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Soil arthropod pests associated with groundnut (*Arachis hypogaea*) in Golinga, Northern Ghana

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Abstract. *Kyerematen R, Issifu I, Adu-Acheampong S. 2024. Soil arthropod pests associated with groundnut (*Arachis hypogaea*) in Golinga, Northern Ghana. Asian J Agric 8: 64-69.* Groundnut (*Arachis hypogaea* L.) production is one of the main livelihood activities in the northern part of Ghana consisting of the five main regions, Upper West, Upper East, Northern, Savannah and North East regions and the principal source of protein for mostly, the rural people. Notwithstanding that, not much research has been conducted on soil arthropod pests associated with the crop in the study area. To fill this gap, this research documented soil arthropod pest diversity of the crop and the damage they cause as baseline data for pest management decisions in the study area. Pitfall traps were set up on twenty-four (24) 5 m × 5 m plots close to harvest time after raising groundnut plants on them in a Randomized Complete Design. The traps were emptied on four occasions from each plot at two-week intervals. Results from the field trials revealed that beetles, termites, wireworms, false wireworms and millipedes were the dominant pest groups in the study area. The results further showed that these key pests caused nearly 90% damage to groundnut pods which goes a long way to impact negatively on the livelihood of farmers in the study area. The study recommended environmentally friendly pest control methods such as the use of botanical extracts and other biorational means in the study area. This was based on findings from our preliminary survey which revealed that the current pesticides that farmers use are largely ineffective in the study area.

Keywords: Damage, diversity, farmers, pesticide, production

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is a leguminous crop that supplies people especially those in the northern part of Ghana with the needed proteins, vitamins, and essential oil (Adjepong et al. 2018; Boadi et al. 2022). It is a staple seed and forms a substantial part of various local diets in Ghana (Adjepong et al. 2018; Boadi et al. 2022). It is estimated that more than 70% of farmers in the five regions in the northern part of Ghana namely; Upper West, Upper East, Northern, Savannah and North East, cultivate groundnut and together account for over 90% of the total production in Ghana (Owusu-Adjei et al. 2017). Groundnut is cultivated in all 16 regions of Ghana although production is relatively higher in Oti, Upper West, Northern, Volta and Upper East regions (Oteng-Frimpong et al. 2015). According to USDA (2023), about 370,000 ha of groundnuts were cultivated across the 16 regions of Ghana in the year 2022, resulting in a yield of a little over 600,000 metric tons. Besides playing an important role in income generation and consumption within households (Ramakrishna et al. 2006; Patil et al. 2015), groundnut improves fertility and moisture of the soil and so improves soil conservation, thereby increasing farmer resilience against climate change (Feldman et al. 2019; Mayes et al. 2019). According to research there are more than 25 million ha. of cultivated groundnut which produces more than 45 million tons of seeds worldwide (Simtowe et al. 2009; Konate et al. 2020). Groundnut is a crop that is produced especially in warm temperate zones as well as tropic and subtropics and can only do well in soil of high humidity and temperature range of 20°C and 30°C, and annual rainfall within the range of 200 and 1200 mm (Singh and Nigam 2016; Infonet Biovision 2017; Kadiyala et al. 2021). Total groundnut cultivation in sub-Saharan regions of Africa makes up about 40% of the total world production area of land although the total seed production in these areas is about 26% of the world production (Angelucci and Bazzucchi 2019).

The groundnut crop is attacked by several pests resulting in rising production cost and yield loss to farmers (Agoyi et al. 2019; Okello et al. 2013). For instance, it has been reported that the crop is attacked by some 360 insect pest species worldwide and that some of the ground-dwelling pests cause higher yield losses even more than foliage feeders (Wightman and Amin 1988; Nataraja et al. 2014). Because farmers are not able to detect the presence of soil pests early enough for prompt management, the pests often cause huge yield losses (Wightman and Amin 1988). Research has shown that jassids, thrips, aphids, whiteflies, leaf miners etc. are among the most notorious pests of groundnuts for which *Amrasca biguttula biguttula,* Ishida (Hemiptera: Cicadellidae), *Helicoverpa armigera,* Hübner (Lepidoptera: Noctuidae), *Aproaerema modicella,* Deventer (Lepidoptera: Gelechiidae), *Spodoptera litura,* Fabricius (Lepidoptera: Noctuidae) and *Aphis craccivora,* Koch (Hemiptera: Aphididae) are reported to be the most destructive (Amin and Mohammad 1980). At the early stages of growth, the main pests of groundnut are leaf miners and then afterwards tobacco caterpillars followed by pod borers and sucking pests with most of the sucking pests also being vectors of groundnut diseases (Amin and Mohammad 1980; Panse 2021; Maheshala et al. 2023).

Despite these studies on pests of groundnuts, studies on soil arthropod pest profile of the crop in traditional farming communities in Golinga in the northern region of Ghana remain relatively understudied. This notwithstanding, preliminary observations within the study area coupled with the results of previous survey conducted in nearby farming communities suggest that soil pests do cause huge damages to the crops in the study area (Tanzubil 2016). Additionally, conventional pesticides applied as a control measure have become less effective within the study area.

As a result, this study aims to document soil pests of groundnut, determining the level of destruction of these pests and the efficacy of the main control methods and recommending alternative effective methods for their management. This is because farmers complained about lack of effectiveness of conventional pesticide application as pest management in the study area. This study also investigates the validity or otherwise of the results of the pest survey records of previous studies in neighbouring communities with similar production dynamics.

MATERIALS AND METHODS

Experimental site and choice of groundnut variety

The research was conducted at Golinga in the Tolon district of the Northern Region of Ghana in August 2022. The experimental site is located on longitude 0^{0} 53 and 1^{0} 25 W, latitude 09^{0} 15 and 10^{0} 02 N and 14.5 km southwest of Tamale and 12 km away from the University for Development Studies, Nyankpala campus (Abagale et al. 2014; Sayibu et al. 2015). The area has an unimodal rainfall pattern with an annual average of 1060 mm and a relative humidity of 20% to 82% in January and August respectively (Sayibu et al. 2015). The annual average minimum and maximum temperatures at Golinga are 20°C and 30°C respectively (Bekoe et al. 2021) (Figure 1). The Chinese groundnut variety was used for the study because it is the most preferred variety for cultivation by farmers in the study area.

Experimental design and data collection

The study was conducted using Completely Randomized Design (CRD). The experimental field was divided into 24 plots for cultivated groundnuts and 12 plots of uncultivated groundnuts with each plot measuring 5 m × 5 m and 2 m alley in between plots and rows. Two 14 x 8 cm pitfall traps (a total of 48 traps for the cultivated plots and 24 traps for the uncultivated plots) were fitted into holes dug out on each of the plots. Each of the plots was fitted with 2 of the pitfall traps randomly at approximately 3 meters intervals to each other. The main factors investigated were the differences in pest records (diversity) between the cultivated and uncultivated plots and pest damage between plots. The containers were filled with clean water and little drops of detergent to break the surface tension to prevent the escape of trapped arthropods. This was done after the containers were firmly fixed to the soil with the top of the container level with the ground. The traps were emptied four times at 12 days, 8 days, 4 days and 1 day before harvesting and stored with 70% alcohol for further identification. In other words, the traps were emptied on 4 occasions at 4 days intervals. The collected insect specimens were identified using reference collections from the laboratory of the Department of Animal Biology and Conservation Science, University of Ghana with guidance from Gullan and Cranston (2014).

Holes and scarification created by pests were observed on pods after harvest and used as criteria to categorize pods into highly damaged versus less damaged per plot. The percentage of pod damage was calculated by subjecting the highly damaged versus less damaged seeds to the formula by Quitco and Quindoza (1986):

$$\% \text{ damage} = \frac{\text{Total number of highly damaged Pods} \times 100}{\text{Total number of Pods}}$$

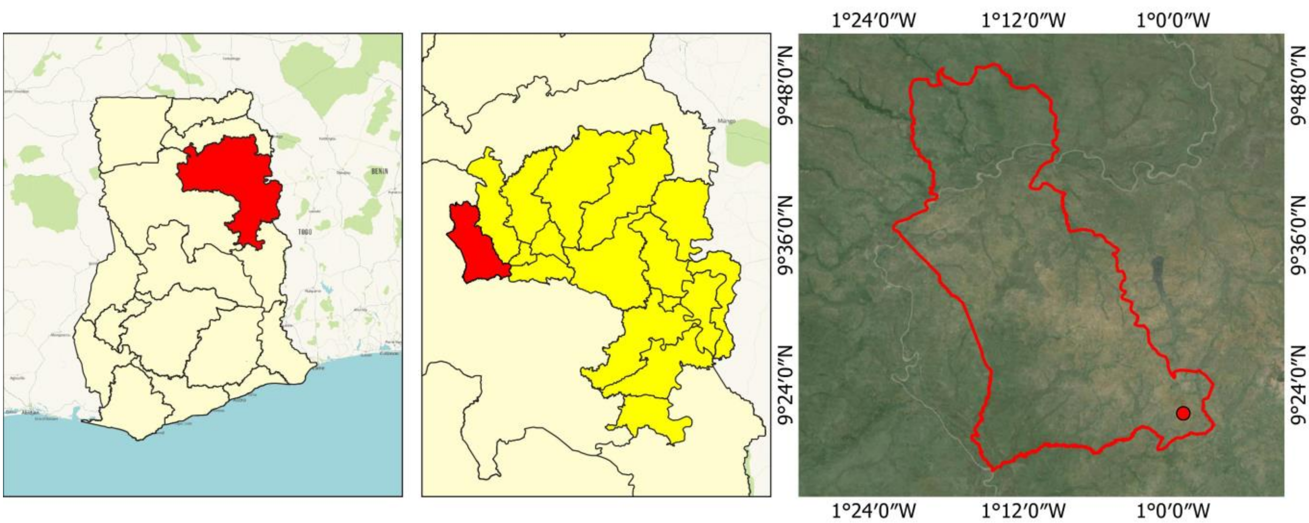

Figure 1. A picture showing Tolon District where Golinga is located on the map of Ghana

Data analysis

Student t-test was employed to measure differences between pest infestation of cultivated versus uncultivated lands and damaged versus undamaged pods per each plot in the study using SPSS software. This was after log transforming the data (count data) and subjecting the transformed data to a Shapiro-Wilk test for normality ($W= 0.94$, $p > 0.05$).

Preliminary survey on pest management

A preliminary survey was conducted for 30 farmers who already belonged to a farmer group in the study area to ascertain their preferred means for controlling soil arthropod pests of groundnuts, and perceptions of the effectiveness of the methods employed, and whether they would want a change as evidence of potential resistance build up within the pest population for pesticides used in general in the area during the 2022 rainy season. This was achieved through random administration of stratified questionnaires (hard copies in person) within the farmer group. The participants were mostly led by the researchers to answer the questions after seeking their consent to participate in the survey. Ethical clearance was received from the Department of Crop Science of the University for Development Studies.

RESULTS AND DISCUSSION

Diversity of soil arthropods

This study recorded a total of 1366 individual arthropods belonging to the orders Coleoptera, Myriapoda, Isoptera and Araneae. The most abundant arthropod group was the class Insecta with Isoptera and Coleoptera being the most abundant orders (Table 1).

There were similar but slight differences in arthropod diversity as reported by surveys conducted by Tanzubil (2016). This is because this study recorded natural enemies, but respondents in the previous study did not have knowledge of any natural arthropod enemy within the groundnut farms (see Table 1). The other difference recorded in the diversity of soil arthropods between this study and that of Tanzubil (2016) could be assumed to be that the current study only focused on soil arthropods and even near harvest time while the previous study considered responses from farmers at all stages covering both foliage and soil arthropods as well as varietal (only Chinese variety was used for this study but the previous study used more than one variety of groundnut) differences between the two studies as reported elsewhere (War et al. 2013; Krishna et al. 2015; Srinivasan et al. 2018). It has been shown that varietal differences affect arthropod preferences and so this may be a factor in the differences in the arthropod records in this study and the previous study (Tooker and Frank 2012; Ebeling et al. 2018)

Soil arthropod pests

The soil arthropod pests recorded for the study included Termites: *Macrotermes* spp. and *Microtermes* spp. and *Odontotermes* spp., Wireworms: *Heteroligus claudius*, Millepedes; *Eurymerodesmus* spp., False wireworms: *Gonocephalum* spp.; *Holotrichia* spp. while Aranae was the main natural enemy recorded for the study (Table 1) and the wireworms, and false wireworms and scarab beetles were the most destructive of them all. Also, the t-test results for the study showed that there was a significantly high pest infestation of groundnuts on the cultivated lands ($M = 88.7$, $SD = 12.21$) compared to the uncultivated lands ($M = 15.0$, $SD = 9.3$); (t (34) = 27.9, $p = 0.0$). This result agrees with that of the study by Umeh et al. (2001) for their research conducted in five West African countries that reported that termites, millipedes, wire worms and scarab beetles were the key arthropod pests of groundnuts. Other similar studies (Panse 2021; Maheshala et al. 2023) in other groundnut production areas have also reported similar ground-dwelling pests, however, there were other pests recorded in those other studies which were not recorded in this study. Such species as *S. litura*, *A. modicella* and *Frankliniella schultzei* were recorded in a previous study conducted elsewhere but were not encountered in the present study (Amin and Mohammad 1980; Panse 2021; Maheshala et al. 2023). There were also slight differences in pest records between the study by Tanzubil and Baba (2017), who reported similar arthropod pest groups except for beetles which were the second most dominant groups, and the former study compared to the latter which beetles dominated. By comparing this study with that of Tanzubil and Baba (2017), which was mainly through farmer interviews, it may be that the respondents in the latter study could not have encountered some of the nocturnal beetles and this might have accounted for their inability to confirm or list some of the soil-dwelling arthropods and nocturnal beetle pests. This is because farming activities do not occur at night in the study area and possible misidentification of pests by respondents could also have played a role in the findings. The insect pest guild recorded in this study agrees with results from other similar research works done in other parts of the world (Okello et al. 2013; Biswas 2014; Harish et al. 2015).

Table 1. A table showing abundance of arthropods recorded for the study

Arthropod	Order	Key pests	Abundance
Beetle	Coleoptera	*Holotrichia* spp., *Conoderus* spp., *Gonocephalum* spp.	797
Millipedes	Myriapoda	Odontopygidae, *Eurymerodesmus* spp.	99
Spider	Aranae	*Latrodectus* spp., *Nephilingis* spp., *Menemerus* spp., *Cyrtophora* spp., *Caerostris* spp.	50
Termites	Isoptera	*Macrotermes* spp., *Microtermes* spp.	420

Figure 2. A picture showing exit and or entry holes of soil arthropods on groundnut pod and a pod filled with frass of arthropod pests

Damage assessment of groundnut pods

All pods collected at harvest per plot were used for the computation of the damage assessment. It was revealed that all the experimental plots were infested with arthropod pests with various degrees of percentage damage to pods ranging from 65% to 100% damage on the various plots with an average of 89% (Figure 2).

The results further showed that the mean values (per each plot) of the damaged pods (M = 88.7, SD = 12.2) were significantly higher than the undamaged pods from a paired two-sample t-test for means (M = 12.17, SD = 12.7); (t (24) = 15.13, p = 0.0). The study further revealed that damages was caused by live insects detected within the pods, creating holes and scarification on pods and dead plants with severely damaged roots and or pods, which confirms reports of the type of damage by soil pest on groundnuts (Culliney 2013). Studies show that groundnut pod borers such as wireworms, termites, scarab beetles, and other pod-destructive pests could cause up to 100% of yield loss as was observed on some plots in this study (Naawe and Angyiereyiri 2020; Pawar et al. 2023) (Figure 3).

According to Okello et al. (2013) and Ajeigbe et al. (2014), soil arthropods contribute to yield loss by damaging pods, kernels and plant roots causing death and loss of up to 100% which was the case with some of the studies plots. Some of the most common damages caused were related to feeding activities of centipedes and termites as reported by Okello et al. (2013) and Tanzubil (2016) although they were not as devastating as damages caused by the coleopteran pests.

Preliminary survey of effectiveness of pest management

Results of the preliminary survey of 30 farmers in a farmers' group at the study area revealed that there is a very high reliance of pesticides for the control of arthropod pests with close to 50% (13 respondents) of the respondents relying solely on synthetic pesticides and the remaining approximated half (17 respondents) preferring a combination of pesticides and other traditional methods of control with only 2 (approximately 7%) respondents opting solely for traditional control methods. Also, when it comes to the efficiency of the control method used, only 3 out of the 30 respondents, representing 10% said that the method they use is good with the rest (90%) showing dissatisfaction with the effectiveness of method they use in controlling arthropod pests of groundnut in the study area (Figure 4).

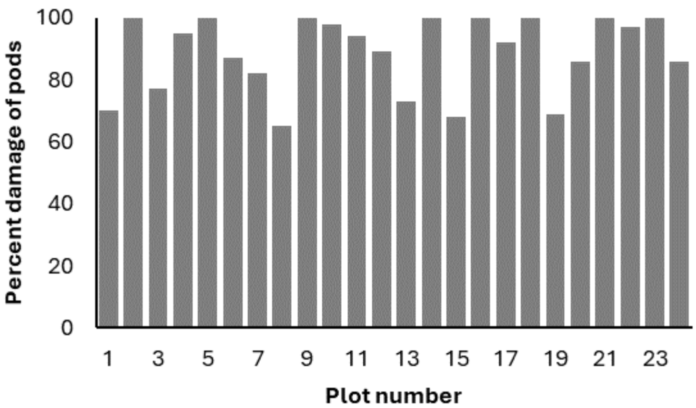

Figure 3. A graph showing percentage damage of groundnut pods on the various study plots

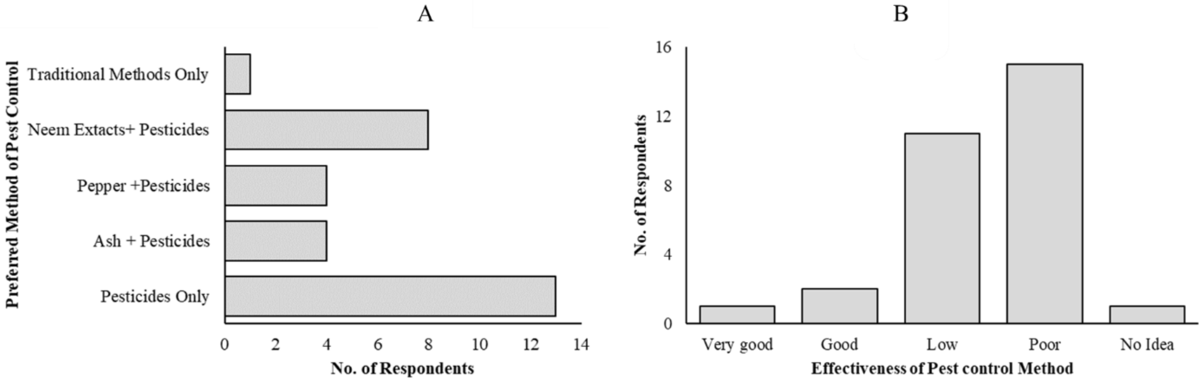

Figure 4. Response of farmers to their preferred method and its effectiveness in controlling arthropod pests in the study area

The finding from the preliminary survey in this study has revealed that there could be a heavy reliance on synthetic pesticide for the cultivation of groundnut in the study area. This may be a worrying sign as it was shown that farmers in the study area rely heavily on synthetic pesticides and such a situation will likely lead to environmental pollution. This is even more serious, especially in a rural area like Golinga where farmers are less educated to know the implications of misapplication of the required dosage of the pesticides they use (Abhilash and Singh 2009; Plianbangchang et al. 2009; Onwona-Kwakye et al. 2019). Under such circumstances, farmers are more likely to abuse the pesticides they use by increasing concentrations above the required level when they realize the required amount is no longer effective (Özkara et al. 2016; Tang et al. 2021). This seems to be the situation in the study area where majority of the respondents claim they could not rely solely on synthetic pesticides for the control of soil pests with most of them complaining of lack of effectiveness of their control method which is mostly synthetic pesticides as reported elsewhere (Sharifzadeh et al. 2018; Khayatnezhad and Nasehi 2021).

In conclusion, the study concludes that close to 90% of pods harvested from the study plots were heavily infested with pests and hence damaged. That could be translated to mean that the soil within Golinga can be said to be heavily infected with soil arthropod pests which will eventually lead to drastic yield reduction in groundnut production. The study further shows that beetles, termites, wireworms, false wireworms and millipedes were the key soil arthropod pests with beetles being dominant among the pest guilds within the farming communities in the study area. Based on the results of the previous studies by Tanzubil (2016) and Tanzubil and Baba (2017) and the preliminary survey of this study, The study recommended the use of biorational methods such as biopesticides from plant extracts to help farmers acquire easy and environmentally friendly control means to manage soil arthropod pest attacks on groundnuts at Golinga. This can help reduce the reliance on conventional pesticides and the problems associated with them as has already been listed. The results of the preliminary survey further show that if farmers use a specific group of pesticides in controlling soil pests amidst indiscriminate application, that might have conferred on them some form of resistance to those pesticides in the study area which require further investigation.

REFERENCES

Abagale FK, Oredola Tunde AK, Agyemang O. 2014. Organochlorine pesticide levels in irrigation water of the Golinga dam, Tolon District Ghana. Ellxir Pollut 72: 25610-25615.

Abhilash PC, Singh N. 2009. Pesticide use and application: An Indian scenario. J Hazard Mater 165: 1-12. DOI: 10.1016/j.jhazmat.2008.10.061.

Adjepong M, Jain R, Pickens CA, Appaw W, Fenton JI. 2018. Quantification of fatty acid and mineral levels of selected seeds, nuts, and oils in Northern Ghana. J Food Sci Technol 55: 4615-4622. DOI: 10.1007/s13197-018-3400-y.

Agoyi EE, N'danikou S, Kafoutchoni M, Ayena M, Sodedji FA, Agbahoungba S, Sossou HS, Vodouhe R, Assogbadjo AE. 2019. Kersting's groundnut [*Macrotyloma geocarpum* (Harms) Maréchal & Baudet] crop attracts more field pests and diseases than reported before. Agric Res Tech: Open Access J 21 (5): 556180. DOI: 10.19080/ARTOAJ.2019.21.556180.

Ajeigbe HA, Waliyar F, Echekwu CA, Ayuba K, Motagi BN, Eniayeju D, Inuwa A. 2014. A Farmer's guide to groundnut production in Nigeria. Patancheru 502 (324): 36.

Amin PW, Mohammad AB. 1980. Groundnut pest research at ICRISAT. https://oar.icrisat.org/3604/

Angelucci F, Bazzucchi A. 2019. Analysis of incentives and disincentives for groundnuts in Ghana. Gates Open Res 3: 426.

Bekoe EMO, Amuah EEY, Abuntori ZN, Sintim E, Kichana E, Quarcoo G. 2021. Water quality impact from the multipurpose use of the golinga reservoir in northern Ghana. Water Air Soil Pollut 232: 1-15. DOI: 10.1007/s11270-021-05331-9.

Biswas GC. 2014. Insect pests of groundnut (*Arachis hypogaea* L.), nature of damage and succession with the crop stages. BARI 39: 273-282. DOI: 10.3329/bjar.v39i2.20429.

Boadi P, Gyimah FT, Aryeetey R. 2022. Descriptive analysis of changes in Ghana's food availability and food safety information between 2010 and 2020. AJFAND 22 (2): 19624-19657. DOI: 10.18697/ajfand.107.21815. DOI: 10.18697/ajfand.107.21815.

Culliney TW. 2013. Role of arthropods in maintaining soil fertility. Agriculture 3: 629-659. DOI: 10.3390/agriculture3040629.

Ebeling A, Hines J, Hertzog LR, Lange M, Meyer ST, Simons NK, Weisser WW. 2018. Plant diversity effects on arthropods and arthropod-dependent ecosystem functions in a biodiversity experiment. Basic Appl Ecol 26: 50-63. DOI: 10.1016/j.baae.2017.09.014.

Feldman A, Ho WK, Massawe F, Mayes S. 2019. Bambara groundnut is a climate-resilient crop: How could a drought-tolerant and nutritious legume improve community resilience in the face of climate change? In: Sarkar A, Sensarma S, vanLoon G (eds). Sustainable Solutions for Food Security: Combating Climate Change by Adaptation. Springer. DOI: 10.1007/978-3-319-77878-5_8.

Gullan PJ, Cranston PS. 2014. The Insects: An Outline of Entomology. John Wiley & Sons, NY.

Harish G, Nataraja MV, Jasrotia P, Holajjer P, Savaliya SD, Gajera M. 2015. Impact of weather on the occurrence pattern of insect pests on groundnut. Legume Res 38: 524-535. DOI: 10.5958/0976-0571.2015.00108.3.

Infonet Biovision. 2017. Geographical Distribution of Groundnut in Africa. www.infonet-biovision.org. Accessed 31/03/24

Kadiyala MDM, Nedumaran S, Padmanabhan J, Gumma MK, Gummadi S, Srigiri SR, Robertson R, Whitbread A. 2021. Modeling the potential impacts of climate change and adaptation strategies on groundnut production in India. Sci Total Environ 776: 145996. DOI: 10.1016/j.scitotenv.2021.145996.

Khayatnezhad M, Nasehi F. 2021. Industrial pesticides and a methods assessment for the reduction of associated risks: A review. Adv Life Sci 8: 202-210.

Konate M, Sanou J, Miningou A, Okello DK, Desmae H, Janila P, Mumm RH. 2020. Past, present and future perspectives on groundnut breeding in Burkina Faso. Agronomy 10 (5): 704. DOI: 10.3390/agronomy10050704.

Krishna G, Singh BK, Kim EK, Morya VK, Ramteke PW. 2015. Progress in genetic engineering of peanut (*Arachis hypogaea* L.)-A review. Plant Biotechnol J 13: 147-162. DOI: 10.1111/pbi.12339.

Maheshala NV, Kurella A, Jena R, Gangaiah H. Thankappan R. 2023. IPM in Groundnut: Current Scenario and in Integrated Pest Management in Diverse Cropping Systems. Apple Academic Press, Florida. DOI: 10.1201/9781003304524-12.

Mayes S, Ho WK, Chai HH, Gao X, Kundy AC, Mateva KI, Zahrulakmal M, Hahiree MKIM, Kendabie P, Licea LC, Massawe F. 2019. Bambara groundnut: An exemplar underutilised legume for resilience under climate change. Planta 250: 803-820. DOI: 10.1007/s00425-019-03191-6.

Naawe EK, Angyiereyiri ED. 2020. Effect and infestation levels of groundnut pod borer (*Elasmolomus sordidus*) on groundnut (*Arachis hypogaea*) and farm control measures in Tedema, Builsa-North District of the Upper East Region, Ghana. Intl J Trop Insect Sci 40: 687-696. DOI: 10.1007/s42690-020-00121-y.

Nataraja MV, Jadon KS, Holajjer P, Thirumalaisamy PP, Jasrotia P, Dutta R. 2014. Integrated Pest and Disease Management in Groundnut. Directorate of Groundnut Research, P. B. No. 05, Junagadh-3 62 001, Gujarat, India, Technical Bulletin, No 02/2014, Page 19.

Okello DK, Monyo E, Deom CM, Ininda J, Oloka HK. 2013. Groundnut Production Guide for Uganda: Recommended Practices for Farmers. National Agricultural Research Organisation, Entebbe.

Onwona-Kwakye M, Mengistie B, Ofosu-Anim J, Nuer ATK, Van den Brink PJ. 2019. Pesticide registration, distribution and use practices in Ghana. Environ Dev Sustain 21: 2667-2691 DOI: 10.1007/s10668-018-0154-7.

Oteng-Frimpong R, Sriswathi M, Ntare BR, Dakor FD. 2015. Assessing the genetic diversity of 48 groundnut (*Arachis hypogaea* L.) genotypes in the Guinea savanna agro-ecology of Ghana, using microsatellite-based markers. Afr J Biotechnol 14: 2485-2485. DOI: 10.5897/AJB2015.14770.

Owusu-Adjei E, Baah-Mintah, Salifu B. 2017. Analysis of the groundnut value chain in Ghana. World J Agric 5: 177-188. DOI: 10.12691/wjar-5-3-8. DOI: 10.12691/wjar-5-3-8.

Özkara A, Akyıl D, Konuk M. 2016. Pesticides, Environmental Pollution, and Health. In: Larramendy ML, Soloneski S (eds). Environmental health risk-hazardous factors to living species. IntechOpen, London. DOI: 10.5772/63094.

Panse RK. 2021. Insect pests of groundnut and their integrated management. In: Mishra YK, Panday AK, Sharma AK (eds). Insect Pest Management Concept and Approaches. AkiNik Publications, New Delhi.

Patil SB, BC, Reddy BCB, Chitgupekar SC, Patil BB. 2015. Modern tillage and integrated nutrient management practices for improving soil fertility and productivity of groundnut (*Arachis hypogaea* L.) under rainfed farming system. Intl Lett Nat Sci 2015: 1-12. DOI: 10.56431/p-la2z91.

Pawar VB, Mutkule DS, Gambhire VS, Bobade SS, Magar SM. 2023. Screening of groundnut genotypes and abundance of groundnut pod. Pharm Innov J 12: 1552-1558.

Plianbangchang P, Jetiyanon K, Wittaya-Areekul S. 2009. Pesticide use patterns among small-scale farmers: A case study from Phitsanulok, Thailand. Southeast Asian J Trop Med Public Health 40 (2): 401-410.

Quitco RT, Quindoza NM. 1986. Assessment of Paddy Loss in Storage. Unpublished Terminal Report, Naphire.

Ramakrishna A, Tam HM, Wani SP, Long TD. 2006. Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. Field Crops Res 95: 115-125. DOI: 10.1016/j.fcr.2005.01.030.

Sayibu AG, Alhassan AL, Adongo TA. 2015. Effect of different water application schedules on the growth and yield of loose-leaf lettuce (*Lactuca sativa* var *crispa*) at Goilinga irrigation scheme in the Tolon District of the Northern Region, Ghana. Greener J Agric Sci 5: 159-166. DOI: 10.15580/GJAS.2015.5.020315028.

Sharifzadeh MS, Abdollahzadeh G, Damalas CA, Rezaei R. 2018. Farmers' criteria for pesticide selection and use in the pest control process. Agriculture 8 (2): 24. DOI: 10.3390/agriculture8020024.

Simtowe F, Shiferaw B, Abate T, Kassie M, Monyo E, Madzonga O, Silim S, Muricho G. 2009. Assessment of the Current Situation and Future Outlooks for the Groundnut Sub-Sector in Malawi. International Crops Research Institute for the Semi Arid Tropics, Nairobi.

Singh KA, Nigam SN. 2016. Arachis gene pools and genetic improvement in groundnut. In: Rajpal VR, Rao SR, Raina SN (eds). Gene Pool Diversity and Crop Improvement. Springer International Publishing, Switzerland. DOI: 10.1007/s42690-020-00121-y.

Srinivasan R, Abney MR, Lai PC, Culbreath AK, Tallury S, Leal-Bertioli SC. 2018. Resistance to thrips in peanut and implications for management of thrips and thrips-transmitted orthotospoviruses in peanut. Front Plant Sci 9: 1604. DOI: 10.3389/fpls.2018.01604.

Tang FH, Lenzen M, McBratney A, Maggi F. 2021. Risk of pesticide pollution at the global scale. Nature Geosci 14: 206-210. DOI: 10.1038/s41561-021-00712-5.

Tanzubil PB, Yahaya BS. 2017. Assessment of yield losses in groundnut (*Arachis hypogaea* L.) due to arthropod pests and diseases in the Sudan savanna of Ghana. J Entomol Zool Stud 5: 1561-1564.

Tanzubil PB. 2016. Incidence of arthropod pests and diseases of groundnut (*Arachis hypogaea* L.) in northern Ghana. J Entomol Zool Stud 4 (04): 29-32.

Tooker JF, Frank SD. 2012. Genotypically diverse cultivar mixtures for insect pest management and increased crop yields. J Appl Ecol 49: 974-985. DOI: 10.1111/j.1365-2664.2012.02173.x.

Umeh VC, Waliyar F, Traore SC, Omar BDJ. 2001. Farmers opinions and influence of cultural practices on soil pest damage to peanuts in West Africa. Insect Sci Appl 21: 257-265. DOI: 10.1017/S1742758400007669.

United States Department of Agriculture (USDA) (Foreign Agriculture Services). 2023. Ghana Oilseeds Voluntary 2023. A Report by Gain Global Agricultural Network.

War AR, Paulraj MG, Ignacimuthu S, Sharma HC. 2013. Defensive responses in groundnuts against chewing and sap-sucking insects. J. Plant Growth Regul 32: 259-272. DOI: 10.1007/s00344-012-9294-4.

Wightman JA, Amin PW. 1988. Groundnut pests and their control in the semi-arid tropics. Trop Pest Manag 34: 218-226. DOI: 10.1080/09670878809371245.