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Effects of conventional pesticide and cultural packages on damage and yield differences of cabbage (*Brassica oleracea* var. capitata) by diamondback moth (*Plutella xylostella* L.)

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Abstract
Different cultural packages in controlling diamondback moth (DBM) on damage and yield differences of Copenhagen market cabbage variety were assessed. 'Neem leaf extract+tomato intercrop+manure+mulch'; 'Tomato intercrop+manure+mulch'; and 'Neem leaf extract+manure+mulch' treatments were compared with a popular commercial pesticide i.e. (Dimethoate) and Unsprayed treatments used as the control. Field experiments laid in randomized complete block design (RCBD) with three replications were carried out between August and December in 2013 and between July and December in 2014 at Koro and Bungatira Sub-counties, respectively, in Gulu district. Significant difference (P<0.05) was observed in the levels of damage scores between Dimethoate treatment and all the cultural packages except for treatment comprising the 'Neem leaf extract+tomato intercrop+manure+mulch'. Treatments that received manure clearly performed better (P<0.05) than those without manure. The result revealed no evidence to believe that there was significant difference (P<0.05) between 'Neem leaf extract+tomato intercrop+manure+mulch' treatment and the conventional dimethoate pesticide in the control of DBM.

Keywords: Cabbage, cultural packages, damage scores, diamondback moth

1. Introduction
Diamondback month (*Plutella xylostella* L.) is one of the most important economic pests of cruciferous crops throughout the world. The pest affects not only the yield, but also the quality of cabbage crop [1]. In the warm humid tropics, this insect pest breeds throughout the year, potentially completing at least ten generations annually [2]. This may mean that at least two to three generations of the pest can be produced during a single growing season for a cabbage crop. The destruction caused by DBM, coupled with the fact that it has the capacity to develop resistance very rapidly to control measure used singly, has made this pest the focus of integrated pest management (IPM) research in many parts of the tropical world. Subsequently, many pest control methods and technologies have been employed at some time or another for the management of DBM [2].

Unfortunately, some of the methods employed heavily relied on the use of inorganic insecticides to control the pest and yet chemical control is often associated with inappropriate and hazardous chemicals [3]. Due to repeated applications of pesticides, there had been induced resistance in the target insect pest population, that has resulted into field control failures of many insect pests including *Trichopulsia ni* and the diamondback moth, *P. xylostella* (L.). The situation is worsened since farmers often assume that the only solution to pest problems is to increase dose and spray frequencies which are very hazardous to human health, affecting users, produce consumers, and the environment [3]. Misuse of inorganic pesticides is attributed to the fact that the small scale farmers rarely have access to training on safe pesticide use and have only limited, or no access, to advice on the management of pesticides. These unsustainable pesticide uses are increasing with the demand for vegetables in expanding cities [4]; [5]. On the overall, the benefits from pesticides of increased yields from sufficient pest control may be outweighed by developed resistance in pests, killing of beneficial natural enemies, besides its effect on man and the entire environment [6].

The risk of negative consequences of inorganic chemical use is exacerbated by limited regulation on pesticides usage in Uganda. This has led to continuous use of banned or outdated chemical products, creating a situation that if not managed will negatively impact on horticultural exports to countries which have more stringent regulatory requirements for fresh crop produce. According to some authors [7], meeting these food safety requirements has become a major challenge for fresh produce export sector of many African countries. Cultural practices would be efficient and ecologically sound methods for the control of diamondback moth [8]. This study was conducted to assess the effectiveness of the cultural packages in controlling damages caused by DBM in cabbage crop.

2. Materials and Methods

2.1 Experiments

Field experiments were conducted from August to December 2013 in Gulu district at Koro Sub-county and from July to December 2014 at Bungatira Sub-county located south and north of Gulu municipality, respectively. A randomized complete block design (RCBD) consisting of five treatments with three replications was used. The five treatments comprised the 'Neem leaf extract+manure+mulch (Nle+Mn+Ml); 'Tomato intercrop+manure+mulch' (Ti+Mn+Ml); 'Neem leaf extract+tomato intercrop+manure+mulch' (Nle+Ti+Mn+Ml); Dimethoate (Dm) used as the current preferred method for the control of DBM; and Unsprayed (Usp) plots used as the control.

The field was prepared using a hand hoe and then marked out using sisal rope, tape measure and wooden pegs into rectangular experimental plot measured 6 m x 4.2 m. Cabbage seedlings were spaced at 60 cm x 45 cm, while tomato plants were spaced at 60 cm x 60 cm [9]. A distance of two (2) meters was left in between the blocks and one (1) meter between the plots in order to minimise interaction effect between the different treatments.

Quality seeds of Copenhagen market variety for cabbage and Heinz Holland variety for tomato were secured from registered agro-input shop in Gulu town. The seeds were sown in nursery bed measuring 1m x 1m cited near the main field to ease management [10]. Composted cattle manure was manually broadcasted at a rate of 2 kg/m^2 one month before transplanting [11], and later incorporated into the soil during the second digging conducted prior to transplanting seedlings in the seed bed. Tomato seedlings were transplanted fifteen (15) days in the main field before cabbage seedlings were transplanted at the age of four (4) weeks after sowing in the nursery bed [11].

Mulching with dry grass was done one week after transplanting cabbage seedlings and maintained to a thickness of 7.5 cm until maturity [12]. Careful manual hand weeding was first conducted at three weeks after transplanting tomato and thereafter done at every one (1) month interval until the crops were harvested. The spaces left between the plots were maintained clean by digging for easy management of the plots.

Neem leaf extract was prepared by soaking one (1) kg of fresh neem leaves in water overnight followed by pounding the sample gently in a mortar. Five (5) litres of clean water was added to the pounded leaf paste and strained in order to obtain a clear solution of neem leaf extract. One hundred (100) mls of liquid soap was added to the extract and stirred well before spraying the crop using a 2L hand sprayer. The liquid soap was added to aid the extract in sticking to the leaves of cabbage [13]. On the other hand, dimethoate pesticide was acquired from a registered agro-input shop in the local market. Five (5) mls of the pesticide was mixed in 2 litres of water in another 2L hand sprayer. This rate is equivalent to the rate of 50mls of dimethoate mixed in 20 litres of water and spraying was done every 14 days [7].

Data were collected on sixteen (16) cabbage plants sampled using simple random procedure from the plants inside the guard rows. The sample plants were tagged to ensure repeated measurement from the same plant. Observation and measurements were taken and recorded from each experimental plot every fourteen days (14) interval [10]. DBM larvae damages were scored and classified into four (4) scales ranging from 0-3 [14]. According to this scale, a score of zero represents no holes, 1 represents some scattered holes, 2 represents more holes but no consequences in the development of the plants, and a score of 3 represents severe damage infesting the head. Yield data was collected at the crop maturity by random sampling of 10 cabbage plants and weighing the heads separately.

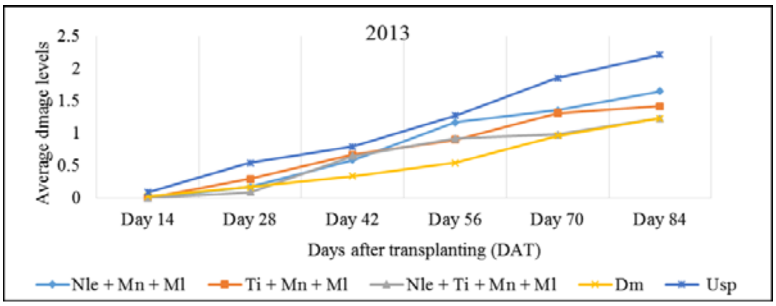
2.2 Data Analysis

Data were entered in spreadsheet and XLSTAT (Version 2014.5.01) [15] was used to generate analyses of variances (ANOVA), correlation matrices and Dunnett (two sided) tables to aid in analyzing data at the Least Significant Difference (LSD) of 5%.

3. Results

3.1 Variation in damage scores on cabbage under cultural packages and conventional chemical pesticide

Damage caused by DBM on cabbage was shown to increase steadily with time from 14 days after transplanting (DAT) to the crop maturity at 84 DAT. This trend was apparent for all the treatments used in the experiment and was consistent across both years and locations for the experiments. This increase could be attributed to the rise in the population of DBM as the cycle for the pest progressed. In line with this finding, several reproductive generations of DBM within a year under suitable conditions was reported [2]. In both seasons and locations, damage scores due to DBM were clearly seen to increase in the order of dimethoate (Dm) < Neem leave extract+tomato+manure+mulch (Nle+Ti+Mn+Ml) < Neem leaf extract+Manure+mulch (Nle+Mn+Ml) < Tomato+manure+mulch (Ti+Mn+Ml) < Unsprayed (Usp). The various cultural packages had a damage values falling in between that of dimethoate and that of the control which presented consistently highest damage scores. The result for the data is presented in figure 1 below.



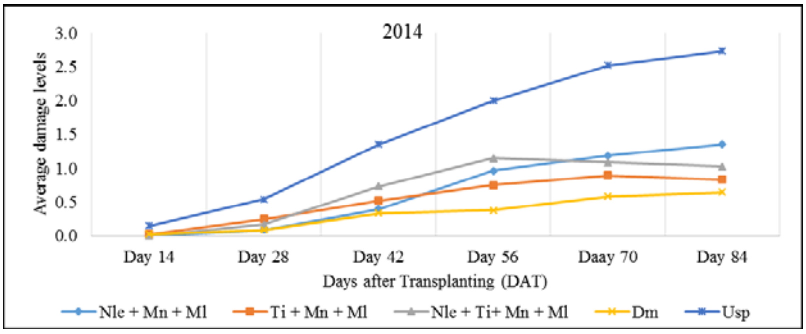


Fig 1: Variation in damage levels against number of days after transplanting for years 2013 and 2014

Key: Dm=dimethoate; Usp=unsprayed; Mn=manure; Ml=mulch; Nle=neem leaf extract; Ti=tomato intercrop

The data further indicated a distinct pattern of disparity in damage score between the control on one hand and the treatments on the other hand as the crop growth progressed through maturity. The various packages did not depict a wide disparity or gap in the damage score among themselves and with dimethoate control option. It was also evident from the two graphs that there was high damage recorded for the control compared to the rest of the treatments in the case of the year 2014. This was not the case in the year 2013.

The photo depicting adult moth, larva (the actual pest) and the damage caused is, respectively provided:-

Source: Field photo by Acaye Genesis 2013 and 2014, Bungatira and Koro Sub-counties-Gulu

Fig 2: Adult DBM (Left), larvae (Middle) and cabbage leaf damaged by the larvae (Right)

The result for the combined end of season damage score in respect to the year in which the experiment was conducted is presented in figure 3 below.

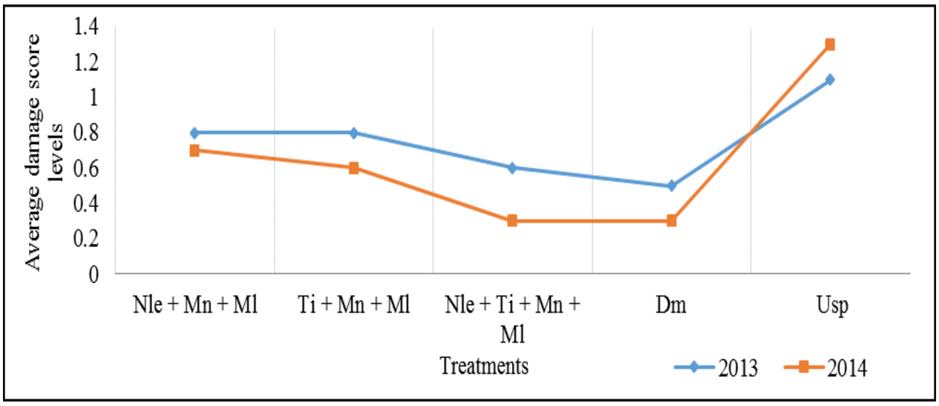


Fig 3: Mean chart extracted for the two experiments showing the levels of damage score according to the treatments subjected at the end of the season

Key: Dm=dimethoate; Usp=unsprayed; Mn=manure; Ml=mulch; Nle=neem leaf extract; Ti=tomato intercrop.

The plot of the mean chart revealed that, the levels of damage scores varied among the treatments, with the cultural packages recording lower score than for the unsprayed control similar indicating probably the effect of location or weather variation in the course of the two years in which the experiments were conducted.

Interval damage assessment indicated the trend in the damage score for each and every treatment. It had also depicted clear disparity in damage score at different time interval. For the purpose of in depth investigation, point assessment of damage due to DBM was conducted using Dunnett (two sided) test against the control. The results indicated that all the treatments differed significantly in both years when compared to the control (unsprayed) as is indicated in Table 1 below:

Table 1: Dunnett (two sided) analysis of the differences between the control treatment (unsprayed) and the other treatments with a confidence interval (CI) of 95% at end of season for year 2013 and 2014, respectively

Treatments	2013	2014
	Pr> Diff	Pr> Diff
Usp vs Dm	0.001*	0.001*
Usp vs 'Nle+Ti+Mn+Ml'	0.001*	0.001*
Usp vs 'Ti+Mn+Ml'	0.015*	0.006*
Usp vs 'Nle+Mn+Ml'	0.025*	0.013*

Key: * Significant at 5%
Dm=dimethoate; Usp=unsprayed; Mn=manure; Ml=mulch; Nle=neem leaf extract; Ti=tomato intercrop

The mean separation for the damage scores at the time of maturity of cabbage was obtained using the Fisher (LSD) is presented in Table 2.

Table 2: Fisher LSD grouping of the treatments basing on level of damage scores in years 2013 and 2014

Treatments	2013	2014
	LS means	LS means
Dm	0.367[a]	0.292[a]
'Nle+Ti+Mn+Ml'	0.400[a]	0.330[ab]
'Ti+Mn+Ml'	0.767[b]	0.649[bc]
'Nle+Mn+Ml'	0.800[b]	0.736[c]
Usp	1.150[c]	1.302[d]

Key: [a] treatment ranked in first group, [ab] treatment ranked in first and second group [b] treatments ranked in second group, [bc]treatment ranked in second and third group, [c] treatment ranked in third group

Dm=dimethoate; Usp=unsprayed; Mn=manure; Ml=mulch; Nle=neem leaf extract; Ti=tomato intercrop

The results showed the differences among the treatments as far as the levels of damage score were concern. The treatments were grouped differently according to their strength in controlling DBM damages. Treatments ranked in group 'a' had lower level of damage score than treatments ranked in group 'b' and group 'c' had the high level of damage score.

3.2 Yield differences of cabbage under the cultural packages and conventional pesticide

The different packages indicated a consistent trend of control level as presented in figure 3 below. In the chart, yield obtained per plot was converted into an equivalent yield expressed in tonnes per acre of land.

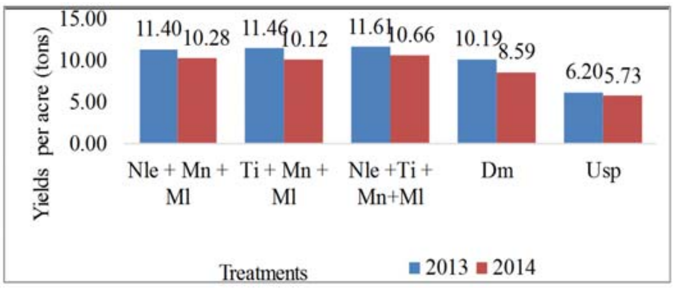


Fig 4: Variation in the yield of cabbage (tons/acre) for the different treatments for years 2013 and 2014.

Key: Dm=dimethoate; Usp=unsprayed; Mn=manure; Ml=mulch; Nle=neem leaf extract; Ti=tomato intercrop.

The chart showed nearly similar yield level for the three cultural package of Neem leave extract (Nle+Mn+Ml), Tomato+manure+mulch (Nle+Mn+Ml), and Neem leaf extract+tomato+manure+mulch (Nle+Ti+Mn+Ml). Cabbage yield under dimethoate control was slightly less than those of the cultural control package. A clear lower yield was observed for unsprayed control when compared to the rest of the treatments. The graph has shown a clear and consistent yield pattern across the two years.

Further analyses revealed significant (P<0.05) differences between the unsprayed plot and the rest of the plots. The detailed result for comparison of the different method conducted using Dunnet (two sided) analysis is presented in Table 3, below;-

Table 3: Dunnett (two sided); Analysis of the differences in yields between the control treatment (Unsprayed) and the other treatments with a CI of 95%

Treatments	2013	2014
	Pr> Diff	Pr> Diff
Usp vs 'Nle+Ti+Mn+Ml'	0.001*	0.001*
Usp vs 'Ti+Mn+Ml'	0.001*	0.001*
Usp vs 'Nle+Mn+Ml'	0.001*	0.001*
Usp vs Dm	0.001*	0.011*

Key: * significant at 5%
Dm=dimethoate; Usp=unsprayed; Mn=manure; Ml=mulch; Nle=neem leaf extract;
Ti=tomato intercrop.

The treatments for the cultural packages, namely Nle+Mn+Ml, Ti+Mn+Ml, and Nle+Ti+Mn+Ml were significantly different from Dm treatment. Usp treatments recorded the least yield hence ranked **'a'**, while Dm was ranked **'b'** and the cultural packages were ranked **'c'** Table 4 below.

Table 4: Fisher LSD grouping of the treatments basing on yields of cabbage in 2013 and 2014

Treatments	2013	2014
	LS means	LS means
Usp	0.558[a]	0.516[a]
Dm	0.917[b]	0.773[b]
'Nle+Mn+Ml'	1.026[c]	0.910[bc]
'Ti+Mn+Ml'	1.031[c]	0.926[c]
'Nle+Ti+Mn+Ml'	1.045[c]	0.960[c]

Key: Dm=dimethoate; Usp=unsprayed; Mn=manure; Ml=mulch; Nle=neem leaf extract; Ti=tomato intercrop.

The study revealed that the cultural packages yielded higher in terms of ton/acre of cabbage when compared to Dm and Usp treatments. Usp and Dm treatments were grouped 'a' and 'b', respectively while all the cultural packages; 'Nle+Ti+Mn+Ml', 'Nle+Mn+Ml' and 'Ti+Mn+Ml' treatments were grouped 'c' in both 2013 and 2014, Table 4.

4. Discussion

The result indicated that the lower damage score by DBM in 2013 and 2014 were achieved through the application of dimethoate (Dm) and the cultural control package comprising the neem leaf extract+tomato intercrop+manure+mulch (Nle+Ti+Mn+Ml). These result was consistent with the previous research report which showed significantly lower egg oviposition rate accompanied by lower DBM infestation of cabbage plants sprayed with dimethoate and neem leaf extract +tomato intercrop+manure+mulch (Nle+Ti+Mn+Ml) [16].

Damages were caused by larvae feeding action on the cabbage leaves, which did not only lower the weight, but also quality of the product. Although DBM are small in size relative to other lepidopteran pests such as cabbage looper (*Trichoplusia ni*) and imported cabbageworm (*Pieris rapae*), densities of diamondback moth larvae can reach levels that result into total damage of leaves. In crops such as broccoli, the presence of larvae of DBM in florets could result into the total rejection of the produce [17].

The research pointed out that cultural package could reduce damage due to DBM, with the most significantly ($P<0.05$) lower damage achieved when cultural package consisting of a combination of neem leave extract+tomato intercrop+manure+mulches ('Nle+Ti+Mn+Ml). The effect of the control of the DBM that ultimately resulted into lower damage on the plant and higher yield of the cabbage plants could be through direct and indirect effects. The direct effect was probably attributed to the integral components of the package on the oviposition, larvae survival and feeding habit and the life cycle of the pest. Neem (*Azadirachta indica*) formulation was found to have high efficacy in the control of DBM [1]. It was reported that intercropping restricts the pest insects' ability to locate and colonize the main crop [8]. In addition, neem leaf extracts was reported to act on various insects affecting their metabolism, growth and development in several ways. The neem extract was found to interfere with pest activities bydisrupting or inhibiting the development of eggs, larvae or pupae; blocking the moulting of larvae or nymphs; disrupting mating and sexual communication; repelling larvae and adults; deterring females from laying eggs, sterilizing adults, poisoning larvae and adults; deterring feeding; blocking the ability to "swallow"; sending metamorphosis at various stages and inhibiting the formation of chitin [13]. Thus application of plant extract including that of bitter olive *Melia azedarach* (Linnaeus) (Meliaceae) has also been found effective in the control of various insect pest including DBM [12].

Similarly, tomato plants were shown to have a repelling odour which interferes with oviposition, thus reducing the infestation level by pests. Intercropping was also reported to interfere with the identification of the right host plants [18]; [8]. Despite of the repellent property of the tomato in the intercrop control package, damages were recorded on cabbage leaves. This is in accordance to previous study that observed some of the eggs that were laid in plots subjected to cultural control package integrating tomato intercrop, manure and mulching (Ti+Mn+Ml) were able to hatch, grow and mature into adult moths. This finding is supported by other scholars who indicated that tomato alone could not completely interfere with the hatching and growing of larvae [19]. Intercropping was also reported to create and provide micro climate with tendency to favour natural enemies of insect pests [20], although this experiment did not validate this aspect. In a similar way, organic mulches were reported to reduce the infestation of pest. Low incidence of pest infestation was associated with increased predator abundance in crops especially those treated with organic mulches [21]. This probably could mean that the numbers of larvae were lowered by natural enemies through predation, hence low damage level. Contribution of mulch in the control of damage by pest was supported by a study conducted in Ethiopia [11]. The study revealed that damage caused by DBM was reduced by manure. The manure in this case seemed to have mitigated the pest indirectly by creating pseudo resistance to the plant against the pest, by providing and maintaining nutrients and moisture in the soil. Cabbage thus had the tendency to quickly suffer lesser consequences created by the damage.

The cabbage plots subjected to the three major cultural control packages of 'Nle+Ti+Mn+Ml'; 'Ti+Mn+Ml'; and 'Nle+Mn+Ml' produced similar yields. The yield pattern for the above treatments followed the same trends in each of the years, namely 2013 and 2014.

The three treatments recorded the highest yields of 11.61, 11.46, and 11.40 tonnes/ acre in the year 2013, while yield values of 10.66, 10.12 and 10.28 tons/acre of cabbage were realized in the year 2014. Plots treated with dimethoate (Dm) yielded 10.19 and 8.59 tons/acre of cabbage in 2013 and 2014, respectively. The control plot without any treatment produced low yields of 6.2 and 5.73 tons/acre of cabbage in the year 2013 and 2014, respectively.

This study provided an estimated yield loss due to DBM of 3.42 to 5.0 tons/acre on average. This can be translated into a yield loss of 8.55 to 12.5 tonnes/ha. This yield loss was quite high when compared to a yield loss of between 3.4-6.6 tonnes/ha reported from a survey of field vegetable production in Tanzania [22].

The observed variations in yields between the treatments were majorly caused by application of manure. The treatments that received manure as a component of the treatment yielded more than treatments that did not receive manure. Presence of manure in the three major treatments of Nle+Ti+Mn+Ml, Ti+Mn+Ml, and Nle+Mn+Ml was responsible for the more less similar yield values obtained for the cabbage, which was significantly different ($P<0.05$) from that of Dm and Usp treatments (Fig 4). Studies conducted elsewhere, similarly revealed that Kale planted with manure yielded higher than the Kale planted under mono-crop and without manure. This difference was due to the contribution of manure releasing additional nutrients, explaining boost in the growth of the plants which was in agreement with the report by Beyene [11].

The differences in the yield realized by the similar treatments applied at the two locations in different years were probably due to the variation in the pattern of rainfall distribution, frequency and intensity. Data from meteorological centre indicated that there was generally more rainfall in year 2013 than in the year 2014. There was consistency in number of rainy days in year 2013 than in 2014, especially in September as shown in Figure 5 and 6 below. The variation in the mean rainfall, number of rainy days and their consistency contributed to the differences in yield of cabbage between the treatments.

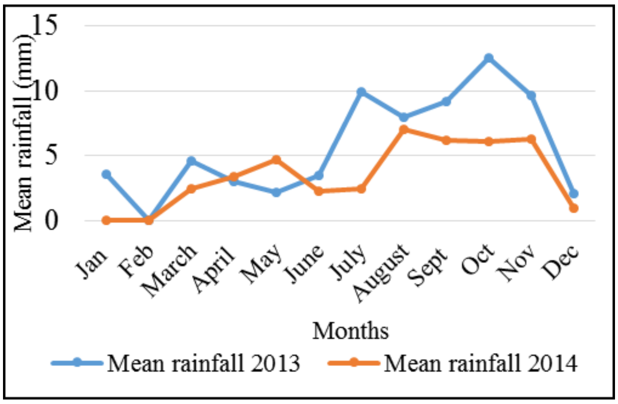


Fig 5: Average rainfall in 2013 and 2014 (Source: Gulu weather station)

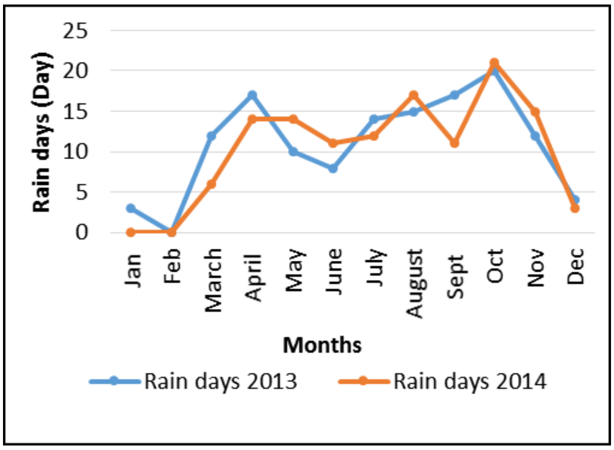


Fig 6: Rainy days during the months for years 2013 and 2014 (Source: Gulu weather station). Rain day's ≥ 0.1mm of rainfall for the station [23].

The package containing mulch such as Nle+Ti+Mn+Ml, Ti+Mn+Ml, and Nle+Mn+Ml performed well in terms of yield as well as sustenance of low damage by DBM. Mulch put around the crop improves the quality of the soil and also smoother weed [24]. They are protective covering of the soil surfaces, moderate temperature, prevent erosion, retain soil moisture, improve soil structure, keep plant clean and disease free and encourage earth worm activities [25]. Mulches from organic materials gradually add to the soil organic matter and nutrient banks as they break down. They encourage growth of worms and beneficial organisms that can help improve soil structure and the availability of nutrients for the plants [26]. In this particular experiment, mulch could have also contributed to some extent in minimizing soil water evaporation through the soil surface.

In conclusion, the cultural package with all the four component control options, that is, 'Nle + Ti + Mn + Ml' package proved effective in the control of the damages caused by DBM larvae. The control offered against DBM by the package was to a greater extent as effective as the control rendered by dimethoate, which is the conventional pesticide widely used in the control of DBM by the farmers. Furthermore, the cultural package evidently produced better yield of cabbage. It was, therefore, recommended that the use of this package could be adopted in the control of DBM. Further studies could, however, focus on economic feasibility of the method compared to use of dimethoate. The effectiveness of the package in controlling multiple pests in cabbage family could also be investigated.

5. Acknowledgements
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