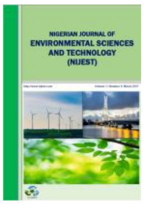
Nigerian Journal of Environmental Sciences and Technology (NIJEST)

www.nijest.com

ISSN (Print): 2734-259X | ISSN (electronic): 2734-2603

Vol 6, No. 2 October 2022, pp 461 - 469



Exploring Varietal Mixtures as a Strategy for Sustainable Management of Insect Pests Associated with Cabbage [*Brassica oleracea*VAR. *capitata* L. (Brassicaceae)]

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https://doi.org/10.36263/nijest.2022.02.0378

ABSTRACT

Cabbage is a highly nutritious vegetable, yet faced with pest challenges. At present, synthetic pesticides are the major control measure and this has some side effects such as; resistance by pest, adverse effect on non-target organisms and hazardous effects on environment. All these problems bring the sustainability of ecosystem to danger. Exploring varietal mixture of cabbage as an alternative for sustainable pest management of cabbage was investigated during the rainy (April, – August 2020) and dry (November, 2020 – March, 2021) seasons. Treatments consisted of Purple-ball, GloriaF1, Oxylus (sole each and mixture) in ratio 1:1 respectively, all raised in nursery beds and transplanted to treatment plots, given a total of 7 treatments, all laid out in a Randomized Complete Block Design (RCBD) with three replicates each. The insect associated with the crop were sampled using sweep net, pitfall traps and the mechanical hand-picking methods. The phytochemical components of each variety were also carried out. Results showed that cabbage which was mixed with purple-ball variety showed reduced attack by insects as compared with Gloria and Oxylus planted sole. This could be attributed to the higher value of cardiac glycoside, tannins, steroids and anthraquinone in Purple-ball variety than other varieties. These compounds are responsible for plant defence which may have caused the low insect population in Purple-ball variety. The yields from Purple-ball variety plots in both seasons were however significantly lower compared with other varieties in both seasons. Notwithstanding, the yield from the mixture of purple-ball with other varieties was not significantly different from others. Therefore, the inclusion of Purple-ball variety in GloriaF1 and Oxylus production is recommended as this may serve as a natural defence against insect pests. Also, the use of this cropping system is not only effective but inexpensive and safe for human health and the environment relative to synthetic insecticides.

Keywords: Cabbage varieties, Crop mixtures, Pest management, Sustainable, feeding guilds Phytochemical composition

1.0. Introduction

Cabbage, *Brassica oleracea*var. *capitata*L.(Brassicaceae) is a leafy vegetable believed to have evolved from a wild form, native to Europe, growing along the coast of the North Sea, the English Channel and northern Mediterranean (DAIS, 2002).The plant is a cool-season crop, and can be planted early or late in the growing season. It grows best in a relatively cool and humid climate. Generally, cabbage comes to harvest in 80 to 180 days from seed and in 60 to 105 days from transplants depending upon the variety (Albert, 2019). Cabbage has been grown extensively for over 2,500 years as a vegetable food crop. It is a very versatile crop and can be eaten raw, cooked, boiled and stuffed. Cabbages are a highly nutritious food source and contain a high amount of vitamins and minerals; they are particularly abundant in Vitamin C content (Starke-Ayres, 2014).

In spite of the numerous importance of this leafy vegetable, there have been significant annual reductions in yield as a result of pest attacks, especially insect pests. Continuous and injudicious use of synthetic pesticides in agricultural pest management often leads to various negative impacts such as development of resistance by the pest, adverse effect on non-target organisms and hazardous effect on environment. These drawbacks led to an alternative approaches for control of crucifer pests that are cost effective, biodegradable, low toxic effect on non-target organisms and eco-friendly**.** (Aktar *et al.*, 2009; Oladejo *et al*., 2021). As a result of human activities, agricultural producers are already experiencing negative effects of global climate change, making it increasingly important to design resilient agricultural systems that can help control pests and at the same time withstand greater climate variability while continuing to promote agricultural and food system (Doring *et al*., 2015). Among such control methods is the use of less-favoured crop cultivars as part of cropping system or integrated pest management (IPM) programmes.

Insect pests and disease resistance/tolerance are also important criteria in the choice of planting cultivar. The use of cabbage varieties that are tolerant to insect pests, diseases, and adverse environmental conditions is desirable (Starke-Ayres, 2014). Interestingly, intra-specific variation in phytochemical constituents in plants exists, and they serve as plant defense compounds against insect herbivory. Research carried out by Wetzel *et al.*, (2016) also suggests that increasing nutrient heterogeneity via intra-specific crop diversity could enhance insect pest control services. This study was carried out to investigate the influence of sole and different mixtures of Purple-ball, GloriaF1 and Oxylus varieties of cabbage on insect pests associated with the crop during the rainy and dry cropping seasons of 2020/2021.

2.0. Materials and Methods

2.1. Study Area:

This study was carried out at the experimental farm of the Federal College of Forestry, Jos (Fig.1). The College lies on latitude $9^{0}57'$N and longitude $8^{0}54'$E in the Northern Guinea Savannah zone of Nigeria with a height of about 1200meters (m) above sea level. The mean annual rainfall for the location ranges between 12.0m and 12.5m. The mean temperature of the area is between 23^{0}C and 25^{0}C (University of Jos Metrological Station, 2013).

2.2. Cabbage cultivars for planting:

Cabbage seeds: GloriaF1 (White); Oxylus (Flat-head); and Purple-ball (Red) were purchased from Plateau Agricultural Development Program (PADP).

2.3. Nursery cultivation:

The seeds of each cabbage cultivar were broadcasted on each nursery beds and were nursed for 4 to 6 weeks for rainy and dry season respectively before transplanting. The seedlings were transplanted when plants are 4 to 6 weeks old having 4 to 6 true leaves with an average height of 12centimeters (cm) (Choudhary *et al*., 2009; Albert, 2019).

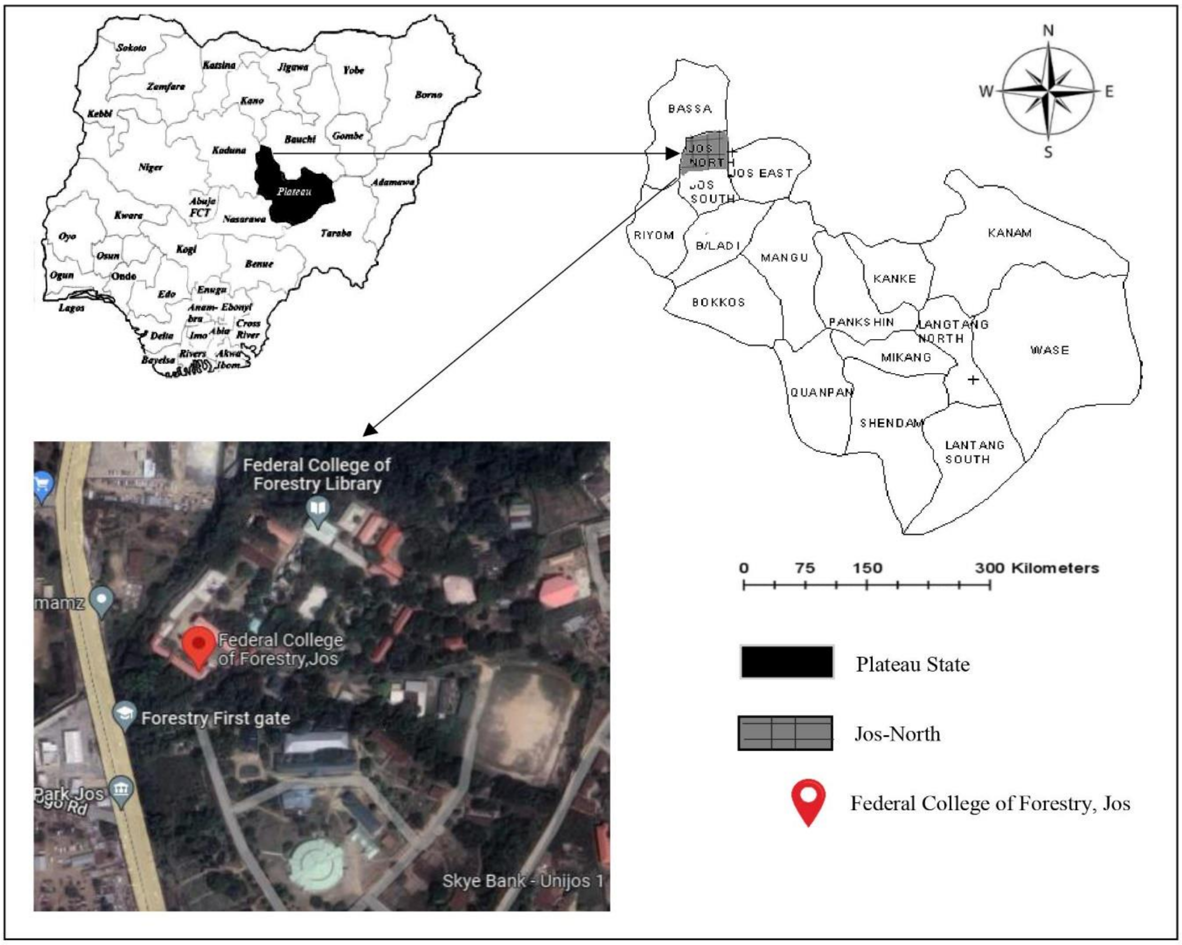

Figure 1: Map of Nigeria showing Plateau state and map of Plateau state showing Jos North L.G.A. and Federal College of Forestry (the study area).

2.4. Field preparation:

The experimental land of about 0.0252 hectares (ha) was ploughed and harrowed, after which 21sampling plots measuring 3m long by 2m wide each were demarcated. 1m interspaced borders were provided between sampling plots. A 40cm intra- and 40cm inter-row spacing was adopted giving approximately a population of 54 plants per plot (90,000 plants ha^{-1}).

Weeding and necessary fertilizer applications were carried out based on the soil test result. 3-cabbage varieties (Gloria F1; Oxylus and Purple-ball) were planted sole and inter-cropped, to give a total of 7 treatments. The experiment was laid out in a Randomized Complete Block Design (RCBD) replicated three times to give a total of 21 plots in the experiment, each treatment was separated from the other by 1m.

2.5. Soil Analysis:

Soil samples were collected from sampling plots at the depth of 0 – 20 cm. These soil samples were analyzed in the Chemistry Laboratory of the Federal College of Forestry Jos, to ascertain the pH and the nutrient content in line with Center for Agriculture, Food and the Environment (2022).

2.6. Arthropod Sampling Procedure:

Arthropod species sampling commenced between 7:00am and 9:00am and 4:00pm and 6:00pm at the nursery stage when seed emergence is about 70% till transplanting and thereafter every other day at the same time until maturity. Different parts of the crop were observed throughout the growing period to record the pest complex associated with cabbage plant using sweep net, pit fall and hand picking. The insect was swept through the 3m length middle row at an approximate walking speed of 1m/sec (sampling period; 3secs/ sub-sampling plot). The pit-fall traps (made from bottles containing 50 mil of 70% ethanol, with a drop of paraffin to reduce evaporation of the ethanol was buried over-night in the soil with a funnel-shaped top measuring 7cm in height) were used to collect samples and crawling arthropod species between 7:00am and 9:00am when the insects were relatively inactive. The mechanical hand-picking method of collecting samples was also used to collect larvae stages and other insects that inhabit both outside and inside of the folded leaves were randomly selected. The insects collected were killed in 90% ethyl acetate in a killing jar and then preserved in 70% ethanol. Butterflies and moths were dried and preserved in an airtight container containing silica gel. Spider species were however treated as a single population following the method of Ndam *et al*. (2012); Souza *et al*. (2012) and Lima *et al*. (2014). Immature insects collected were reared to the adult stage on the appropriate food resource in the laboratory for identification.

2.7. Insect identification:

All insects collected were sent to the Insect Museum Center of Ahmadu Bello University Zaria, Nigeria for identification and then categorized into feeding guilds in agreement with Southwood *et al.* (2004); Andrew and Hughes (2005); Wardhaugh *et al*. (2012); Neves *et al.* (2014).

2.8. Phytochemical analysis

The phytochemical analysis of the different cabbage species was determined at National Veterinary Research Institute (NVRI), Vom. This was to determine (if any), the reason(s) for insect selection among the different cabbage species.

2.9. Data Collection/Analysis

The diversity and number of arthropod taxa/species and others were collected from each cabbage variety. The yield from each cultivar / plot was also determined and converted to percentages. Data collected were subjected to analysis of variance. Where significant differences occurred among treatments, means were separated using Student Newman Keul's test at 5% level of probability.

3.0. Results and Discussion

3.1. Phytochemical components of cabbage

Phytochemical analysis showed that alkaloids, flavanoids, glycoside and cardiac glycoside were found to be present in very high concentration in all the three Cabbage varieties planted while saponins, tannins, steroids and terpenoids were found to be moderately present, but purple-ball variety (V1) has the highest qualitative value of cardiac glycoside (4.50±0.4), tannins (8.00±0.51) and steroids (6.00±0.21), it was also observed that the presence of anthraquinone was only found in Purple-ball cabbage while racines was in Purple-ball and Gloria but not found in Oxylus (table 1). This supports the findings of Broadley *et al*., (2007) that varieties of *Brassica oleracea* are known to vary widely in their mineral nutrient composition and glucosinolate profiles; phytochemicals that offer protection from insect herbivores.

Generally, the population density of insect arthropods was more on Gloria (V2) and Oxylus (V3) varieties as compared to Purple-ball (V1) in both rainy and dry seasons (Table 3 and 4). Also, Cabbage that was mixed with purple-ball variety showed reduced attack by insects as compared with Gloria and Oxylus planted sole. This confirms the work of Ethan *et al.*, (2018) that plants of the same species may differ greatly from one another in their defense against insect attack. Also, the preponderance of tannins, steroids, anthraquinones, and cardiac glycoside in purple-ball cabbage in high quantity may suggest a role in its pesticidal and anti-feedant potencies against some insect and pathogens (Thomas and Krishnakumari, 2015). Karamanoli *et al*., (2011), complemented this report by explaining that tannins exert its action by a combination of mechanisms that include iron chelation and enzyme inhibition. It was also observed that Saponins and Cardiac-glycosides are present in purple-ball cabbage; this could be linked to the insecticidal interaction with cholesterol which results in impairing ecdysteroid synthesis (Chaieb, 2010; Lengai *et al*., 2020). Also, Terpenoids are known to have a pungent odour and act as a deterrent to the insect (Martini *et al*., 2003).

Another school of thought acclaimed plant resistance (reduced infestation) as was observed in purple-ball cabbage to insect pests as a heritable characteristic whose mechanism and magnitude can be determined by studying the mutual interactions between the plant and insect for example, behavioural and metabolic (physiological) responses of insect to the host plant and the growth and development of the plant in response to insect feeding and reproduction (Ethan *et al.,* 2018). While Nazanin *et al*., (2017) and George (2022) regarded resistance/reduced infestation as a relative term associated with interaction between a herbivore and a plant host and categorized it into 3 operational basis; (1.) Antixenosis, (2.) Antibiosis and (3.) Tolerance. The unique advantages of resistant varieties of this kind are that, irrespective of the level of resistance, they reduce insect numbers at all levels of infestations, are cumulative in their effect and are compatible with other methods of insect control. In addition, they do not require additional expenses to the farmer and cause no toxicity or environmental pollution hazards.

Table 1. Phytochemical profile of Three Varieties of Cabbage

Phytochemical	Purpleball	GloriaF1	Oxylus
Tannins	+ 8.00±0.51	+ 3.01±0.42	+ 2.04±0.74
Anthraquinones	+ 5.00±0.25	- 6.02±0.14	- 2.42±0.07
Steroids	+ 6.00±0.21	+ 2.01±0.60	++ 5.04±0.17
Terpenoids	+ 4.00±0.12	+ 3.04±0.81	+ 6.04±0.47
Flavonoids	+ 4.10±0.04	++ 4.10±0.28	++ 4.02±0.07
Alkaloids	++ 4.02±0.24	+ 6.00±0.24	++ 4.00±0.09
Saponins	++ 3.10±0.10	+ 5.01±0.31	+ 6.08±0.14
Rasins	+ 4.2±0.25	+ 5.00±0.53	- 4.04±0.49
Glycoside	++ 3.20±0.07	++ 4.00±0.41	++ 3.07±0.14
Cardiac Glycoside	++ 4.50±0.40	++ 4.04±0.70	++ 8.02±0.04

Key: (++) Highly present; (+) Present; (-) Absent

3.2. Feeding Guilds:

The feeding guilds of the dominant taxa/species (RA ≥ 1%) are shown in table 2. Most insects associated with cabbage were vegetative feeders (stem and leaves), with Aphididae from Hemiptera; Pieridae, Pyralidae, and Yponomeutidae from order Lepidoptera, and Acrididae from order Orthoptera being the major pest. Some predator /parasitoids of these major insect pests were also observed during this study; from Order Hymenoptera and family Coccinellidae 4 species (*C. sulphurea, E. flaripes, H. pumila*and*A.variegata*); Braconidae 1 species (*Rhaconotumsp*) and from order Coleoptera and family Formicidae 3 species (*C. maccilatus, C.perrisi*and *C. sericus*) were observed along some unidentified (Arachinda) spider (Table 2).

The correlation analysis between inter-varieties cropping system of cabbage production performance during rainy and dry seasons cultivation indicated a strong positive linear correlation ($P \leq 0.01$). This means that their respective performances tend to move in the same direction (Table 3and 4). However, there is a significant difference in the varietal yield. The most consistent insect pest populations (table 4) shows a direct relationship to yield in all the cabbage varieties under both rainy and dry seasons. The mean yield values of inter-varieties cropping system of cabbage on the field under both rainy and dry seasons showed that Oxylus variety recorded the highest mean yield value during rain fell season and Gloria recorded the highest value during the dry season while the least yield value was observed in the Purple-ball plots for both seasons. This is in line with the finding of several authors who established cultivars of the same crop species having variation in terms of productivity (Mirenda *et al.,* 2012; FAO and CIRAD, 2015; Bazile *et al.,* 2016). This suggests the choice of Gloria and Oxylus cabbage with heavy use of synthesized chemicals in most growing areas of Nigeria, even though purple-ball cabbage is high in nutritional values and resistant to some insect attacks (Ebojie, 2016; Oladejo, *et al.,* 2021).

Table 2: Feeding guilds of dominant arthropods associated with cabbage

Guild	Order	Family	Genus/Species[a]	Pest stage	Plant part attack/Prey
Pr	Coleoptera	Coccinellidae	*Cheilomenes sulphurea* (Oliv) *Exochomusflaripes* (Thmb) *Hyperaspispumila* (Muls) *Adoniaveregata* (Gze)	Adult & larvae	Aphids, lepidopterous larvae, white flies and termite
Ph		Lagriidae	*Lagriavillosa* (F)	Adult	Leaves
Ph	Diptera	Muscidae	*Musca domestica*	Adult & Maggot	Rotten leaves
Ph	Lepidoptera	Hespiridae Sphingidae Yponomeutidae Pieridae Pyralidae Noctuidae	*Platyleschesmoritili* (Wallen) *Temnora* sp. *Plutella xylostella* (Linn) *Trichophusia ni* (Hbn) *Pierisrapae* (Linn) *Hellula phidileato* *Agrotis* sp. *Spodoptera littoralis* (Smith)	Caterpillars	Leaves & Head of cabbage
Ph	Hemiptera	Aleyrodidae	*Aleyrodes proletella* (L)	Adult & Nymphs	Under-side leaves, transmit Virus diseases
Ph		Aphididae	*Brevicoryne brassicsae* (L)	Adult & Nymphs	Pierce and suck sap from leaves and shoot
Ph	Homoptera	Platidae	*Cryptoflataunipunctata* (Oliv)	Adult	Leaves
Pa	Hymenoptera	Braconidae	*Rhaconotus* sp.	Adult	Aphids, Mites & soft bodies insects
Pr		Formicidae	*Camponotus maccilatus* (Fab) *Camponotus perrisi* (For) *Camponotus sericeus* (Fab)	Adult	Aphids,lepidopterous larvae, flies & larvae larvae of beetles.
Ph		Lygaeidae	*Aspilocoryphus fasciativentris* (S)	Adult & Nymphs	Pierce and suck sap from leaves and shoot.
Ph	Orthoptera	Acrididae	*Catantops basalis* (Walk)	Adult & Nymphs	Leaves
			Catantopsilus taenilatus (Karsch)	Adult & Nymphs	Leaves
Ph		Gryllidae	*Gymnogryllus lucens* (Walker)	Adult & Nymphs	Leaves
Ph		Pyrgomorphidae	*Pyrgomorpha vignaudi* (Guer)	Adult & Nymphs	Leaves
			*Zonocerus variagatus (*L)	Adult &Nymp	Leaves
			Phaneropterananasparsa (Stal)	Adult & Nymphs	Leaves
Pr		Spiders	Not identified	Adult	Polyphagous

[a]Arthropods with Relative Abundance ≥ 1%
Ph = Phytophagous (including defoliators, sap suckers from stem & leaves)
Pa = Parasitoid
Pr = Predators

Table 3: Effect of crop mixtures on phytophagous insect pest populations associated with cabbage (*Brassica oleracea*Var. *capitata* L.) Population per plot.

	Catantops basalis W.		Brevicorynehr assicae L.		Aleyrodesprol etella L.		Plutellaxyloste lla L.		Trichphusia niHbn		Pieris rapae L.		Hellula phidilealis S.	
Crop mixtures	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**	**Rainy**	**Dry**
Purple head	23d	19f	17d	23e	12e	17d	9f	13d	12e	11f	11g	11g	15f	22d
Gloria F1	28c	38c	30a	42a	18c	18c	26a	31a	30a	26b	22c	24c	24b	28c
Oxylus	38a	41b	25b	42a	16d	16e	22c	28b	28b	27a	30a	37a	28a	35a
Purple + Gloria	19f	15g	22c	36c	12e	12f	9f	9e	15d	16c	15e	20d	16e	18e
Purple + Oxylus	17g	20e	25b	34d	19b	19b	11e	9e	15d	13e	13f	19e	13g	17f
Gloria + Oxylus	32b	47a	30a	40b	21a	26a	24b	26c	24c	26b	23b	32b	20c	29b
Purple + Gloria + Oxylus	21e	27d	30a	34d	12e	9g	14d	13d	15d	14d	16d	17f	17d	18e

SE ± 0.719
T-test 5.254*

*Means followed by the same letter in a column are not significantly different from each other at P< 0.05, * =significant.*

Table 4: Mean yield per plot of inter-varieties cropping system of cabbage production during dry and rainy seasons

	Mean yield (Kg)	
Crop mixtures	**Rainy season**	**Dry season**
Purple head	35.100 [b]	46.802 [b]
Gloria F1	123.298 [a]	162.000 [a]
Oxylus	162.902 [a]	124.200[a]
Purple + Gloria	118.102 [a]	123.298 [a]
Purple + Oxylus	130.502 [a]	125.102 [a]
Gloria + Oxylus	130.502 [a]	124.200 [a]
Purple + Gloria + Oxylus	126.900 [a]	118.800 [a]
SE ±	0.145	
T-test	0.758*	

*Means followed by the same letter in a column are not significantly different from each other at P< 0.05, * =significant.*

4.0. Conclusion

Based on the result of this research, the inclusion of Purple-ball variety in GloriaF1 and Oxylus cabbage production will not only help in pest management and yield maintenance but will support sustainable agro-ecosystem services. These approaches can provide the importance of the economic benefits of using biological control method over synthetic products and will gain insight of accepting the sustainable way of cabbage pest management. However, evaluation of this potential in cabbage varietal mixture to pest control can be extended to other agricultural crops.

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Cite this article as:

Oladejo, A.O, Ukwela, U.M., Okoroafor, E and Ekoja, E.E, 2022**.** Exploring Varietal Mixtures as a Strategy for Sustainable Management of Insect Pests Associated with Cabbage [Brassica oleraceaVAR. capitata L. (Brassicaceae)].*Nigerian Journal of Environmental Sciences and Technology*, 6(2), pp. 418-426. https://doi.org/10.36263/nijest.2022.02.0378