Journal of Applied Biosciences 110: 10802-10807

ISSN 1997-5902

Build-up of insect pests and their natural enemies on rotated and non-rotated okra (*Abelmoschus esculentus* (L.) Moench), tomato (*Lycopersicon esculentus* Mill) and egg plant (*Solanum melongena* (L.) Moench.) fields

P. K. Baidoo,[1]M.B. Mochiah,[2] W. Apo[1], and H. K. Teye-Anim[1]
[1]Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
[2] Entomology Section, Crops Research Institute, P. O. Box 3785, Kwadaso, Kumasi, Ghana.
Corresponding Author's Email address: pkbaidoo2002@yahoo.com

Original submitted in on 19th November 2016. Published online at www.m.elewa.orgon 28th February 2017
http://dx.doi.org/10.4314/jab.v110i1.10

ABSTRACT

Objective: The quest for increased food production requires crops to be protected from pests and diseases. The readily available means of controlling pests is the application of chemical pesticides, with its attendant negative effects on humans and the environment. The study was conducted to assess the effectiveness of crop rotation as a pest control measure and how this affects the population of natural enemies of the pests.

Methodology and Results: The build-up of insect pests' of tomato, okra and eggplant and their natural enemies on rotated and non-rotated fields were studied. The rotated and non-rotated fields were each replicated 3 times. The different insect pests that infested the crops were identified and counted. Aphids and whiteflies were assessed using a scoring scale from 0 to 5. Natural enemies of the pests were also identified and counted. Significantly, larger numbers of *Bemisia tabaci, Aphis gossypii*, *Podagrica uniforma*, *Zonocerus variegatus* and *Locusta migratoria* were sampled on the crops on the non-rotated than the rotated fields. Numbers of natural enemies, *Dictynia* sp *Coccinella* sp and *Camponotus* sp were not significantly different on the rotated and non-rotated fields but crop yields were significantly higher on the rotated field.

Conclusion and application of findings: The results of the study indicated that rotating crops on the same piece of land resulted in reduction in pests' numbers and an increase in crop yields. The reliance on pesticides alone to manage pests may not be the best option to reduce pests because of the negative effects of pesticides on the environment. Crop rotation can therefore be adopted as a cultural control option in the overall management of pests.

INTRODUCTION

Vegetables are important sources of vital mineral salts and vitamins as well as dietary fibre. They contain enough roughage for easy digestion of food, thereby preventing constipation (Norman, 1992). They are therefore important components of healthy well-balanced diets in areas where malnutrition is a serious challenge. The importance of vegetables in the diets of many African countries has resulted in their increased production. The quest for increased vegetable production is however constrained by a number of factors such as poor seed quality, soil infertility, inadequate rainfall and high incidence of pests and diseases. Agricultural pests destroy more than 30 % of crops worldwide (Miguel *et al*., 2005) thereby limiting efforts to reduce hunger. In Ghana, many vegetable crops are grown for local consumption and for export. These include cabbage, tomato, eggplant okra and onion, which are cultivated by both rural and urban farmers. These vegetables are attacked by a variety of pests and diseases, which result in reduction in yield and quality of the produce. Even though there are insect pests, which are common to these crops, each of them has specific pests. The damage by pests results from their feeding on the fruits and the leaves and in some cases; they spread diseases between plants (Shankara *et al*., 2005). The use of synthetic chemicals to control insect pests has been the preferred option by many farmers because of their quick action; however, the continuous use of pesticides negatively affects the food chain. Indiscriminate use of pesticides tends to destroy the natural enemies of these pests; it affects the health of farmers and may accumulate in food products (Solomon *et al*., 2000) as well as contaminate water sources. The continuous use of pesticides has resulted in insect pests developing resistance to some of the conventional products. These problems have necessitated the need to adopt environmentally friendly and more sustainable methods of managing pests to reduce crop losses. The rotation of crops on the same piece of land is an alternative way of reducing pest infestation. Crop rotation is the successive cultivation of different crops in an orderly manner on the same field. It involves the changing of crops over time (Wszelaki and Broughton, 2012). In situations where an insect has a narrow host range, adults that emerge from diapause will be presented with a non-host plant, which will reduce their food source leading to starvation and death. Crop rotation as a cultural control method reduces the use of chemical insecticides. Other advantages of crop rotation include improved efficiency in use of soil nutrients by different plants, thereby maintaining soil fertility, reduction in soil erosion and better control of weeds (Linker *et al*., 2009). The current study assessed the effectiveness of crop rotation as an option to control the build-up of insect pests of okra, tomato and eggplant and the effect of this practice on the population of natural enemies of the pests.

MATERIALS AND METHODS

Study site: The study was undertaken on a piece of experimental farm of the Department of Theoretical and Applied Biology of Kwame Nkrumah University of Science and Technology, Kumasi during the minor rainy season of 2015. The area is located in the forest zone and has a bimodal rainfall, with peaks in April-July and September-November. The nature of the soil is sandy–loam with moderate drainage. Previously other crops such as cabbage and cowpea have been cultivated in this same area. The area is surrounded by tall elephant grass, which is occasionally cut down to make way for cultivation of crops.

Land Preparation and Experimental Design: Eighteen plots each measuring 8 m × 2.5 m were prepared, nine (9) each for the rotated and the non-rotated fields. A 5-metre alley separated the rotated from the non-rotated fields. Each plot was separated by a 1-metre alley for easy movement between the plots. The experiment was conducted in a Randomised Complete Block Design, with two treatments: rotated and non-rotated fields. Each treatment contained plots planted with tomato, okra and eggplant, each of which was replicated 3 times.

Seedling propagation: Seeds for the experiment were obtained from the Horticulture Department of Crops Research Institute (CRI) Kwadaso, Kumasi. The varieties used were CRI PO34, Dwomo and Kpando Torkor for tomato, eggplant and okra, respectively. These varieties, developed by the Crops' Research Institute are high yielding and have been released to farmers for cultivation. Tomato and eggplant seeds were raised and transplanted 3 weeks after germination, while okra seeds were sown directly. There were 4 columns and 10 rows on each plot. The planting interval was 75 cm between the columns and 75 cm within a column.

Weed control: Weeds were controlled using a hand hoe at 3 and 6 weeks after transplanting. Subsequently weeds were removed by uprooting.

Data collection: Data collection started 2 weeks after transplanting. Records of pests and natural enemies were taken between 6:00 am and 9:00 am, when they were less active. Sampling was done weekly until the fruits were matured to be harvested. At every sampling, 5 plants were randomly selected and carefully examined for the presence of pests and their natural enemies. Aphids and whiteflies were monitored on the selected plants using a visual rating scale. The rating scale was: no whiteflies/Aphids (0), few individuals (1), few isolated small colonies (2), several small colonies (3), large isolated colonies (4), large continuous colonies (5) Salifu, (1982). Other insects were collected into labelled bottles and taken to the laboratory for identification and counting and their numbers were recorded.

Harvesting of fruits: This was done from 8 to 12 weeks after transplanting (WAT). Fruits from each treatment were harvested twice a week; each was put in labelled envelopes and weighed on a top-pan balance. The weight of harvested fruits for each crop was recorded and the means were calculated.

Data analysis: Data collected on number of pests' and natural enemies' and yields of crops were subjected to Welch two sample t-test to compare the mean numbers of pests and natural enemies on the rotated and non-rotated fields. Significant difference was determined at P ≤ 0.05.

RESULTS

Insect Pests encountered on the fields: Five different pests' species were sampled and identified on the entire experimental field. These were the white fly, *Bemisia tabaci* Glenn., aphid, *Aphis gossypii* Glover; the flea beetle, *Podagrica uniforma* (Jacoby) *Locusta migratoria* (L.) and the grasshopper, *Zonocerus variegatus* (L.) (Table 1). With the exception of *P. uniformis*, all the pests were identified on eggplant . On tomato plants, the major pest was *B. tabaci*. A mean *B. tabaci* score of 2.58 was recorded on the rotated field while significantly larger score was recorded on the non-rotated field (P= 0.034). Very low numbers of *Z. vareigatus* were recorded on tomato plants for both the rotated and non-rotated fields, the difference of which was not significant (P=0.09).

Table 1: Levels of pests' infestation on tomato, okra and garden eggs on rotated and non-rotated fields.

Insect pest	**Tomato**			**Okra**			**Garden eggs**		
	Rotated	Non-rotated	P-value	Rotated	Non-rotated	P-value	Rotated	Non-rotated	P-value
Bemisia tabaci	2.58±0.41	3.67±0.24	0.03	0.00±0.00	0.00±0.00	-	2.19±0.34	3.61±0.16	0.001
Zonocerus variegatus	0.19±0.09	0.56±0.32	0.09	0.14±0.08	0.53±0.16	0.040	0.39±0.08	0.91±0.16	0.11
Podagrica uniforma	0.00±0.00	0.00±0.00	-	4.50±1.27	14.81±3.03	0.006	0.00±0.00	0.00±0.00	-
Aphis gossypii	0.00±0.00	0.00±0.00	-	0.00±0.00	0.00±0.00	-	2.36±0.41	3.92±0.52	0.027
Locusta migratoria	0.00±0.00	0.00±0.00	-	0.00±0.00	0.00±0.00	-	0.92±0.45	9.01±3.54	0.04

Mean and standard deviation

Table 2: Natural enemies of pests of tomato, okra and garden eggs on rotated and non-rotated fields.

Insect pest	**Tomato**			**Okra**			**Garden eggs**		
	Rotated	Non-rotated	P-value	Rotated	Non-rotated	P-value	Rotated	Non-rotated	P-value
Dictyna sp	0.97±0.34	0.42±0.21	0.17	0.86±0.23	0.58±0.21	0.38	1.39±0.42	0.86±0.27	0.30
Coccinella sp	0.00±0.00	0.00±0.00	-	0.25±0.07	0.05±0.01	0.56	0.00±0.00	0.00±0.00	-
Camponotus sp	0.00±0.00	0.00±0.00	-	5.53±1.93	0.67±0.30	0.03	16.31±2.51	3.23±1.63	0.003

Mean and standard deviation

Pests of okra: The flea beetle*, Podagrica uniforma* was one of the major pests on okra plants during the study period. Infestation of the plants by *P. uniforma* was detected 2 weeks after germination, and they remained on the plants throughout the study period. Significantly, larger numbers of this pest were recorded on the non-rotated plots than the rotated plots (Table 1). Even though *Z. variegatus* numbers on okra were low, significantly larger numbers were recorded on the non-rotated than the rotated field.

Pests of garden egg: The different pests species identified on eggplant are listed in Table 1*. Aphis gossypii* and *B. tabaci* scores on the non-rotated fields were significantly higher than that on the rotated field (P = 0.027 and P =0.001, respectively). *Locusta migratoria* numbers were significantly larger on the non-rotated field. *Zonocerus variegatus* infestation was very low on both the rotated and the non-rotated fields; the difference was not significant (P = 0.11).

Natural enemies of insect pests : Three species of natural enemies of insect pests were identified on both the rotated and non-rotated fields. These were the spider, *Dictyna* sp. (Araneae: Dictynidae) the ladybird beetle *Coccinnella* sp (Coleoptera: Coccinellidae) and the black carpenter ant, *Camponotus* sp (Hymenoptera: Formicidae). *Dyctina* sp was identified on all three crops but very low numbers of this natural enemy were sampled on the crops. The numbers of *Dictyina* sp. on the rotated and non-rotated fields were not significantly different (Table 2). On okra plants, all three natural enemies were sampled with no significant differences in numbers between the rotated and non-rotated fields. The numbers of *Camponotus* sp. were significantly larger on the rotated than the non-rotated field for both garden eggs and okra. This natural enemy was totally absent on tomato plants. *Coccinnella* sp. was identified on okra plants only and very low numbers of this insect were sampled on both the rotated and non-rotated okra plants. The differences were not statistically significant (Table 2).

Crop yields: Mean weights of harvested vegetables from the rotated and non-rotated fields are presented in Table 3. In general, the rotated fields produced significantly better yields than the non-rotated fields for all three crops. Percentage increases in yield on the rotated fields were 67.7 %, 70% and 94 % for okra, garden egg and tomato, respectively.

Table 3: Mean weights (g) of tomato, okra and garden eggs harvested on rotated and non-rotated fields.

Cropping system	Tomato	Okra	Garden eggs
Rotated	72.00± 20.20	123.80±36.31	195.69±12.26
Non-rotated	37.10±7.80	73.80±20.90	115.07±20.96
P-value	0.033	0.013	0.003

DISCUSSION

Protection of cultivated crops from damage by pests and diseases is very important for increased food production. The attack by pests affects vegetative growth, destruction of flowers and consequently low yields and economic losses to the farmer. According to Miguel *et al*. (2014), agricultural pests destroy more than 30% of crops worldwide. This huge loss has necessitated the application of pest control measures, including the application of chemical insecticides. The persistently high loss is indicative that insecticides on their own have not been effective in reducing the pests on crops. It was observed during the study that all parts of the plants were infested by the insect pests' to some extent, an indication of the fact that none of the crops was immune to attack by these pests. The insect pests were observed at different stages of growth of the plants. *Bemisia tabaci* was observed on garden eggs 1 week after transplanting and remained on the plants till harvest. Severely affected plants wilted because of removal of sap. Similar observation was made by Smith and McAuslane (2015) who indicated that heavy infestation by whiteflies could lead to seedling death and drying of leaves because of the removal of sap. *Bemisia tabaci* scores remained relatively high on tomato and okra plants but reduced in weeks 11 and 12 due to heavy rainfall, which washed them from the plants. Throughout the study period, *A. gossypii* was absent on tomato on both the rotated and non-rotated fields. This pest was observed only on the okra plants, with larger score on the non-rotated field. In both cropping systems. *A. gossypii* was found on the underside of okra leaves where they were protected from direct sunlight. Infestation by this pest resulted in deformation of the leaves, a feature that was also observed by Flint (2013). In a study by Mochiah *et al*. (2011) in which they intercropped tomato with cabbage, they observed that the highest aphid population was on sole cabbage, whilst the least population was recorded on 3 rows of cabbage to one row of tomato. This indicates that planting crops in a monoculture promotes the incidence of pests. On the okra plots, *P. uniforma* and *Z. variegatus* were the insects sampled, with the non-rotated plots recording significantly larger numbers. *P. uniforma* was responsible for the presence of holes in the leaves, whilst *Z. vareigatus* chewed the leaves thereby reducing the surface area exposed to sunlight for photosynthesis. *P. uniforma* has been reported as the major pest of okra, causing significant damage to the plant (Parker *et al*., 2012; Mochiah *et al*., 2011). Feeding activities of *P. uniforma* resulted in sieve-like appearance on the leaves and in some cases defoliation of the leaves. Several other insects have been reported as pests of okra. These include the stem and pod borer, *Earias vitella*, the common cutworm, *Spodoptera litura* and the cotton thrip, *Thrips palmi*, all of which have been shown to cause significant damage to the plant (Shabozoi *et al*., 2011). Non-rotation or monoculture, which is practised by large-scale farmers tend to make use of available soil nutrients from the same level. This is in contrast to crop rotation in which soil nutrients from different soil depths are used during successful growing season. This makes it possible for the same piece of land to support many plant species with different nutrient requirements. Rotation also reduces the incidence of pests on crops, as was observed in the case *P. uniforma* on okra and *B. tabaci* on tomato. Crop rotation, according to Linker *et al*. (2009) is designed to present a non-host crop to pests. This is particularly true for insects, which go through diapause at the pupal stage, a process that normally occurs during unfavourable conditions. Thus, adults that emerge when favourable conditions return are presented with crops that they cannot survive on. In this way, the insect will starve to death. Non-rotation on the other hand provides more and continuous resources for exploitation by pests. Movement of insect pests on the non-rotated crops was made easier, hence the spread of insect infestation. In a similar work by Braimah (1998) on eggplant, okra, pepper and tomato, he indicated that lepidopterous pests could be controlled by rotating the crops on the field. The most frequently encountered natural enemy of the insect pests on both the rotated and non-rotated field was the spider, *Dictyna* sp. This arthropod preyed on the pests of okra, tomato and garden eggs. On the other hand, *Coccinella* sp was identified as the natural enemy of *A. gossypii* and was therefore identified on okra plants only. Very low numbers of *Coccinella* sp were recorded on both the rotated and non-rotated fields. *Coccinella* sp feeds on many different species of aphids. The low numbers of *Coccinella* sp. was due to the low numbers of *A. gossypii* on okra. In any ecosystem, a reduction in prey population will ultimately lead to a reduction in predator food source and consequently a reduction in predator population. The black ant, *Camponotus* sp is an omnivorous insect, feeding on a variety of food sources, including honeydew, produced by aphids. *Camponotus* sp. seemed to have been attracted to eggplant by the honeydew produced by *A. gossypii*. Larger numbers were recorded on the rotated field. Rotation of crops on a field ensures that natural enemy populations are provided with resources continuously. This explains why *Camponotus* sp and *Dictyna* sp. numbers were larger on the rotated field. A study by Wszelaki and Broughton (2012) indicated that fields containing varieties of crops are rich in above and below ground natural enemies that control pests. Linker *et al*. (2009) stated that intercropping and crop rotation promote insect interaction, which is part of comprehensive plan to enhance natural control of insect pests and diseases. The rotational cropping system recorded better yields than the non-rotational crops. Lower pest pressure on the rotated field was partly responsible for this observation. Results of a study by Rausen (1997) on rotation of okra with other crops resulted in significant increase in yield than monocropping system. In our study, it was observed that the pests destroyed the flowers, thereby reducing fruit formation and reduction in yield.

CONCLUSION

The results of the study indicated that rotating crops on the same piece of land resulted in reduction in pest numbers and increased yields of the different crops. In Ghana and many other African countries where insecticide use is accompanied by problems such as environmental contamination the use of crop rotation will be a better alternative to the management of pests and diseases. Crop rotation can therefore be adopted as a cultural control method in the overall management of pests. This will lead to a reduction in reliance of chemical pesticides.

REFERENCES

Addo-Fordjour P., Yeboah-Gyan K., Lawson B. W. L. and Akanwariwiak W. G. (2007). Diversity and distribution of ferns on the campus of Kwame Nkrumah University of Science and Technology, Kumasi. *Journal of Science and Technology*, 27(1) 35-44.

Braimah, H. (1998). Report and Training Manual on Integrated Pest Control Training for Frontline Staff of the Ministry of Food and Agriculture (MOFA) in Sunyani, Brong Ahafo Region, Ghana 4th-13th February 1998. 6-8 pp.

Flint, M. L. (2013) Aphids. Integrated Pest Management for Home Gardeners and Landscape Professionals. Pets Notes. Agriculture and Natural Resources. Statewide-Integrated Pest Management Program. University of California. Publication 7404 Pp.1-2.

Linker, H. M. Orr, D. B. and Barbercheck. M. E. (2009). Insect Management on Organic Farms. CEFS Organic Production Guide. North Carolina State University, Raleigh, North Carolina. Pp. 19.

Mochiah, M. B., Baidoo, P. K., Obeng, A. and Owusu-Akyaw, M. (2011). Tomato as an intercropped plant on the pests and the natural enemies of the pests of cabbage (*Brassica oleracea*). *International Journal of Plant, Animal and Environmental Sciences* 1(3): 233-240.

Miguel, A. A., Clara, I. N. and Marlene, A. F. (2005). Manage insects on your farm. A guide to Ecological Strategies. Published by Sustainable Agriculture Research and Education (SARE), College Park. MD.

Norman, J. C. (1992). Tropical Vegetable Crops. In: Elms Court Ilfracombe, Stockwell, H.(Ed.) Devon Publishers, UK., pp: 52-77.

Parker, J., Miles, C., Murray, T and Snyder, W. (2012). Organic management of flea beetles: A Pacific Northwest Extension Publication. PNW 640 pg 2.

Rausen, T. (1997). Integrated Soil Fertility Management on small-scale farms in Eastern Province of Zambia. A review of current knowledge and experiences for agricultural extension workers. Technical Handbook No. 15, pp. 97-108.

Salifu, A. B. (1982). Biology of cowpea flower thrips and host-plant resistance. MSc. Thesis University of Ghana.

Shabozoi, N. U. K., Abro, G. H and Syed, T. S. and Awan, M. S. (2011). Economic appraisal for pest management options in okra. *Pakistan Journal of Zoology* Vol. 43 (5) 869-878.

Shankara, N., Joep, V. L. J., Maria, G., Martin, H and Barbara, V. D. (2005). Agrodok 17. Cultivation of tomatoes: Production, Processing and Marketing. Pp 1-55.

Smith, H. A. and McAuslane (2015). Sweet potato whiteflies B. Biotype, *Bemisia tabaci* (Gennadium) (Insecta:Hemiptera) (Alegrodidae) IFAS Extension. University of Florida. E6NY pg 4.

Solomon, G., Ogunseltan, O. A. and Kirsch, J. (2000). Pesticides and Human Health: A Resource for Healthcare Professionals. Published by Physicians for Social Responsibility and Californians for Pesticide Reforms. Pg. 5.

Wszelaki, A. and Broughton, S. (2012). Crop Rotation. The University of Tenneesee Institute of Agriculture. W23-E9rev). R12-5110-011-13, 13-0076.