Variable performance of white-skinned *Ipomoea batatas* with and without insect herbivory using physical and chemical exclusion techniques

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CERTIFICATION

This is to certify that this project research was carried out by Omo Mary IJOGBE in the Department of Animal and Environmental Biology, Faculty of Life Sciences.

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DEDICATION

I dedicate my project research to Almighty God for His Divine strength, favor, mercy and grace upon my life. I also dedicate it to my parents for their moral and financial support.

ACKNOWLEGEMENT

It is my earnest intention to express my profound gratitude to Almighty God for his enabling grace and to all that have contributed in one way or the other to the successful completion of my project. My gratitude goes to my project supervisor Dr. I.N. Egbon for his constructive supervision which helped to bring out the best in me. Thank you very much sir. God bless you for your candid support. Also my sincere gratitude goes to the Head of Department Prof. (Mrs.) A.A Imaseun for her academic and moral support. My gratitude also goes to all my lecturers Prof. Mike Omogberale, Dr. Nosakhere O. Erhunmwuse and Dr. (Mrs) Edo.Taiwo.

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ABSTRACT

The use of pest control techniques in Agriculture have proven to be highly effective in addressing food insecurity and agricultural production issues. This study was conducted to compare growth and evaluate the yield of sweet potato under three different pest control techniques in relation to exposure to insect herbivory.These pest control techniques include physical exclusion, chemical exclusion and those without exclusion (no control). Sweet potato plants excluded physically were completely screened from herbivory using a net house, those excluded chemically were sprayed weekly with 0.01% Lambda-cyhalothrin and those without exclusion were fully exposed to herbivory. Stem length, number of leaves, number of runners, percentage herbivory and number of damaged leaves were parameters used to compare growth while tuber count, heaviest tuber and average tuber weight were used to evaluate yield. Sweet potatoes physically excluded significantly ($p < 0.05$) gave highest growth rates and this was evidently seen in their stem length, number of leaves and runners. Plants subjected to chemical exclusion and those without exclusion statistically had higher mean values in terms of yield than those physically excluded. However, the difference in yield from the three treatments did not vary significantly ($p > 0.05$) in tuber count ($H_2 = 2.34$, $p > 0.05$), heaviest tuber ($F_2 = 1.67$, $p > 0.05$) and average tuber weight ($H_2 = 4.24$, $p > 0.05$). Sweet potatoes allocate more resources on growth when completely screened off from insect herbivory as seen by those physically excluded but this is was not enough to warrant improved yield.

1.0 CHAPTER ONE INTRODUCTION

Ipomoea batatas Lam. (Convulvulaceae), commonly known as sweet potato, is a tropical tuber crop that is native to the Americas, particularly from regions that comprise Central America and South America (Claudio *et al*., 2020). The crop is important for both small and middle-scale growers with a potential to increase income and create jobs. Since its introduction, sweet potato has become the seventh most consumed food crop after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*), Irish potato (*Solanum tuberosum*), Barley (*Hordeum vulgare*) and cassava (*Manihot esculenta*) (ASHS, 2007; Janlow *et al*., 2015; CIP, 2017). Increased production of sweet potato can improve the socio-economic well-being of farmers and using improved varieties of sweet potato have positively contributed to yield (Andreas *et al*., 2007). While the white skinned variety is preferred in Brazil and Uganda, the increasing awareness of the value of vitamin A rich in orange variety, attracts much more consumers to the latter as opposed to the former (Andreas *et al* ., 2007).

During its vegetative phase, *I. batatas* hosts a community of organisms; some of which compromise growth and yields. Insects such as Sweet-potato butterfly *Acraea acerata* (Lepidoptera: Nymphalidae), sweet-potato hornworm *Agrius convolvuli* (Lepidoptera: Sphingidae) and *Cyclas puncticollis* (Coleoptera: Curculionidae) are well known for infesting *I. batatas* with an infestation rate of over 90% (Okonya & Kroschel, 2013; Tanzubil, 2015). These insect herbivores include foliage feeders, root feeders and vectors of virus (Sorensen, 2009; Smith & Beuzelin, 2015). Stem damage contribute greatly to yield loss and severe defoliation and root damage can account for total yield loss (Okonya & Kroschel, 2013). Foliage feeding insects of potato include *Agrius cingulata* and beet armyworm *Spodoptera exigua* (Lepidoptera: Noctuidae), whereas the notable root feeders are *Phyllophaga ephilida* (Coleoptera: Scarabaeidae), *C.*

formicarius elegantulus, Aphis gossypii (Homoptera: Aphididae) and *Bemisia tabaci* (Homoptera: Aleyrodidae) (Smith & Beuzelin, 2015; Ray & Ravis, 2005; Simmons & Abd-Raboul, 2007; Shonga *et al.,* 2013). Unlike *Cyclas* species, the root feeders such as wireworms, cucumber beetles and white grubs are cryptic feeders. To counter insect herbivory, *I. batatas* induce defenses (e.g., terpenes and phenolic compounds) to minimize or eliminate tissue loss (Janz *et al.*, 2000).

Potato production in developing countries is vital for food insecurity if susceptibility to pests and diseases are managed timeously and equipped with proper knowledge of its economic threshold. Economic threshold is the lowest pest population density at which control measures should be implemented to prevent economic damage (Ramsden *et al*., 2017). For thresholds to be effective, knowledge about the potential damage of an insect pest and tolerance of the host plant is needed as well as a reliable monitoring system. An array of herbivore management strategies e.g., chemical, physical, biological, sterile insect techniques, host plant resistance and integrated methods abound in literature (Lagnaoui *et al.,* 2000; Bassey, 2019; Okonya *et al*., 2014). The extent of herbivory that can sufficiently warrant control response without compromising crop yield is not well understood. Here, with the white variety of sweet potato as a model plant, the role of three pest management options viz.: physical, chemical and a no-control against insect herbivory were evaluated using growth parameters (leaf counts and stem lengths), crop yield, and percentage herbivory.

1.1 Aim and Specific objectives

Generally, to understand the role of pest exclusion in minimsing herbivory and improve plant fitness and yield of the white variety of *I. batatas* informed the execution of this study. To achieve this aim, the following specific objectives were to:

1. Compare and contrast the impact of insect herbivory on vegetative fitness parameter of white-skin colored potato using three management options.
2. Evaluate the plant yield under three different pest management practices in relation to exposure to insect herbivory.

2.0 CHAPTER TWO LITERATURE REVIEW

The genus *Ipomoea* has over 500 species of which *I. batatas* is only the economically viable member (Kreuze & Fuenktes, 2008). It is native to Central and South America but redistributed elsewhere with an estimated worldwide production of 104 million ton in 2011 (Pitrat, 2012; FAO, 2013). *I. batatas* is ranked the 7th most valued food crop in the world (ASHS, 2007; Janlow *et al.*, 2015; CIP, 2017). In Africa, Nigeria is the largest producer and second to China (FAO, 2014).

For man and animals, *I. batatas* remains a vital source of nourishment with low fat and protein content as well as carbohydrate, dietary fibers, antioxidant, Zinc, Potassium, Sodium, Magnesium, Manganese, Iron and Vitamin C. (NCSPC, 2006; Miranda, 2002; Bovel, 2007; Padmaja, 2009). The consumption of its tuberous roots and leaves can assist in tackling negative health issues caused by high incidence of malnutrition among women, pregnant women and children (Meira *et al.*, 2012; Mu *et al.*, 2017; Sigh, 2019). All these features point to sweet potato’s importance in mitigating food insecurity. Different varieties of *I. batatas* are suited to agro-climatic zones. In terms of taste, texture, total sugar and flesh color, sweet potatoes comprises white, yellow, orange and purple-skinned variety (Tumwegamire *et al.*, 2011). Notably, the consumption of orange fleshed sweet potatoes is known to increase vitamin A in the body. So researchers recommend the daily consumption of sweet potatoes to stimulate beneficial health effects (Wang *et al.*, 2016; Alam, 2021; Amagloh *et al.*, 2021).

Sweet potatoes grows well in wide range of agro-ecologies and soils with pH ranging 5.5-6.5 (Nedunchezhiyan *et al.*, 2012). It is an herbaceous perennial plant that can be vegetatively propagated by stem cuttings or plant sprouts from storage roots (Truong *et al.*, 2018). In comparison to other staple food crops, *I .batatas* has good adaptability to marginal growing conditions, short production cycle and high yield potential (Andrade *et al.*, 2009) .While some farmers prefer sole cropping system, others intercrop sweet potato with pigeon pea to ensure diversification of rural income, reduction in pest and diseases and better yield stability. In addition *I. batatas* has huge potential for improving the profitability of investors in the marketing system. Ensuring the sustainable production of *I. batatas* is an important challenge facing agriculture globally, as insect pest are the major biotic constraints affecting sweet potato yield and tuber quality (Vincent *et al*., 2013). Insect pests of sweet potatoes if not routinely controlled can cause 30-70 percentage reduction in tuber yield and quality (Mujica & Kroschel, 2013; Kroschel & Schaub, 2013). The major insects found on the crop include foliar feeders, stem and root feeders and virus transmitters. Members of the foliar pest are primarily lepidopterous and include the *Spodoptera exigua* (Lepidoptera: Noctuidae). They feed on the foliage causing irregular shaped holes and severe yield loss. Stem and root feeders constitute the most destructive sweet potatoes weevils.

Injury caused by insect pests severely limits the growth of sweet potatoes thus inducing the production of chemicals as a defense response in the plant. Glycoalkaloids naturally function as stress metabolite and help protect sweet potato plants from insect attack (Omayio *et al*., 2016). In addition several studies have concluded that compounds such as caffeic acids, coumaric acid esters inhibit sweet potato weevils feeding and reduce ovipositioning (Koussoube *et al* ., 2018). Different control strategies have been developed to adequately manage insect herbivores affecting sweet potatoes and these include chemical control, cultural management, host plant resistance, physical control and biological control (Bamalyi *et al*., 2011; Mulyinza *et al*., 2012; Stevenson, 2009). Insecticides have been a major tool used to combat root feeding pests in commercial production and remain the basis of insect pest management in most potato field around the world as more and more insecticides are becoming phased out due to environment concerns or become ineffective due to resistance development in targeted insect populations (Carlson, 1962). Currently used insecticides are in the organophosphate and pyrethroids classes. Pyrethroid insecticides commonly used on vine crops include the Lambda-cyhalothrin.

Cyhalothrin is a man-made insecticide and organic compound used as a pesticide (CAMEO, 2008). Synthetic pyrethroids, like the Lambda-cyhalothrin is often preferred as an active ingredient in insecticides because it remain effective for a longer period of time. It is used in cotton crops and is applicable to other crops (Robert, 2002). The minimum detection limit of Lambda-cyhalothrin is 0.005mg/kg (FAO, 1986). Cyhalothrin has different trade names such as Charge, Excalibur, Grenade, Hallmark, Icon, Shogan and Karate (CAMEO, 2008).

With the risk of some chemical insecticides being deregistered, alternative method of control must be considered. One of such method is the use of eco-friendly net covers or physical exclusion (Mujumdar, 2010). Net covers protect crops from excessive solar radiation and pests with better microclimate for crop growth compared to open field environment (Shahak *et al*., 2004). Shahak *et al*. (2004) reviewed the protective function of physical exclusion in enhancing microclimate for improved crop performance and quality. The use of netting leads to temperature build up within the netted house, however, this temperature tends to be higher under neutral colors such as white, multicolored and grey compared to colored net covers (Tanny *et al*., 2003). Physical exclusion is an effective barrier against large size insect pests especially those with body length > 2mm. Beyond pest prevention, stabilizing climate conditions and improving crops yield and quality are other possible benefits of physical exclusion.

Crops grown with net coverings maybe prone to some pathogens such as fursarium wilt, verticilliun wilt and anthracnose disease (Farr & Rossman, 2013). The anthracnose disease is a disease transmitted by the fungus *Colletotrichum* spp. This pathogen has been recorded on more than 40 host species worldwide including *I. batatas* (Farr & Rossman, 2013). The symptoms of anthracnose varies according to the relative humidity, temperature, age of the leaves and varieties. Some of the diagnostic characteristics of this fungus include yellowish circular leaf spots which turn brown as lesion expands, curling, wilting and gradual death of infected leaves. Although the fungus *Colletotrichum* cannot survive in soil for more than a few weeks, it is able to survive between growing seasons on crop debris (Jackson, 2002). When death occurs on the leaves of young plants and whole vines, a few lower leaves may survive but this usually results in no or poor yields. Jackson (2002) reported that though each stem has the ability to produce healthy storage root, plants affected by the fungus may have several small immature storage roots of reduced weight instead of the normal one or two heavy weighted roots. This study is focused on the use of chemical insecticides and net tags to control insect herbivores, and improving crop performance (growth and yield).

3.0 CHAPTER THREE MATERIALS AND METHODS

3.1 Study Site

The study was carried out from August 2021- January 2022 within the Botanical Garden of the University of Benin situated at Ugbowo Campus, Benin City Nigeria . The rainfall pattern in this region is bimodal with peaks in June/July and September respectively and accompanied by high atmospheric humidity with variable temperature ranging from 20 °C to 40 °C (Osawaru *et al*., 2014).

3.2 Plant preparation

Runners of white-skinned potato were obtained from an established potato farm in Benin City. The length of these runners were 40 cm. Each runner was cultivated in a plant bag made up of sacs for easy percolation of water using the same sandy loam soil. The top soil of the study site on which the planting bags were laid, was screened off using an opaque plastic sheet to minimize weed incursion and arthropod intrusion.

3.3 Plant fitness, scale of herbivory, and plant yield in response to herbivore exclusion

For fitness trials, three pest management conditions used were adopted, were: i). plants that were physically excluded from insect herbivores with no other forms of pest management, ii). plants that were chemically excluded from insect herbivore using a standardised systemic insecticide, and iii). plants that were neither excluded physically or chemically. Firstly, the physically excluded plants were achieved using fine mesh clothing (commonly known as organza). Secondly, those excluded using chemical were exposed to herbivory but treated with systemic insecticide weekly (a concentration of 0.01percentage of Lambda-cyhalothrin 2.5EC was prepared using serial dilution and 1ml of the prepared Concentration was diluted in 9 ml of H_2O). Lastly, plants that were neither excluded physically nor chemical were exposed to full herbivory.

Three parameters were used to assess growth weekly and these were: i). stem length (both the main runners and sub runners with the aid of a metric tape (cm), ii). total leaf count per potted plant, and iii). the number of stem runners: per potted plant. Herbivory was assessed using i). the total number of leaves with at least 0.5percentage insect-herbivore damage, ii). the percentage damage on the topmost 10 leaves, and iii). the percentage of general herbivory on each potted plant. Plant yield in response to herbivore exclusion was evaluated using the i). tuber count, ii). the average weight of tubers per potted plant and iii). the heaviest weight of tuber per potted plant.

Plate 1: General view of the experimental set up and the different treatments

3.4 Statistical analysis

All response variables were screened to ascertain whether they met the assumptions of parametric tests or not using statistical tools viz.: Shapiro-Wilk’s test, and Levene’s test and virtual tools (boxplots and Q-Q plots). All variables that violated the assumptions of normality, homogeneity of variance and showed presence of outliers were analyzed using to the appropriate non-parametric test i.e. Kruskal-Wallis test. All data validation and analyses were conducted in SPSS version 23.0.

4.0 CHAPTER FOUR RESULTS

4.1. Growth Performance of *I. batatas* with or without Insect Herbivory

The performance of *I. batatas* was assessed using number of leaves, stem length, number of runners, number of damaged leaves and percentage herbivory under three treatment conditions namely physical exclusion, chemical exclusion and no exclusion (no control).

4.1.1. Number of leaves

The potato plants that were physically excluded from herbivory, across all weeks of observation significantly ($H_2 = 0.04$, $p = 0.04$) had more leaves than those that were subjected to chemical exclusion and without exclusion. Specifically, in week one (i.e. three weeks after planting) no significant difference was observed as there was slight variation in the number of leaves from the three treatments ($H_2 = 3.21$, $p = 0.20$). At week two (i.e. four weeks after planting), physically excluded potato plants significantly ($H_2 = 9.42$, $p = 0.01$) had more number of leaves than those chemically and non-excluded. Also, plants subjected to chemical and non-exclusion relatively had similar number of leaves. Results from week three ($H_2 = 14.20$, $p < 0.001$), four ($H_2 = 16.90$, $p < 0.001$) and five ($H_2 = 12.45$, $p < 0.001$) also showed similar trends. However, Potato plants from week six ($H_2 = 6.68$, $p = 0.04$) and 15 ($H_2 = 1.69$, $p = 0.43$) followed a different trend with chemically excluded plants recording more number of leaves followed by those physically and non-excluded respectively. Result from this two weeks were not significantly different ($p > 0.05$) (Figure 1).

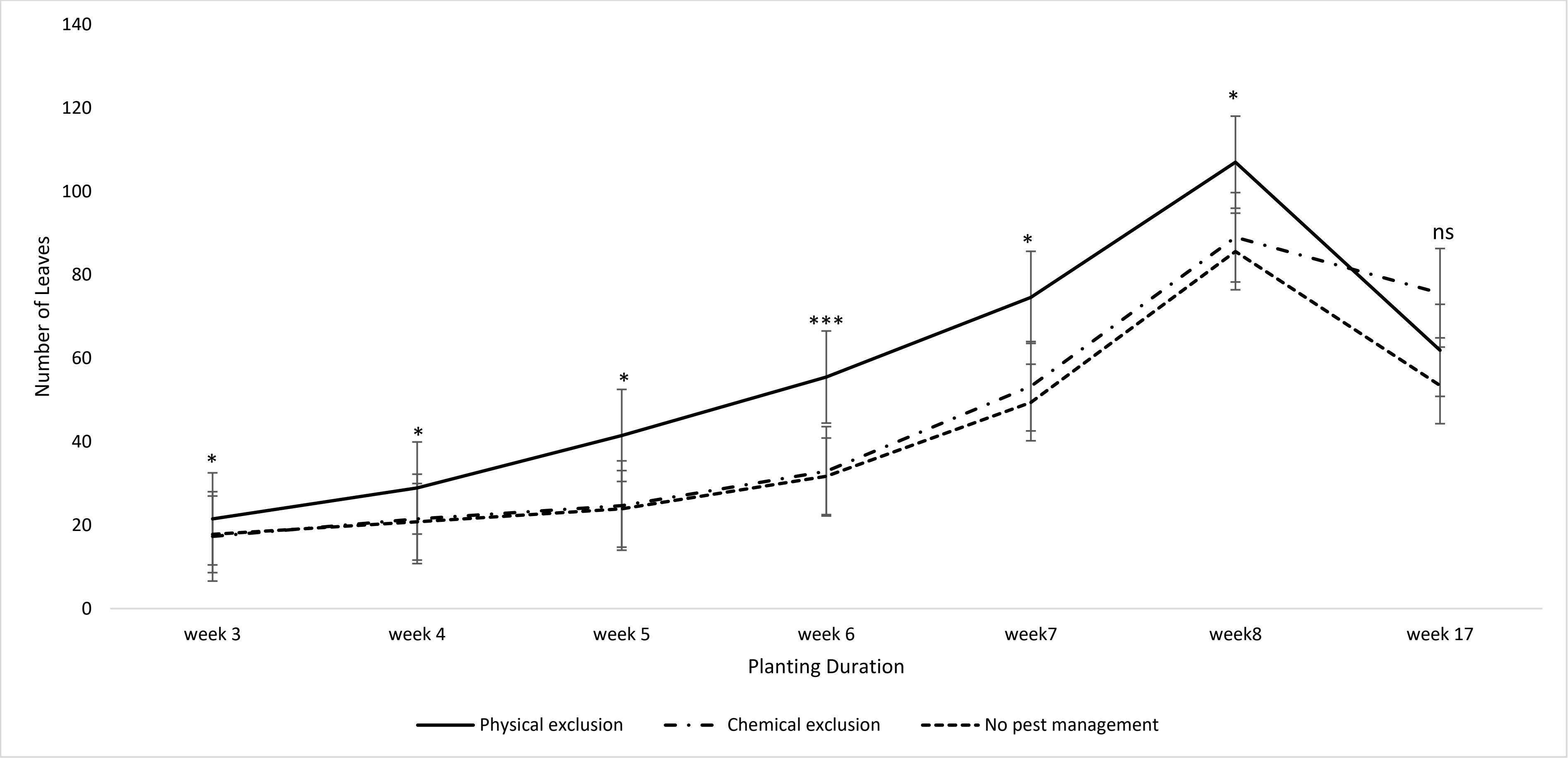

Fig 1: Variation in number of leaves from sweet potato plants physically, chemically and non-excluded. NOTE: ns- $p > 0.05$**; ***$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

4.1.2. Stem Length

Physically excluded potato plants generally attained the highest stem length with significant difference (H_2 = 18.35, $p < 0.001$) recorded all through 15 weeks (i.e. 17 weeks after planting) of cultivation. The graphical presentation in Figure 2 shows that from week one (H_2 = 7.23, $p = 0.03$), two (H_2 = 12.84, $p < 0.001$), three (H_2 = 17.45, $p < 0.001$), four (H_2 = 19.38, $p < 0.001$) and five (H_2 = 18.98, $p < 0.001$) chemically and non-excluded potatoes had similar increase in stem length which were significantly different ($p < 0.001$). However, at week six (H_2 = 19.59, $p < 0.001$) and 15 (H_2 = 18.35, $P < 0.001$) non-excluded plants recorded higher stem length compared to that of the chemically excluded (Figure 2).

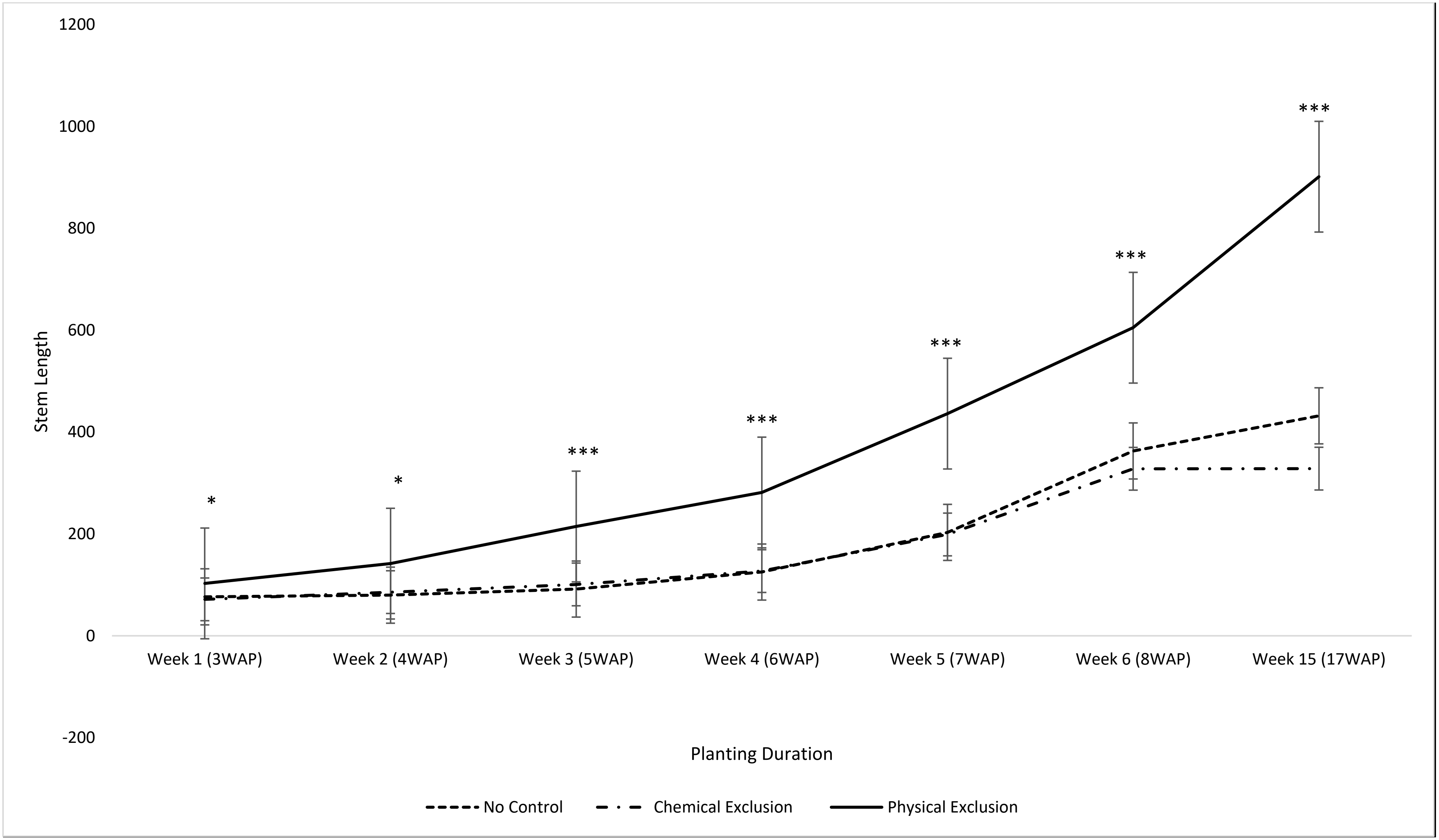

Fig 2: Variation in stem length of sweet potato plants physically, chemically and non-excluded. NOTE: ns- $p > 0.05$; *****$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

4.1.3. Number of Runners

It was noted that the highest overall number of leaves were recorded from runners obtained from plants physically excluded (H_2 = 2.17, p = 0.34) than those that were not excluded and chemically excluded. No significant difference ($p > 0.05$) was established from week one (H_2 = 0.04, p = 0.98), three (H_2 =4.74, p = 0.09), four (H_2 = 1.08, p = 0.58), five (H_2 = 5.06, p = 0.08) and six (H_2 = 2.17, p = 0.34) and 15 (H_2 = 2.69, p = 0.26). However, significant interaction only occurred at week two (i.e. four weeks after planting) (H_2 = 6.91, p = 0.031). Figure 3 clearly shows fluctuations in the performance of plants from non-exclusion and physical exclusion from week one to 15.

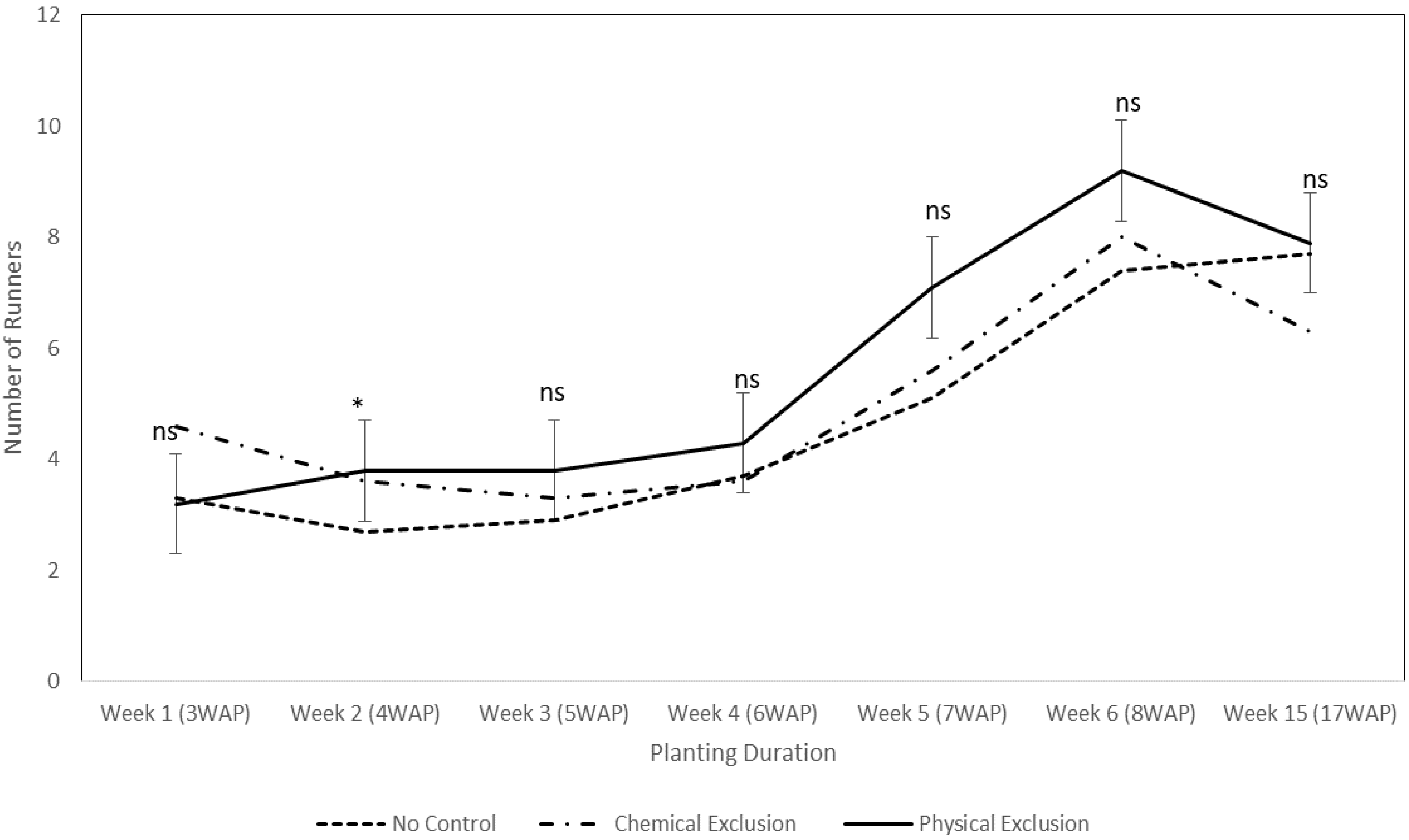

Fig 3: Variation in number of runners of sweet potato plants physically, chemically and non-excluded. NOTE: ns- $p > 0.05$; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$

4.1.4. Damaged Number of Leaves

Significant interaction ($p < 0.05$) was established from plants under physical, chemical and no exclusion at week five ($H_2 = 14.02$, $p = 0.001$) and six ($H_2 = 6.57$, $p = 0.04$). Apart from these two weeks, no significant difference was recorded. Assessment from week one ($H_2 = 1.16$, $p = 0.56$), two ($H_2 = 3.45$, $p = 0.18$), three ($H_2 = 3.38$, $p = 0.18$), four ($H_2 = 5.04$, $p = 0.08$), five (H-statistic = 14.02, $p < 0.001$), six ($H_2 = 6.57$, $p = 0.04$) showed that plants that were chemically excluded recorded the lowest number of damaged leaves. At week six ($H_2 = 6.57$, $p = 0.04$) and 15 ($H_2 = 2.50$, $p = 0.29$), an increase in the number of damaged leaves occurred. Both physically and non-excluded potato plants experienced a similar trend in the number of damaged leaves from week one to three. However from six to eight weeks after planting, a clear difference was observed from physically excluded plants recording more damaged leaves compared to non-excluded plants (Figure 4).

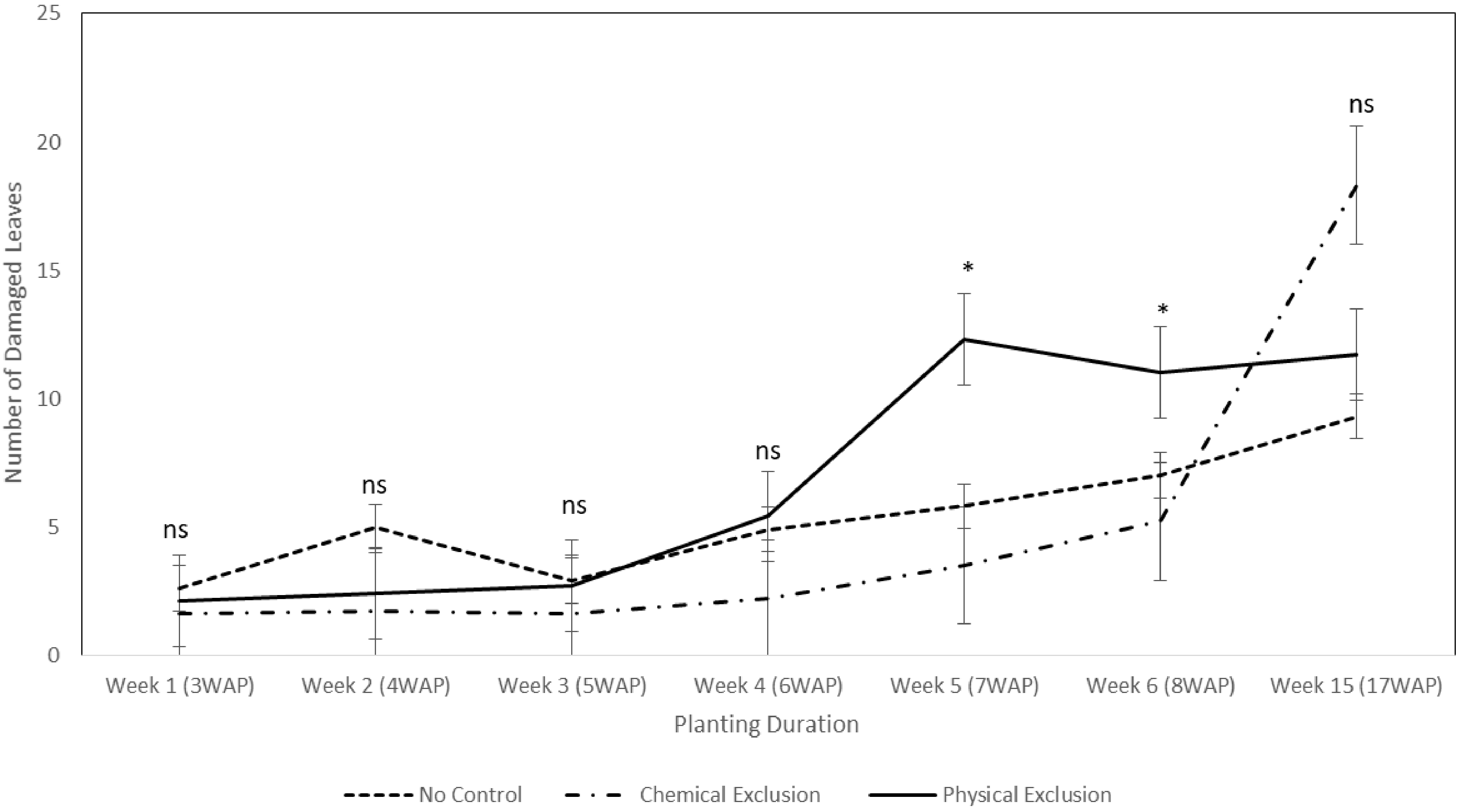

Fig 4: Variation in the number of damaged leaves of sweet potato plants physically, chemically and non-excluded. NOTE: ns- $p > 0.05$; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

4.1.5 Percentage Herbivory

Generally, chemically (H_2 = 3.33, p = 0.19) excluded potatoes incurred higher percentage herbivory than physically and non-excluded potato plants. Result from percentage herbivory only recorded a significant difference at week five (H_2 = 7.11, p = 0.03). These results varied on a weekly basis and was not significantly different at week one (H_2 = 3.53, p = 0.17), two (H_2 = 1.73, p = 0.42), three (H_2 = 0.57, p = 0.78), four (H_2 = 3.00, p = 0.22), six (H_2 = 0.09, p = 0.09) and 15 (H_2 = 3.33, p = 0.19) (Figure 5).

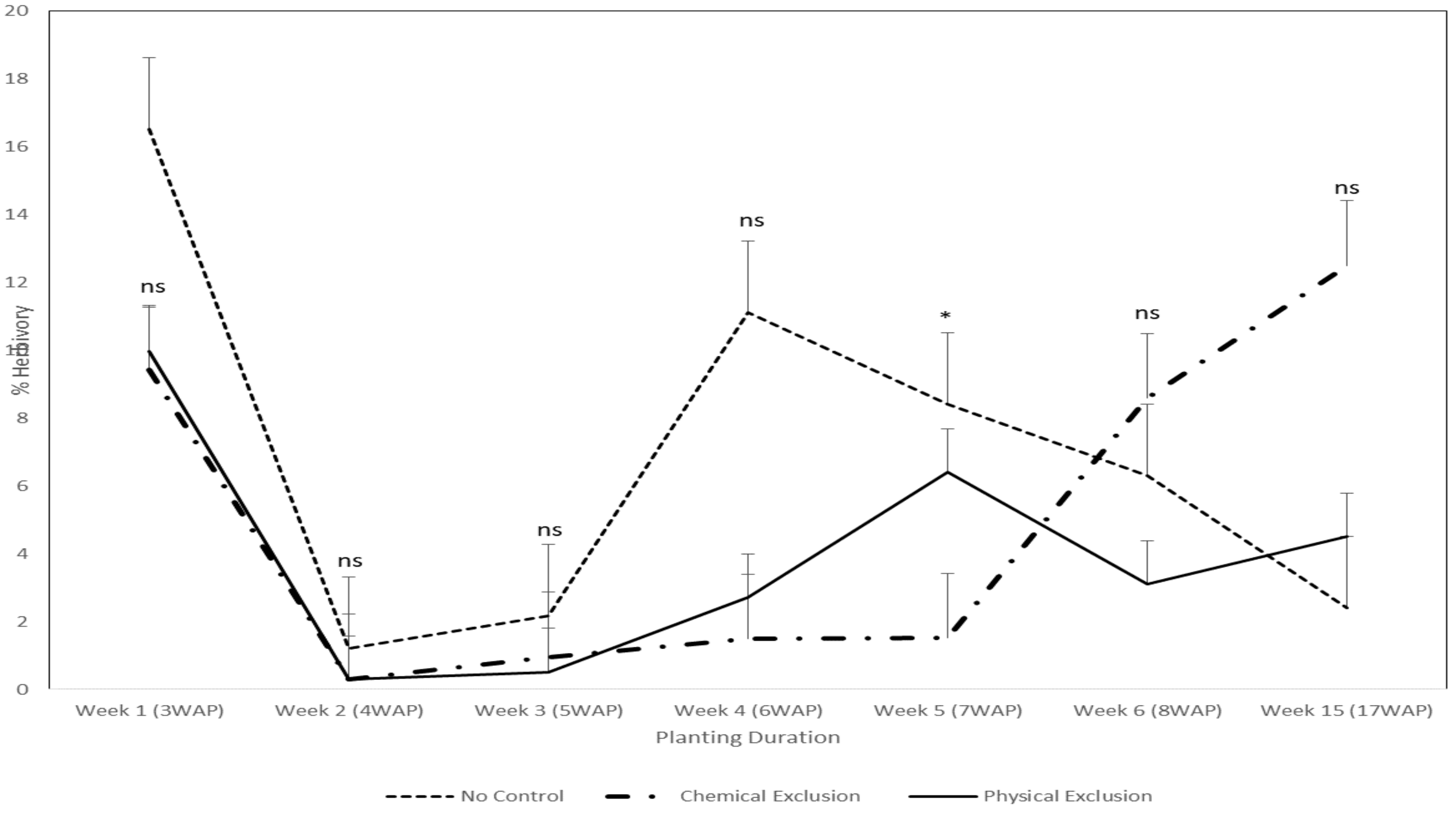

Fig 5: Variation in percentage herbivory of sweet potato plants physically, chemically and non-excluded. NOTE: ns**-** $p > 0.05$; *$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$.

4.1.6. Yield Performance of *I. batatas*

Growing *I. batatas* under the three treatments influenced its yields in terms of average tuber weight, tuber count and heaviest tuber. Results obtained showed no significant difference ($p > 0.05$), however plants under the chemical exclusion recorded the highest mean values in terms of average tuber weight ($H_2 = 4.24$, $p = 0.12$) while the lowest was recorded in the physical exclusion Heaviest tuber weight ($F_2 = 1.67$, $p = 0.21$) also followed similar trend to that of average tuber weight with highest and lowest values obtained under chemical and physical exclusion respectively.

Highest tuber count ($H_2 = 2.34$, $p = 0.31$) was recorded for non-excluded plants, followed by those under chemical exclusion and lastly physical exclusion ($H_2 = 2.70$, $p = 0.26$).

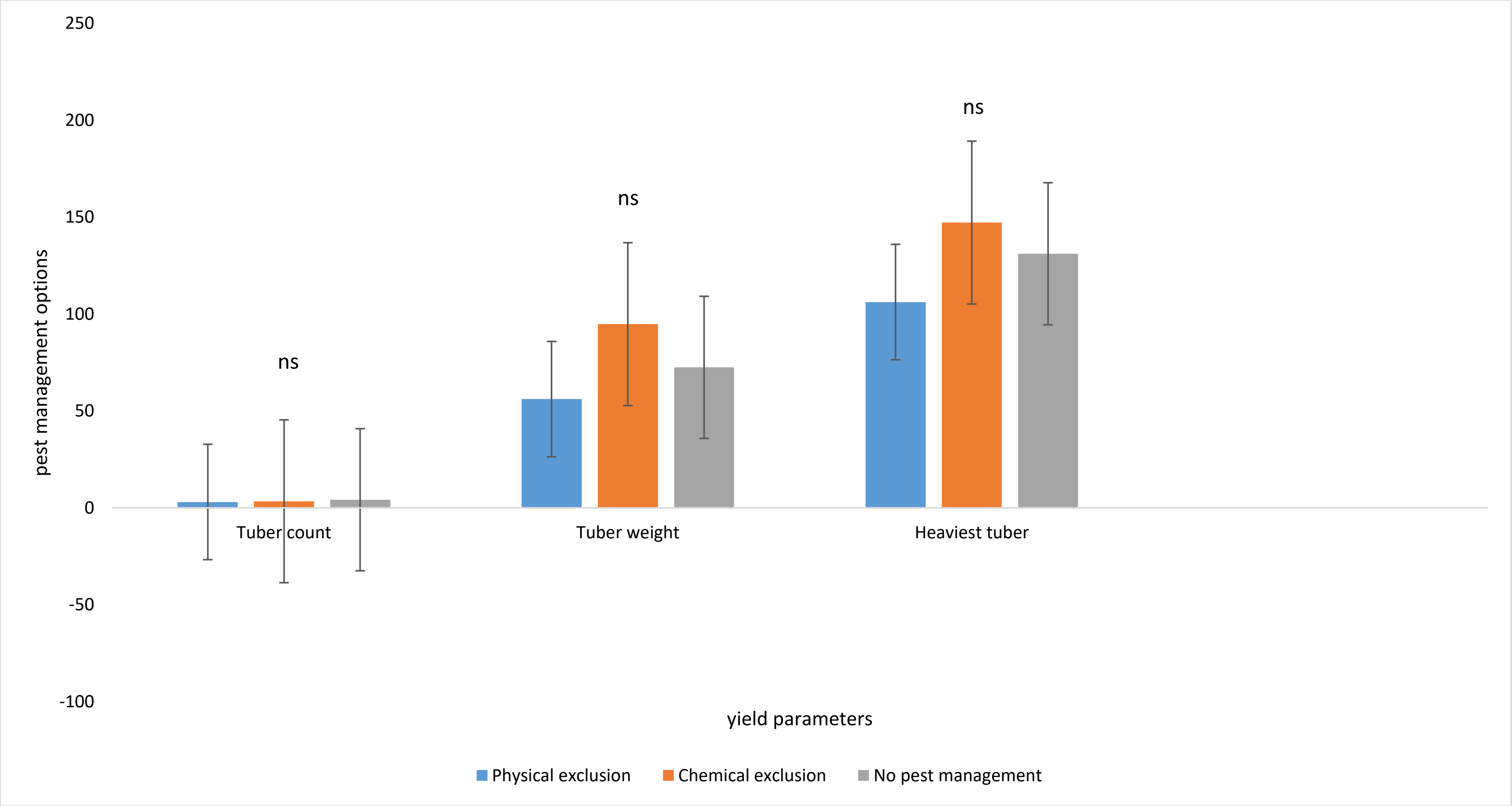

Figure 6: Performance of yield across three P**ests management options**. Physical exclusion was completely screened off from insect herbivory, Chemical exclusion was sprayed with insecticides and No pest management was fully exposed to Herbivory. NOTE: ns**-** $p > 0.05$; $*p \leq 0.05$; $**p \leq 0.01$; $***p \leq 0.001$.

5.0 CHAPTER FIVE DISCUSSION

The present study investigated the performance of white skinned *Ipomoea batatas* with and without insect herbivory using three treatments. Six parameters were used in this study namely number of leaves, stem length, number of runners, number of damaged leaves, percentage herbivory and yield.

Physically excluded plants invested more resources on growth as opposed to those with chemical exclusion and those without any exclusion (no control). Vegetative performance of both chemically and non-excluded potato plants points to the existence or contribution of external factors such as sunlight, water, space and insect pests. The outcome of this study is consistent with Abdrabbo *et al*. (2013) which suggests that vine performance in screened house provides a favorable microclimate conditions and ward off insect herbivory. Nonetheless potato plants treated with chemicals and those without any treatments were prone to interactions with insect herbivores. Such uninterrupted or continual interactions with herbivores may have made the plant to redirect their costly resources in producing anti-herbivore induced defenses against potential herbivores. Secondary defense is costly for plants as its implementation imposes a substantial demand for resources enough to compromise growth (Garcia *et al.,* 2021; Kirschbaum, 2011). This reduction in growth appears to result from plant allocation decisions intended to maintain optimal fitness while responding to stress from insect herbivores.

Similarly, number of leaves and number of runners of potato plants chemically and non-excluded were lower than those of the physically excluded. Data from week six (Figure 1) recorded reduction in the number of leaves for potato plants physically excluded. This can be attributed to the occurrence of the fungi disease Anthracnose, judging from the symptoms observed alongside comparison with previous articles (Yonhhgao, 2014). Yonhhgao (2014) reviewed some diagnostic characteristics of this fungus such as yellowish, circular leaf spots which turns brown as lesion expands, curling, wilting and gradual death of leaves which were similarly observed in this study.

Furthermore, plants chemically excluded recorded the lowest number of damaged leaves compared to those that were physically and non-excluded. This reduction in the number of damaged leaves can be attributed to the application of insecticide (0.0l % of Lambda-cyhalothrin) against root and foliar herbivory (Robert, 2002). The increase in the number of damaged leaves for physically excluded plants was probably due to inefficient maintenance and renewal of the netted house over time of cultivation. Presence of little holes on the netted house towards late cultivation of the crop could have created an easy access for insects to lay eggs within the netted house and feed on the potato plants.

Percentage herbivory of chemically excluded plants were higher towards harvest time (17 weeks after planting) than those of physical and non-exclusion indicating resistance of the insect herbivore to the concentration of the chemical insecticide over time. However, the concentration of the insecticide was not increased overtime to validate the above statement.

The mean difference in tuber count, heaviest tuber and average tuber weight across treatment was probably due to variations in the plants response to the external environmental even though no significant difference was recorded. Although the chemically and non-excluded plants cultivated in an open field initially had a slower growth rate, over time they acclimatized faster to the field conditions hence contributing to the better yield performance. Canola (2005) further reported that growth rate of a crop was closely related to the amount of solar radiation captured by the leaves hence rapid leaf development encouraged root growth and more dry matter production. Potato plants that were physically excluded showed low yield performance indicating that plants within the netted house may have experienced reduced solar radiation. Increased stem length and number of leave may have also lead to competition for light, space and nutrients, and disease infestation. Generally, the yield results from potato plants subjected to physical, chemical and no exclusion were not significantly different from each other.

CONCLUSION

In summary, the cultivation of white-skinned variety *I. batatas* in screened faculties will not necessarily translate to improved yield. Furthermore, it is unproductive to invest any money (either for chemical control or physical control) if the outcome does not manifest as improved returns on yield. However, for those who will use the foliage of potatoes as a source of food (i.e. as vegetables) and medicinal use, the output of yield maybe inconsequential as opposed to the vegetative part of the crop (i.e. leaves). This inference is consistent with the observed outcome of this study that shows that potato plants invest more resources in vegetative growth as seen in increase number of leaves and stem (vine) lengths when excluded from insects herbivory.

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APPENDICES

APPENDIX A: Growth Parameter (number of damaged leaves, number of runners, percentage herbivory, number of leaves and stem length) Assessing the Weekly Performance of *I. batatas*

	Mean ± SE					
Weeks	**Management Options**	**Number of Damaged Leaves**	**Number of Runners**	**percentage Herbivory**	**Number of Leaves**	**Stem Length**
3	**No pest Management**	2.60 ± 0.78	3.30 ±0.42	16.51 ± 3.08	17.80 ± 1.82	76.55 ± 8.08
	Chemical Exclusion	1.60 ± 0.58	4.60 ± 1.63	9.43 ±2.86	17.30 ± 1.14	71.60 ± 4.19
	Physical Exclusion	2.10 ±0.50	3.20± 1.40	9.97 ±2.73	21.50 ± 1.65	102.9 ± 8.61
	H-Statistics	1.159	0.036	3.53	3.208	7.228
	P-Value	0.56	0.982	0.171	0.201	0.027
4	**No pest Management**	5.00 ± 2.29	2.70 ± 0.26	1.21 ± 0.64	20.80 ± 2.11	79.85 ± 8.69
	Chemical Exclusion	1.70 ± 0.62	3.60 ± 0.40	0.31 ± 0.20	21.50 ± 1.79	85.75 ±4.82
	Physical Exclusion	2.40 ± 0.37	3.80 ± 0.25	0.29 ± 0.10	28.90 ± 1.72	141.7±13.14
	H-Statistics	3.448	6.918	1.725	9.419	12.839
	P-Value	0.178	0.031	0.422	0.009	0.002
5	**No pest Management**	2.90 ± 0.59	2.90 ±0.23	2.16 ± 1.08	23.90 ±2.43	91.80 ± 8.91
	Chemical Exclusion	1.60 ± 0.58	3.30 ± 0.37	0.96 ± 0.50	24.70 ±2.35	100.90±5.64
	Physical Exclusion	2.70 ± 0.42	3.80 ± 0.25	0.51 ± 0.22	41.50 ± 2.85	214.60±22.70
	H-Statistics	3.384	4.741	0.565	14.198	17.454
	P-Value	0.184	0.093	0.754	0.001	0.000
6	**No pest Management**	4.90 ± 1.39	3.70 ± 0.30	11.10± 6.67	31.70 ± 2.64	125.20 ±9.70
	Chemical Exclusion	2.20 ± 0.49	3.60 ± 0.43	1.50 ±0.97	32.90 ± 2.96	127.10±10.00
	Physical Exclusion	5.40 ± 1.27	4.30 ± 0.47	2.71 ±0.99	55.50 ± 3.19	281.40±20.91
	H-Statistics	5.04	1.077	2.988	16.904	19.38
	P-Value	0.08	0.584	0.224	0.000	0.000
7	**No pest Management**	5.80 ± 1.05	5.10 ± 0.57	8.40 ±5.00	49.40 ± 3.98	203.05±19.50
	Chemical Exclusion	3.50 ± 0.56	5.60 ± 0.27	1.53 ±0.98	52.30 ± 4.84	199.00±15.27
	Physical Exclusion	12.30 ±1.76	7.10 ± 0.66	6.40 ± 2.67	74.60 ± 4.72	436.30±28.13
	H-Statistics	14.023	5.057	7.112	12.487	18.98
	P-Value	0.001	0.08	0.029	0.002	0.000
8	**No pest Management**	7.00 ±1.40	7.40 ±0.79	6.30 ±3.24	85.60 ±4.11	362.95±33.09
	Chemical Exclusion	5.20 ±1.48	8.00 ±0.47	8.60 ±4.52	89.00 ±4.81	327.80±24.09
	Physical Exclusion	11.00 ±1.81	9.20 ±0.88	3.10 ±0.89	107.0±6.10	604.60±27.87
	H-Statistics	6.565	2.174	0.092	6.676	19.59
	P-Value	0.038	0.337	0.092	0.036	0.000

17	**No pest Management**	9.30 ±1.57	7.70 ±0.52	2.40 ±0.48	53.30 ±4.53	432.00±43.18
	Chemical Exclusion	18.30± 4.63	6.30 ±0.82	12.50 ±5.56	75.60 ±14.98	328.30±30.00
	Physical Exclusion	11.70 ±2.26	7.90 ±0.86	4.50 ±1.06	61.90 ±8.62	901.60±68.36
	H-Statistics	2.496	2.689	3.333	1.691	18.351
	P-Value	0.287	0.261	0.189	0.429	0.000

APPENDIX B: Productivity (Tuber count, heaviest tuber and Average Tuber weight) of *I. batatas* (18 WAP) under three pest management options

	Mean ± **SE**		
Management Options*	**Tuber Count**	**Heaviest Tuber**	**Average Tuber Weight**
No pest Management	4.24 ± 0.57	131.1 ± 14.2	72.5 ± 5.6
Chemical Exclusion	3.4 ± 0.45	147.2 ± 18.8	94.8 ± 21.5
Physical Exclusion	3.04± 0.37	106.2 ± 14.5	56.1 ± 8.6
H-Statistics	2.34	-	4.24
F-Statistic	-	1.67	-
P-Value	0.31	0.21	0.12
Degree of Freedom	2,27	2,27	2,27

*No pest management options was exposed to full herbivory, Chemical exclusion was sprayed with insecticides and physical exclusion was screened completely screened off from herbivory. Values represent Mean±SE and not statistically significant according to non-parametric Kruskal Wallis test (H-Statistics) and One-Way Anova (F-Statistics) at ($p<0.05$).