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ANTON DE KOM UNIVERSITEIT VAN SURINAME
FACULTEIT DER TECHNOLOGISCHE WETENSCHAPPEN
AGRARISCHE PRODUCTIE

Evaluation of AGASI on the yield of pepper (*Capsicum chinense*)

A thesis submitted to obtain
for the degree of
Bachelor of Science (BSc)
in Agricultural Production

Njarlie Jaggessar

November 28, 2020
Paramaribo, Suriname

ANTON DE KOM UNIVERSITEIT VAN SURINAME
FACULTEIT DER TECHNOLOGISCHE WETENSCHAPPEN
AGRARISCHE PRODUCTIE

Evaluation of AGASI on the yield of pepper (*Capsicum chinense*)

Curriculum subject	**:**	A thesis to complete the study of Bachelor of Science in Agricultural Production
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Paramaribo, *November 28, 2020*

ANTON DE KOM UNIVERSITEIT VAN SURINAME
FACULTEIT DER TECHNOLOGISCHE WETENSCHAPPEN
AGRARISCHE PRODUCTIE

Evaluatie van AGASI op de opbrengst van peper (*Capsicum chinense*)

Curriculum onderdeel	**:**	Een afstudeerverslag ter afronding van de studie van Bachelor of Science in Agrarische Productie
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Paramaribo, 28 *November 2020*

ANTON DE KOM UNIVERSITEIT VAN SURINAME
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STATEMENT OF APPROVAL REGARDING FINAL THESIS

The supervisory committee declares to have given its approval to the Bachelor thesis written by:

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Evaluation of AGASI on the yield of pepper (Capsicum chinense)

Date of Examination: December 15, 2020

On behalf of the Supervisory committee,

Lydia Ori, Ph.D., Faculty Supervisor

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Jamillah Salarbaks, M.Sc., Practical Supervisor

Preface

This thesis is submitted for the fulfillment of the requirements of the degree of Bachelor of Science in Agricultural Production, orientation Agriculture. The research described herein was conducted under the supervision of Mrs. L. Ori Ph.D.-Lector Magnus and Mrs. M. Narain M.Sc. of the Department of Agricultural Production (AP) at the Faculty of Technology (FTeW) of the Anton de Kom University of Suriname (AdeKUS) and Mrs. J. Salarbaks M.Sc. of the Ministry of Agriculture, Animal Husbandry and Fisheries (LVV).

During my study I have gained more skills and knowledge in pepper farming. It was not easy to carry out the field tasks, but with the assistance of my parents I succeeded. I was also enthusiastic about gathering the data so that I could finalize the results, I had always looked forward to conduct this research project. However, writing this thesis was not always easy. In the end, I have gained a lot of knowledge and skills during the research project implementation process.

I would first like to express my appreciation and gratitude to my Supervisor, Mrs. L. Ori Ph.D.-Lector Magnus, for her time, encouragement, guidance, and valuable input throughout the entire process. I would also like to thank my Co-supervisor, Mrs. M. Narain M.Sc. and practical supervisor, Mrs. J. Salarbaks, M.Sc. for their time and valuable input through the process of this research project.

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Finally, I want to express my very profound gratitude to my family and friends, especially my parents (Mr. Parmanand Sharma Jaggessar and Mrs. Tjanderwatie Jaggessar Kisoensingh) and my brother (Chandrieka persad Jaggessar), for helping me with every tasks in the field and encouraging me through the process of conducting this project and writing this thesis.

Njarlie Jaggessar

Paramaribo, November 28, 2020

Abstract

Capsicum sp. is an essential spice which originates from the Solanaceae family of nightshades. The genus is native to Middle and South America and consists of around 30 species. Red pepper is widely cultivated worldwide and is the most popular vegetable in the world, after tomatoes. Pepper plants need a lot of nutrients and require adequate soil fertility maintenance to grow. The growth and development of plants depends on macro- and micronutrients, as well as amino acids. Amino acids have various prominent functions in plants. Such as resistance to stress conditions, root development, aroma-, taste- and color precursors, increase in seed germination, photosynthesis and chlorophyll reinforcement, nitrogen reserve, and much more. A field study is conducted during the period from August 2019 to April 2020 to determine the effect of amino acid application on the optimum yield of pepper (*Capsicum chinense*). Pepper seedlings are subjected to four levels of amino acid fertilizers (0, 3.75, 6.25- and 8.75-ml l^{-1}). These are assigned randomly into three replicates and arranged in a Randomized Complete Block Design (RCBD). The research factor is to compare four different levels of amino acid fertilizers. The collected data is statistically analyzed using a One-way analysis of variance and Post-hoc using the statistics software program SPSS. Plant variables that are observed and or measured are: plant height, stem diameter, number of flowers, number of dropped flowers, fruit length, fruit circumference, single fruit weight, total fruit weight, biomass, root weight and root system. The results showed that growth contributing parameters, including plant height, stem diameter, number of flowers and number of dropped flowers, are not influenced significantly ($P<0.05$), whereas yield contributing parameters, including fruit length, fruit circumference and single fruit weight, were significantly ($P<0.05$) influenced by different doses of amino acids. The growth parameters plant height, stem diameter, number of flowers and number of dropped flowers showed an increasing response to all the treatments as the amino acid level increased. This was also the case for the total fruit weight per plot. Based on the obtained results, it can be stated that the application of amino acids (AGASI) increased the fruit yield of pepper. However, it is recommended to further investigate whether the number of times amino acids are administered is relevant to the yield and if the application of amino acids have the same effect on different crops and finally if there is a difference between foliar application and soil application.

Keywords: **AGASI, Amino acid, Capsicum, Pepper production**

Samenvatting

Capsicum is een essentieel kruid dat afkomstig is van de Solanaceae familie van nachtschaduwen. Het geslacht is afkomstig uit Midden- en Zuid-Amerika en bestaat uit ongeveer 30 soorten. Rode peper wordt wereldwijd op grote schaal geteeld en is de meest populaire groente in de wereld, na tomaten. Peperplanten gebruiken veel nutriënten en vereisen voldoende onderhoud van bodemvruchtbaarheid om te groeien. De groei en ontwikkeling van planten zijn afhankelijk van macro- en micronutriënten, evenals aminozuren. Aminozuren hebben verschillende prominente functies in planten, zoals weerstand tegen stressomstandigheden, wortelontwikkeling, aroma-, smaak- en kleurprecursoren, toename van zaadkieming, fotosynthese en chlorofylversterking, stikstofreserve en nog veel meer. In de periode van augustus 2019 tot april 2020 is een veldstudie uitgevoerd om het effect van aminozuur op de opbrengst van peper (*Capsicum chinense*) te bepalen. Peper zaailingen zijn onderworpen aan 4 niveaus van aminozuur meststoffen (0, 3.75, 6.25- en 8.75 ml l^{-1}). Deze zijn willekeurig toegewezen in drie replica's en gerangschikt in een Compleet gerandomiseerd blokontwerp. De onderzoek factor is om vier verschillende niveaus van aminozuur meststoffen te vergelijken. De verzamelde gegevens zijn statistisch geanalyseerd met behulp van een One-way analyse van variantie en Post-hoc met behulp van de statistieken softwareprogramma SPSS. De plantvariabelen die zijn waargenomen of gemeten zijn: planthoogte, stengeldiameter, aantal bloemen, aantal gevallen bloemen, vruchtlengte, vruchtomtrek, vrucht gewicht, totaal vrucht gewicht, biomassa, wortelgewicht en wortelstelsel. Uit de resultaten kan gehaald worden dat de groeiparameters, waaronder planthoogte, stengeldiameter, aantal bloemen en aantal gevallen bloemen, niet significant zijn beïnvloed ($P<0,05$), terwijl de opbrengst parameters, waaronder vruchtlengte, vruchtomtrek en vrucht gewicht, significant ($P<0.05$) zijn beïnvloed door de verschillende doses aminozuren. De groeiparameters zoals de planthoogte, stengeldiameter, het aantal bloemen en het aantal gevallen bloemen hebben een toenemende respons op alle behandelingen naarmate het aminozuurgehalte toenam, dit geldt ook voor het totale vruchtgewicht per plot. Op basis van de huidige resultaten kan worden gesteld dat de toepassing van aminozuren (AGASI) de opbrengst van peper verhoogd. Het wordt echter aanbevolen om verder te onderzoeken of het aantal keren dat aminozuren worden toegediend relevant is voor de opbrengst, en of de toepassing van aminozuren hetzelfde effect heeft op verschillende gewassen en ten slotte, als er een verschil is tussen bladbemesting en bodembemesting van AGASI.

Sleutelwoorden: **AGASI, Aminozuur, Capsicum, Groei en Peper.**

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ANOVA	Analysis of variance
C. chinense	Capsicum chinense
Cm	Centimeter
DAS	Days After Sowing
DAT	Days After Transplanting
D1	Dosage 1
D2	Dosage 2
D3	Dosage 3
D4	Dosage 4
EC	Electrical Conductivity
g	gram
g/l	gram/liter
ha	Hectare
K	Potassium
LVV	Ministry of Agriculture, Animal Husbandry and Fisheries
m	meter
micro S/cm	micro Siemens per centimeter
ml/gallon	milliliter per gallon
ml/l	milliliter per liter
mm	millimeter
n.d.	no date
N	Nitrogen
N organic	Organic Nitrogen
Org. C	Organic Carbon
P	Phosphor
pH	Scale used to specify the acidity or basicity of an aqueous solution
ppm	parts per million
SPSS	Statistical Product and Service Solutions
SRD/kg	Surinamese Dollars per kilogram
Ton/ha	Ton per hectare

1. INTRODUCTION

1.1 Background information

Hot pepper (*Capsicum*) is an important spice that originates from the nightshade family Solanaceae. Worldwide, Red pepper is commonly cultivated and is after tomatoes, the most important vegetable in the world. Pepper grows well in both wet and dry seasons but draws in a huge profit during the dry season when the demand is often higher than the supplies. Capsicum occurrence is in different color-range from green to yellow, red, orange, purple and black. Capsicum is a genus that contains approximately 20 species, with *Capsicum annuum L.* (hot and sweet peppers), *Capsicum frutescens L.* (bird pepper), *Capsicum chinense* (aromatic chili pepper), *Capsicum baccatum L.* (aji) and *Capsicum pubescens* as the domesticated ones. Pepper plants require a lot of nutrients and require adequate soil fertility maintenance to grow. Each nutrient has its function and should be applied at the right time and in the right quantity. The use of fertilizers for pepper production is considered as advantageous. (Olaniyi & Ojetayo, 2010). Foliar fertilizing is known as a complement to ground fertilization. In living cells, protein is the basic component. Amino acids are utilized in the formation of protein. In plant tissues, urea is a source of nitrogen and/or amino acids. Nitrogen from amino acids is required to increase growth and yield for all crops. To complete the protein synthesis process, amino acids are needed. According to some studies, amino acids can directly or indirectly influence the physiological activities in plant growth and development. For example, foliar application of amino acids caused improvements in plant growth, fruits yield and its components on cucumber, garlic, potato, and sweet pepper (Abd El-Aal, Shaheen, Ahmad & Mahmoud, 2010; Mendes et al., 2016).

1.2 Statement of the problem

The growth and development of plants depends on macro- and micronutrients, as well as amino acids. Farmers in Suriname are not familiar with the use of amino acids. Studies have shown improvements in vegetable crops production when fertilizers, including fertilizers with amino acids are used. Fertilization research should focus on amino acids. Therefore, it is essential to study the effect of AGASI (amino acids) on plants so that Surinamese farmers can increase their yield.

1.3 Objectives

The objective of this study is to evaluate the response of the fertilizer AGASI as a foliar application on the yield of pepper.

Research question:

Does AGASI (amino acids) fertilization result in higher pepper production?

Sub-questions:

- Are there significant differences among treatments?
- Does foliar application of amino acids in hot pepper influence the plant height, stem diameter, number of flowers and number of dropped flowers?
- Does foliar application of amino acids in hot pepper increase the circumference, weight and the length of fruits?
- Does foliar application of amino acids in hot pepper influence the biomass of the plant and the root development and does this effect the pepper production?

1.4 Research design

The research study will be set up as a fully randomized single-factor design with three replications (Figure 6). The foliar treatments levels of AGASI (amino acids) are: 0 ml/l, 3.75 ml/l, 6.25 ml/l and 8.75 ml/l. Each block is divided into 4 sub-plots with a length and width of 6 meters and 2 meters respectively (Figure 5). The first foliar application of the amino acid will be applied fourteen days after transplanting, and the subsequent in breaks of 14 days after the first application. The following data will be collected: Plant height, stem diameter, number of flowers, number of fruits, weight of pepper, fruit diameter of pepper, biomass of the plant. At the end of the experiment, root- system and mass per treatment will be measured.

1.5 Relevance of the study

The relevance of this research is to evaluate a foliar amino acid spray (AGASI), which is available in agronomic shops, on hot pepper. The results are important for hot pepper farmers in Suriname. Based on the results it can be advised which of the tested treatments is the most suitable in terms of economic benefits for hot pepper farmers in Suriname.

1.6 Structure

This thesis consists of the following chapters namely chapter two which describes an overview of the literature associated with the subject, after which chapter 3 represents the materials and methods. Subsequently, chapter 4 presents the results with discussion and finally the conclusions, recommendations and appendices are presented.

2. LITERATURE REVIEW

2 .1 *Capsicum chinense* (Pepper)

Pepper belongs to the Solanaceae family, genus *Capsicum*. This genus originates from Middle- and South-America and consists of approximately 30 species. There is a big diversity in the kind of fruit, color, shape, flavor, and biochemical content of *Capsicum*. It is used as food, medicine, cosmetic, insecticide as well as a source of income. Using these sub-specific characteristics, industries can use correct peppers for the intended product. Pepper culture is seen as suitable for use in poverty alleviation and food safety improvement programs (Dagnoko et al., 2013; Bosland & Votava, 1999).

2.2 Growth of pepper

Pepper (dicots, with epigeal germination) can be cultivated as an annual or perennial crop. It can be cultivated in the greenhouse and open field. Pepper can be produced in a wide range of climate, which makes it impossible to use the same culture system. Direct sowing or transplanting, rain or irrigation, manual or mechanical harvest can be chosen if the pepper is planted in the field. Growth duration can lie between 60 to 150 days depending on the variety. After the plant is matured it will start flowering. Pepper can be spaced 35 to 46 cm in the row and 1 meter between the rows. Pepper is a self-pollinating crop with great chances of cross-pollination. Seeds derived from the fruits can be used for propagation, while fresh seeds may exhibit dormancy. It is suggested to give the seeds a period of 6 weeks to get out of the dormancy. An excess of fertilization or irrigation can be fatal to the plant, so it is important to ensure that it is avoided (Bosland & Votava, 1999; Chili pepper madness, 2018).

2.2.1 Climate requirements for the growth of pepper

The ideal growing day temperature for pepper plants is between 20 to 30 °C. Pepper is better adapted to warm weather, but fruit deposits do not take place properly when night temperatures exceed 24 °C. The growth and yield decrease when the temperature is lower than 15 °C or higher than 32 °C for a long period. Day length does not affect the flowering or fruit setting of pepper (Berke et al., 2015; Hochmuth, n.d.). Rainfall of more than 2000 mm is required during the vegetative and productive phase of pepper cultivation. If the rainfall is less than 2000 mm per year or irregular, it is necessary to irrigate. Irregular rainfall can cause fruit and flower abortion (Ashilenje, 2013). The optimal relative humidity for pepper plants varies between '55% to 65%' (Antonios, 2013). High humidity can cause diseases and difficult fertilization, while low humidity causes the dropping of newly formed fruits and flowers (agriculture infoagro.com, n.d.).

2.2.2 Soil requirements for the growth of pepper

pH

Pepper grows best in loamy soils with good water-holding capacity, but it can also grow in other soil types if the soil contains good drainage. Soil pH must range between 5,5 and 7,5 (Berke et al., 2015; Hochmuth, n.d.; The garden helper. 2020).

Electrical conductivity

Electrical conductivity (EC) in soil is a measure of the ability of the soil to conduct an electrical current. It indicates the availability of nutrients in the soil. High EC means that there are more negatively charged sites (clay and organic particles) in the soil, which means that there are more cations (which have a positive charge, such as sodium (Na+), ammonium (NH4+), potassium (K+), magnesium (Mg2+), etc.) held in the soil. If the EC gets too high, too many of these nutrients, especially Na and Mg, can be detrimental to soil health. An optimal EC range for soil is 110-570 milli Siemens per meter (mS/m). Low EC levels are found in sandy soils (which means low nutrient availability), while high EC levels are found in soils with high clay content. Soil EC's also used as a salinity indicator. Salinity is an indication of how many salts there are in the soil. The general rule of thumb for salinity is that very high EC values are an indicator of deep saline soils (> 1600 mS / m). In comparison, low EC values (0-200 mS / m) are an indicator of non-saline soils. Effective practices for controlling soil fertility should help preserve optimum EC levels. The two most important things to remember are that nutrient scarcity should be addressed in low EC soils, and that nutrient build-up should be addressed in high EC soils (Fourie, 2017).

High levels of conductivity also minimize the crop's vegetative and reproductive yields. This is associated with a decrease in water absorption, leaf water content and a decrease in crop photosynthetic ability. High ionic strength of the nutrient solution also decreases the firmness of the fruit and its water content (Tadesse, Nichols and Fisher, 1999)

Soil Organic Matter

Soil organic matter is the portion of the soil that consists of plant or animal tissue in different stages of breakdown (decomposition). There is between 3 to 6 % organic matter in most of our productive agricultural soils. Organic matter from the soil contributes in many different ways to soil productivity (Fenton, Albers and Katterings, 2008). Leaving grass on the surface of the soil after mowing can increase the carbon level in the soil (Poeplau, Marstorp, Thored, and Kätterer, 2016).

2.3 Fertilizers

Solanaceae plants, including pepper, generally consume large amounts of nutrients. The nutrient intake depends on the amount of fruit and dry matter they produce, which in turn is influenced by a number of genetic and environmental variables. Application of fertilizers through split application at 30-day intervals is recommended to achieve maximum yields and profits in pepper production (Hegde, n.d.). Nutrient requirements of *Capsicum chinense* are 76kg N/ha, 48kg P205/ha and 60kg K20/ha (Olaniyi & Ojetayo, 2010).

Table 1: Interpretation of Mehlich-1 soil test and nutrient recommendation for pepper.

	Very low	Low	Medium	High	Very high
P (ppm)	< 10	10 – 15	16 – 30	31 – 60	60 >
K (ppm)	< 20	20 – 35	36 – 60	61 – 125	125 >

Adapted from "Fertilization of Pepper in Florida" by Hochmuth G. and Hanlon E., 1995. *IFAS standardized fertilization recommendations for vegetable crops,* p. 6. Copyright 1995 by the University of Florida.

Table 2: Classification of Nitrogen (N) in soil

Percentage N	**Categorie**
< 0.05	Too low
0.05 – 0.15	Low
0.15 – 0.25	Medium
0.25 – 0.50	High
> 0.50	Too high

Reprinted from Apal Agricultural Laboratory. (n.d). Soil Test Interpretation Guide p. 12. Copyright by Agricultural Laboratory.

N (Nitrogen)

Adequate Nitrogen can increase quality, fruit size and retain quality, color and taste (Shukla & Nair, 1993). It also influences the flower setting of different vegetables, including pepper. Adequate nitrogen supply is essential for vegetative growth and desirable yield. Exceeding N-fertilization is not only unprofitable, but also induces physiological disorder and pollutes to the environment (Md. Islam et al., 2018).

P (Phosphorus)

For the normal growth and development of the plant phosphorus is required (depending on the nutrient content in the soil). It is one of the most important macro-essential elements for plants. Phosphorus can lead to formation and translocation of carbohydrates, root development, nodulation and growth, it also induces premature flowering and fruit deposition, including seed formation. Shortages of phosphorus limit plant growth and it causes plants to remain immature (Tajer, 2016).

K (Potassium)

Fertilizing with potassium has a significant effect on the growth and yield of pepper. Potassium is needed for good fruit quality. The maximum dose of potassium featured for pepper plants with a soil containing very low, low or medium potassium are 165,00, 148,50 and 127,50 kg K2O/ha or equal to 275,00, 247,50 and 212,50 kg K Cl/ha. Soils containing high or very high value of potassium don't need any application of potassium. It is very important to apply adequate amount of fertilizers to improve the productivity of agricultural land (Amisnaipa, Susila, Nursyamsi, & Purnomo, 2016).

2.4 Yield of pepper

Peppers can be harvested 2 to 2,5 months after transplanting. Pepper can be harvested in the morning or late afternoon every 3 to 4 days. Depending on the use it can be harvested when its green or red. Harvest lasts about 3-6 months, but it can take up to a year or longer if it's taken care of. The yield varies from 10 to 24 MT/ha/season depending on the variety, duration of the harvest and the level of management (Lim, n.d.; Chili pepper madness, 2018). According to Table 1, there is an increase in the planted area for peppers as well as the production from 2013 to 2018 (LVV, 2019).

Table 3: Statistics of hot pepper production in Suriname

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Planted area (ha)	98	127	126	134	124	130	117
Production (Ton/ha)	2308	2821	2648	3051	2709	2884	2131
Consumer Price (SRD/kg)	6.47	11.26	24.11	11.26	21.68	17.67	---

Adapted from Statistics Department of the Ministry of Agriculture, Animal Husbandry and Fisheries (LVV). 2019. Copyright 2019 by LVV.

2.5 Amino acids

2.5.1 General

For the formation of protein amino acids are needed. A protein is made of a chain of amino acids. Amino acids consist of an amino group (NH2), a carboxyl group (COOH), a side chain (R-group) specific to each amino acid and a carbon atom (Figure 1). There are several amino acids and each amino acid can be acid, alkaline, polar and not polar. It depends entirely on the properties of the present side-chain in the structure of an amino acid (Khan Academy, 2019).

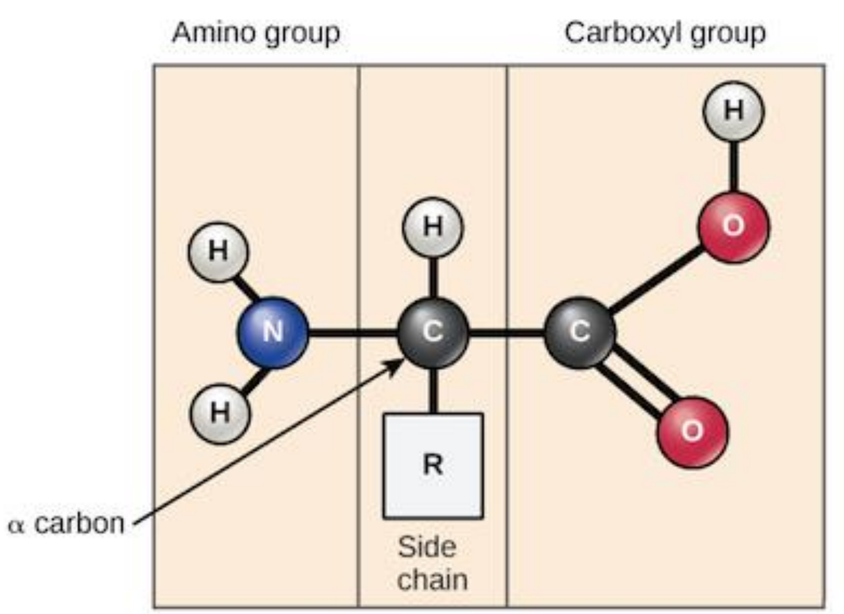

Figure 1: Structure formula of an amino acid. Reprinted from “Types and Functions of Proteins” open stax, 2020. Copyright 2020 by open stax.

L-shaped free amino acids play an important role in the Krebs cycle (citric acid cycle) in plants. This cycle is a series of chemical reactions used by all aerobic organisms to generate energy for maintenance, growth and production. During this cycle the conversion takes place from amino acids to glucose for energy or for storage as glycogen, starch and fat. There may be increased stress due to drought, administration of pesticides, diseases, etc. To reduce this proces, amino acids can be administered. In Table 4, some amino acids with their function are listed in the plant (Dacam, 2015).

Table 4: Amino acids and their function in the plant

Function in the plant	**Responsible amino acid element(s)**
Radicular Development	Methionine and arginine
Resistance to stress conditions	Proline, valine, serine, lysine, glutamine acid and cysteine
Nitrogen Reserve	Asparagine acid, glutamine acid, arginine and proline
Hormone precursors	Tryptophan and methionine
Aroma precursors	Valine, leucine, isoleucine and alanine
Taste precursors	Alanine, glycine and proline
Color precursors	Phenylalanine
Increase of (pollen) germination force	Proline and glutamine acid

Increase seed germination	Proline
Photosynthesis and chlorophyll reinforcement	Alanine, glycine, lysine, glutamine acid and proline
Complexing capacity	Glycine, glutamine acid and asparagine acid
Antioxidant capacity	Histidine, cysteine, tryptophan, lysine, methionine and threonine
Osmosis regulation	Proline
Stomatal opening	Alanine, glutamine acid, lysine, proline and methionine

Adapted from "Aminozuren" by Dacam, 2015. Copyright 2015 by Dacam.

The pepper pericarps contain 18 amino acids. The main amino acids were glutamic acid and aspartic acid, followed by proline, serine, leucine, alanine, arginine, valine. The contents of methionine, cysteine, tyrosine, tryptophan, isoleucine, and lysine were low (Zou, Ma and Tian, 2015; Kim et al., 2019).

2.5.2 Advantages of amino acids used for vegetables

According to Mendes et al, 2016, benefits of amino acids used for vegetables include:

- improved photosynthesis by decreasing the phytotoxicity of some defensives
- improved absorption and translocation of nutrients by foliar fertilization
- well and strongly developed root system
- increased tolerance against pests and diseases
- moderating the hormonal activities of the plants
- providing more tolerance to hydric and frost stress
- increased flowering
- better quality of harvested products

According to some researches amino acids could influence the physiologic activities during the plant's growth, increasing the productivity. Foliar fertilization with amino acids provided improved growth and quality of fruits in plants of potatoes, chili pepper, cucumber, garlic and pigeon pea (Mendes et al., 2016). Mendes et al. (2016) stated that "The application of amino acids by foliar in plants of Bell pepper, increased the diameter and the length of fruits", but there were no changes noticed in the quantity and total productivity. Foliar application of amino acids at 0.25 ml/ L on potato significantly increased vegetative growth expressed as plant height and dry weight of plant. It was also found that applying amino acids at 0.5 and 1.0 g/L on strawberry plants significantly increased total nitrogen, phosphorus and potassium in plant foliage as well as total yield, weight, vitamin C and total sugars content of fruits compared to control treatments (Shehata, Abdel-Azem, Abou El-Yazied & El-Gizawy, 2011). According to the study of Sadak, Abdelhamid & Schmidhalter (2014) the "application of amino acid mixture as foliar spray with different concentrations (500, 1000 or 1500 mg/L) significantly improved all the reduced parameters due to seawater stress" (p.

150). A study on radish showed (Basha & El-Aila, 2015) that “spraying the plants with amino acids at higher rate had statistically effect on fresh and dry weight of shoot and root, root length and diameter as well as nutrient content and uptake. Moreover, the highest values of chlorophyll a, b, a+b and carotenoids were obtained from the application of amino acid”, also Nitrate accumulation decreased significantly by applying amino acid. A research on soy bean revealed that treatments of amino acids significantly improved growth parameters of shoots and fresh weight as well as pod yield (Sadak, Abdelhamid & Schmidhalter, 2014). According to the study of Mohga, Ibrahim, Hewidy and Hosni (2016) on octopus’ tree, the results obtained showed that in the two studied seasons, the use of amino acids in general increased plant height, number of leaves/plants, number of branches/plants, stem diameter, fresh and dry vegetative weight (root and shoot weight). El-Zohiri and Asfour (2009) on potato found that spraying of amino acids significantly increased vegetative growth expressed as plant height and dry weight of plant.

2.5.3 AGASI

AGASI fertilizer

An amino seaweed fertilizer named AGASI is an extremely flexible and efficient fertilizer that helps to promote several phenological phases of the crop and boost the crop performances qualitatively and quantitatively. AGASI has a low molecular weight which makes it quickly penetrate the leaves when it is applied by foliar application. It contains 19 amino acids combined with brown seaweed properties and selected carboxylic acids. It also consists of more than 70 minerals, vitamins and enzymes. AGASI contains important carboxylic acids such as lactic acid, acetic acid and butyric acid (AGAFERT, 2013; Caribbean Chemicals and Agencies Limited, 2018).

AGAFERT (2013) stated: “AGASI is the right instrument to help manage the crop to their maximum potential, enhancing both metabolic and enzymatic activities of the plant due to its high content of natural vitamins derived from its diverse organic matrix including seaweed”

The product AGASI is composed as follows (W/W) (AGAFERT, 2013):

- N: 2,0%
- N organic: 2,0%
- P_2O_5: 0,2%
- K_2O: 1,5%
- Organic carbon: 11,4%
- Amino acids: 10,4%
- Organic acids: 2,6%

According to Khan et al. (2019), better root production accompanied by the addition of amino acids will improve the fixation of nitrogen, which induces nutrient uptake by an enhanced root surface. Amino acids function as a growth regulator, improving the initiation of roots, and allowing the plant to consume more nutrients, which can promote endogenous hormone homeostasis and is important for the development of hairy roots at the optimum level (Khan et al., 2019).

2.5.4 Foliar fertilizers

A quick way to feed the plants is through foliar feeding. Leaves are made up of stomata along which the nutrients are absorbed. The normal soil fertilization is not replaced by the foliar feed, but can support it to a large extent. The use of foliar fertilizers can have a lot of benefits for the soil, such as: stimulating the growth of beneficial bacteria in the soil; better drainage; less compact soil and higher water holding capacity (BioSolutions, 2018).

2.6 Pest and diseases

Pepper can be affected by a lot of pest and diseases. Some of the important pest and diseases of pepper are:

Whiteflies

The symptoms of whitefly are yellowing of the leaf (due to larvae sucking) and black coloring of the underlying leaves (soot dew). The eggs are deposited at the bottom of the leaves. The larvae (1-2 mm) are oval, light green and covered with white wax. The mature insects (± 1 mm) are white and have clear wings. For the control of white fly, one must not plant too closely. Pruning grown-up plants is required so that the wind can pass through them (Milton, 2005). There are still white flies during rainy seasons, but they reproduce faster when it is dry (Kendrick, 2018).

Figure 2: White fly infestation at the bottom of a leaf. Reprinted from Chilli Cultivation by Lim, n.d. Copyright by Agriculture Research Centre.

Anthracnose
Anthracnose can be found in the field or develop after postharvest decay of pepper. Symptoms of anthracnose are small, water soaked, sunken lesions that rapidly expand (up to 3 – 4 cm in diameter). They appear on mature fruits in dark red to light tan color. Overhead irrigation or rainfed conditions are one of the causes of anthracnose, it can also be seedborne or present is crop residues. They have a wide host range. For the control of pepper, one should use pathogen-free seeds, crop rotation, fungicides, remove affected fruits and plants, prevent mechanical damage as much as possible, harvest fruits in immature stage and apply adequate fertilization (Berke et al., 2015). According to Prom et al. (2014), cumulative rainfall, frequency of rainfall and relative humidity are critical factors for disease development. The plants suffer more in rainy seasons than in dry seasons from anthracnose (Prom et al., 2014).

Figure 3: Anthracnose. Reprinted from Chilli Cultivation by Lim, n.d.
Copyright by Agriculture Research Centre.

Mites
The symptoms are small persistent leaves that are narrow, rough and scraped. Large leaves curl around the main grain down. In Pepper, the leaf is light green in color. The mites are very small (± 3 mm) (Milton, 2005). Rainfall does not make the mites go away, it just allows plants to recover and slows down the reproductive rate of mite species. Mites are often at some stage in each and every field. They can return to an outbreak situation if the weather returns to hot and dry (Ag professional, 2011).

Figure 4: Mite Infestation. Reprinted from Chilli Cultivation by Lim, n.d. Copyright by Agriculture Research Centre.

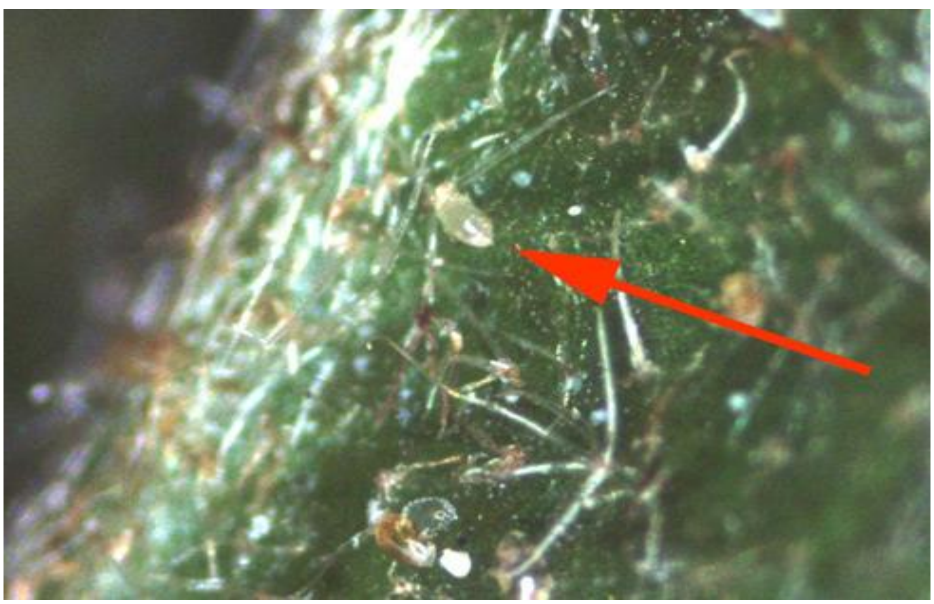

Figure 5: Mites. Reprinted from Mite Pests in Greenhouse Crops: Description, Biology and Management by Murphy, Ferguson and Shipp, 2014. Copyright 2014 by ministry of agriculture, food and rural affairs

3. METHODOLOGY

3.1 Research Methodology

This research was conducted on a dam of a field located at the C. R. Biswamitreweg, in Nickerie during the period 27 August 2019 - 28 April 2020. The research study was set up as a Completely Randomized Block Design with a single factor and three replicates (Figure 11). Observations and registrations were made every week after transplanting on plant height, leaf area, stem diameter, and flowers. At harvesting data collection started from the beginning of December and ended in April 2020, depending on the results on harvest parameters including the number of fruits /plants, length, and weight of pepper. At the end of the experiment, biomass, root-length, and mass were determined per treatment.

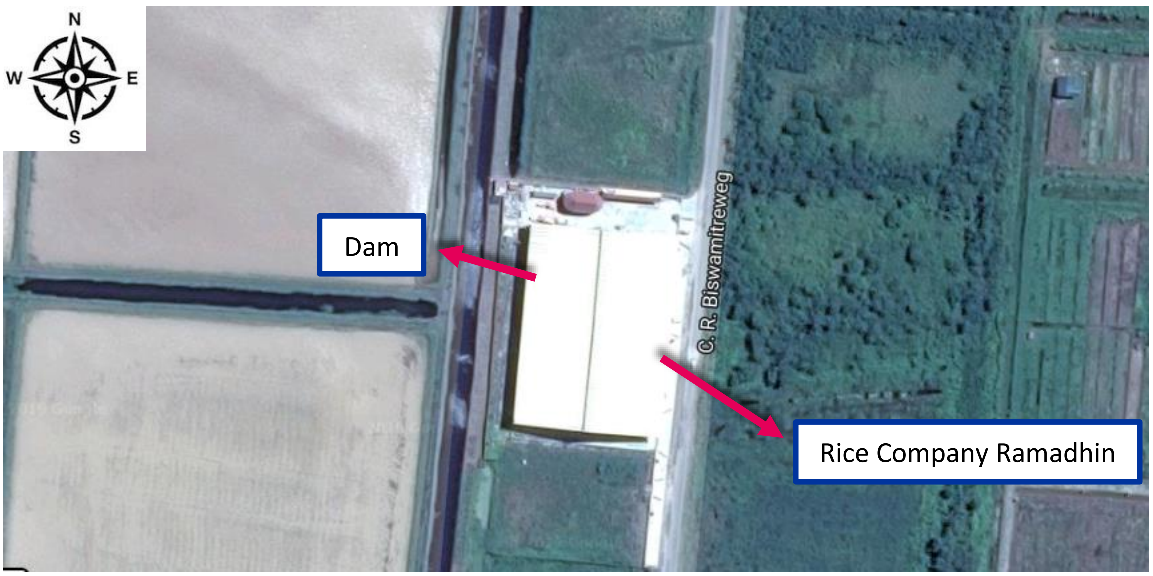

Figure 6: Map of the research location. Adapted from PlacesMap.net, by Map data 2020. Copyright 2020 by CNES Airbus Maxar Technologies

3.2 Preliminary study

3.2.1 Interviews

A preparatory study was conducted through interviews with five pepper farmers in the district Nickerie to gather information about which pepper cultivars they use, the cultivation method they apply, including which plant space and fertilization schedule they use. In addition, information was also collected about various pesticides that they use. Furthermore, interviews with representatives of the Ministry of Agriculture, Livestock and Fisheries (LVV) were carried out regarding the production of pepper in Suriname. Information about temperature, rainfall and relative humidity was obtained from the Meteorological Service in Suriname.

3.2.2 Soil analysis

For the analysis of the soil, where the experiment has been carried out, a randomized soil sample was collected to gain insight into the chemical properties of the soil pre- and post-cropping. Soil samples at depths of 0-20, 20-40 and 40-75 cm (pre-cropping) and 0-20 and 20-50 cm (post-cropping) were analyzed in the Soil Laboratory of the Faculty of Technology (FTeW) at the Anton de Kom University of Suriname (AdeKUS). The analysis was performed on pH $_{H2O}$, salinity (EC), % organic carbon (% C), % organic matter (% O. M), Total nitrogen (N-total), Total phosphorus (P-total), and Total potassium (K-total).

3.2.3 Seeding

The seeds were sown in a plastic container (Figure 7). After germination, healthy seedlings were transferred into trays (Figure 8). After about 6 weeks, healthy plants were transplanted in the field (Figure 9).

Figure 7: Seeds sown in a sowing tray of 60 by 35 cm

Figure 8: Healthy plants transplanted into planters

Figure 9: Seedlings of pepper

3.3 Experimental set up

A single factorial experiment with four treatments was conducted in a Randomized Complete Block Design in three replicates with *Capsicum chinense*. Each block was divided into 4 sub-plots with a length and width of respectively 6 meters and 2 meters, between each plot a space of 1 meter was left. Figure 10 shows a schematic representation of one block. Figure 11 shows the order of the 3 blocks with the coding.

The following four dosages of the amino acid preparation were used:
Treatment 1: D1 = 0.00 ml/liter (control treatment)
Treatment 2: D2 = 3.75 ml/liter
Treatment 3: D3 = 6.25 ml/liter
Treatment 3: D4 = 8.75 ml/liter

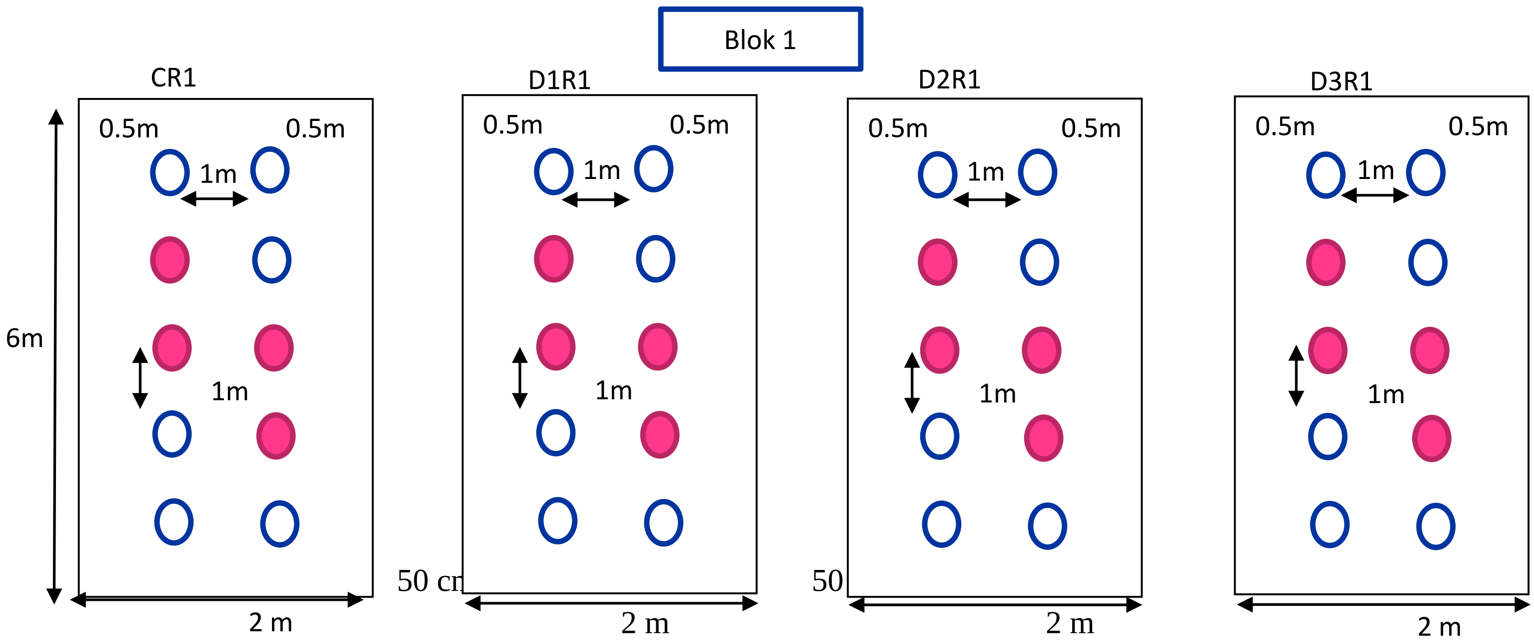

Figure 10: Schematic representation of the experimental layout of a block in the field.

The circles in pink indicate which plants are observed.

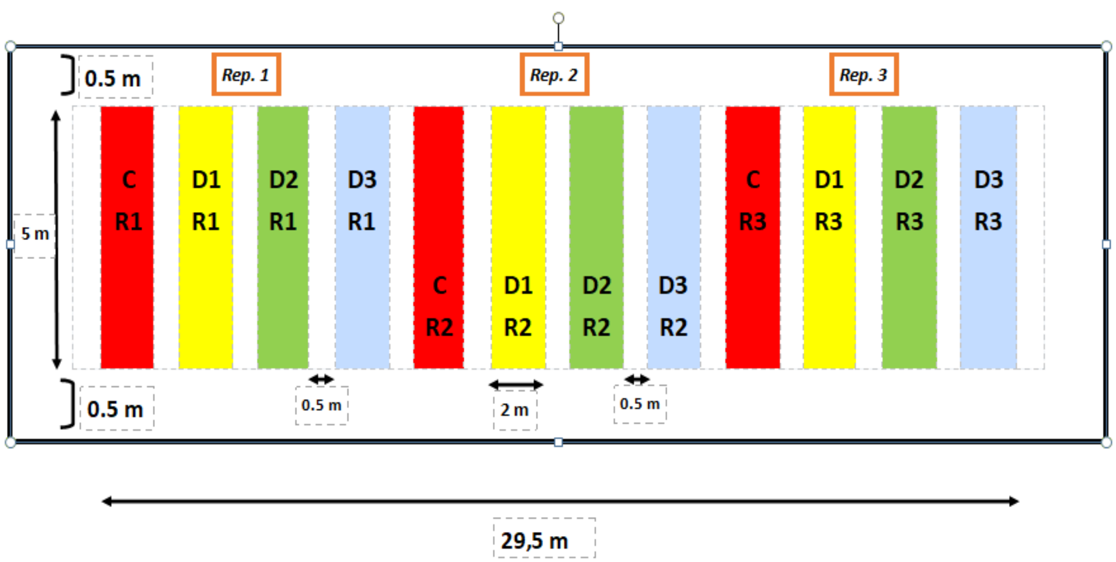

Figure 11: An overview of the experimental field

Variety Pepper:

For this experiment, the hot pepper variety of the Solanaceae family was used with a planting space of 1 x 1 m. The diameter of a planting hole was about 25 cm with a depth of 15-20 cm. Variety was not a factor, so a random breed was chosen for the study. Based on the number of flowers per node, seed color and apex fruit shape, it can be concluded that it concerns the variety *Capsicum chinense*. This was determined using the herbarium of the Anton de Kom University of Suriname (Villota-Cerón, Bonilla-Betancourt, Carmen-Carrillo, Jaramillo-Vásquez & García-Dávila, 2012).

3.4 Crop Management

In Table 5 a schedule of all crop management activities is listed.

Table 5: Crop management

DATE	DAS	Activity
Aug 27	0	Sowing seeds (300)
Sep 13	17	Planting healthy germinated plants in planters
Oct 5	35	Weed control with Carista (Herbicide)
Oct 6	36	Tillage
Oct 9	39	Weed control with Prowl (Herbicide)
DATE	**DAT**	**Activity**
Oct 24	0	Transplanting
Nov 1	7	Fertilization with NPK 26-0-0 (5 g/plant)
Nov 15	14	Fertilization with AGASI and NPK 15-15-15 (20 g/plant)
Nov 29	28	Fertilization with AGASI and NPK 15-15-15 (30 g/plant)
Nov 24	30	Fungicide application (Preventive) with Bellis and Carbendazim
Dec 13	42	Fertilization with AGASI and NPK 12-12-17 (50 g/plant).
Dec 27	56	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Dec 24	60	Fungicide application (Preventive) with Bellis and Carbendazim
Jan 10	70	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Jan 16	83	First harvest
Jan 23	90	Second harvest
Jan 24	91	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Jan 30	97	Third harvest
Feb 6	104	Fourth Harvest
Feb 7	105	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Feb 13	111	Fifth harvest
Feb 20	118	Sixth harvest
Feb 21	119	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Mar 6	133	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Mar 20	147	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)

Mar 26	153	Seventh harvest
Apr 3	161	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Apr 17	175	Fertilization with AGASI and NPK 12-12-17 (50 g/plant)
Apr 23	181	Eighth harvest

***Watering plants 1 or 2 times a day (From sowing to the end)
*DAS= Days after sowing You need to place 1
*DAT= Days after transplanting

3.5 Observations of variables during growth of pepper plants on experimental field

Table 6 provides an overview of all variables observed, the time at which the observations/registrations took place, as well as the used method.

Table 6: Data collection

#	Parameter	Time of observation/determination	Method
1	Plant height	During plant growth (after transplant; 1 time per week; 13 weeks long)	From the bottom of the plant to the highest growth point with a measure tape
2	Diameter of the stem	During plant growth (after transplant; 1 time per week; 11 weeks long)	Using a caliper
3	Number of flowers	From the first appearance of flowering (1 time per week; 6 weeks long)	Count
4	Number of fruits	After harvesting (1 time per week; 6 weeks long)	Count
4	Weight per pepper	After harvesting (1 time per week; 6 weeks long)	Weighing using scale
6	Circumference of pepper	After harvesting (1 time per week; 6 weeks long)	Using a measure tape
7	Length of pepper	After harvesting (1 time per week; 6 weeks long)	Using a ruler
7	Weight total yield per plot	After harvesting (1 time per week; 6 weeks long)	4 plants per plot
8	Plant weight	End of trial	1 plant per treatment (total 4 plants)
9	Root system	End of trial	1 plant per treatment (total 4 plants)
10	Taste test	At 4th harvest	Soya chunks prepared with 15 grams of pepper for each dosage were tastes and ranked from mild - medium - hot to extra hot.

The determination of the pepper varieties occurred at the herbarium of the Anton de Kom University of Suriname. At the end of the research photos of the different treatments are captured and the biomass of the upper plant part were measured.

3.6 Data collection and statistics

The collected data was organized using Electronic Xylophones Create Electronic Listening (EXCEL) to perform the appropriate statistical analysis, including the ANOVA and post-hoc tests. All results were statistically analyzed using a One-way analysis of variance where $P < 0.05$ using the statistics software program SPSS.

4. RESULTS AND DISCUSSION

4.1 General information

This chapter outlines and discusses the results obtained during the research project. First, the results of the soil analysis are presented in paragraph 4.2. Next, the results of the climatological conditions are presented in paragraph 4.3. After that, the results of the interviews are presented in paragraph 4.4. Then the results of the field study are presented in paragraph 4.5, following with the results of pungency of peppers in paragraph 4.6. At last, the discussion is presented in paragraph 4.7.

4.2. Results of soil analyses, before and after cropping

The collected soil samples were analyzed in the soil laboratory of the Anton de Kom University of Suriname for the physical and chemical characteristics of the soil. As shown in table 7, the soil analysis (pre cropping) revealed a soil pH fluctuating between 5.8 and 7.3, which is adequate for pepper cultivation. The EC-value of the soil fluctuated from 465 to 2380 micro S/cm. Looking at the organic carbon values, it can be concluded that there is enough organic matter in the upper layer of 0 to 20 cm, while not between '20 to 75' cm (Fenton et al., 2008). As per table 7 (compared to the values of Table 1 and Table 2) the total P and K for pepper are very high, but the total N seems to be medium for the layer 0 to 20 cm and low for the layer 20 to 75 cm.

According to table 8, the soil analysis (post cropping) revealed a soil pH fluctuating between 6.8 and 7.6, which is also adequate for pepper cultivation. The EC-value of the soil fluctuated from 598 to 2070 micro S/cm. From the organic carbon values, it can be concluded that there is enough organic matter in the upper layer of 0 to 20 cm, while not between '20 to 50 cm' (Fenton et al., 2008). According to the values of Table 7 and Table 8, the total P and K for pepper (post cropping) are very high and total N for both layers are low.

Table 7: Results of the pre- cropping soil analysis of the experimental site

Diepte (cm)	pH H2O (1:2.5)	EC (microS/cm)	Organic C (%)	Organic Matter (%)	Total N (%)	Total P (ppm)	Total K (ppm)
0-20	7.2	1003	2.90	5.80	0.20	624	4573
20-40	7.3	2380	1.36	2.72	0.09	310	5214
40-75	5.8	465	1.01	2.02	0.07	304	5049

Table 8: Results of the post- cropping soil analysis of the experimental site

Diepte (cm)	pH H2O (1:2.5)	EC (microS/cm)	Organic C (%)	Organic Matter (%)	Total N (%)	Total P (ppm)	Total K (ppm)
0-20	6.8	598	2.09	4.19	0.13	796	5459
20-50	7.6	2070	0.99	1.99	0.06	603	5812

*1 micro Siemens/centimeter = 0,1 milli Siemens/meter

4.3. Climatological conditions

Figure 12 shows that the average monthly temperature between October 2019 and April 2020 fluctuated between 27.5 and 29.1 °C. The ideal temperature for pepper plants is between 20 - 30 °C. It can be concluded that the temperature is between the ideal temperature range of pepper cultivation.

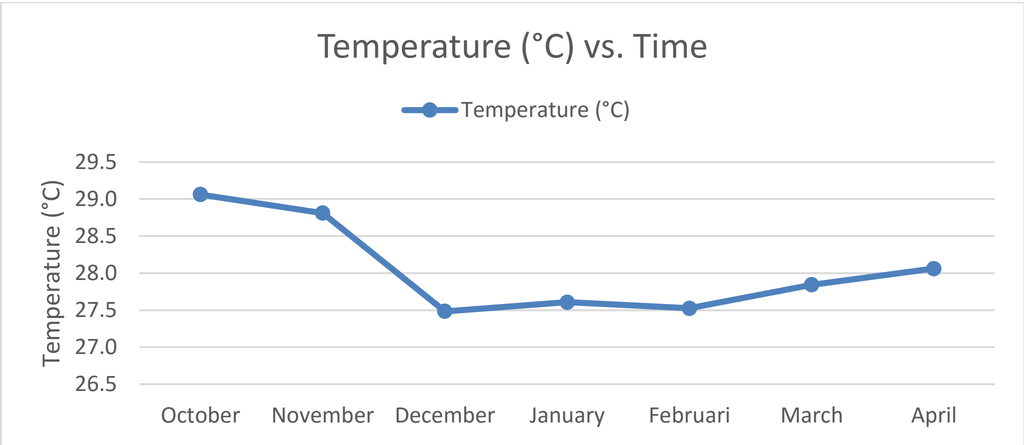

Figure 12: The mean Temperature from October 2019 - April 2020

According to figure 13, the highest monthly total precipitation was recorded in November and was 151.1 mm. The harvest of the fruits took place from January, 2 to April 23, 2020. The total rainfall during those months varied between 39.1 to 104.6 mm. The ideal precipitation for good pepper cultivation is more than 2000 mm, well distributed during vegetative growth and fruiting. The total rainfall the plants received was around 541.2 mm.

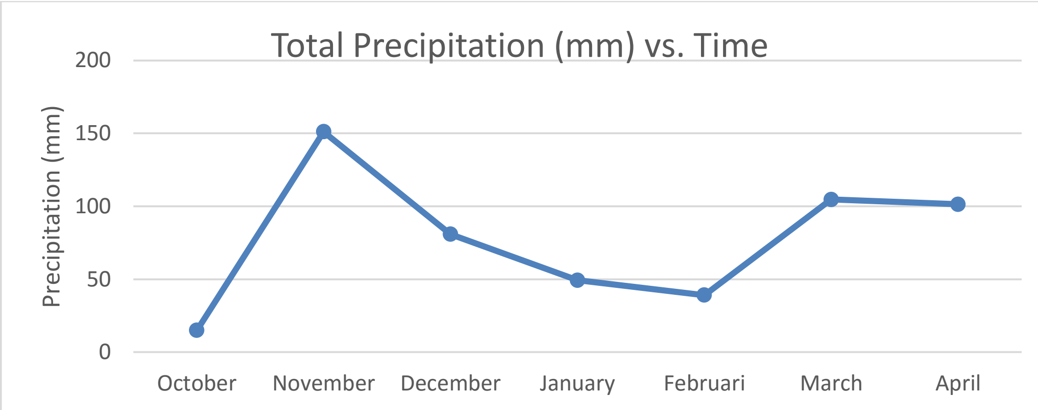

Figure 13: Total monthly precipitation from October 2019 - April 2020

From figure 14 it is observed that the monthly average relative humidity varied between 75 - 82 %. The optimum relative humidity required for pepper plants varies between '55% to 65%'.

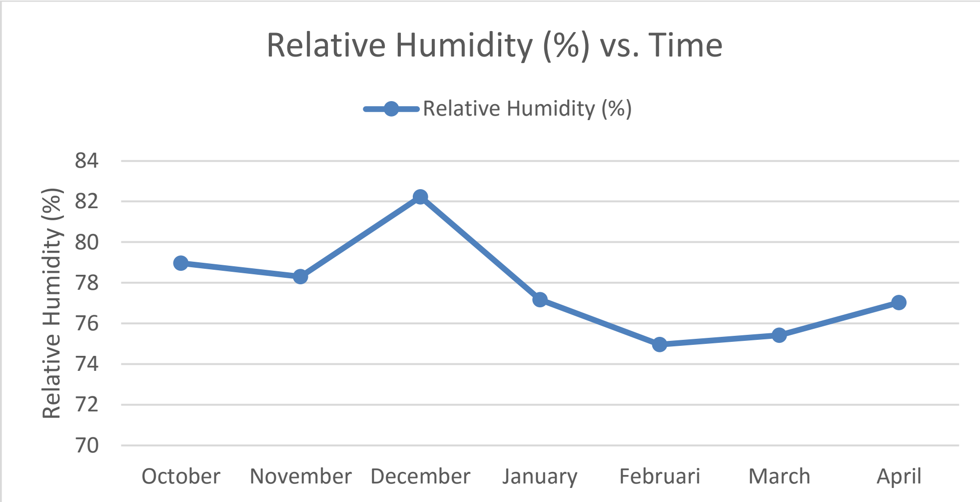

Figure 14: The mean Relative Humidity from October 2019 - April 2020

4.4 Interviews

On 26 September 2019, five pepper farmers were interviewed. Several questions were asked about the cultivation system they apply, their personal experiences, pests and diseases and postharvest activities. The farmers interviewed are full time farmers from Nickerie. Besides pepper (*Capsicum chinense*) they also plant eggplant, lady fingers, tomato, long yard beans and parsley on commercial scale. In Appendix 1 Table 12, a summary of the survey of the farmers is presented in a table form.

According to the interview, it appears that all five farmers are using the pepper variety used in this study. According to all they just call it 'de rode peper' variety. It is called 'rode peper' because of the red color of the peppers. The number of years of experience these farmers have varies from 5 - 32 years. Pepper is grown in open field by all these farmers, each using a distinct plant distance of 1 by 1, 1.2 by 1.5, 0.8 by 0.6, 0.6 by 1.5 and 0.8 by 1.2-meter respectively in the row and between the rows. In this research, the planting distance used was 1 by 1 meter. For further cultivation, all the farmers harvest their own seeds.

They plant 500 -5000 pepper plants every season. About 40% of the farmers stated that the pepper production during rainy seasons produces a higher yield compared to the dry seasons. However, the majority (60%) indicates that adequate water supply is important for pepper plants to achieve optimal production during the dry seasons (2 times a day depending on the humidity of the soil). This means that, for the production of pepper, irrigation is very important. Some farmers (40 %) say that the dry season peppers are spicier, while the majority (60 %) claim that the spiciness depends on the fertilization. According to these farmers, the more the fertilization, the less spicy the peppers are. In previous years, the production of peppers was higher than nowadays, as the plants are affected by anthracnose. The plants will produce a high yield throughout the season if the cultivation of the peppers is done properly.

In general, these farmers use: NPK 15-15-15, NPK 20-15-15, NPK 12-12-17, white grain, Urea, phosphate, Patent Kali and INTEC (26 % N and 24 % S). Fertilization for the first time occurs 4 or 7 days after transplantation and begins at 20 grams, 60 % of the farmers fertilizes 40 – 60 grams every two weeks, 20 % fertilizes 15 -20 grams every week, while the remaining 20% fertilizes depends on the plant's situation. None of these farmers had heard of AGASI before. Mites, whitefly and anthracnosis are the pests and diseases that these farmers suffer from. They use insecticides and fungicides to combat these pests and diseases. In general, these farmers use: Antracol and Carbendazim as fungicides and Cure, Caprid, Roma waspoeder, Cetemax and Bactral as insecticides. The yield is 20 to 25 peppers per plant and the harvest takes place about 24 to 36 weeks.

According to the Product Development Agronomist, Jaggessar Chandriekapersad of Caribbean Chemicals, farmers suffer from the diseases in rainy seasons and the pests in dry seasons. In addition, he also indicated that the pest and diseases most pepper farmers suffer from are mites, whitefly and anthracnosis.

4.5 Field study

The parameters observed for this study are plant height, stem diameter, number of flowers and dropped flowers, fruit length, fruit circumference, single fruit weight, total fruit weight, biomass, and root weight.

4.5.1 Plant height

In Figure 15 small differences are seen in the plant height from week 7 – week 14. The lowest plant height average was recorded for Dosage 4 (74.3 cm), while the highest plant height average was recorded for Dosage 3 (80.8 cm). According to the ANOVA analysis (Table 11, Appendix 2) there were no significant differences (p>0.05) recorded among the different treatments.

Figure 15: Plant height over time

4.5.2 Stem diameter

From figure 16 it can be noted that there were some slight differences noticed in the stem diameter from week 7 – week 14. The lowest average stem diameter was recorded for Dosage 1 and was 22.3 mm, while the highest average stem diameter was recorded for Dosage 2 which was 23.9 mm. According to the ANOVA analysis (Table 11, Appendix 2) there were no significant differences (P<0.05) among the different treatments.

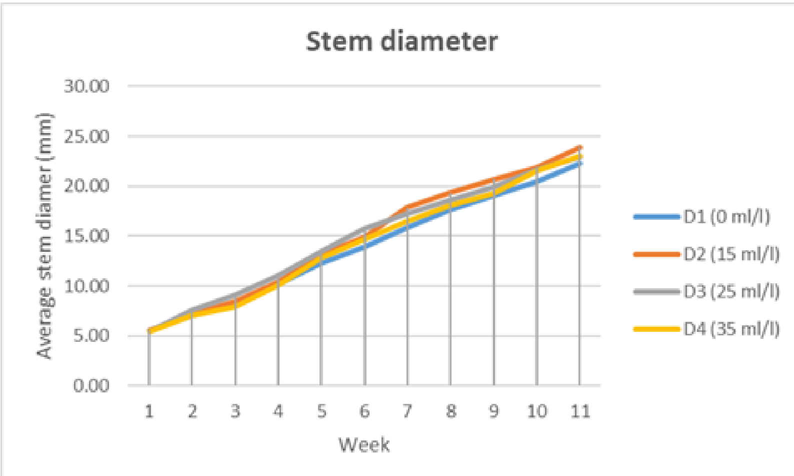

Figure 16: Stem diameter over time

4.5.3 Number of flowers and dropped flowers

In figure 17 and 18 small differences can be observed among the number of flowers and the number of dropped flowers for the different dosages. Figure 17 shows that the average number of flowers were higher for Dosage 2 and the lowest for Dosage 1 (control treatment), while figure 18 shows that the average number of dropped flowers were higher for the Dosages 2 and 4 and the lowest for the Dosages 1 and 3. The ANOVA analyses results (Table 11, Appendix 2) shows that there were no significant differences (P> 0.05) among the different dosages.

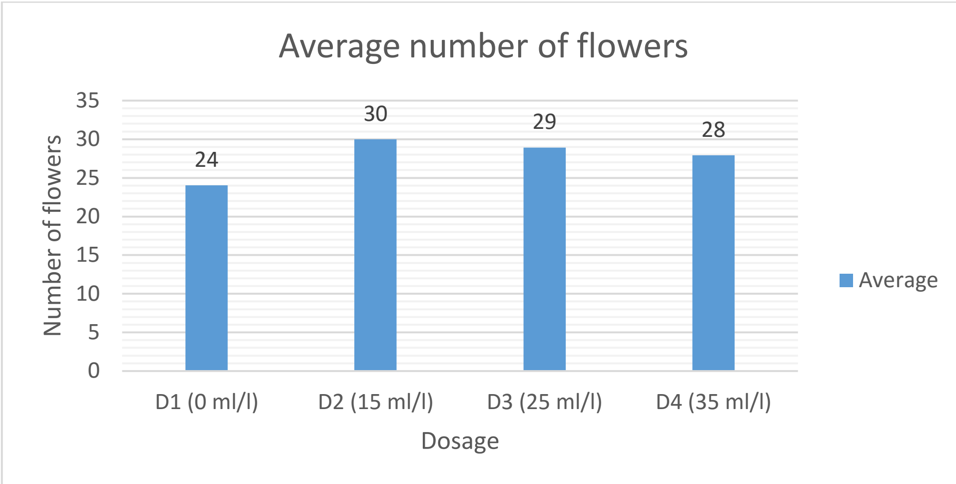

Figure 17: Number of flowers per dosage

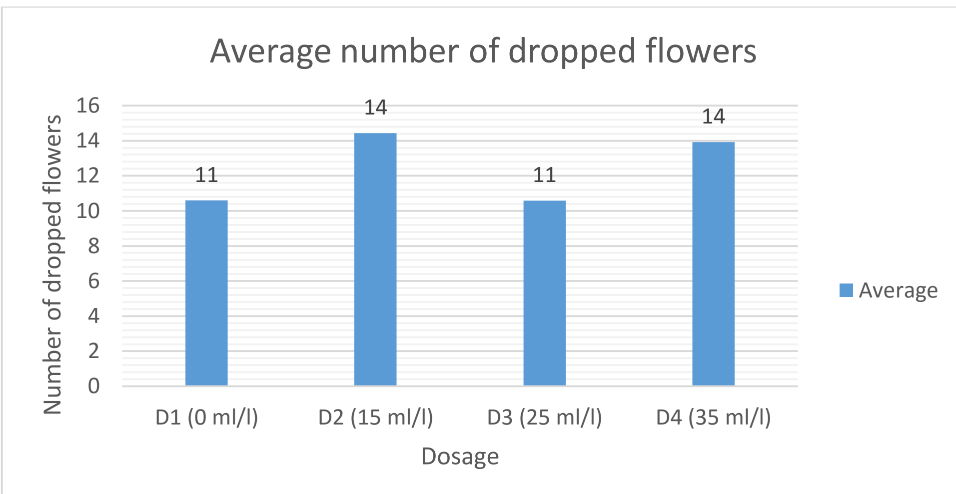

Figure 18: Number of dropped flowers per dosage

4.5.4 Fruit length

The tallest length of fruit (8.1 cm) was observed from D2 while the shortest fruit length (7.4 cm) was measured from D1 (control treatment). According to the One-way ANOVA test significant variation ($P<0.05$) was observed among the different treatments due to different doses of AGASI in respect of average fruit length of peppers (Table 12, Appendix 2). The tallest fruit length (8.1 cm) was statistically (Tukey HSD, Table 16) similar to D3 (7.8 cm) and D4 (7.8 cm).

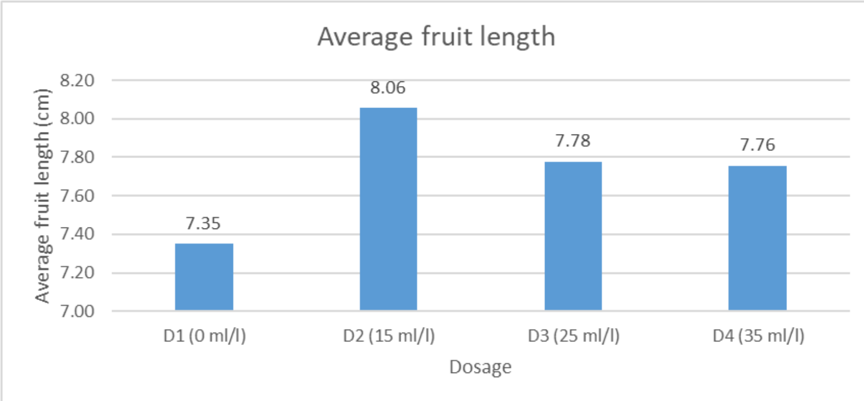

Figure 19: Average fruit length among various dosages

4.5.5 Fruit circumference

According to Figure 20, the highest fruit circumference (9.9 cm) was observed from D2 while the shortest (9.0 cm) was measured from D1 or control treatment. According to the One-way ANOVA significant influence ($P<0,05$) was observed of fruit circumference of pepper due to different doses of AGASI (Table 12, Appendix 2). The longest fruit circumference (9.9 cm) was statistically (Tukey HSD, Table 16) similar to D3 (9.6 cm) and D4 (9.3 cm). D1 was also statistically similar to D3 and D4.

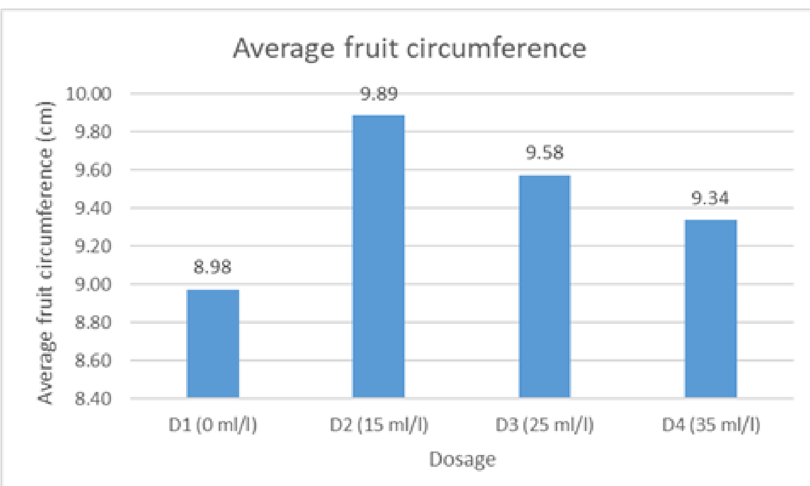

Figure 20: Average Fruit circumference among various dosages

4.5.6 Fruit weight

The highest single fruit weight (17.2 g) was observed from D2 while the lowest single fruit weight (13.8 g) was found in D1 (control treatment). According to the One-way ANOVA test significant variation ($P<0.05$) was observed among the different treatments due to different doses of AGASI in respect of average fruit weight of peppers (Table 12, Appendix 2). The highest single fruit weight

(17.2 g) was statistically (Tukey HSD, Table 16) similar to D3 (15.8 g), while the lowest single fruit weight (13.8 g) was statistically similar to D4 (15.3 g). There was also a statistical similarity between D3 and D4.

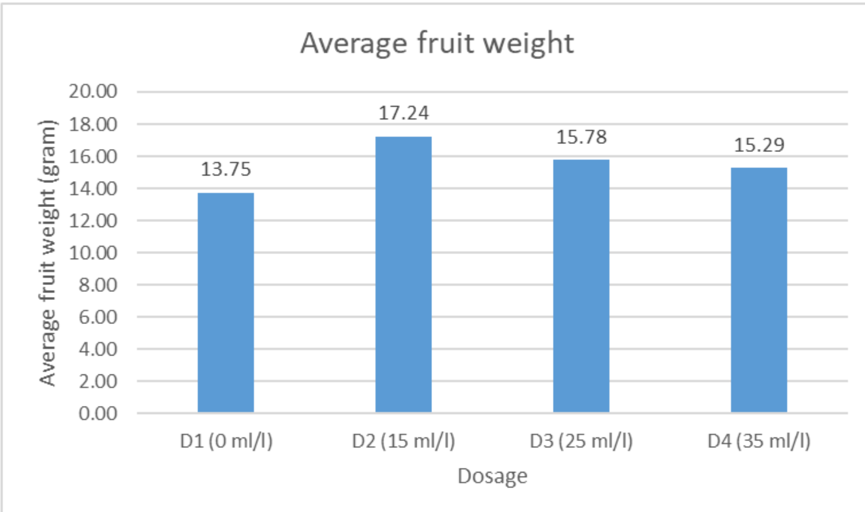

Figure 21: Average Fruit weight among various dosages

4.5.7 Total harvested pepper weight per plot

According to Figure 19, the highest total fruit weight was observed from D2 (1406.5 g), the lowest total fruit weight (1114.1 g) was measured from D1 (control treatment), while the total fruit weight of D3 (1271.17 g) and D4 (1347.79 g) were in the same range of weight. The One-way ANOVA test (Table 12, Appendix 2) showed that there was no significant difference ($P>0,05$) among the different treatments due to different doses of AGASI in respect of average total fruit weight of peppers.

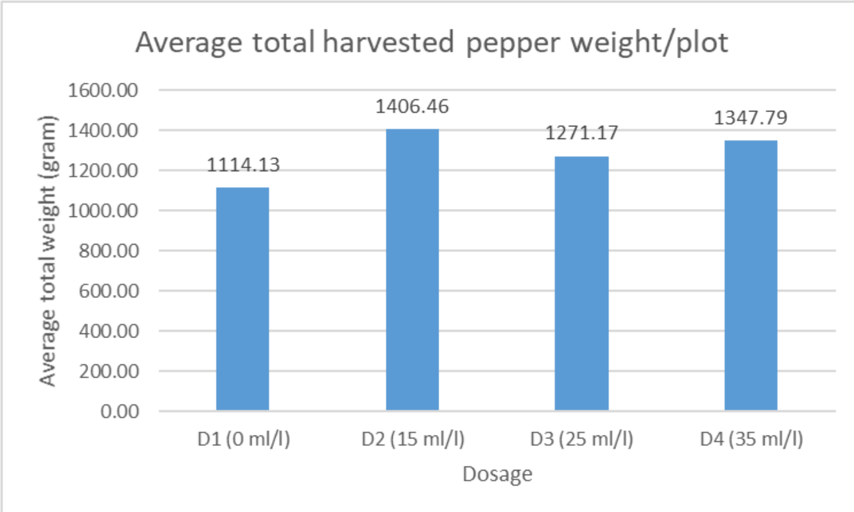

Figure 22: Average total fruit weight per dosage

4.5.8 Biomass

The highest plant weight (1838.3 g) was observed from D3, whereas the lowest biomass (653.3 g) was measured from D1 (control treatment). According to the One-way ANOVA test significant variation ($P<0.05$) was observed among the different treatments due to different doses of AGASI in respect of average root weight of pepper (Table 14, Appendix 2). The highest plant weight (1838.3 g) was statistically (Tukey HSD, Table 17) similar to D2 (1715 g) and D4 (1050 g) while the lowest biomass (653.3 g) was also statistically similar to D4.

4.5.9 Root weight

The highest root weight (175 g) was observed from D3, whereas the lowest root weight (81.7 g) was measured from D1 (control treatment). According to the One-way ANOVA test significant variation ($P<0.05$) was observed among the different treatments due to different doses of AGASI in respect of average root weight of pepper (Table 14, Appendix 2). The highest root weight (175 g) was statistically (Tukey HSD, Table 17) similar to D2 (163 g) and D4 (123.3 g) whereas the lowest root weight (81.7 g) was also statistically similar to D2 and D4.

4.5.10 Root system

There is a clear difference between the 4 root systems in Figure 23. The root system of D1 is smaller compared to the root system of the remaining dosages. Mendes et al (2016) also reported that the application of amino acids will result in well and strongly developed root systems.

Figure 23: Image of the root system of D1 (control treatment), D2 (3.75ml/l), D3 (6.25 ml/l) and D4 (8.75ml/l)

4.6 Pungency of peppers

For the taste test soya chunks were prepared with the same number of pepper (15 grams) for each dosage. In the taste test, 10 persons participated. The results of the sensory test, is shown in table 9 below. The pungency of the peppers was rated on a scale from mild – medium – hot – to extra hot. From table 9 it can be seen, that the majority of respondents ranked the peppers of Dosage 2 as extra hot, Dosage 4 as hot, Dosage 3 as medium and Dosage 1 as mild.

Table 9: Percentage of people ranking the Pungency of the peppers from mild to extra hot

Pungency (%)	Mild	Medium	Hot	Extra hot
Dosage 1	50	40	0	10
Dosage 2	0	0	30	70
Dosage 3	40	60	0	0
Dosage 4	10	0	70	20

4.7 Discussion

Soil analysis

The pH value of the soil was within the pH range 6 – 8 which indicated that the pH was good for pepper cultivation (The garden helper, 2020). This indicates that the soil pH is suitable for the cultivation of pepper. According to (Marno, 2017), the EC value of every layer (Table 7 & 8) was within the optimum EC range for the cultivation of pepper. Which means that there was no need to increase or decrease the soil EC. The soil organic matter for productive soils range from 3 to 6 % (Fenton et al., 2008), which was the case for the upper layer (0-20 cm) of the soil. Grass were left on the surface of the soil after mowing, this could be the reason for enough carbon in the soil (Poeplau et al., 2016). According to the results of the pre-cropping analysis, nitrogen addition is required in the field to improve the growth and yield of pepper, while there was enough P and K according to the classification of Table 1 (Amisnaipa, Susila, Nursyams and Purnomo, 2016).

Climatological conditions

The average temperature differences during the months October to April were within the ideal temperature range (20 - 30 °C) for the cultivation of pepper (Berke et al., 2015). According to Ashilenje (2013) crop irrigation is necessary for pepper cultivation, when the rainfall value is below 2000 mm. The optimum relative humidity for peppers varies between 55 - 65 %, while the relative humidity for this study was 10 - 17 % higher than the optimum humidity, which indicates that there were possibilities for diseases during the whole cultivation phase (Antonios, 2013). But because of the preventive cultivation system (treating the plants in advance with fungicides and pesticides for pest and diseases the plants were prone for) little to no pest and diseases were observed, this could also be because of the increased tolerance against pests and diseases due to the application of AGASI (Mendes et al., 2016).

Growth parameters

The study of Mohga et al. (2016) indicated that the use of amino acids in general increased plant height, stem diameter, root- and shoot weight and other growth-related parameters. El-Zohiri and Asfour (2009) on potato also found that spraying of amino acids significantly increased vegetative growth expressed as plant height and dry weight of plant. The results obtained from this study partly do not agree with those results. There were no significant differences ($P<0.05$) observed among the dosages for plant height and stem diameter in comparison to the control treatment. But there were significant differences ($P<0.05$) observed for the root weight and biomass of the pepper plants. As the results show, there was a higher root weight recorded for the plants that were treated with amino acids compared to the control treatment. This result is also in agreement with the research of Khan et al. (2019) and Basha and El-Aila (2015). On the other hand, there is a higher biomass recorded for the plants that were treated with amino acids compared to the control treatment, this is in agreement with the statement of Sadak, Abdelhamid & Schmidhalter (2014), El-Zohiri and Asfour (2009) and Mohga et al. (2016). According to Mendes et al. (2016) amino acids increase flowering, which was the case in this study, where the treated plots showed a higher number of flowers with lower values of dropped flowers compared to the control treatment, but the results were not significantly different ($P<0.05$).

Fruit and yield parameters

The results showed that the plants treated with Dosage 2 gave the highest results for fruit length, fruit circumferences and single fruit weight. On the contrary, Dosage 1 (control treatment) provided the lowest results. The increase in fruit length, fruit circumference and single fruit weight brought by amino acids has also been reported by Mendes et al. (2016). The results are to some extent in agreement with Sadak et al. (2014), who observed an improvement in fresh weight as well as pod yield of soybean with treatments of amino acids. Also, according to AGAFERT (2013), AGASI is the right product to help manage the crop to reach its maximum potential. According to Mendes et al. (2016), the application of amino acids as a foliar on plants of Bell pepper, increased the fruit characteristics such as diameter and the length of fruits, but there were no changes noticed in the quantity and total productivity, which also was the case for the total weight of pepper/plot in the study in Suriname. A greater fruit length and fruit circumference can cause production to increase in number of buckets.

According to Dacam (2015), alanine, glycine and proline function as taste precursors. The pepper pericarps (Zou, Ma and Tian, 2015 & Kim et al., 2019) and AGASI (AGAFERT, 2013; Caribbean Chemicals and Agencies Limited, 2018) did contain those amino acids. Which could possibly be the reason for the taste differences in the peppers. The majority of respondents (70 %) ranked the peppers of Dosage 2 as extra hot, while Dosage 1 (control treatment) was ranked as the mildest pepper (50 %).

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The conclusions of this study were as follows:

- There are no significant differences ($P<0.05$) calculated for plant height, stem diameter, number of flowers and dropped flowers, but generally the plant treated with Dosage 2 performed better than the other dosages.
- The results indicated that the foliar spray of amino acids enhanced the fruit and yield parameters of the pepper plants.
- The results of the study showed that the optimum concentration of the amino acid was 3.75 ml/liter (15 ml/gallon).
- The root system, root weight and biomass are increased by applying amino acids.
- The hottest peppers are ranked for Dosage 2, while the mildest peppers are ranked for Dosage 1 (control treatment).
- The results of this research support the application of naturally occurring amino acid bio stimulants as a potential aid to stimulate plant growth and increase marketable yield of hot pepper plants, with minimal harmful risks to the environment and farm personnel.
- Farmers do not have knowledge about the use/function of amino acids.

5.2 Recommendations

The recommendations from this study are as follows:

- In order to gain a better understanding of the administering of amino acids, it is also possible to investigate whether the number of times amino acids are administered is relevant to the yield.
- The effect of amino acids needs to be investigated on different crops.
- Furthermore, it can also be investigated whether there is a difference in application in dry- and wet seasons over a one-year period.
- Furthermore, amino acid application can also take place through the soil. It is therefore also possible to check whether there is a difference between foliar application and soil application.

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APPENDICES

Appendix 1

Table 10: Results of the interview

	Jaggessar Parmanandsharma	Bhajan Krishnadath	Ganga Chanderdew	Ganga Ishwardath	Ganga Pradiepkoemar
Geslacht	m	m	m	m	m
Locatie	Biswamitre weg, (Dam van Baitali)	Waterloo	Europolder Serie 10 #148	Europolder Serie 10 #149	Europolder Serie 10 #149
Leeftijd	57	55	53	47	48
1) Hoe lang bent u reeds bezig met het telen van peper? (Jaren)	5	30	20	32	25
2) Welke peper variëteit teelt u? Rode of gele (bekende naam)?	Madame Jeanette, Rode peper	Madame Jeanette, Adjuma en Rode peper	Madame Jeanette, Adjuma, paprika (rode en gele) en Rode peper	Madame Jeanette, Adjuma en Rode peper	Madame Jeanette, Adjuma en Rode peper
3) Plant u in de vollegrond of in potten?	Vollegrond	Vollegrond	Vollegrond	Vollegrond	Vollegrond
4) Wat is de plantafstand van de planten in de rij en tussen de rijen van een plantbed?	1 m in de rij en 1 m tussen de rij	120 cm in de rij en 150 cm tussen de rij	80 cm in de rij en 60 cm tussen de rij	60 cm in de rij en 150 cm tussen de rij	80 cm in de rij 120 cm tussen de rij
5) Wat is de afkomst van uw peperzaad?	Eigen zaden	Eigen zaden, soms lokale zaailingen	Eigen zaad	Eigen zaad	Eigen zaad
6) Hoeveel peperplanten heeft u?	500	500 - 1500	1000>	4000 - 5000	5000
7) Is de productie groter in de droge tijd of in de regentijd?	Regentijd	Regentijd	Geen verschil	Droge tijd (Maar genoeg en op tijd water geven)	Droge tijd (Maar genoeg en op tijd water geven)
8) Wat is de productie in de:	Regentijd: 60 emmers/week	Regentijd: 200 emmers/week	Regentijd en drogetijd:	Regentijd: 300 krat/week	Niet bijgehouden, naar schatting

regentijd en in de droge tijd?	Droge tijd: 40 emmers/week	Droge tijd: 50 – 60 emmers/week	Ongeveer 250 emmers/week	Droge tijd: 500 krat/week	20000 kg/ seizoen
9) Is de peper volgens u pittiger in de regentijd of in de droge tijd?	Droge tijd	Zelfde	Zelfde, afhankelijk van bemesting (Bij hoge bemesting worden de pepers minder pittig)	Zelfde, afhankelijk van bemesting (Bij hoge bemesting worden de pepers minder pittig)	Droge tijd
10) Wat is de productie geweest in de laatste 2 tot 3 jaren? (Zowel regen als droge tijd)?	Regentijd: 60 emmers/week Droge tijd: 40 emmers/week	Regentijd: 200 emmers/week Droge tijd: 50 - 60 emmers/week	Ongeveer 250 emmers/week. Sinds hij last heeft van anthracnose is de productie gedaald.	300 krat/week. De productie is dit jaar met 10 – 15 % gedaald, door anthracnose.	Niet bijgehouden, maar dit jaar is de productie door anthracnose gedaald.
11) Wanneer is de productie het hoogst? (In welke maanden van het jaar)	Mei, Juni en July	April, mei en Juni	September, oktober, November, februari en maart	Augustus, September, februari, maart en april	Mei, Juni
12) Wat voor bodem type heeft u?	Kleibodem	Kleibodem	Kleibodem	Leemgrond	Leemgrond
13) Welke meststoffen gebruikt u?	NPK, 12-12-17 en Stikstof	NPK 15-15-15, NPK 20-15-15, NPK 12-12-17, wittekorrel en INTEC (26 % N en 24 % S).	Blauwkorrel, Ureum, Intec en fosfaat.	NPK 15-15-15, Intec, Ureum en soms Patentkalium en fosfaat	NPK, Kalium en Ureum
14) Hoeveel weken na inzaai van peper voert u de eerste bemesting uit?	5 dagen na overplanten bemesten met vloeibaar kippenmest	1 week na overplanten	1 week na overplanten	4 – 5 dagen na overplanten	4 dagen na overplanten. Als de planten nog in zaaibakken zijn doet hij aan bladbemesting
15) Hoe vaak bemest u de peperplanten? (En hoeveelheid in grammen)	2 weken na overplanten bemesten met ongeveer 20 gram blauw en groene	Elke week 15 tot 20 gram.	Hij bemest afhankelijk van de toestand van de peper.	Om de 2 weken (50 tot 60 gram)	Om de 2 weken (ongeveer 40 gram)

	korrel. Hierna ongeveer 50 gram (om de 2 weken)				
16) Bent u op de hoogte van het product AGASI? Indien ja, hoe vaak maakt u gebruik van dit product?	Nee	Nee	Nee	Nee	Nee
17) Heeft u last van ziekten en plagen? Zoja, welke ziekten en plagen? En kunt u aangeven in welke ontwikkelingsfase van de plant deze ziekte of/en plaag voorkomt?	Ja, Mijten (vanaf overplanten) Witten vlieg (6 weken na overplanten)	Ja, Mijten (vanaf overplanten) Witten vlieg (6 weken na overplanten)	Ja, Anthracnose (Als de plant al vruchten draagt) Wittevlieg (Als de plant al vruchten draagt)	Ja, Anthracnose (Als de plant al vruchten draagt) Wittevlieg (Als de plant al vruchten draagt)	Ja, Anthracnose (Als de plant al vruchten draagt) Wittevlieg (Als de plant al vruchten draagt)
18) Welke pesticiden gebruikt u tegen welke plaag en welke ziekte?	Mijten > CURE (insecticide/miticide) Wittevlieg > Caprid	Wittevlieg > Bestac Mijten >Roma waspoeder	Anthracnose > Antracol Wittevlieg > Caprid en Cetamax	Anthracnose > Antracol Wittevlieg > Bactral	Anthracnose > Antracol en Carbendazim Wittevlieg > Cure en Caprid
19) Hoe vaak irrigeert u in de regentijd? En in de droge tijd?	Regentijd: Geen irrigatie Droge tijd: 2 keer/dag	Regentijd: Geen irrigatie Droge tijd: Bijna elke dag middels sproeiers	Regentijd: Geen irrigatie Droge tijd: Om de ene dag middels sproeiers	Regentijd: Geen irrigatie Droge tijd: Elke dag middels sproeiers	Regentijd: Geen irrigatie Droge tijd: Elke dag middels sproeiers
20) Wat is de opbrengst per plant?	Ongeveer 25 pepers/plant	Droge tijd: ongeveer 15 pepers/plant Regentijd: ongeveer 25 pepers/plant	Ongeveer 20 pepers/plant	Ongeveer 25 pepers/plant	Ongeveer 25 pepers per plant
21) Hoe lang oogst u? (Uitdrukken in weken)	Ongeveer 28 weken	Ongeveer 24 weken	Ongeveer 24 weken	Ongeveer 36 weken	Ongeveer 36 weken
22) Neemt de oogst in tijd af (met hoeveel %,	Ja, vanaf 4de maand met 30 tot 35%	Ja, daalt met ongeveer 30 %	Ja, daalt met ongeveer 50 %	Ja, daalt met ongeveer 30 %	Nee, maar pepers worden wel kleiner

worden de pepers kleiner)	Pepers worden kleiner	Pepers blijven van zelfde formaat (Goed bemesten)	Pepers worden kleiner	Pepers worden kleiner	
23) Hoe slaat u uw peper op?	Geen opslag, direct verkocht	Geen opslag, direct verkocht	Opslag (1 dag) in plastic zakken.	Geen opslag, direct verkocht	Geen opslag, direct verkocht

Appendix 2

Table 11: One-way analysis of variance of the growth parameters of pepper

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Plant height	Between Groups	110.933	3	36.978	.066	.978
	Within Groups	26951.301	48	561.485		
	Total	27062.234	51			
Stem diameter	Between Groups	7.134	3	2.378	.066	.977
	Within Groups	1436.714	40	35.918		
	Total	1443.848	43			
Number of flowers	Between Groups	140.910	3	46.970	.707	.557
	Within Groups	1595.052	24	66.460		
	Total	1735.961	27			
Number of dropped flowers	Between Groups	91.056	3	30.352	.382	.767
	Within Groups	1908.615	24	79.526		
	Total	1999.671	27			

Table 12: One-way analysis of variance of the fruit and yield parameters

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fruit length	Between Groups	2.011	3	.670	4.164	.015
	Within Groups	4.508	28	.161		
	Total	6.519	31			
Fruit Circumference	Between Groups	3.562	3	1.187	4.321	.013
	Within Groups	7.694	28	.275		
	Total	11.256	31			
Fruit weight	Between Groups	49.845	3	16.615	8.852	.000
	Within Groups	52.554	28	1.877		
	Total	102.399	31			
Total fruit weight	Between Groups	348178.819	3	116059.606	.402	.753
	Within Groups	8080673.278	28	288595.474		
	Total	8428852.097	31			

Table 13: Post hoc test of the fruit and yield parameters of peppers

Multiple Comparisons

Dependent Variable		(I) Dosage	(J) Dosage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Fruit length	Tukey HSD	Dosage 1	Dosage 2	-.70292*	.20063	.008	-1.2507	-.1551
			Dosage 3	-.42625	.20063	.170	-.9740	.1215
			Dosage 4	-.40500	.20063	.205	-.9528	.1428
		Dosage 2	Dosage 1	.70292*	.20063	.008	.1551	1.2507
			Dosage 3	.27667	.20063	.522	-.2711	.8244
			Dosage 4	.29792	.20063	.460	-.2499	.8457
		Dosage 3	Dosage 1	.42625	.20063	.170	-.1215	.9740
			Dosage 2	-.27667	.20063	.522	-.8244	.2711
			Dosage 4	.02125	.20063	1.000	-.5265	.5690
		Dosage 4	Dosage 1	.40500	.20063	.205	-.1428	.9528

			Dosage 2	-.29792	.20063	.460	-.8457	.2499
			Dosage 3	-.02125	.20063	1.000	-.5690	.5265
Fruit Circumference	Tukey HSD	Dosage 1	Dosage 2	-.91333*	.26210	.008	-1.6289	-.1977
			Dosage 3	-.59958	.26210	.125	-1.3152	.1160
			Dosage 4	-.36500	.26210	.514	-1.0806	.3506
		Dosage 2	Dosage 1	.91333*	.26210	.008	.1977	1.6289
			Dosage 3	.31375	.26210	.634	-.4019	1.0294
			Dosage 4	.54833	.26210	.180	-.1673	1.2639
		Dosage 3	Dosage 1	.59958	.26210	.125	-.1160	1.3152
			Dosage 2	-.31375	.26210	.634	-1.0294	.4019
			Dosage 4	.23458	.26210	.807	-.4810	.9502
		Dosage 4	Dosage 1	.36500	.26210	.514	-.3506	1.0806
			Dosage 2	-.54833	.26210	.180	-1.2639	.1673
			Dosage 3	-.23458	.26210	.807	-.9502	.4810
Fruit weight	Tukey HSD	Dosage 1	Dosage 2	-3.49583*	.68501	.000	-5.3661	-1.6256
			Dosage 3	-2.02917*	.68501	.030	-3.8994	-.1589
			Dosage 4	-1.54167	.68501	.134	-3.4119	.3286
		Dosage 2	Dosage 1	3.49583*	.68501	.000	1.6256	5.3661
			Dosage 3	1.46667	.68501	.165	-.4036	3.3369
			Dosage 4	1.95417*	.68501	.038	.0839	3.8244
		Dosage 3	Dosage 1	2.02917*	.68501	.030	.1589	3.8994
			Dosage 2	-1.46667	.68501	.165	-3.3369	.4036
			Dosage 4	.48750	.68501	.892	-1.3828	2.3578
		Dosage 4	Dosage 1	1.54167	.68501	.134	-.3286	3.4119
			Dosage 2	-1.95417*	.68501	.038	-3.8244	-.0839
			Dosage 3	-.48750	.68501	.892	-2.3578	1.3828

*. The mean difference is significant at the 0.05 level.

Table 14: One-way analysis of variance of the root weight and biomass of pepper plants

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Root weight (gram)	Between Groups	16141.667	3	5380.556	4.283	.044
	Within Groups	10050.000	8	1256.250		
	Total	26191.667	11			
Biomass	Between Groups	2825708.333	3	941902.778	6.771	.014
	Within Groups	1112933.333	8	139116.667		
	Total	3938641.667	11			

Table 15: Post hoc test of the root weight and biomass of pepper plants

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Dosage	(J) Dosage	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Root weight (gram)	1	2	-81.667	28.940	.086	-174.34	11.01
		3	-93.333*	28.940	.048	-186.01	-.66
		4	-41.667	28.940	.512	-134.34	51.01
	2	1	81.667	28.940	.086	-11.01	174.34
		3	-11.667	28.940	.976	-104.34	81.01
		4	40.000	28.940	.543	-52.67	132.67
	3	1	93.333*	28.940	.048	.66	186.01
		2	11.667	28.940	.976	-81.01	104.34
		4	51.667	28.940	.346	-41.01	144.34
	4	1	41.667	28.940	.512	-51.01	134.34
		2	-40.000	28.940	.543	-132.67	52.67
		3	-51.667	28.940	.346	-144.34	41.01
Biomass	1	2	-1061.667*	304.540	.034	-2036.91	-86.42
		3	-1185.000*	304.540	.019	-2160.24	-209.76
		4	-396.667	304.540	.586	-1371.91	578.58
	2	1	1061.667*	304.540	.034	86.42	2036.91
		3	-123.333	304.540	.976	-1098.58	851.91
		4	665.000	304.540	.207	-310.24	1640.24

3	1	1185.000*	304.540	.019	209.76	2160.24
	2	123.333	304.540	.976	-851.91	1098.58
	4	788.333	304.540	.119	-186.91	1763.58
4	1	396.667	304.540	.586	-578.58	1371.91
	2	-665.000	304.540	.207	-1640.24	310.24
	3	-788.333	304.540	.119	-1763.58	186.91

*. The mean difference is significant at the 0.05 level.

Table 16: The effect of different levels of amino acids on yield contributing parameters of peppers

Treatments	Fruit length (cm)	Fruit Circumference (cm)	Fruit weight (gram)
Dosage 1 (control)	7.4 a	9.0 a	13.8 c
Dosage 2	8.1 b	9.9 b	17.2 a
Dosage 3	7.8 ab	9.6 ab	15.8 ab
Dosage 4	7.8 ab	9.3 ab	15.3 bc

Table 17: The effect of different levels of amino acids on root weight and biomass of peppers

Treatments	Root weight (gram)	Biomass (gram)
Dosage 1 (control)	81.7 a	653.3 a
Dosage 2	163.3 ab	1715 b
Dosage 3	175 b	1838.3 b
Dosage 4	123.3 ab	1050 ab