.78	0.96	0.33
Variety	3	3.878	1.29	1.59	0.19
Site	1	20.11	20.1	24.8	<.001
Treatment.Variety	24	14.76	0.62	0.76	0.78
Contrast 1.Variety	3	2.083	0.69	0.86	0.47
Contrast 2.Variety	3	4.272	1.42	1.76	0.16
Contrast 3.Variety	3	0.605	0.2	0.25	0.86
Contrast 4.Variety	3	2.036	0.68	0.84	0.48
Contrast 5.Variety	3	1.209	0.4	0.5	0.69
Contrast 6.Variety	3	1.315	0.44	0.54	0.66
Treatment.Site	8	5.461	0.68	0.84	0.57
Contrast 1.Site	1	0.036	0.04	0.04	0.83
Contrast 2.Site	1	0.021	0.02	0.03	0.87
Contrast 3.Site	1	1.08	1.08	1.33	0.25
Contrast 4.Site	1	0.378	0.38	0.47	0.5
Contrast 5.Site	1	0.03	0.03	0.04	0.85
Contrast 6.Site	1	0.165	0.16	0.2	0.65
Variety.Site	3	3.773	1.26	1.55	0.2
Treatment.Variety.Site	24	17.09	0.71	0.88	0.63
Contrast 1.Variety.Site	3	4.562	1.52	1.88	0.14
Contrast 2.Variety.Site	3	2.213	0.74	0.91	0.44
Contrast 3.Variety.Site	3	3.83	1.28	1.57	0.2
Contrast 4.Variety.Site	3	0.358	0.12	0.15	0.93
Contrast 5.Variety.Site	3	0.738	0.25	0.3	0.82
Residual	144	116.8	0.81		
Total	215	188.9			

Plant height cm week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1.16	0.15	0.91	0.509
Contrast 1	1	0.05	0.05	0.3	0.583
Contrast 2	1	0.1	0.1	0.6	0.442
Contrast 3	1	0.12	0.12	0.73	0.394
Contrast 4	1	0.56	0.56	3.49	0.064
Contrast 5	1	0.57	0.57	3.58	0.06
Contrast 6	1	0.68	0.68	4.25	0.041
Variety	3	0.4	0.13	0.85	0.471
Site	1	3.28	3.28	20.6	<.001
Treatment.Variety	24	3.85	0.16	1.01	0.462
Contrast 1.Variety	3	0.48	0.16	1.01	0.39
Contrast 2.Variety	3	0.53	0.18	1.1	0.351
Contrast 3.Variety	3	0.42	0.14	0.88	0.452
Contrast 4.Variety	3	0.59	0.2	1.23	0.301
Contrast 5.Variety	3	0.52	0.17	1.09	0.356
Contrast 6.Variety	3	0.58	0.19	1.22	0.305
Treatment.Site	8	1.16	0.15	0.91	0.508
Contrast 1.Site	1	0.11	0.11	0.67	0.414
Contrast 2.Site	1	0.08	0.08	0.5	0.481
Contrast 3.Site	1	0.1	0.1	0.6	0.439
Contrast 4.Site	1	0.51	0.51	3.2	0.076
Contrast 5.Site	1	0.52	0.52	3.27	0.072
Contrast 6.Site	1	0.63	0.63	3.92	0.05
Variety.Site	3	0.39	0.13	0.82	0.485
Treatment.Variety.Site	24	3.62	0.15	0.95	0.539
Contrast 1.Variety.Site	3	0.35	0.12	0.73	0.537
Contrast 2.Variety.Site	3	0.47	0.16	0.99	0.401
Contrast 3.Variety.Site	3	0.46	0.15	0.97	0.408
Contrast 4.Variety.Site	3	0.5	0.17	1.06	0.37
Contrast 5.Variety.Site	3	0.45	0.15	0.93	0.426
Residual	144	23	0.16		
Total	215	36.8			

Plant height cm week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	20	2.529	2.28	0.025
Contrast 1	1	0.1	0.141	0.13	0.722
Contrast 2	1	1.2	1.201	1.08	0.3
Contrast 3	1	7.3	7.337	6.61	0.011
Contrast 4	1	11	10.693	9.63	0.002
Contrast 5	1	9	9.015	8.12	0.005
Contrast 6	1	12	11.801	10.6	0.001
Variety	3	1.4	0.453	0.41	0.748
Site	1	16	15.789	14.2	<.001
Treatment.Variety	24	30	1.241	1.12	0.332
Contrast 1.Variety	3	4.1	1.361	1.23	0.303
Contrast 2.Variety	3	0.6	0.207	0.19	0.905
Contrast 3.Variety	3	6.8	2.255	2.03	0.112
Contrast 4.Variety	3	3.1	1.037	0.93	0.426
Contrast 5.Variety	3	4.8	1.597	1.44	0.234
Contrast 6.Variety	3	3.5	1.171	1.05	0.371
Treatment.Site	8	18	2.261	2.04	0.046
Contrast 1.Site	1	4.3	4.263	3.84	0.052
Contrast 2.Site	1	1.1	1.139	1.03	0.313
Contrast 3.Site	1	2.8	2.763	2.49	0.117
Contrast 4.Site	1	9.8	9.815	8.84	0.003
Contrast 5.Site	1	4.7	4.657	4.19	0.042
Contrast 6.Site	1	6.4	6.417	5.78	0.017
Variety.Site	3	0.9	0.302	0.27	0.846
Treatment.Variety.Site	24	26	1.073	0.97	0.514
Contrast 1.Variety.Site	3	0.8	0.252	0.23	0.877
Contrast 2.Variety.Site	3	3.1	1.041	0.94	0.424
Contrast 3.Variety.Site	3	4.7	1.566	1.41	0.242
Contrast 4.Variety.Site	3	4.2	1.397	1.26	0.291
Contrast 5.Variety.Site	3	2.5	0.848	0.76	0.516
Residual	144	160	1.11		
Total	215	272			

Plant height cm week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	32.6	4.07	1.34	0.23
Contrast 1	1	5.2	5.203	1.72	0.19
Contrast 2	1	4.39	4.387	1.45	0.23
Contrast 3	1	8.06	8.061	2.66	0.11
Contrast 4	1	21.6	21.62	7.14	0.01
Contrast 5	1	7.03	7.025	2.32	0.13
Contrast 6	1	14.4	14.39	4.75	0.03
Variety	3	8.09	2.697	0.89	0.45
Site	1	127	126.9	41.92	<.001
Treatment.Variety	24	70.8	2.948	0.97	0.5
Contrast 1.Variety	3	22.4	7.451	2.46	0.07
Contrast 2.Variety	3	5.98	1.995	0.66	0.58
Contrast 3.Variety	3	1.23	0.41	0.14	0.94
Contrast 4.Variety	3	9.57	3.189	1.05	0.37
Contrast 5.Variety	3	14.2	4.735	1.56	0.2
Contrast 6.Variety	3	7.98	2.66	0.88	0.45
Treatment.Site	8	30.9	3.857	1.27	0.26
Contrast 1.Site	1	22.3	22.26	7.35	0.01
Contrast 2.Site	1	2.21	2.208	0.73	0.39
Contrast 3.Site	1	0	0.003	0	0.98
Contrast 4.Site	1	4.21	4.211	1.39	0.24
Contrast 5.Site	1	0.63	0.626	0.21	0.65
Contrast 6.Site	1	0.33	0.333	0.11	0.74
Variety.Site	3	31.6	10.54	3.48	0.02
Treatment.Variety.Site	24	67.1	2.796	0.92	0.57
Contrast 1.Variety.Site	3	1.06	0.355	0.12	0.95
Contrast 2.Variety.Site	3	19.8	6.587	2.18	0.09
Contrast 3.Variety.Site	3	11.2	3.723	1.23	0.3
Contrast 4.Variety.Site	3	19.7	6.568	2.17	0.09
Contrast 5.Variety.Site	3	9.73	3.242	1.07	0.36
Residual	144	436	3.027		
Total	215	804			

Plant height cm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	128	16.01	2.93	0.01
Contrast 1	1	12.3	12.33	2.25	0.14
Contrast 2	1	18.9	18.86	3.45	0.07
Contrast 3	1	43.8	43.76	8	0.01
Contrast 4	1	70.8	70.75	12.9	<.001
Contrast 5	1	42.9	42.91	7.85	0.01
Contrast 6	1	61.9	61.85	11.3	<.001
Variety	3	18.4	6.131	1.12	0.34
Site	1	543	542.6	99.3	<.001
Treatment.Variety	24	137	5.724	1.05	0.41
Contrast 1.Variety	3	44.3	14.77	2.7	0.05
Contrast 2.Variety	3	14.3	4.779	0.87	0.46
Contrast 3.Variety	3	14.1	4.716	0.86	0.46
Contrast 4.Variety	3	16.3	5.434	0.99	0.4
Contrast 5.Variety	3	27.4	9.122	1.67	0.18
Contrast 6.Variety	3	28.6	9.519	1.74	0.16
Treatment.Site	8	59.2	7.399	1.35	0.22
Contrast 1.Site	1	15.6	15.6	2.85	0.09
Contrast 2.Site	1	5.2	5.203	0.95	0.33
Contrast 3.Site	1	0.78	0.779	0.14	0.71
Contrast 4.Site	1	29.9	29.86	5.46	0.02
Contrast 5.Site	1	14.7	14.71	2.69	0.1
Contrast 6.Site	1	15	15.04	2.75	0.1
Variety.Site	3	26.5	8.846	1.62	0.19
Treatment.Variety.Site	24	78.1	3.255	0.6	0.93
Contrast 1.Variety.Site	3	4.94	1.646	0.3	0.83
Contrast 2.Variety.Site	3	20.3	6.783	1.24	0.3
Contrast 3.Variety.Site	3	15.7	5.244	0.96	0.41
Contrast 4.Variety.Site	3	4.72	1.573	0.29	0.83
Contrast 5.Variety.Site	3	9.34	3.112	0.57	0.64
Residual	144	787	5.467		
Total	215	1778			

Plant height cm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	134	16.8	2.41	0.02
Contrast 1	1	12.6	12.64	1.82	0.18
Contrast 2	1	4.33	4.332	0.62	0.43
Contrast 3	1	87.7	87.72	12.6	<.001
Contrast 4	1	51.1	51.08	7.34	0.01
Contrast 5	1	13	13	1.87	0.17
Contrast 6	1	18.6	18.62	2.68	0.1
Variety	3	33.8	11.25	1.62	0.19
Site	1	572	571.9	82.2	<.001
Treatment.Variety	24	146	6.099	0.88	0.63
Contrast 1.Variety	3	33.6	11.21	1.61	0.19
Contrast 2.Variety	3	2.87	0.956	0.14	0.94
Contrast 3.Variety	3	38.4	12.78	1.84	0.14
Contrast 4.Variety	3	2.12	0.706	0.1	0.96
Contrast 5.Variety	3	34.8	11.59	1.67	0.18
Contrast 6.Variety	3	11.2	3.742	0.54	0.66
Treatment.Site	8	20.9	2.612	0.38	0.93
Contrast 1.Site	1	5.44	5.442	0.78	0.38
Contrast 2.Site	1	3.23	3.234	0.46	0.5
Contrast 3.Site	1	5.07	5.065	0.73	0.4
Contrast 4.Site	1	6.24	6.238	0.9	0.35
Contrast 5.Site	1	6.53	6.526	0.94	0.34
Contrast 6.Site	1	2.75	2.745	0.39	0.53
Variety.Site	3	6.99	2.331	0.33	0.8
Treatment.Variety.Site	24	107	4.463	0.64	0.9
Contrast 1.Variety.Site	3	5.46	1.818	0.26	0.85
Contrast 2.Variety.Site	3	25.4	8.459	1.22	0.31
Contrast 3.Variety.Site	3	9.96	3.32	0.48	0.7
Contrast 4.Variety.Site	3	7.58	2.528	0.36	0.78
Contrast 5.Variety.Site	3	23.4	7.805	1.12	0.34
Residual	144	1002	6.961		
Total	215	2024			

Plant height cm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	34.4	4.3	0.47	0.874
Contrast 1	1	8.55	8.55	0.94	0.334
Contrast 2	1	0.03	0.03	0	0.953
Contrast 3	1	19.6	19.6	2.16	0.144
Contrast 4	1	7.11	7.11	0.78	0.378
Contrast 5	1	5.93	5.93	0.65	0.421
Contrast 6	1	13	13	1.42	0.235
Variety	3	35.3	11.8	1.29	0.28
Site	1	613	613	67.24	<.001
Treatment.Variety	24	130	5.4	0.59	0.933
Contrast 1.Variety	3	52.2	17.4	1.91	0.131
Contrast 2.Variety	3	2.46	0.82	0.09	0.965
Contrast 3.Variety	3	6.71	2.24	0.25	0.864
Contrast 4.Variety	3	9.53	3.18	0.35	0.79
Contrast 5.Variety	3	0.66	0.22	0.02	0.995
Contrast 6.Variety	3	8.46	2.82	0.31	0.819
Treatment.Site	8	46.2	5.78	0.63	0.748
Contrast 1.Site	1	8.92	8.92	0.98	0.324
Contrast 2.Site	1	0.34	0.34	0.04	0.847
Contrast 3.Site	1	0.39	0.39	0.04	0.836
Contrast 4.Site	1	0.03	0.03	0	0.955
Contrast 5.Site	1	1.92	1.92	0.21	0.647
Contrast 6.Site	1	2.14	2.14	0.23	0.629
Variety.Site	3	24.4	8.14	0.89	0.446
Treatment.Variety.Site	24	206	8.59	0.94	0.545
Contrast 1.Variety.Site	3	12.4	4.13	0.45	0.715
Contrast 2.Variety.Site	3	43.5	14.5	1.59	0.194
Contrast 3.Variety.Site	3	7.21	2.4	0.26	0.851
Contrast 4.Variety.Site	3	37	12.3	1.35	0.259
Contrast 5.Variety.Site	3	38.9	13	1.42	0.238
Residual	144	1312	9.11		
Total	215	2400			

Plant height cm week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	153	19.1	1.19	0.31
Contrast 1	1	3.6	3.6	0.22	0.64
Contrast 2	1	32.4	32.4	2.01	0.16
Contrast 3	1	36.8	36.8	2.29	0.13
Contrast 4	1	72.8	72.8	4.52	0.04
Contrast 5	1	37.1	37.1	2.3	0.13
Contrast 6	1	67.2	67.2	4.17	0.04
Variety	3	112	37.2	2.31	0.08
Site	1	1289	1289	80.1	<.001
Treatment.Variety	24	480	20	1.24	0.22
Contrast 1.Variety	3	175	58.2	3.62	0.02
Contrast 2.Variety	3	22.1	7.37	0.46	0.71
Contrast 3.Variety	3	29.1	9.68	0.6	0.62
Contrast 4.Variety	3	60.5	20.2	1.25	0.29
Contrast 5.Variety	3	132	43.9	2.73	0.05
Contrast 6.Variety	3	42	14	0.87	0.46
Treatment.Site	8	91.7	11.5	0.71	0.68
Contrast 1.Site	1	51.9	51.9	3.23	0.08
Contrast 2.Site	1	0.6	0.6	0.04	0.85
Contrast 3.Site	1	0.11	0.11	0.01	0.93
Contrast 4.Site	1	4.47	4.47	0.28	0.6
Contrast 5.Site	1	0.46	0.46	0.03	0.87
Contrast 6.Site	1	0.07	0.07	0	0.95
Variety.Site	3	39.9	13.3	0.83	0.48
Treatment.Variety.Site	24	176	7.32	0.45	0.99
Contrast 1.Variety.Site	3	4.48	1.49	0.09	0.96
Contrast 2.Variety.Site	3	65.3	21.8	1.35	0.26
Contrast 3.Variety.Site	3	2.03	0.68	0.04	0.99
Contrast 4.Variety.Site	3	12.5	4.15	0.26	0.86
Contrast 5.Variety.Site	3	8.66	2.89	0.18	0.91
Residual	144	2318	16.1		
Total	215	4659			

Stem thickness week 1					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.18	0.02	0.75	0.65
Contrast 1	1	0.01	0.01	0.36	0.55
Contrast 2	1	0.04	0.04	1.28	0.26
Contrast 3	1	0.01	0.01	0.21	0.65
Contrast 4	1	0.06	0.06	2.02	0.16
Contrast 5	1	0.08	0.08	2.66	0.11
Contrast 6	1	0.06	0.06	2.02	0.16
Variety	3	0.13	0.04	1.47	0.22
Site	1	0.81	0.81	27.2	<.001
Treatment.Variety	24	0.62	0.03	0.87	0.65
Contrast 1.Variety	3	0.07	0.02	0.75	0.52
Contrast 2.Variety	3	0.05	0.02	0.58	0.63
Contrast 3.Variety	3	0.06	0.02	0.67	0.57
Contrast 4.Variety	3	0.07	0.02	0.76	0.52
Contrast 5.Variety	3	0.08	0.03	0.89	0.45
Contrast 6.Variety	3	0.07	0.02	0.77	0.51
Treatment.Site	8	0.19	0.02	0.81	0.59
Contrast 1.Site	1	0.03	0.03	1.16	0.28
Contrast 2.Site	1	0.01	0.01	0.3	0.59
Contrast 3.Site	1	0.04	0.04	1.47	0.23
Contrast 4.Site	1	0.11	0.11	3.7	0.06
Contrast 5.Site	1	0.09	0.09	2.94	0.09
Contrast 6.Site	1	0.11	0.11	3.7	0.06
Variety.Site	3	0.06	0.02	0.72	0.54
Treatment.Variety.Site	24	0.58	0.02	0.81	0.73
Contrast 1.Variety.Site	3	0.06	0.02	0.67	0.57
Contrast 2.Variety.Site	3	0.08	0.03	0.9	0.44
Contrast 3.Variety.Site	3	0.07	0.02	0.81	0.49
Contrast 4.Variety.Site	3	0.1	0.03	1.13	0.34
Contrast 5.Variety.Site	3	0.09	0.03	0.99	0.4
Residual	144	4.28	0.03		
Total	215	6.86			

Stem thickness week 2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.3	0.04	1.18	0.32
Contrast 1	1	0	0.02	0.6	0.44
Contrast 2	1	0	0.03	0.9	0.34
Contrast 3	1	0.2	0.16	5.18	0.02
Contrast 4	1	0.2	0.17	5.69	0.02
Contrast 5	1	0.1	0.14	4.76	0.03
Contrast 6	1	0.1	0.13	4.32	0.04
Variety	3	0	0.01	0.42	0.74
Site	1	0	0.03	0.98	0.32
Treatment.Variety	24	0.5	0.02	0.63	0.91
Contrast 1.Variety	3	0	0.01	0.47	0.7
Contrast 2.Variety	3	0	0.01	0.33	0.81
Contrast 3.Variety	3	0.1	0.05	1.61	0.19
Contrast 4.Variety	3	0.1	0.03	1.03	0.38
Contrast 5.Variety	3	0.1	0.05	1.52	0.21
Contrast 6.Variety	3	0.1	0.03	0.93	0.43
Treatment.Site	8	0.2	0.03	1.01	0.43
Contrast 1.Site	1	0	0.02	0.6	0.44
Contrast 2.Site	1	0	0.03	0.9	0.34
Contrast 3.Site	1	0.1	0.12	4.1	0.05
Contrast 4.Site	1	0.1	0.14	4.56	0.03
Contrast 5.Site	1	0.1	0.12	4.06	0.05
Contrast 6.Site	1	0.1	0.1	3.34	0.07
Variety.Site	3	0	0.01	0.39	0.76
Treatment.Variety.Site	24	0.4	0.02	0.57	0.95
Contrast 1.Variety.Site	3	0	0.01	0.47	0.7
Contrast 2.Variety.Site	3	0	0.01	0.33	0.81
Contrast 3.Variety.Site	3	0.1	0.04	1.22	0.31
Contrast 4.Variety.Site	3	0.1	0.02	0.8	0.5
Contrast 5.Variety.Site	3	0.1	0.03	1.13	0.34
Residual	144	4.3	0.03		
Total	215	5.8			

Stem thickness week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	4.99	0.624	1.36	0.22
Contrast 1	1	0.01	0.009	0.02	0.89
Contrast 2	1	1.05	1.047	2.28	0.13
Contrast 3	1	1.93	1.927	4.21	0.04
Contrast 4	1	3.52	3.524	7.69	0.01
Contrast 5	1	2.22	2.22	4.84	0.03
Contrast 6	1	1.35	1.349	2.94	0.09
Variety	3	1.24	0.415	0.9	0.44
Site	1	74.6	74.63	162.9	<.001
Treatment.Variety	24	7.8	0.325	0.71	0.84
Contrast 1.Variety	3	1.94	0.647	1.41	0.24
Contrast 2.Variety	3	0.99	0.331	0.72	0.54
Contrast 3.Variety	3	0.06	0.02	0.04	0.99
Contrast 4.Variety	3	0.33	0.109	0.24	0.87
Contrast 5.Variety	3	1.56	0.521	1.14	0.34
Contrast 6.Variety	3	0.41	0.136	0.3	0.83
Treatment.Site	8	2.94	0.368	0.8	0.6
Contrast 1.Site	1	0.08	0.077	0.17	0.68
Contrast 2.Site	1	0.87	0.867	1.89	0.17
Contrast 3.Site	1	0.39	0.388	0.85	0.36
Contrast 4.Site	1	2.45	2.453	5.35	0.02
Contrast 5.Site	1	0.12	0.118	0.26	0.61
Contrast 6.Site	1	0.67	0.666	1.45	0.23
Variety.Site	3	0.9	0.3	0.65	0.58
Treatment.Variety.Site	24	6.33	0.264	0.58	0.94
Contrast 1.Variety.Site	3	0.61	0.204	0.44	0.72
Contrast 2.Variety.Site	3	0.63	0.208	0.45	0.71
Contrast 3.Variety.Site	3	0.6	0.2	0.44	0.73
Contrast 4.Variety.Site	3	1.04	0.345	0.75	0.52
Contrast 5.Variety.Site	3	0.76	0.253	0.55	0.65
Residual	144	66	0.458		
Total	215	165			

Stem thickness week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	15.7	1.964	2.94	0.004
Contrast 1	1	0.2	0.204	0.31	0.582
Contrast 2	1	0.24	0.242	0.36	0.548
Contrast 3	1	2.28	2.279	3.41	0.067
Contrast 4	1	7.61	7.608	11.4	<.001
Contrast 5	1	5.46	5.463	8.18	0.005
Contrast 6	1	9.16	9.159	13.7	<.001
Variety	3	1.27	0.423	0.63	0.594
Site	1	1.73	1.725	2.58	0.11
Treatment.Variety	24	23.9	0.995	1.49	0.079
Contrast 1.Variety	3	5.09	1.698	2.54	0.059
Contrast 2.Variety	3	1.51	0.502	0.75	0.523
Contrast 3.Variety	3	1.88	0.626	0.94	0.425
Contrast 4.Variety	3	2.28	0.76	1.14	0.336
Contrast 5.Variety	3	2.29	0.765	1.15	0.333
Contrast 6.Variety	3	1.29	0.429	0.64	0.589
Treatment.Site	8	12.9	1.615	2.42	0.018
Contrast 1.Site	1	2.56	2.563	3.84	0.052
Contrast 2.Site	1	0.02	0.022	0.03	0.857
Contrast 3.Site	1	0.06	0.058	0.09	0.769
Contrast 4.Site	1	3.71	3.709	5.55	0.02
Contrast 5.Site	1	1.25	1.246	1.87	0.174
Contrast 6.Site	1	0.76	0.761	1.14	0.288
Variety.Site	3	1.53	0.511	0.77	0.515
Treatment.Variety.Site	24	22.1	0.921	1.38	0.127
Contrast 1.Variety.Site	3	1.5	0.5	0.75	0.525
Contrast 2.Variety.Site	3	4.8	1.601	2.4	0.071
Contrast 3.Variety.Site	3	0.84	0.279	0.42	0.741
Contrast 4.Variety.Site	3	1.37	0.457	0.68	0.563
Contrast 5.Variety.Site	3	1.04	0.345	0.52	0.671
Residual	144	96.1	0.668		
Total	215	175			

Stem thickness week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.62	1.077	1.73	0.096
Contrast 1	1	0.38	0.379	0.61	0.436
Contrast 2	1	0.32	0.322	0.52	0.473
Contrast 3	1	5.8	5.804	9.34	0.003
Contrast 4	1	2.56	2.559	4.12	0.044
Contrast 5	1	4.6	4.595	7.39	0.007
Contrast 6	1	1.07	1.072	1.72	0.191
Variety	3	1.32	0.441	0.71	0.547
Site	1	0.88	0.885	1.42	0.235
Treatment.Variety	24	15.7	0.653	1.05	0.409
Contrast 1.Variety	3	1.46	0.488	0.78	0.504
Contrast 2.Variety	3	0.23	0.078	0.13	0.945
Contrast 3.Variety	3	5.9	1.967	3.16	0.026
Contrast 4.Variety	3	0.71	0.237	0.38	0.766
Contrast 5.Variety	3	6.74	2.247	3.61	0.015
Contrast 6.Variety	3	1.55	0.517	0.83	0.478
Treatment.Site	8	4.36	0.545	0.88	0.538
Contrast 1.Site	1	0.08	0.078	0.13	0.724
Contrast 2.Site	1	0.65	0.646	1.04	0.31
Contrast 3.Site	1	0.44	0.444	0.71	0.4
Contrast 4.Site	1	1.14	1.137	1.83	0.178
Contrast 5.Site	1	0	0	0	0.994
Contrast 6.Site	1	2.33	2.329	3.75	0.055
Variety.Site	3	1.18	0.394	0.63	0.594
Treatment.Variety.Site	24	11.6	0.485	0.78	0.756
Contrast 1.Variety.Site	3	0.82	0.272	0.44	0.727
Contrast 2.Variety.Site	3	1.69	0.564	0.91	0.439
Contrast 3.Variety.Site	3	0.89	0.298	0.48	0.697
Contrast 4.Variety.Site	3	1.21	0.403	0.65	0.585
Contrast 5.Variety.Site	3	3.45	1.149	1.85	0.141
Residual	144	89.5	0.622		
Total	215	133			

Stem thickness week 6				
Source of variation	d.f.	s.s.	m.s.	v.r.
Treatment	8	0.68	0.08	0.13
Contrast 1	1	0	0	0.01
Contrast 2	1	0.01	0.01	0.02
Contrast 3	1	0.2	0.2	0.31
Contrast 4	1	0.01	0.01	0.01
Contrast 5	1	0.06	0.06	0.09
Contrast 6	1	0.08	0.08	0.12
Variety	3	0.6	0.2	0.3
Site	1	6.03	6.03	9.19
Treatment.Variety	24	8.73	0.36	0.55
Contrast 1.Variety	3	2.47	0.82	1.25
Contrast 2.Variety	3	0.94	0.31	0.48
Contrast 3.Variety	3	0.28	0.09	0.14
Contrast 4.Variety	3	0.21	0.07	0.11
Contrast 5.Variety	3	0.85	0.28	0.43
Contrast 6.Variety	3	0.36	0.12	0.18
Treatment.Site	8	5.46	0.68	1.04
Contrast 1.Site	1	0.12	0.12	0.19
Contrast 2.Site	1	0.05	0.05	0.07
Contrast 3.Site	1	0.1	0.1	0.16
Contrast 4.Site	1	1.05	1.05	1.59
Contrast 5.Site	1	0.09	0.09	0.13
Contrast 6.Site	1	0.02	0.02	0.03
Variety.Site	3	1.96	0.65	1
Treatment.Variety.Site	24	18	0.75	1.15
Contrast 1.Variety.Site	3	4.34	1.45	2.21
Contrast 2.Variety.Site	3	3.3	1.1	1.68
Contrast 3.Variety.Site	3	0.56	0.19	0.28
Contrast 4.Variety.Site	3	2.95	0.98	1.5
Contrast 5.Variety.Site	3	0.52	0.17	0.26
Residual	144	94.5	0.66	
Total	215	136		

Stem thickness week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.2	1.02	1.26	0.27
Contrast 1	1	0.02	0.02	0.02	0.88
Contrast 2	1	0.27	0.27	0.33	0.57
Contrast 3	1	2.95	2.95	3.64	0.06
Contrast 4	1	5.82	5.82	7.18	0.01
Contrast 5	1	5.16	5.16	6.37	0.01
Contrast 6	1	5	5	6.17	0.01
Variety	3	6.28	2.09	2.58	0.06
Site	1	83	83	102.5	<.001
Treatment.Variety	24	19.9	0.83	1.02	0.44
Contrast 1.Variety	3	4.12	1.37	1.69	0.17
Contrast 2.Variety	3	0.67	0.22	0.27	0.84
Contrast 3.Variety	3	1.27	0.42	0.52	0.67
Contrast 4.Variety	3	0.77	0.26	0.32	0.81
Contrast 5.Variety	3	3.1	1.03	1.28	0.29
Contrast 6.Variety	3	2.98	0.99	1.22	0.3
Treatment.Site	8	8.03	1	1.24	0.28
Contrast 1.Site	1	4.86	4.86	6	0.02
Contrast 2.Site	1	0.39	0.39	0.48	0.49
Contrast 3.Site	1	1.09	1.09	1.34	0.25
Contrast 4.Site	1	2.06	2.06	2.55	0.11
Contrast 5.Site	1	0.9	0.9	1.11	0.29
Contrast 6.Site	1	2.45	2.45	3.02	0.08
Variety.Site	3	0.77	0.26	0.32	0.81
Treatment.Variety.Site	24	22.1	0.92	1.13	0.31
Contrast 1.Variety.Site	3	0.43	0.14	0.18	0.91
Contrast 2.Variety.Site	3	1.12	0.37	0.46	0.71
Contrast 3.Variety.Site	3	6.3	2.1	2.59	0.06
Contrast 4.Variety.Site	3	7.09	2.36	2.92	0.04
Contrast 5.Variety.Site	3	5.32	1.77	2.19	0.09
Residual	144	117	0.81		
Total	215	265			

Root length cm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	47.2	5.9	1.2	0.305
Contrast 1	1	0	0	0	0.977
Contrast 2	1	5.59	5.59	1.13	0.289
Contrast 3	1	0.79	0.79	0.16	0.69
Contrast 4	1	8.75	8.75	1.77	0.185
Contrast 5	1	8.74	8.74	1.77	0.185
Contrast 6	1	13.6	13.6	2.75	0.099
Variety	3	47	15.7	3.18	0.026
Site	1	3.59	3.59	0.73	0.395
Treatment.Variety	24	267	11.1	2.26	0.002
Contrast 1.Variety	3	90.8	30.3	6.14	<.001
Contrast 2.Variety	3	11.5	3.82	0.77	0.51
Contrast 3.Variety	3	9.72	3.24	0.66	0.58
Contrast 4.Variety	3	30.6	10.2	2.07	0.107
Contrast 5.Variety	3	40	13.3	2.71	0.048
Contrast 6.Variety	3	48.7	16.2	3.29	0.023
Treatment.Site	8	47.3	5.91	1.2	0.304
Contrast 1.Site	1	2.35	2.35	0.48	0.491
Contrast 2.Site	1	3.66	3.66	0.74	0.391
Contrast 3.Site	1	15.1	15.1	3.07	0.082
Contrast 4.Site	1	0.04	0.04	0.01	0.926
Contrast 5.Site	1	3.42	3.42	0.69	0.406
Contrast 6.Site	1	0.24	0.24	0.05	0.826
Variety.Site	3	23.3	7.78	1.58	0.197
Treatment.Variety.Site	24	158	6.6	1.34	0.15
Contrast 1.Variety.Site	3	41.1	13.7	2.78	0.043
Contrast 2.Variety.Site	3	23.2	7.74	1.57	0.2
Contrast 3.Variety.Site	3	3.05	1.02	0.21	0.892
Contrast 4.Variety.Site	3	4.8	1.6	0.32	0.808
Contrast 5.Variety.Site	3	13.5	4.48	0.91	0.438
Residual	144	710	4.93		
Total	215	1304			

Root length cm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	15.7	1.96	0.23	0.99
Contrast 1	1	0	0	0	0.99
Contrast 2	1	0.95	0.95	0.11	0.74
Contrast 3	1	1.85	1.85	0.22	0.64
Contrast 4	1	2.11	2.11	0.25	0.62
Contrast 5	1	3.45	3.45	0.4	0.53
Contrast 6	1	0	0	0	0.99
Variety	3	72.7	24.2	2.82	0.04
Site	1	1.67	1.67	0.19	0.66
Treatment.Variety	24	230	9.58	1.12	0.33
Contrast 1.Variety	3	50.2	16.7	1.95	0.13
Contrast 2.Variety	3	9.22	3.07	0.36	0.78
Contrast 3.Variety	3	9.51	3.17	0.37	0.78
Contrast 4.Variety	3	25.4	8.46	0.98	0.4
Contrast 5.Variety	3	45	15	1.75	0.16
Contrast 6.Variety	3	16.8	5.58	0.65	0.58
Treatment.Site	8	88.1	11	1.28	0.26
Contrast 1.Site	1	1.97	1.97	0.23	0.63
Contrast 2.Site	1	2.82	2.82	0.33	0.57
Contrast 3.Site	1	0.08	0.08	0.01	0.93
Contrast 4.Site	1	9.22	9.22	1.07	0.3
Contrast 5.Site	1	46.6	46.6	5.43	0.02
Contrast 6.Site	1	17.6	17.6	2.05	0.15
Variety.Site	3	2.36	0.79	0.09	0.96
Treatment.Variety.Site	24	182	7.57	0.88	0.63
Contrast 1.Variety.Site	3	28.5	9.51	1.11	0.35
Contrast 2.Variety.Site	3	23.1	7.7	0.9	0.44
Contrast 3.Variety.Site	3	51.1	17	1.98	0.12
Contrast 4.Variety.Site	3	33.4	11.1	1.3	0.28
Contrast 5.Variety.Site	3	34.9	11.6	1.36	0.26
Residual	144	1236	8.59		
Total	215	1829			

Root length cm week 8						
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Treatment	8		56.7	7.09	0.58	0.796
Contrast 1	1		6.34	6.34	0.52	0.474
Contrast 2	1		8.71	8.71	0.71	0.401
Contrast 3	1		0.79	0.79	0.06	0.801
Contrast 4	1		1	1	0.08	0.776
Contrast 5	1		10.3	10.34	0.84	0.361
Contrast 6	1		18.6	18.6	1.51	0.221
Variety	3		23.6	7.86	0.64	0.591
Site	1		458	457.7	37.2	<.001
Treatment.Variety	24		301	12.54	1.02	0.445
Contrast 1.Variety	3		38.3	12.75	1.04	0.378
Contrast 2.Variety	3		26.9	8.97	0.73	0.536
Contrast 3.Variety	3		103	34.38	2.8	0.042
Contrast 4.Variety	3		15	4.99	0.41	0.749
Contrast 5.Variety	3		2.49	0.83	0.07	0.977
Contrast 6.Variety	3		22	7.32	0.6	0.619
Treatment.Site	8		111	13.84	1.13	0.349
Contrast 1.Site	1		3.4	3.4	0.28	0.6
Contrast 2.Site	1		24.1	24.12	1.96	0.163
Contrast 3.Site	1		17.1	17.11	1.39	0.24
Contrast 4.Site	1		82.1	82.12	6.68	0.011
Contrast 5.Site	1		34.7	34.72	2.82	0.095
Contrast 6.Site	1		16.3	16.27	1.32	0.252
Variety.Site	3		41.2	13.72	1.12	0.345
Treatment.Variety.Site	24		436	18.16	1.48	0.084
Contrast 1.Variety.Site	3		40.1	13.36	1.09	0.357
Contrast 2.Variety.Site	3		30.4	10.14	0.83	0.482
Contrast 3.Variety.Site	3		39.1	13.02	1.06	0.369
Contrast 4.Variety.Site	3		83.7	27.9	2.27	0.083
Contrast 5.Variety.Site	3		83.1	27.69	2.25	0.085
Residual	142	-2	1745	12.29		
Total	213	-2	3172			

No of nodules week 5						
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Treatment	8		861.6	107.7	2.59	0.012
Contrast 1	1		12	12	0.29	0.592
Contrast 2	1		113.8	113.8	2.73	0.101
Contrast 3	1		43.13	43.13	1.04	0.311
Contrast 4	1		577.6	577.6	13.9	<.001
Contrast 5	1		388.2	388.2	9.32	0.003
Contrast 6	1		273.1	273.1	6.56	0.012
Variety	3		317.2	105.7	2.54	0.059
Site	1		150.7	150.7	3.62	0.059
Treatment.Variety	24		1490	62.08	1.49	0.08
Contrast 1.Variety	3		175.8	58.61	1.41	0.243
Contrast 2.Variety	3		161.8	53.94	1.3	0.279
Contrast 3.Variety	3		128.1	42.69	1.02	0.384
Contrast 4.Variety	3		218.1	72.71	1.75	0.16
Contrast 5.Variety	3		118.2	39.39	0.95	0.42
Contrast 6.Variety	3		80.97	26.99	0.65	0.585
Treatment.Site	8		549	68.62	1.65	0.117
Contrast 1.Site	1		0.33	0.33	0.01	0.929
Contrast 2.Site	1		3.05	3.05	0.07	0.787
Contrast 3.Site	1		109.5	109.5	2.63	0.107
Contrast 4.Site	1		259	259	6.22	0.014
Contrast 5.Site	1		371.3	371.3	8.91	0.003
Contrast 6.Site	1		240.8	240.8	5.78	0.018
Variety.Site	3		222.2	74.06	1.78	0.154
Treatment.Variety.Site	24		1656	69.01	1.66	0.038
Contrast 1.Variety.Site	3		43.17	14.39	0.35	0.792
Contrast 2.Variety.Site	3		170.9	56.97	1.37	0.255
Contrast 3.Variety.Site	3		82.02	27.34	0.66	0.58
Contrast 4.Variety.Site	3		38.68	12.89	0.31	0.818
Contrast 5.Variety.Site	3		237.7	79.24	1.9	0.132
Residual	140	-4	5831	41.65		
Total	211	-4	11066			

No of nodules week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	226.6	28.3	0.89	0.53
Contrast 1	1	0.33	0.33	0.01	0.92
Contrast 2	1	6.02	6.02	0.19	0.67
Contrast 3	1	4.08	4.08	0.13	0.72
Contrast 4	1	50.02	50	1.56	0.21
Contrast 5	1	11.02	11	0.34	0.56
Contrast 6	1	130	130	4.07	0.05
Variety	3	113.4	37.8	1.18	0.32
Site	1	2347	2347	73.4	<.001
Treatment.Variety	24	621.5	25.9	0.81	0.72
Contrast 1.Variety	3	64.5	21.5	0.67	0.57
Contrast 2.Variety	3	142.7	47.6	1.49	0.22
Contrast 3.Variety	3	85.08	28.4	0.89	0.45
Contrast 4.Variety	3	162.2	54.1	1.69	0.17
Contrast 5.Variety	3	72.73	24.2	0.76	0.52
Contrast 6.Variety	3	57.73	19.2	0.6	0.62
Treatment.Site	8	176.1	22	0.69	0.7
Contrast 1.Site	1	0.75	0.75	0.02	0.88
Contrast 2.Site	1	15.19	15.2	0.47	0.49
Contrast 3.Site	1	1.33	1.33	0.04	0.84
Contrast 4.Site	1	31.69	31.7	0.99	0.32
Contrast 5.Site	1	28.52	28.5	0.89	0.35
Contrast 6.Site	1	117.2	117	3.66	0.06
Variety.Site	3	39.74	13.3	0.41	0.74
Treatment.Variety.Site	24	671.2	28	0.87	0.64
Contrast 1.Variety.Site	3	60.75	20.3	0.63	0.6
Contrast 2.Variety.Site	3	118.6	39.5	1.24	0.3
Contrast 3.Variety.Site	3	176.5	58.8	1.84	0.14
Contrast 4.Variety.Site	3	143.6	47.9	1.5	0.22
Contrast 5.Variety.Site	3	71.23	23.7	0.74	0.53
Residual	144	4605	32		
Total	215	8800			

No of nodules week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1192	149	2.4	0.019
Contrast 1	1	102.1	102	1.64	0.202
Contrast 2	1	2.08	2.08	0.03	0.855
Contrast 3	1	238.5	239	3.84	0.052
Contrast 4	1	0	0	0	1
Contrast 5	1	144.7	145	2.33	0.129
Contrast 6	1	252.1	252	4.06	0.046
Variety	3	672.9	224	3.61	0.015
Site	1	6895	6895	111	<.001
Treatment.Variety	24	952.5	39.7	0.64	0.9
Contrast 1.Variety	3	36.75	12.3	0.2	0.898
Contrast 2.Variety	3	71.42	23.8	0.38	0.765
Contrast 3.Variety	3	223.4	74.5	1.2	0.312
Contrast 4.Variety	3	223.8	74.6	1.2	0.312
Contrast 5.Variety	3	169.9	56.6	0.91	0.437
Contrast 6.Variety	3	398.8	133	2.14	0.098
Treatment.Site	8	1583	198	3.19	0.002
Contrast 1.Site	1	444.1	444	7.15	0.008
Contrast 2.Site	1	75	75	1.21	0.274
Contrast 3.Site	1	150.5	151	2.42	0.122
Contrast 4.Site	1	126.8	127	2.04	0.155
Contrast 5.Site	1	131.1	131	2.11	0.148
Contrast 6.Site	1	75	75	1.21	0.274
Variety.Site	3	500.5	167	2.69	0.049
Treatment.Variety.Site	24	1188	49.5	0.8	0.736
Contrast 1.Variety.Site	3	147.4	49.1	0.79	0.501
Contrast 2.Variety.Site	3	51.17	17.1	0.27	0.844
Contrast 3.Variety.Site	3	52.06	17.4	0.28	0.84
Contrast 4.Variety.Site	3	41.42	13.8	0.22	0.881
Contrast 5.Variety.Site	3	12.53	4.18	0.07	0.977
Residual	144	8945	62.1		
Total	215	21929			

Number of leaves week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	331185	41398	2.62	0.01
Contrast 1	1	1314	1314	0.08	0.77
Contrast 2	1	37322	37322	2.36	0.13
Contrast 3	1	50014	50014	3.16	0.08
Contrast 4	1	220561	220561	14	<.001
Contrast 5	1	107087	107087	6.77	0.01
Contrast 6	1	237699	237699	15	<.001
Variety	3	78459	26153	1.65	0.18
Site	1	209271	209271	13.2	<.001
Treatment.Variety	24	276547	11523	0.73	0.82
Contrast 1.Variety	3	77172	25724	1.63	0.19
Contrast 2.Variety	3	55287	18429	1.17	0.33
Contrast 3.Variety	3	8259	2753	0.17	0.91
Contrast 4.Variety	3	12619	4206	0.27	0.85
Contrast 5.Variety	3	19069	6356	0.4	0.75
Contrast 6.Variety	3	12948	4316	0.27	0.85
Treatment.Site	8	552905	69113	4.37	<.001
Contrast 1.Site	1	34743	34743	2.2	0.14
Contrast 2.Site	1	40226	40226	2.54	0.11
Contrast 3.Site	1	450	450	0.03	0.87
Contrast 4.Site	1	201068	201068	12.7	<.001
Contrast 5.Site	1	129688	129688	8.2	0.01
Contrast 6.Site	1	62323	62323	3.94	0.05
Variety.Site	3	424803	141601	8.96	<.001
Treatment.Variety.Site	24	319524	13314	0.84	0.68
Contrast 1.Variety.Site	3	52816	17605	1.11	0.35
Contrast 2.Variety.Site	3	87490	29163	1.84	0.14
Contrast 3.Variety.Site	3	12978	4326	0.27	0.84
Contrast 4.Variety.Site	3	39560	13187	0.83	0.48
Contrast 5.Variety.Site	3	4042	1347	0.09	0.97
Residual	144	2276272	15807		
Total	215	4468967			

Number of leaves week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1620685	202586	3.35	0.002
Contrast 1	1	46654	46654	0.77	0.381
Contrast 2	1	237156	237156	3.92	0.05
Contrast 3	1	270613	270613	4.47	0.036
Contrast 4	1	1277279	1277279	21.1	<.001
Contrast 5	1	464609	464609	7.67	0.006
Contrast 6	1	933298	933298	15.4	<.001
Variety	3	1450141	483380	7.98	<.001
Site	1	1634411	1634411	27	<.001
Treatment.Variety	24	1318345	54931	0.91	0.592
Contrast 1.Variety	3	387126	129042	2.13	0.099
Contrast 2.Variety	3	222230	74077	1.22	0.303
Contrast 3.Variety	3	94264	31421	0.52	0.67
Contrast 4.Variety	3	72651	24217	0.4	0.753
Contrast 5.Variety	3	31662	10554	0.17	0.914
Contrast 6.Variety	3	147978	49326	0.81	0.488
Treatment.Site	8	2814338	351792	5.81	<.001
Contrast 1.Site	1	96279	96279	1.59	0.209
Contrast 2.Site	1	394591	394591	6.52	0.012
Contrast 3.Site	1	8267	8267	0.14	0.712
Contrast 4.Site	1	1236601	1236601	20.4	<.001
Contrast 5.Site	1	371082	371082	6.13	0.014
Contrast 6.Site	1	468658	468658	7.74	0.006
Variety.Site	3	2124577	708192	11.7	<.001
Treatment.Variety.Site	24	857525	35730	0.59	0.934
Contrast 1.Variety.Site	3	11230	3743	0.06	0.98
Contrast 2.Variety.Site	3	188208	62736	1.04	0.379
Contrast 3.Variety.Site	3	37097	12366	0.2	0.893
Contrast 4.Variety.Site	3	22318	7439	0.12	0.946
Contrast 5.Variety.Site	3	49823	16608	0.27	0.844
Residual	144	8717928	60541		
Total	215	20537950			

Number of leaves week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2346658	293332	2.13	0.036
Contrast 1	1	137771	137771	1	0.319
Contrast 2	1	552730	552730	4.02	0.047
Contrast 3	1	289316	289316	2.1	0.149
Contrast 4	1	1827748	1827748	13.28	<.001
Contrast 5	1	622323	622323	4.52	0.035
Contrast 6	1	1095047	1095047	7.96	0.005
Variety	3	2403358	801119	5.82	<.001
Site	1	5803976	5803976	42.17	<.001
Treatment.Variety	24	2293986	95583	0.69	0.851
Contrast 1.Variety	3	265822	88607	0.64	0.588
Contrast 2.Variety	3	272568	90856	0.66	0.578
Contrast 3.Variety	3	181341	60447	0.44	0.725
Contrast 4.Variety	3	180471	60157	0.44	0.727
Contrast 5.Variety	3	357003	119001	0.86	0.461
Contrast 6.Variety	3	387414	129138	0.94	0.424
Treatment.Site	8	3783673	472959	3.44	0.001
Contrast 1.Site	1	287499	287499	2.09	0.151
Contrast 2.Site	1	658945	658945	4.79	0.03
Contrast 3.Site	1	39065	39065	0.28	0.595
Contrast 4.Site	1	1858291	1858291	13.5	<.001
Contrast 5.Site	1	299523	299523	2.18	0.142
Contrast 6.Site	1	407012	407012	2.96	0.088
Variety.Site	3	2748993	916331	6.66	<.001
Treatment.Variety.Site	24	1338660	55778	0.41	0.994
Contrast 1.Variety.Site	3	18595	6198	0.05	0.987
Contrast 2.Variety.Site	3	277679	92560	0.67	0.57
Contrast 3.Variety.Site	3	3114	1038	0.01	0.999
Contrast 4.Variety.Site	3	126410	42137	0.31	0.821
Contrast 5.Variety.Site	3	39517	13172	0.1	0.962
Residual	144	19820944	137645		
Total	215	40540249			

Number of leaves week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2361427	295178	1.31	0.25
Contrast 1	1	272051	272051	1.2	0.27
Contrast 2	1	120820	120820	0.53	0.47
Contrast 3	1	187727	187727	0.83	0.36
Contrast 4	1	875924	875924	3.87	0.05
Contrast 5	1	540300	540300	2.39	0.12
Contrast 6	1	1538684	1538684	6.81	0.01
Variety	3	5488588	1829529	8.09	<.001
Site	1	21529031	21529031	95.2	<.001
Treatment.Variety	24	4112636	171360	0.76	0.78
Contrast 1.Variety	3	1413997	471332	2.08	0.11
Contrast 2.Variety	3	778192	259397	1.15	0.33
Contrast 3.Variety	3	27167	9056	0.04	0.99
Contrast 4.Variety	3	739973	246658	1.09	0.36
Contrast 5.Variety	3	233297	77766	0.34	0.79
Contrast 6.Variety	3	590634	196878	0.87	0.46
Treatment.Site	8	3362331	420291	1.86	0.07
Contrast 1.Site	1	842591	842591	3.73	0.06
Contrast 2.Site	1	56015	56015	0.25	0.62
Contrast 3.Site	1	134260	134260	0.59	0.44
Contrast 4.Site	1	931962	931962	4.12	0.04
Contrast 5.Site	1	142399	142399	0.63	0.43
Contrast 6.Site	1	273005	273005	1.21	0.27
Variety.Site	3	6776589	2258863	9.99	<.001
Treatment.Variety.Site	24	2899557	120815	0.53	0.96
Contrast 1.Variety.Site	3	126152	42051	0.19	0.91
Contrast 2.Variety.Site	3	943398	314466	1.39	0.25
Contrast 3.Variety.Site	3	128927	42976	0.19	0.9
Contrast 4.Variety.Site	3	359165	119722	0.53	0.66
Contrast 5.Variety.Site	3	309247	103082	0.46	0.71
Residual	144	32555108	226077		
Total	215	79085267			

Number of leaves week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8631049	1078881	1.99	0.051
Contrast 1	1	806992	806992	1.49	0.224
Contrast 2	1	1165727	1165727	2.15	0.144
Contrast 3	1	897581	897581	1.66	0.2
Contrast 4	1	4436240	4436240	8.2	0.005
Contrast 5	1	2151982	2151982	3.98	0.048
Contrast 6	1	4513214	4513214	8.34	0.004
Variety	3	13517195	4505732	8.33	<.001
Site	1	41725699	41725699	77.1	<.001
Treatment.Variety	24	11125563	463565	0.86	0.659
Contrast 1.Variety	3	2898798	966266	1.79	0.153
Contrast 2.Variety	3	754170	251390	0.46	0.707
Contrast 3.Variety	3	348803	116268	0.21	0.886
Contrast 4.Variety	3	1391937	463979	0.86	0.465
Contrast 5.Variety	3	1798951	599650	1.11	0.348
Contrast 6.Variety	3	1115508	371836	0.69	0.561
Treatment.Site	8	7978148	997268	1.84	0.074
Contrast 1.Site	1	1413044	1413044	2.61	0.108
Contrast 2.Site	1	249531	249531	0.46	0.498
Contrast 3.Site	1	28532	28532	0.05	0.819
Contrast 4.Site	1	1659128	1659128	3.07	0.082
Contrast 5.Site	1	68339	68339	0.13	0.723
Contrast 6.Site	1	53665	53665	0.1	0.753
Variety.Site	3	10758082	3586027	6.63	<.001
Treatment.Variety.Site	24	7146265	297761	0.55	0.956
Contrast 1.Variety.Site	3	522411	174137	0.32	0.81
Contrast 2.Variety.Site	3	1944704	648235	1.2	0.313
Contrast 3.Variety.Site	3	69570	23190	0.04	0.988
Contrast 4.Variety.Site	3	567320	189107	0.35	0.79
Contrast 5.Variety.Site	3	288455	96152	0.18	0.911
Residual	144	77928671	541171		
Total	215	178810673			

Appendix 7: Contrasting SWE basal application versus biofix and combined bio-stimulators (Set 5) and their anova tables

Contrasts	SWE basal application	Biofix	SWE foliar	Humates +SWE basal	Humates +SWE basal+ SWE foliar	Humates + SWE foliar
1	1	-1	0	0	0	0
2	1	0	-1	0	0	0
3	1	0	0	-1	0	0
4	1	0	0	0	-1	0
5	1	0	0	0	0	-1

Rate of emergence_%					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	10276	1285	3.71	<.001
Contrast 1	1	4618.4	4618	13.4	<.001
Contrast 2	1	153.5	153.5	0.44	0.506
Contrast 3	1	1031.4	1031	2.98	0.086
Contrast 4	1	201.4	201.4	0.58	0.447
Contrast 5	1	271.5	271.5	0.78	0.377
Site	1	52813	52813	153	<.001
Variety	3	5133.7	1711	4.95	0.003
Treatment.Site	8	21772	2722	7.87	<.001
Contrast 1.Site	1	5472	5472	15.8	<.001
Contrast 2.Site	1	153.5	153.5	0.44	0.506
Contrast 3.Site	1	1742	1742	5.04	0.026
Contrast 4.Site	1	2.8	2.8	0.01	0.928
Contrast 5.Site	1	1662.6	1663	4.81	0.03
Treatment.Variety	24	6929	288.7	0.83	0.688
Contrast 1.Variety	3	362.2	120.7	0.35	0.79
Contrast 2.Variety	3	2411.5	803.8	2.32	0.077
Contrast 3.Variety	3	1176.1	392	1.13	0.338
Contrast 4.Variety	3	310	103.3	0.3	0.826
Contrast 5.Variety	3	105.7	35.2	0.1	0.959
Site.Variety	3	6859.2	2286	6.61	<.001
Treatment.Site.Variety	24	7049.8	293.7	0.85	0.669
Contrast 1.Site.Variety	3	1497	499	1.44	0.233
Contrast 2.Site.Variety	3	2103.9	701.3	2.03	0.113
Contrast 3.Site.Variety	3	2677.2	892.4	2.58	0.056
Contrast 4.Site.Variety	3	764.4	254.8	0.74	0.532
Contrast 5.Site.Variety	3	674.3	224.8	0.65	0.584
Residual	144	49812	345.9		
Total	215	160644			

Days_to_emergence					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	934.33	116.8	12.6	<.001
Contrast 1	1	368.52	368.5	39.7	<.001
Contrast 2	1	0.083	0.083	0.01	0.93
Contrast 3	1	123.52	123.5	13.3	<.001
Contrast 4	1	0.188	0.188	0.02	0.89
Contrast 5	1	0.083	0.083	0.01	0.93
Site	1	453.56	453.6	48.8	<.001
Variety	3	75.495	25.17	2.71	0.05
Treatment.Site	8	278.15	34.77	3.74	<.001
Contrast 1.Site	1	0.188	0.188	0.02	0.89
Contrast 2.Site	1	0	0	0	1
Contrast 3.Site	1	67.688	67.69	7.29	0.01
Contrast 4.Site	1	0.187	0.187	0.02	0.89
Contrast 5.Site	1	0	0	0	1
Treatment.Variety	24	132.63	5.526	0.6	0.93
Contrast 1.Variety	3	56.062	18.69	2.01	0.12
Contrast 2.Variety	3	2.75	0.917	0.1	0.96
Contrast 3.Variety	3	0.729	0.243	0.03	0.99
Contrast 4.Variety	3	1.563	0.521	0.06	0.98
Contrast 5.Variety	3	1.75	0.583	0.06	0.98
Site.Variety	3	38.199	12.73	1.37	0.25
Treatment.Site.Variety	24	191.26	7.969	0.86	0.66
Contrast 1.Site.Variety	3	93.062	31.02	3.34	0.02
Contrast 2.Site.Variety	3	4.167	1.389	0.15	0.93
Contrast 3.Site.Variety	3	0.562	0.188	0.02	1
Contrast 4.Site.Variety	3	1.562	0.521	0.06	0.98
Contrast 5.Site.Variety	3	1.833	0.611	0.07	0.98
Residual	144	1337.3	9.287		
Total	215	3441			

Survival rate					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	13915	1739.3	3.2	0.002
Contrast 1	1	7375.5	7375.5	13.6	<.001
Contrast 2	1	379.7	379.7	0.7	0.404
Contrast 3	1	1485.2	1485.2	2.74	0.1
Contrast 4	1	697.7	697.7	1.29	0.259
Contrast 5	1	229.7	229.7	0.42	0.516
Site	1	69948	69948	129	<.001
Variety	3	6926.1	2308.7	4.25	0.007
Treatment.Site	8	33478	4184.7	7.71	<.001
Contrast 1.Site	1	6603.5	6603.5	12.2	<.001
Contrast 2.Site	1	165	165	0.3	0.582
Contrast 3.Site	1	2255	2255	4.15	0.043
Contrast 4.Site	1	111	111	0.2	0.652
Contrast 5.Site	1	3120.2	3120.2	5.75	0.018
Treatment.Variety	24	10315	429.8	0.79	0.742
Contrast 1.Variety	3	678.9	226.3	0.42	0.741
Contrast 2.Variety	3	3416.2	1138.7	2.1	0.103
Contrast 3.Variety	3	1797.9	599.3	1.1	0.35
Contrast 4.Variety	3	603.2	201.1	0.37	0.774
Contrast 5.Variety	3	310.6	103.5	0.19	0.903
Site.Variety	3	12510	4170	7.68	<.001
Treatment.Site.Variety	24	9857.9	410.7	0.76	0.784
Contrast 1.Site.Variety	3	1437.6	479.2	0.88	0.452
Contrast 2.Site.Variety	3	2570.6	856.9	1.58	0.197
Contrast 3.Site.Variety	3	3687.7	1229.2	2.26	0.084
Contrast 4.Site.Variety	3	722.6	240.9	0.44	0.722
Contrast 5.Site.Variety	3	805.1	268.4	0.49	0.687
Residual	144	78163	542.8		
Total	215	235113			

Chlorophyll					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1119.63	139.95	1.44	0.186
Contrast 1	1	445.24	445.24	4.57	0.034
Contrast 2	1	106.58	106.58	1.09	0.297
Contrast 3	1	273.64	273.64	2.81	0.096
Contrast 4	1	39.56	39.56	0.41	0.525
Contrast 5	1	1.76	1.76	0.02	0.893
Site	1	1653.66	1653.7	17	<.001
Variety	3	528.56	176.19	1.81	0.148
Treatment.Site	8	958.6	119.82	1.23	0.286
Contrast 1.Site	1	245.66	245.66	2.52	0.115
Contrast 2.Site	1	0.54	0.54	0.01	0.941
Contrast 3.Site	1	110.44	110.44	1.13	0.289
Contrast 4.Site	1	3.4	3.4	0.03	0.852
Contrast 5.Site	1	0.27	0.27	0	0.958
Treatment.Variety	24	5683.77	236.82	2.43	<.001
Contrast 1.Variety	3	751.69	250.56	2.57	0.057
Contrast 2.Variety	3	214.85	71.62	0.73	0.533
Contrast 3.Variety	3	460.39	153.46	1.57	0.198
Contrast 4.Variety	3	76.2	25.4	0.26	0.854
Contrast 5.Variety	3	32.83	10.94	0.11	0.953
Site.Variety	3	574.55	191.52	1.97	0.122
Treatment.Site.Variety	24	4926.85	205.29	2.11	0.004
Contrast 1.Site.Variety	3	447.86	149.29	1.53	0.209
Contrast 2.Site.Variety	3	317.92	105.97	1.09	0.356
Contrast 3.Site.Variety	3	243.18	81.06	0.83	0.478
Contrast 4.Site.Variety	3	43.01	14.34	0.15	0.931
Contrast 5.Site.Variety	3	65.41	21.8	0.22	0.88
Residual	144	14033.1	97.45		
Total	215	29478.7			

Leaf_area_cm^2					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	7797	974.6	2.5	0.014
Contrast 1	1	603.4	603.4	1.55	0.215
Contrast 2	1	363.7	363.7	0.93	0.335
Contrast 3	1	160.8	160.8	0.41	0.521
Contrast 4	1	47.4	47.4	0.12	0.727
Contrast 5	1	156	156	0.4	0.528
Site	1	1193	1193	3.07	0.082
Variety	3	9108	3036	7.8	<.001
Treatment.Site	8	1096	136.9	0.35	0.944
Contrast 1.Site	1	74.4	74.4	0.19	0.663
Contrast 2.Site	1	76.7	76.7	0.2	0.658
Contrast 3.Site	1	2.1	2.1	0.01	0.941
Contrast 4.Site	1	22.6	22.6	0.06	0.81
Contrast 5.Site	1	242	242	0.62	0.432
Treatment.Variety	24	6481	270	0.69	0.851
Contrast 1.Variety	3	551.4	183.8	0.47	0.702
Contrast 2.Variety	3	173.8	57.9	0.15	0.93
Contrast 3.Variety	3	719.9	240	0.62	0.605
Contrast 4.Variety	3	239.6	79.9	0.21	0.893
Contrast 5.Variety	3	1761	587	1.51	0.215
Site.Variety	3	294.7	98.2	0.25	0.859
Treatment.Site.Variety	24	2937	122.4	0.31	0.999
Contrast 1.Site.Variety	3	579.4	193.1	0.5	0.685
Contrast 2.Site.Variety	3	248.4	82.8	0.21	0.887
Contrast 3.Site.Variety	3	207.4	69.1	0.18	0.911
Contrast 4.Site.Variety	3	147.1	49	0.13	0.945
Contrast 5.Site.Variety	3	393	131	0.34	0.799
Residual	144	56024	389.1		
Total	215	84929			

Leaf weight					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	7.0463	0.8808	1.09	0.38
Contrast 1	1	0.7811	0.7811	0.96	0.33
Contrast 2	1	0.0002	0.0002	0	0.99
Contrast 3	1	0.0037	0.0037	0	0.95
Contrast 4	1	0.0455	0.0455	0.06	0.81
Contrast 5	1	0.0977	0.0977	0.12	0.73
Site	1	20.107	20.107	24.8	<.001
Variety	3	3.8777	1.2926	1.59	0.19
Treatment.Site	8	5.4612	0.6826	0.84	0.57
Contrast 1.Site	1	0.1646	0.1646	0.2	0.65
Contrast 2.Site	1	0.0042	0.0042	0.01	0.94
Contrast 3.Site	1	0.855	0.855	1.05	0.31
Contrast 4.Site	1	0.3357	0.3357	0.41	0.52
Contrast 5.Site	1	0.0436	0.0436	0.05	0.82
Treatment.Variety	24	14.763	0.6151	0.76	0.78
Contrast 1.Variety	3	1.3145	0.4382	0.54	0.66
Contrast 2.Variety	3	0.7952	0.2651	0.33	0.81
Contrast 3.Variety	3	1.6689	0.5563	0.69	0.56
Contrast 4.Variety	3	3.352	1.1173	1.38	0.25
Contrast 5.Variety	3	5.3066	1.7689	2.18	0.09
Site.Variety	3	3.7733	1.2578	1.55	0.2
Treatment.Site.Variety	24	17.085	0.7119	0.88	0.63
Contrast 1.Site.Variety	3	1.7048	0.5683	0.7	0.55
Contrast 2.Site.Variety	3	0.5622	0.1874	0.23	0.88
Contrast 3.Site.Variety	3	0.4883	0.1628	0.2	0.9
Contrast 4.Site.Variety	3	1.0965	0.3655	0.45	0.72
Contrast 5.Site.Variety	3	0.9911	0.3304	0.41	0.75
Residual	144	116.76	0.8109		
Total	215	188.88			

Plant height cm week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	32.557	4.07	1.34	0.226
Contrast 1	1	14.386	14.39	4.75	0.031
Contrast 2	1	1.533	1.533	0.51	0.478
Contrast 3	1	6.275	6.275	2.07	0.152
Contrast 4	1	1.305	1.305	0.43	0.512
Contrast 5	1	0.733	0.733	0.24	0.623
Site	1	126.89	126.9	41.9	<.001
Variety	3	8.09	2.697	0.89	0.447
Treatment.Site	8	30.856	3.857	1.27	0.261
Contrast 1.Site	1	0.333	0.333	0.11	0.741
Contrast 2.Site	1	0	0	0	0.995
Contrast 3.Site	1	3.589	3.589	1.19	0.278
Contrast 4.Site	1	0.046	0.046	0.02	0.902
Contrast 5.Site	1	2.175	2.175	0.72	0.398
Treatment.Variety	24	70.763	2.948	0.97	0.504
Contrast 1.Variety	3	7.98	2.66	0.88	0.454
Contrast 2.Variety	3	2.832	0.944	0.31	0.817
Contrast 3.Variety	3	9.808	3.269	1.08	0.36
Contrast 4.Variety	3	7.327	2.442	0.81	0.492
Contrast 5.Variety	3	4.345	1.448	0.48	0.698
Site.Variety	3	31.632	10.54	3.48	0.018
Treatment.Site.Variety	24	67.107	2.796	0.92	0.57
Contrast 1.Site.Variety	3	13.58	4.527	1.5	0.218
Contrast 2.Site.Variety	3	8.374	2.791	0.92	0.432
Contrast 3.Site.Variety	3	7.428	2.476	0.82	0.486
Contrast 4.Site.Variety	3	1.736	0.579	0.19	0.902
Contrast 5.Site.Variety	3	8.469	2.823	0.93	0.427
Residual	144	435.87	3.027		
Total	215	803.76			

Plant height cm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	128.074	16.009	2.93	0.01
Contrast 1	1	61.852	61.852	11.3	<.001
Contrast 2	1	14.412	14.412	2.64	0.11
Contrast 3	1	8.745	8.745	1.6	0.21
Contrast 4	1	1.726	1.726	0.32	0.58
Contrast 5	1	0.299	0.299	0.05	0.82
Site	1	542.647	542.65	99.3	<.001
Variety	3	18.392	6.131	1.12	0.34
Treatment.Site	8	59.194	7.399	1.35	0.22
Contrast 1.Site	1	15.044	15.044	2.75	0.1
Contrast 2.Site	1	0.484	0.484	0.09	0.77
Contrast 3.Site	1	0.107	0.107	0.02	0.89
Contrast 4.Site	1	0.002	0.002	0	0.99
Contrast 5.Site	1	2.514	2.514	0.46	0.5
Treatment.Variety	24	137.388	5.724	1.05	0.41
Contrast 1.Variety	3	28.557	9.519	1.74	0.16
Contrast 2.Variety	3	20.319	6.773	1.24	0.3
Contrast 3.Variety	3	24.282	8.094	1.48	0.22
Contrast 4.Variety	3	4.851	1.617	0.3	0.83
Contrast 5.Variety	3	13.512	4.504	0.82	0.48
Site.Variety	3	26.537	8.846	1.62	0.19
Treatment.Site.Variety	24	78.12	3.255	0.6	0.93
Contrast 1.Site.Variety	3	9.812	3.271	0.6	0.62
Contrast 2.Site.Variety	3	11.469	3.823	0.7	0.55
Contrast 3.Site.Variety	3	8.872	2.957	0.54	0.66
Contrast 4.Site.Variety	3	2.762	0.921	0.17	0.92
Contrast 5.Site.Variety	3	7.647	2.549	0.47	0.71
Residual	144	787.293	5.467		
Total	215	1777.64			

Plant height cm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	134.43	16.8	2.41	0.02
Contrast 1	1	18.621	18.62	2.68	0.1
Contrast 2	1	0.563	0.563	0.08	0.78
Contrast 3	1	0.308	0.308	0.04	0.83
Contrast 4	1	0.503	0.503	0.07	0.79
Contrast 5	1	8.021	8.021	1.15	0.29
Site	1	571.92	571.9	82.2	<.001
Variety	3	33.752	11.25	1.62	0.19
Treatment.Site	8	20.896	2.612	0.38	0.93
Contrast 1.Site	1	2.745	2.745	0.39	0.53
Contrast 2.Site	1	0.917	0.917	0.13	0.72
Contrast 3.Site	1	0.219	0.219	0.03	0.86
Contrast 4.Site	1	0.806	0.806	0.12	0.73
Contrast 5.Site	1	0.707	0.707	0.1	0.75
Treatment.Variety	24	146.37	6.099	0.88	0.63
Contrast 1.Variety	3	11.226	3.742	0.54	0.66
Contrast 2.Variety	3	10.496	3.499	0.5	0.68
Contrast 3.Variety	3	13.508	4.503	0.65	0.59
Contrast 4.Variety	3	17.075	5.692	0.82	0.49
Contrast 5.Variety	3	5.664	1.888	0.27	0.85
Site.Variety	3	6.992	2.331	0.33	0.8
Treatment.Site.Variety	24	107.11	4.463	0.64	0.9
Contrast 1.Site.Variety	3	5.725	1.908	0.27	0.84
Contrast 2.Site.Variety	3	21.471	7.157	1.03	0.38
Contrast 3.Site.Variety	3	1.953	0.651	0.09	0.96
Contrast 4.Site.Variety	3	8.754	2.918	0.42	0.74
Contrast 5.Site.Variety	3	1.046	0.349	0.05	0.99
Residual	144	1002.3	6.961		
Total	215	2023.8			

Plant height cm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	34.43	4.304	0.47	0.87
Contrast 1	1	12.98	12.98	1.42	0.24
Contrast 2	1	1.237	1.237	0.14	0.71
Contrast 3	1	6.107	6.107	0.67	0.41
Contrast 4	1	1.361	1.361	0.15	0.7
Contrast 5	1	0.875	0.875	0.1	0.76
Site	1	612.5	612.5	67.2	<.001
Variety	3	35.3	11.77	1.29	0.28
Treatment.Site	8	46.2	5.775	0.63	0.75
Contrast 1.Site	1	2.135	2.135	0.23	0.63
Contrast 2.Site	1	3.508	3.508	0.39	0.54
Contrast 3.Site	1	0.018	0.018	0	0.97
Contrast 4.Site	1	0.006	0.006	0	0.98
Contrast 5.Site	1	1.665	1.665	0.18	0.67
Treatment.Variety	24	129.5	5.396	0.59	0.93
Contrast 1.Variety	3	8.457	2.819	0.31	0.82
Contrast 2.Variety	3	33.45	11.15	1.22	0.3
Contrast 3.Variety	3	57.2	19.07	2.09	0.1
Contrast 4.Variety	3	6.307	2.102	0.23	0.88
Contrast 5.Variety	3	29.69	9.897	1.09	0.36
Site.Variety	3	24.41	8.135	0.89	0.45
Treatment.Site.Variety	24	206	8.585	0.94	0.55
Contrast 1.Site.Variety	3	25.48	8.492	0.93	0.43
Contrast 2.Site.Variety	3	23.11	7.702	0.85	0.47
Contrast 3.Site.Variety	3	30.01	10	1.1	0.35
Contrast 4.Site.Variety	3	5.201	1.734	0.19	0.9
Contrast 5.Site.Variety	3	7.629	2.543	0.28	0.84
Residual	144	1312	9.109		
Total	215	2400			

Plant height cm week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	152.67	19.08	1.19	0.31
Contrast 1	1	67.19	67.19	4.17	0.04
Contrast 2	1	28.67	28.67	1.78	0.18
Contrast 3	1	4.29	4.29	0.27	0.61
Contrast 4	1	4.45	4.45	0.28	0.6
Contrast 5	1	0.11	0.11	0.01	0.93
Site	1	1289.5	1289.5	80.1	<.001
Variety	3	111.54	37.18	2.31	0.08
Treatment.Site	8	91.68	11.46	0.71	0.68
Contrast 1.Site	1	0.07	0.07	0	0.95
Contrast 2.Site	1	1.17	1.17	0.07	0.79
Contrast 3.Site	1	0.93	0.93	0.06	0.81
Contrast 4.Site	1	0.88	0.88	0.05	0.82
Contrast 5.Site	1	3.45	3.45	0.21	0.64
Treatment.Variety	24	480	20	1.24	0.22
Contrast 1.Variety	3	42.04	14.01	0.87	0.46
Contrast 2.Variety	3	20.51	6.84	0.42	0.74
Contrast 3.Variety	3	16.82	5.61	0.35	0.79
Contrast 4.Variety	3	29.68	9.89	0.61	0.61
Contrast 5.Variety	3	28.86	9.62	0.6	0.62
Site.Variety	3	39.85	13.28	0.83	0.48
Treatment.Site.Variety	24	175.63	7.32	0.45	0.99
Contrast 1.Site.Variety	3	11.25	3.75	0.23	0.87
Contrast 2.Site.Variety	3	26.9	8.97	0.56	0.64
Contrast 3.Site.Variety	3	17.11	5.7	0.35	0.79
Contrast 4.Site.Variety	3	6.55	2.18	0.14	0.94
Contrast 5.Site.Variety	3	22.75	7.58	0.47	0.7
Residual	144	2318.2	16.1		
Total	215	4659.1			

Stem thickness mm week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	4.99	0.62	1.36	0.22
Contrast 1	1	1.35	1.35	2.94	0.09
Contrast 2	1	0.09	0.09	0.21	0.65
Contrast 3	1	0.03	0.03	0.07	0.79
Contrast 4	1	0.11	0.11	0.24	0.63
Contrast 5	1	0.51	0.51	1.12	0.29
Site	1	74.6	74.6	163	<.001
Variety	3	1.24	0.41	0.9	0.44
Treatment.Site	8	2.94	0.37	0.8	0.6
Contrast 1.Site	1	0.67	0.67	1.45	0.23
Contrast 2.Site	1	0.03	0.03	0.07	0.79
Contrast 3.Site	1	0.01	0.01	0.02	0.9
Contrast 4.Site	1	0.22	0.22	0.49	0.49
Contrast 5.Site	1	0.56	0.56	1.23	0.27
Treatment.Variety	24	7.8	0.33	0.71	0.84
Contrast 1.Variety	3	0.41	0.14	0.3	0.83
Contrast 2.Variety	3	1.56	0.52	1.14	0.34
Contrast 3.Variety	3	0.42	0.14	0.31	0.82
Contrast 4.Variety	3	0.56	0.19	0.41	0.75
Contrast 5.Variety	3	0.98	0.33	0.72	0.54
Site.Variety	3	0.9	0.3	0.65	0.58
Treatment.Site.Variety	24	6.33	0.26	0.58	0.94
Contrast 1.Site.Variety	3	0.91	0.3	0.66	0.58
Contrast 2.Site.Variety	3	0.65	0.22	0.48	0.7
Contrast 3.Site.Variety	3	1.77	0.59	1.29	0.28
Contrast 4.Site.Variety	3	0.4	0.13	0.29	0.83
Contrast 5.Site.Variety	3	0.87	0.29	0.63	0.6
Residual	144	66	0.46		

Stem thickness mm week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	15.7118	1.964	2.94	0.004
Contrast 1	1	9.1593	9.1593	13.7	<.001
Contrast 2	1	0.05	0.05	0.07	0.785
Contrast 3	1	2.0735	2.0735	3.11	0.08
Contrast 4	1	0.4749	0.4749	0.71	0.4
Contrast 5	1	0.0719	0.0719	0.11	0.743
Site	1	1.7253	1.7253	2.58	0.11
Variety	3	1.27	0.4233	0.63	0.594
Treatment.Site	8	12.9204	1.6151	2.42	0.018
Contrast 1.Site	1	0.7607	0.7607	1.14	0.288
Contrast 2.Site	1	1.4437	1.4437	2.16	0.144
Contrast 3.Site	1	0.9195	0.9195	1.38	0.243
Contrast 4.Site	1	0.0597	0.0597	0.09	0.765
Contrast 5.Site	1	1.1101	1.1101	1.66	0.199
Treatment.Variety	24	23.8832	0.9951	1.49	0.079
Contrast 1.Variety	3	1.2862	0.4287	0.64	0.589
Contrast 2.Variety	3	4.8542	1.6181	2.42	0.068
Contrast 3.Variety	3	2.0814	0.6938	1.04	0.377
Contrast 4.Variety	3	0.3267	0.1089	0.16	0.921
Contrast 5.Variety	3	1.6004	0.5335	0.8	0.496
Site.Variety	3	1.5343	0.5114	0.77	0.515
Treatment.Site.Variety	24	22.1143	0.9214	1.38	0.127
Contrast 1.Site.Variety	3	1.01	0.3367	0.5	0.68
Contrast 2.Site.Variety	3	5.2608	1.7536	2.63	0.053
Contrast 3.Site.Variety	3	1.1971	0.399	0.6	0.618
Contrast 4.Site.Variety	3	0.0151	0.005	0.01	0.999
Contrast 5.Site.Variety	3	0.0828	0.0276	0.04	0.989
Residual	144	96.1493	0.6677		
Total	215	175.309			

Stem thickness mm week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.6161	1.077	1.73	0.1
Contrast 1	1	1.0717	1.072	1.72	0.19
Contrast 2	1	0	0	0	1
Contrast 3	1	0.073	0.073	0.12	0.73
Contrast 4	1	1.2285	1.229	1.98	0.16
Contrast 5	1	0.3187	0.319	0.51	0.48
Site	1	0.8849	0.885	1.42	0.24
Variety	3	1.3242	0.441	0.71	0.55
Treatment.Site	8	4.3576	0.545	0.88	0.54
Contrast 1.Site	1	2.3286	2.329	3.75	0.06
Contrast 2.Site	1	1.5958	1.596	2.57	0.11
Contrast 3.Site	1	0.2448	0.245	0.39	0.53
Contrast 4.Site	1	2.3101	2.31	3.72	0.06
Contrast 5.Site	1	0.2115	0.212	0.34	0.56
Treatment.Variety	24	15.662	0.653	1.05	0.41
Contrast 1.Variety	3	1.5508	0.517	0.83	0.48
Contrast 2.Variety	3	0.7712	0.257	0.41	0.74
Contrast 3.Variety	3	0.872	0.291	0.47	0.71
Contrast 4.Variety	3	3.3127	1.104	1.78	0.15
Contrast 5.Variety	3	0.5192	0.173	0.28	0.84
Site.Variety	3	1.1821	0.394	0.63	0.59
Treatment.Site.Variety	24	11.648	0.485	0.78	0.76
Contrast 1.Site.Variety	3	0.9488	0.316	0.51	0.68
Contrast 2.Site.Variety	3	1.1822	0.394	0.63	0.59
Contrast 3.Site.Variety	3	0.1995	0.067	0.11	0.96
Contrast 4.Site.Variety	3	2.5829	0.861	1.39	0.25
Contrast 5.Site.Variety	3	0.0876	0.029	0.05	0.99
Residual	144	89.495	0.622		
Total	215	133.17			

Stem thickness mm week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	0.679	0.085	0.13	0.998
Contrast 1	1	0.077	0.077	0.12	0.732
Contrast 2	1	0.103	0.103	0.16	0.692
Contrast 3	1	0.206	0.206	0.31	0.576
Contrast 4	1	0.002	0.002	0	0.961
Contrast 5	1	0.042	0.042	0.06	0.8
Site	1	6.026	6.026	9.19	0.003
Variety	3	0.598	0.199	0.3	0.822
Treatment.Site	8	5.464	0.683	1.04	0.408
Contrast 1.Site	1	0.019	0.019	0.03	0.867
Contrast 2.Site	1	0.445	0.445	0.68	0.411
Contrast 3.Site	1	2.234	2.234	3.41	0.067
Contrast 4.Site	1	0.025	0.025	0.04	0.845
Contrast 5.Site	1	0.785	0.785	1.2	0.276
Treatment.Variety	24	8.73	0.364	0.55	0.954
Contrast 1.Variety	3	0.357	0.119	0.18	0.909
Contrast 2.Variety	3	1.442	0.481	0.73	0.534
Contrast 3.Variety	3	3.153	1.051	1.6	0.192
Contrast 4.Variety	3	0.201	0.067	0.1	0.959
Contrast 5.Variety	3	0.216	0.072	0.11	0.954
Site.Variety	3	1.965	0.655	1	0.396
Treatment.Site.Variety	24	18.04	0.752	1.15	0.303
Contrast 1.Site.Variety	3	0.407	0.136	0.21	0.892
Contrast 2.Site.Variety	3	1.057	0.352	0.54	0.658
Contrast 3.Site.Variety	3	4.336	1.445	2.2	0.09
Contrast 4.Site.Variety	3	0.31	0.103	0.16	0.925
Contrast 5.Site.Variety	3	3.246	1.082	1.65	0.181
Residual	144	94.45	0.656		
Total	215	136			

Stem thickness mm week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8.1992	1.0249	1.26	0.27
Contrast 1	1	4.9991	4.9991	6.17	0.01
Contrast 2	1	0.116	0.116	0.14	0.71
Contrast 3	1	0.0735	0.0735	0.09	0.76
Contrast 4	1	0.0013	0.0013	0	0.97
Contrast 5	1	0.0312	0.0312	0.04	0.85
Site	1	83.013	83.013	102	<.001
Variety	3	6.2783	2.0928	2.58	0.06
Treatment.Site	8	8.028	1.0035	1.24	0.28
Contrast 1.Site	1	2.4463	2.4463	3.02	0.08
Contrast 2.Site	1	0.5624	0.5624	0.69	0.41
Contrast 3.Site	1	0.1132	0.1132	0.14	0.71
Contrast 4.Site	1	0.3767	0.3767	0.46	0.5
Contrast 5.Site	1	0.0163	0.0163	0.02	0.89
Treatment.Variety	24	19.922	0.8301	1.02	0.44
Contrast 1.Variety	3	2.9752	0.9917	1.22	0.3
Contrast 2.Variety	3	2.7607	0.9202	1.14	0.34
Contrast 3.Variety	3	0.6155	0.2052	0.25	0.86
Contrast 4.Variety	3	0.4556	0.1519	0.19	0.91
Contrast 5.Variety	3	2.4007	0.8002	0.99	0.4
Site.Variety	3	0.771	0.257	0.32	0.81
Treatment.Site.Variety	24	22.07	0.9196	1.13	0.31
Contrast 1.Site.Variety	3	6.2333	2.0778	2.56	0.06
Contrast 2.Site.Variety	3	1.0219	0.3406	0.42	0.74
Contrast 3.Site.Variety	3	0.7566	0.2522	0.31	0.82
Contrast 4.Site.Variety	3	0.4686	0.1562	0.19	0.9
Contrast 5.Site.Variety	3	0.6082	0.2027	0.25	0.86
Residual	144	116.68	0.8103		
Total	215	264.96			

Root length week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	47.2	5.903	1.2	0.305
Contrast 1	1	5.58	5.583	1.13	0.289
Contrast 2	1	2.19	2.187	0.44	0.507
Contrast 3	1	0	0	0	0.999
Contrast 4	1	14.8	14.78	3	0.086
Site	1	3.59	3.586	0.73	0.395
Variety	3	47	15.66	3.18	0.026
Treatment.Site	8	47.3	5.907	1.2	0.304
Contrast 1.Site	1	0.02	0.021	0	0.948
Contrast 2.Site	1	31.3	31.28	6.34	0.013
Contrast 3.Site	1	4.23	4.23	0.86	0.356
Contrast 4.Site	1	13.5	13.55	2.75	0.1
Treatment.Variety	24	267	11.12	2.26	0.002
Contrast 1.Variety	3	47.4	15.81	3.21	0.025
Contrast 2.Variety	3	33.9	11.29	2.29	0.081
Contrast 3.Variety	3	16.6	5.529	1.12	0.343
Contrast 4.Variety	3	35.9	11.98	2.43	0.068
Site.Variety	3	23.3	7.779	1.58	0.197
Treatment.Site.Variety	24	158	6.6	1.34	0.15
Contrast 1.Site.Variety	3	12.3	4.09	0.83	0.48
Contrast 2.Site.Variety	3	64.7	21.55	4.37	0.006
Contrast 3.Site.Variety	3	2.32	0.772	0.16	0.925
Contrast 4.Site.Variety	3	12.8	4.268	0.87	0.461
Residual	144	710	4.932		
Total	215	1304			

Root length week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	15.71	1.96	0.23	0.99
Contrast 1	1	5.446	5.45	0.63	0.43
Contrast 2	1	3.378	3.38	0.39	0.53
Contrast 3	1	10.95	10.9	1.28	0.26
Contrast 4	1	7.914	7.91	0.92	0.34
Site	1	1.67	1.67	0.19	0.66
Variety	3	72.67	24.2	2.82	0.04
Treatment.Site	8	88.08	11	1.28	0.26
Contrast 1.Site	1	4.46	4.46	0.52	0.47
Contrast 2.Site	1	24.94	24.9	2.9	0.09
Contrast 3.Site	1	14.38	14.4	1.68	0.2
Contrast 4.Site	1	10.98	11	1.28	0.26
Treatment.Variety	24	230	9.58	1.12	0.33
Contrast 1.Variety	3	38.07	12.7	1.48	0.22
Contrast 2.Variety	3	23.86	7.95	0.93	0.43
Contrast 3.Variety	3	16.57	5.52	0.64	0.59
Contrast 4.Variety	3	47.77	15.9	1.85	0.14
Site.Variety	3	2.364	0.79	0.09	0.96
Treatment.Site.Variety	24	181.7	7.57	0.88	0.63
Contrast 1.Site.Variety	3	5.771	1.92	0.22	0.88
Contrast 2.Site.Variety	3	76.94	25.6	2.99	0.03
Contrast 3.Site.Variety	3	6.365	2.12	0.25	0.86
Contrast 4.Site.Variety	3	16.45	5.48	0.64	0.59
Residual	144	1236	8.59		
Total	215	1829			

Root length week 8						
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Treatment	8		56.7	7.09	0.58	0.796
Contrast 1	1		0.54	0.54	0.04	0.835
Contrast 2	1		23.4	23.4	1.9	0.17
Contrast 3	1		4.92	4.92	0.4	0.528
Contrast 4	1		3.55	3.55	0.29	0.592
Site	1		458	458	37.2	<.001
Variety	3		23.6	7.86	0.64	0.591
Treatment.Site	8		111	13.8	1.13	0.349
Contrast 1.Site	1		3.03	3.03	0.25	0.62
Contrast 2.Site	1		0	0	0	0.997
Contrast 3.Site	1		10.1	10.1	0.82	0.367
Contrast 4.Site	1		24.3	24.3	1.97	0.162
Treatment.Variety	24		301	12.5	1.02	0.445
Contrast 1.Variety	3		63.4	21.1	1.72	0.166
Contrast 2.Variety	3		44.4	14.8	1.2	0.311
Contrast 3.Variety	3		9.75	3.25	0.26	0.851
Contrast 4.Variety	3		77.1	25.7	2.09	0.104
Site.Variety	3		41.2	13.7	1.12	0.345
Treatment.Site.Variety	24		436	18.2	1.48	0.084
Contrast 1.Site.Variety	3		14.8	4.93	0.4	0.752
Contrast 2.Site.Variety	3		57.6	19.2	1.56	0.202
Contrast 3.Site.Variety	3		12.9	4.3	0.35	0.789
Contrast 4.Site.Variety	3		13.3	4.43	0.36	0.781
Residual	142	-2	1745	12.3		
Total	213	-2	3172			

number of nodules week 5						
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Treatment	8		861.6	107.7	2.59	0.012
Contrast 1	1		273.1	273.1	6.56	0.012
Contrast 2	1		9.99	9.99	0.24	0.625
Contrast 3	1		93.52	93.52	2.25	0.136
Contrast 4	1		10.08	10.08	0.24	0.623
Contrast 5	1		56.33	56.33	1.35	0.247
Site	1		150.7	150.7	3.62	0.059
Variety	3		317.2	105.7	2.54	0.059
Treatment.Site	8		549	68.62	1.65	0.117
Contrast 1.Site	1		240.8	240.8	5.78	0.018
Contrast 2.Site	1		1.37	1.37	0.03	0.857
Contrast 3.Site	1		72.52	72.52	1.74	0.189
Contrast 4.Site	1		14.08	14.08	0.34	0.562
Contrast 5.Site	1		0.33	0.33	0.01	0.929
Treatment.Variety	24		1490	62.08	1.49	0.08
Contrast 1.Variety	3		80.97	26.99	0.65	0.585
Contrast 2.Variety	3		481.2	160.4	3.85	0.011
Contrast 3.Variety	3		307.7	102.6	2.46	0.065
Contrast 4.Variety	3		100.4	33.47	0.8	0.494
Contrast 5.Variety	3		513.2	171.1	4.11	0.008
Site.Variety	3		222.2	74.06	1.78	0.154
Treatment.Site.Variety	24		1656	69.01	1.66	0.038
Contrast 1.Site.Variety	3		59.68	19.89	0.48	0.698
Contrast 2.Site.Variety	3		537.7	179.2	4.3	0.006
Contrast 3.Site.Variety	3		126.1	42.02	1.01	0.391
Contrast 4.Site.Variety	3		225.1	75.03	1.8	0.15
Contrast 5.Site.Variety	3		182.8	60.94	1.46	0.227
Residual	140	-4	5831	41.65		
Total	211	-4	11066			

number of nodules week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	226.6	28.3	0.89	0.53
Contrast 1	1	130	130	4.07	0.05
Contrast 2	1	3.52	3.52	0.11	0.74
Contrast 3	1	67.69	67.7	2.12	0.15
Contrast 4	1	65.33	65.3	2.04	0.16
Contrast 5	1	18.75	18.8	0.59	0.45
Site	1	2347	2347	73.4	<.001
Variety	3	113.4	37.8	1.18	0.32
Treatment.Site	8	176.1	22	0.69	0.7
Contrast 1.Site	1	117.2	117	3.66	0.06
Contrast 2.Site	1	82.69	82.7	2.59	0.11
Contrast 3.Site	1	58.52	58.5	1.83	0.18
Contrast 4.Site	1	30.08	30.1	0.94	0.33
Contrast 5.Site	1	27	27	0.84	0.36
Treatment.Variety	24	621.5	25.9	0.81	0.72
Contrast 1.Variety	3	57.73	19.2	0.6	0.62
Contrast 2.Variety	3	182.1	60.7	1.9	0.13
Contrast 3.Variety	3	58.06	19.4	0.61	0.61
Contrast 4.Variety	3	12.5	4.17	0.13	0.94
Contrast 5.Variety	3	114.8	38.3	1.2	0.31
Site.Variety	3	39.74	13.3	0.41	0.74
Treatment.Site.Variety	24	671.2	28	0.87	0.64
Contrast 1.Site.Variety	3	48.56	16.2	0.51	0.68
Contrast 2.Site.Variety	3	34.9	11.6	0.36	0.78
Contrast 3.Site.Variety	3	57.56	19.2	0.6	0.62
Contrast 4.Site.Variety	3	4.42	1.47	0.05	0.99
Contrast 5.Site.Variety	3	56.5	18.8	0.59	0.62
Residual	144	4605	32		
Total	215	8800			

number of nodules week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1192	149	2.4	0.019
Contrast 1	1	252.1	252	4.06	0.046
Contrast 2	1	208.3	208	3.35	0.069
Contrast 3	1	56.33	56.3	0.91	0.343
Contrast 4	1	14.81	14.8	0.24	0.626
Contrast 5	1	252.1	252	4.06	0.046
Site	1	6895	6895	111	<.001
Variety	3	672.9	224	3.61	0.015
Treatment.Site	8	1583	198	3.19	0.002
Contrast 1.Site	1	75	75	1.21	0.274
Contrast 2.Site	1	126.8	127	2.04	0.155
Contrast 3.Site	1	154.1	154	2.48	0.117
Contrast 4.Site	1	7.79	7.79	0.13	0.724
Contrast 5.Site	1	396.8	397	6.39	0.013
Treatment.Variety	24	952.5	39.7	0.64	0.9
Contrast 1.Variety	3	398.8	133	2.14	0.098
Contrast 2.Variety	3	199.5	66.5	1.07	0.364
Contrast 3.Variety	3	197.2	65.7	1.06	0.369
Contrast 4.Variety	3	129.7	43.2	0.7	0.556
Contrast 5.Variety	3	36.42	12.1	0.2	0.899
Site.Variety	3	500.5	167	2.69	0.049
Treatment.Site.Variety	24	1188	49.5	0.8	0.736
Contrast 1.Site.Variety	3	165.2	55.1	0.89	0.45
Contrast 2.Site.Variety	3	171.8	57.3	0.92	0.432
Contrast 3.Site.Variety	3	120.4	40.1	0.65	0.587
Contrast 4.Site.Variety	3	134.9	45	0.72	0.539
Contrast 5.Site.Variety	3	241.4	80.5	1.3	0.278
Residual	144	8945	62.1		
Total	215	21929			

Number of leaves week 3					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	331185	41398	2.62	0.01
Contrast 1	1	237699	237699	15	<.001
Contrast 2	1	44561	44561	2.82	0.1
Contrast 3	1	35248	35248	2.23	0.14
Contrast 4	1	25697	25697	1.63	0.2
Contrast 5	1	321	321	0.02	0.89
Site	1	209271	209271	13.2	<.001
Variety	3	78459	26153	1.65	0.18
Treatment.Site	8	552905	69113	4.37	<.001
Contrast 1.Site	1	62323	62323	3.94	0.05
Contrast 2.Site	1	3	3	0	0.99
Contrast 3.Site	1	27501	27501	1.74	0.19
Contrast 4.Site	1	12205	12205	0.77	0.38
Contrast 5.Site	1	39505	39505	2.5	0.12
Treatment.Variety	24	276547	11523	0.73	0.82
Contrast 1.Variety	3	12948	4316	0.27	0.85
Contrast 2.Variety	3	46823	15608	0.99	0.4
Contrast 3.Variety	3	12214	4071	0.26	0.86
Contrast 4.Variety	3	14764	4921	0.31	0.82
Contrast 5.Variety	3	7785	2595	0.16	0.92
Site.Variety	3	424803	141601	8.96	<.001
Treatment.Site.Variety	24	319524	13314	0.84	0.68
Contrast 1.Site.Variety	3	66762	22254	1.41	0.24
Contrast 2.Site.Variety	3	111065	37022	2.34	0.08
Contrast 3.Site.Variety	3	109173	36391	2.3	0.08
Contrast 4.Site.Variety	3	47413	15804	1	0.4
Contrast 5.Site.Variety	3	4767	1589	0.1	0.96
Residual	144	2276272	15807		
Total	215	4468967			

Number of leaves week 4					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	1620685	202586	3.35	0.002
Contrast 1	1	933298	933298	15.4	<.001
Contrast 2	1	104260	104260	1.72	0.192
Contrast 3	1	165354	165354	2.73	0.101
Contrast 4	1	80912	80912	1.34	0.25
Contrast 5	1	26927	26927	0.44	0.506
Site	1	1634411	1634411	27	<.001
Variety	3	1450141	483380	7.98	<.001
Treatment.Site	8	2814338	351792	5.81	<.001
Contrast 1.Site	1	468658	468658	7.74	0.006
Contrast 2.Site	1	40291	40291	0.67	0.416
Contrast 3.Site	1	291325	291325	4.81	0.03
Contrast 4.Site	1	5688	5688	0.09	0.76
Contrast 5.Site	1	182705	182705	3.02	0.084
Treatment.Variety	24	1318345	54931	0.91	0.592
Contrast 1.Variety	3	147978	49326	0.81	0.488
Contrast 2.Variety	3	250554	83518	1.38	0.251
Contrast 3.Variety	3	364487	121496	2.01	0.116
Contrast 4.Variety	3	132494	44165	0.73	0.536
Contrast 5.Variety	3	164113	54704	0.9	0.441
Site.Variety	3	2124577	708192	11.7	<.001
Treatment.Site.Variety	24	857525	35730	0.59	0.934
Contrast 1.Site.Variety	3	96527	32176	0.53	0.661
Contrast 2.Site.Variety	3	384698	128233	2.12	0.101
Contrast 3.Site.Variety	3	119214	39738	0.66	0.58
Contrast 4.Site.Variety	3	43167	14389	0.24	0.87
Contrast 5.Site.Variety	3	100515	33505	0.55	0.647
Residual	144	8717928	60541		
Total	215	20537950			

Number of leaves week 5					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2346658	293332	2.13	0.036
Contrast 1	1	1095047	1095047	7.96	0.005
Contrast 2	1	191810	191810	1.39	0.24
Contrast 3	1	199279	199279	1.45	0.231
Contrast 4	1	66343	66343	0.48	0.489
Contrast 5	1	93329	93329	0.68	0.412
Site	1	5803976	5803976	42.2	<.001
Variety	3	2403358	801119	5.82	<.001
Treatment.Site	8	3783673	472959	3.44	0.001
Contrast 1.Site	1	407012	407012	2.96	0.088
Contrast 2.Site	1	7489	7489	0.05	0.816
Contrast 3.Site	1	222660	222660	1.62	0.205
Contrast 4.Site	1	8224	8224	0.06	0.807
Contrast 5.Site	1	525939	525939	3.82	0.053
Treatment.Variety	24	2293986	95583	0.69	0.851
Contrast 1.Variety	3	387414	129138	0.94	0.424
Contrast 2.Variety	3	519099	173033	1.26	0.291
Contrast 3.Variety	3	526893	175631	1.28	0.285
Contrast 4.Variety	3	331526	110509	0.8	0.494
Contrast 5.Variety	3	453037	151012	1.1	0.352
Site.Variety	3	2748993	916331	6.66	<.001
Treatment.Site.Variety	24	1338660	55778	0.41	0.994
Contrast 1.Site.Variety	3	193063	64354	0.47	0.705
Contrast 2.Site.Variety	3	665066	221689	1.61	0.19
Contrast 3.Site.Variety	3	130159	43386	0.32	0.814
Contrast 4.Site.Variety	3	70576	23525	0.17	0.916
Contrast 5.Site.Variety	3	327019	109006	0.79	0.5
Residual	144	19820944	137645		
Total	215	40540249			

Number of leaves week 6					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	2361427	295178	1.31	0.245
Contrast 1	1	1538684	1538684	6.81	0.01
Contrast 2	1	425262	425262	1.88	0.172
Contrast 3	1	463085	463085	2.05	0.155
Contrast 4	1	255415	255415	1.13	0.29
Contrast 5	1	92738	92738	0.41	0.523
Site	1	21529031	2.2E+07	95.2	<.001
Variety	3	5488588	1829529	8.09	<.001
Treatment.Site	8	3362331	420291	1.86	0.071
Contrast 1.Site	1	273005	273005	1.21	0.274
Contrast 2.Site	1	42522	42522	0.19	0.665
Contrast 3.Site	1	31187	31187	0.14	0.711
Contrast 4.Site	1	21066	21066	0.09	0.761
Contrast 5.Site	1	196145	196145	0.87	0.353
Treatment.Variety	24	4112636	171360	0.76	0.783
Contrast 1.Variety	3	590634	196878	0.87	0.458
Contrast 2.Variety	3	886754	295585	1.31	0.274
Contrast 3.Variety	3	1354399	451466	2	0.117
Contrast 4.Variety	3	320346	106782	0.47	0.702
Contrast 5.Variety	3	211759	70586	0.31	0.817
Site.Variety	3	6776589	2258863	9.99	<.001
Treatment.Site.Variety	24	2899557	120815	0.53	0.963
Contrast 1.Site.Variety	3	486075	162025	0.72	0.544
Contrast 2.Site.Variety	3	1208149	402716	1.78	0.153
Contrast 3.Site.Variety	3	319923	106641	0.47	0.702
Contrast 4.Site.Variety	3	242810	80937	0.36	0.783
Contrast 5.Site.Variety	3	208869	69623	0.31	0.82
Residual	144	32555108	226077		
Total	215	79085267			

Number of leaves week 8					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	8	8631049	1078881	1.99	0.051
Contrast 1	1	4513214	4513214	8.34	0.004
Contrast 2	1	1205346	1205346	2.23	0.138
Contrast 3	1	879438	879438	1.63	0.204
Contrast 4	1	432266	432266	0.8	0.373
Contrast 5	1	331	331	0	0.98
Site	1	41725699	4.2E+07	77.1	<.001
Variety	3	13517195	4505732	8.33	<.001
Treatment.Site	8	7978148	997268	1.84	0.074
Contrast 1.Site	1	53665	53665	0.1	0.753
Contrast 2.Site	1	310120	310120	0.57	0.45
Contrast 3.Site	1	97817	97817	0.18	0.671
Contrast 4.Site	1	886	886	0	0.968
Contrast 5.Site	1	1116012	1116012	2.06	0.153
Treatment.Variety	24	11125563	463565	0.86	0.659
Contrast 1.Variety	3	1115508	371836	0.69	0.561
Contrast 2.Variety	3	1180379	393460	0.73	0.537
Contrast 3.Variety	3	1973792	657931	1.22	0.306
Contrast 4.Variety	3	569513	189838	0.35	0.789
Contrast 5.Variety	3	1362048	454016	0.84	0.475
Site.Variety	3	10758082	3586027	6.63	<.001
Treatment.Site.Variety	24	7146265	297761	0.55	0.956
Contrast 1.Site.Variety	3	1111625	370542	0.68	0.563
Contrast 2.Site.Variety	3	3576696	1192232	2.2	0.09
Contrast 3.Site.Variety	3	1121677	373892	0.69	0.559
Contrast 4.Site.Variety	3	730718	243573	0.45	0.718
Contrast 5.Site.Variety	3	1297094	432365	0.8	0.496
Residual	144	77928671	541171		
Total	215	178810673			

Appendix 8: Contrasting Control and bio-stimulators in cowpea seed production (Set 6) and their anova tables

Contrasts	Treatment	Biofix	Humates	SWE basal application
1	Control	-1	0	0
2	Control	0	-1	0
3	Control	0	0	-1
4	Humates	-1	0	0
	Humates	0	0	-1
5	SWE	-1	0	0

Number of seeds per pod

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	5	3.329	0.666	0.13	
rep.*Units* stratum					
Treatment	3	305.5	101.8	20.39	<.001
Contrast 1	1	94.72	94.73	18.96	<.001
Contrast 2	1	46.24	46.24	9.26	0.003
Contrast 3	1	11.85	11.86	2.37	0.12
Contrast 4	1	273.3	273.3	54.72	<.001
Contrast 5	1	11.26	11.27	2.26	0.13
Contrast 6	1	173.6	173.6	34.75	<.001
Variety	3	35.03	11.68	2.34	0.08
Treatment.Variety	9	15.98	1.776	0.36	0.95
Contrast 1.Variety	3	13.13	4.378	0.88	0.45
Contrast 2.Variety	3	0.512	0.17	0.03	0.99
Contrast 3.Variety	3	3.06	1.02	0.2	0.89
Contrast 4.Variety	3	8.6	2.86	0.57	0.63
Contrast 5.Variety	3	1.214	0.40	0.08	0.97
Contrast 6.Variety	3	5.45	1.81	0.36	0.77
Residual	75	374.6	4.99		
Total	95	734.5			

Length of pod

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	5	21.84	4.37	1.42	
rep.*Units* stratum					
Treatment	3	131.2	43.7	14.3	<.001
Contrast 1	1	48.4	48.4	15.8	<.001
Contrast 2	1	7.26	7.26	2.37	0.13
Contrast 3	1	10.2	10.2	3.3	0.07
Contrast 4	1	93.1	93.2	30.4	<.001
Contrast 5	1	0.24	0.25	0.08	0.78
Contrast 6	1	103.1	103	33.6	<.001
Variety	3	172.4	57.5	18.7	<.001
Treatment.Variety	9	18.7	2.09	0.68	0.73
Contrast 1.Variety	3	4.77	1.59	0.52	0.67
Contrast 2.Variety	3	2.74	0.91	0.3	0.83
Contrast 3.Variety	3	2.06	0.69	0.22	0.88
Contrast 4.Variety	3	14.6	4.87	1.59	0.2
Contrast 5.Variety	3	0.24	0.08	0.03	0.99
Contrast 6.Variety	3	13.1	4.37	1.42	0.24
Residual	75	230.2	3.07		
Total	95	574.5			

Number of pods

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	5	33935	6787	1.45	
rep.*Units* stratum					
bTreatment	3	431106	143702	30.7	<.001
Contrast 1	1	250708	250708	53.6	<.001
Contrast 2	1	4370	4370	0.93	0.337
Contrast 3	1	1018	1018	0.22	0.642
Contrast 4	1	321278	321278	68.6	<.001
Contrast 5	1	1170	1170	0.25	0.619
Contrast 6	1	283669	283669	60.6	<.001
Variety	3	21038	7013	1.5	0.222
Treatment.Variety	9	14922	1658	0.35	0.953
Contrast 1.Variety	3	7671	2557	0.55	0.652
Contrast 2.Variety	3	3454	1151	0.25	0.864
Contrast 3.Variety	3	6128	2043	0.44	0.728
Contrast 4.Variety	3	6080	2027	0.43	0.73
Contrast 5.Variety	3	5272	1757	0.38	0.771
Contrast 6.Variety	3	1240	413	0.09	0.966
Residual	75	351060	4681		
Total	95	852061			

Total weight of seeds

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
rep stratum	5	8999	1800	0.33	
rep.*Units* stratum					
Treatment	3	87321	29107	5.29	0.002
Contrast 1	1	4106	4106	0.75	0.391
Contrast 2	1	23513	23513	4.27	0.042
Contrast 3	1	35212	35212	6.4	0.014
Contrast 4	1	47270	47270	8.59	0.004
Contrast 5	1	1177	1177	0.21	0.645
Contrast 6	1	63365	63365	11.5	0.001
Variety	3	8453	2818	0.51	0.675
Treatment.Variety	9	88859	9873	1.79	0.083
Contrast 1.Variety	3	17377	5792	1.05	0.375
Contrast 2.Variety	3	24710	8237	1.5	0.223
Contrast 3.Variety	3	10606	3535	0.64	0.59
Contrast 4.Variety	3	41784	13928	2.53	0.064
Contrast 5.Variety	3	28744	9581	1.74	0.166
Contrast 6.Variety	3	54497	18166	3.3	0.025
Residual	75	412919	5506		
Total	95	606551			

days_to_flowering

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	5	81.12	16.23	1.46	
Block.*Units* stratum					
Treatment	3	88.88	29.62	2.66	0.054
Variety	3	153.38	51.13	4.59	0.005
Treatment.Variety	9	122.38	13.60	1.22	0.296
Residual	75	835.87	11.14		
Total	95	1281.62			

days_to_podding

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Block stratum	5	103.344	20.669	4.01	
Block.*Units* stratum					
Treatment	3	127.865	42.622	8.26	<.001
Variety	3	285.031	95.010	18.42	<.001
Treatment.Variety	9	117.344	13.038	2.53	0.014
Residual	75	386.823	5.158		
Total	95	1020.406			