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The efficacy of selected local pesticides in prevention of leaf damage and improvement of yield in *Brassica rapa* subsp. *pekinensis* L. (Chinese cabbage)

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Abstract

Vegetable constitutes a healthy diet which is rich in vitamins, minerals and fibre. However, production of vegetable is currently hindered by several factors including pest infestation/pathogen infection. Pests and pathogens affect vegetable by interfering with growth and yield. The impacts may be manifested in holes on leaves or reduced numbers of leaves that subsequently affect the yield. To overcome problems associated with pests and/or pathogens synthetic pesticides are widely used. However, synthetic pesticides are blamed to be costful and environmentally unfriendly. As a result vegetable growers in many countries have decided to rely on local pesticides in attempt to improve growth and yield of crops. This study aims to evaluate the efficacy of a mixture of wood ash and soil, cow urine, pawpaw seeds, chilli fruits and neem leaves for growing Chinese cabbage which is widely consumed in Tanzania. Standard methods were used to prepare extracts of the aforementioned local materials and later on sprayed on growing Chinese cabbage. Normal water was used for control plots. The results of One Way ANOVA revealed significant difference in leaf damage and yield of Chinese cabbage ($p < 0.05$). The order of increasing effectiveness of the local materials in protecting leaves of Chinese cabbage was: mixture of wood ash and soil > cow urine > pawpaw seeds > chilli fruits > neem leaves > control. A similar trend was obtained for improvement of yield of Chinese cabbage. Intactness of leaves and improved yield of Chinese cabbage can be attained by spraying a mixture of wood ash and soil, and cow urine. Further studies are recommended on the efficacy of the studied local materials in other horticultural crops. Also isolation of active compounds in mixture of wood ash and soil, and cow urine for development of cheap and environmentally friendly pesticide is recommended.

Keywords: Chinese cabbage; leaf damage; pesticides; local materials; yield

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1. Introduction

Many parts of the world experience steady losses of crops due to pest infestation among other factors. It is estimated that up to 40% of crop annual production is lost due to pest infestation (Food and Agriculture Organisation (FAO), 2021). Thus reliance on pesticides particularly the synthetic ones in attempt to increase agricultural production cannot be avoided. Synthetic pesticides are chemical compounds that are used to kill pests such as insects, rodents, fungi and noxious weeds (World Health Organisation (WHO), 2020). Synthetic pesticides have contributed to substantial increase in agricultural yield because of their ability to control pests and diseases (Abhilash and Singh, 2009). However, the practices of using synthetic pesticides render farmers vulnerable to chemical, physical and biological hazards (Litchfield, 1999). This is because synthetic pesticides are reported to negatively affect ecosystems ranging from polluting the soil, air, ground and surface water, to contributing to human health problems such as cancer, chronic kidney diseases, suppression of immune system, sterility as well as causing neurological and behavioural disorders within children (Damalas and Eleftherohorinos, 2011; Pallangyo *et al*., 2019; Pathak *et al*., 2022). To plants synthetic pesticides contribute to wilting and rusting of stems and branches (Maningo, 2019). Yet, it is said that the negative impacts of synthetic pesticides occur when these chemicals are excessively and/or inappropriately used (Pathak *et al*., 2022).

It follows therefore that due to environmental issues and high costs associated with the synthetic pesticides, farmers have decided to use locally available resources as alternatives to the synthetic pesticides (Abate *et al*., 2000). In Tanzania materials reported to be widely used as local pesticides include mixture of soil and kitchen ash (Maningo, 2019), *Carica papaya* (pawpaw) seeds, *Azadirachta indica* (neem) leaves, *Capsicum annuum* fruits (Chilli) and cow urine (Dahlin, 2009). But there is scanty information regarding efficacy of these materials for growing Chinese cabbage particularly enabling intactness of leaves and enhancement of yield. Thus evaluation of pesticidal potential of locally available materials like these against pests/pathogens threatening vegetable farming is important.

In Tanzania like other countries vegetable farming is expanding at a high pace. Statistics show that cabbage is the third most important vegetable after tomato and onion (Massomo *et al*., 2005). Cabbage is widely used and plays a very important role in the human nutrition especially as source of vitamins such as C and K, minerals *(*K, Ca and Mg) and dietary fibre (Craig and Beck, 1999). In 2020 the countrywide production of cabbage was 35,154 tons on 4,484 ha of land. Dodoma Region ranked the third in production of cabbage after Lindi and Kilimanjaro with an average productivity of 30.8 tons/ha (United Republic of Tanzania (URT), 2021). The main pests of Chinese cabbage include aphids, spider mites and cutworms (AGRI farming, 2018). These pests deteriorate plants in different ways, including sucking of cell sap, consequently causing leaf roll, holes, curl and stunted growth (Carter and Sorensen, 2013; Balasha and Nsele, 2019). A reasonable reduction of leaves due aphid invasion on vegetable was reported by Munthali and Tshegofatso (2014). The size and number of leaves are important attributes needed for controlling biomass accumulation and hence the yield of vegetable (Jefferies, 1995; Rozentsvet *et al*., 2022). Thus evaluation of vegetable leaves can be linked to leafy yield.

With these views in mind, this study therefore aims to investigate the suitability of mixture of kitchen ash and agricultural soil, powdered neem leaves, pawpaw seeds and chilli fruits in protecting leaves of *Brassica rapa* subsp. *pekinensis* L. (Chinese cabbage) and subsequently maximizing the yield. The control involved the use of normal water on Chinese cabbage.

2. Materials and methods

2.1 Description of the study area

The present study was conducted at the University of Dodoma which is found in Dodoma District, in Tanzania (Figure 1). The study area is located along latitude 6°10′23"S and longitude 35°44′31"E. It is a semi-arid region getting a modest amount of rainfall which ranges from 550 to 600 mm per year; the rainy season usually begins in December through April (Gayo, 2021). The average annual temperature of this area is 29ºC, with the lowest and highest peaks of 13ºC and 30ºC experienced in July and November, respectively (Kayombo *et al*., 2020). The soils of Dodoma are categorised on the basis of hydrological characteristics, these include Phaeozems and Leptosols with poor groundwater retention as well as Vertisol and Acrisols but with moderately suitable groundwater permeability and retention properties, respectively (Mseli *et al*., 2021). In Dodoma the soil textural classes are comprised of coarse sand, loamy and clays underlaid with hard sub-soils (Msanya *et al*., 2018). Dodoma Region has a population of 3,085,625 people (United Republic of Tanzania (URT), 2022). The main economic activity in that area is agriculture. The recent increase in population in that area has contributed to mushrooming of horticultural crops cultivation particularly Chinese cabbage. In order to get high yield of the vegetable, local pesticides are applicable by farmers though with limited information regarding their efficacy.

2.2 Research design

The method recommended by AGRI farming (2018) was used to design this study. In this study a Completely Randomized Design (CRD) with five (5) treatments, replicated to four times were used. A hand hoe was used to prepare six plots separated by 2 m. Each plot had four rows separated by 20 cm; within each row there were 15 holes with 3.5 cm depth and 2 cm spaced. In plot numbers 1, 2, 3, 4, 5 and 6, several healthy seeds of Chinese cabbage that were purchased from a vendor in Dodoma city were planted in each hole. Neem leaves, chilli fruits and pawpaw seeds were washed with distilled water to remove debris, and then air-dried to constant weights. The local pesticides were freshly prepared whenever needed. This was important in order to prevent deterioration of the local pesticides. For example, keeping cow urine for a long time was seen as a suitable medium for growth of microorganisms and easy escape of ammonia. On the day of application, dried leaves of neem, fruits of chilli and seeds of pawpaw were ground using mortar and pestle as recommended by Phoofolo *et al*. (2013). Then 200 g of each of the local pesticide was separately dissolved in 1 L distilled water for 24 hours to give 20% (w/v) suspension.

On the other hand, 10 ml of cow urine was added to I L distilled water to give 10% solution as recommended by Singh (2022). Lastly, a mixture of kitchen ash and agricultural soil was prepared by adding 100 g of ash to 100 g soil; the resulting mixture was added to 1 L distilled water. Kitchen ash and agricultural soil were seen appropriate because they are within the reach of the majority of farmers. All the resulting mixtures (ash and soil, powdered neem leaves, chill fruits and pawpaw seeds) were left overnight, after which decantate and the cow urine were ready for application on whole plants/Chinese cabbage. After two days of germination of Chinese cabbage, suspensions from kitchen ash and soil, powdered neem leaves, pawpaw seeds and chilli fruits as well as normal water and cow urine were sprayed on aboveground parts of the Chinese cabbage at intervals of five days in plot numbers 1, 2, 3, 4, 5 and 6, respectively. Plot 5 was used as control.

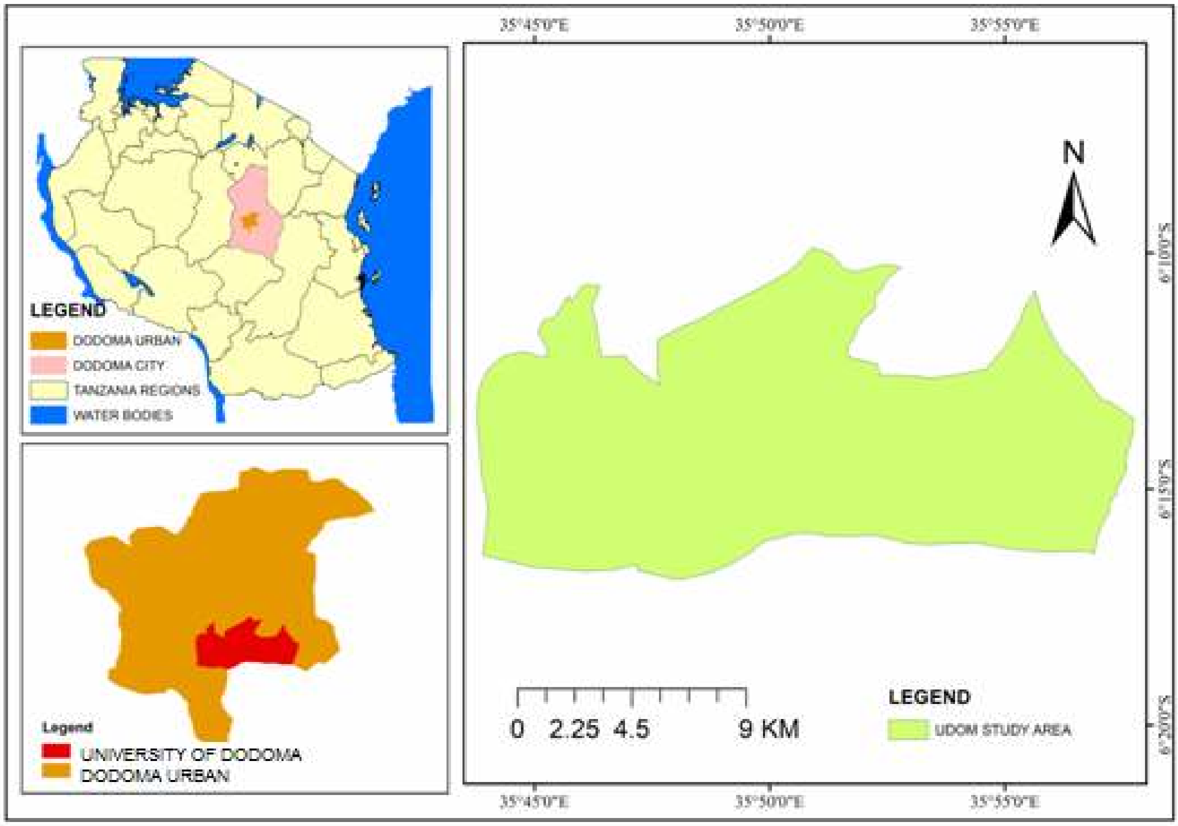

Figure 1: Location of University of Dodoma

2.3 Data collection

After six weeks following germination and intermittent spraying of the local pesticides, Chinese cabbage leaves were closely examined for injury or any sign caused by pathogens or pests and recorded by their numbers as recommended by Nutter *et al*. (1993). Finally, all Chinese cabbage leaves were harvested by cutting them at the base for fresh weight measurement using a chemical balance and subsequent actual yield analysis.

2.4 Data processing and analysis

Assessment of leaf damage of Chinese cabbage was done through close observation of the leaves for destruction by whichever pests/pathogens in the field and then using the method recommended by Piotrowski *et al*. (2021), as follows:

Percentage leaf damage (%) = (Number of damaged leaves[slight, moderate or severe]/Number of total leaves) x 100 (1)

Efficiency of the local pesticides to enhance yield of Chinese cabbage was evaluated using the following formula (Young, 2013):

Efficiency of Chinese cabbage yield (%) =[Actual yield (yield with a local pesticide (kg/m^2)/Attainable yield (theoretical yield (kg/m^2)] x 100 (2)

Theoretical yield of Chinese cabbage = 4 kg/m^2 (AGRI farming, 2018)

Data on percentage leaf damage and efficiency of Chinese cabbage yield were statistically analysed by One Way ANOVA because of their parametric nature and treatment means compared using Tukey's test.

3. Results

3.1. Protection of Chinese cabbage leaves on treatment with local pesticides

The results in Figure 2 show the leaf damage of Chinese cabbage under different treatments of the local pesticides. The means of leaf damage (%) with ranges in brackets on application of a mixture of ash and soil, chilli fruits, neem leaves, pawpaw seeds, cow urine and control were 1.7 ± 0.4 (0.96 – 2.91), 12.1 ± 0.6 (10.8 – 13.5), 14.4 ± 1.3 (11.1 – 17.7), 11.5 ± 1 (8.8 – 13.9), 6.2 ± 0.5 (5.3 – 7.3) and 30.3 ± 2 (25.6 – 35.1), respectively (Figure 2). The trend of decreasing shoot damage of Chinese cabbage by the local pesticides was ash/soil mixture < cow urine < pawpaw seeds < chill fruits < neem leaves < control. The results of One Way ANOVA revealed significant difference in percentage shoot damage in the studied local pesticides ($p < 0.05$). The results of Tukey's test indicated significant differences in all paired groups ($p < 0.05$); except for ash and soil vs cow urine, chill fruits vs neem leaves, chill fruits vs pawpaw seeds and neem leaves vs pawpaw seeds (Table 1).

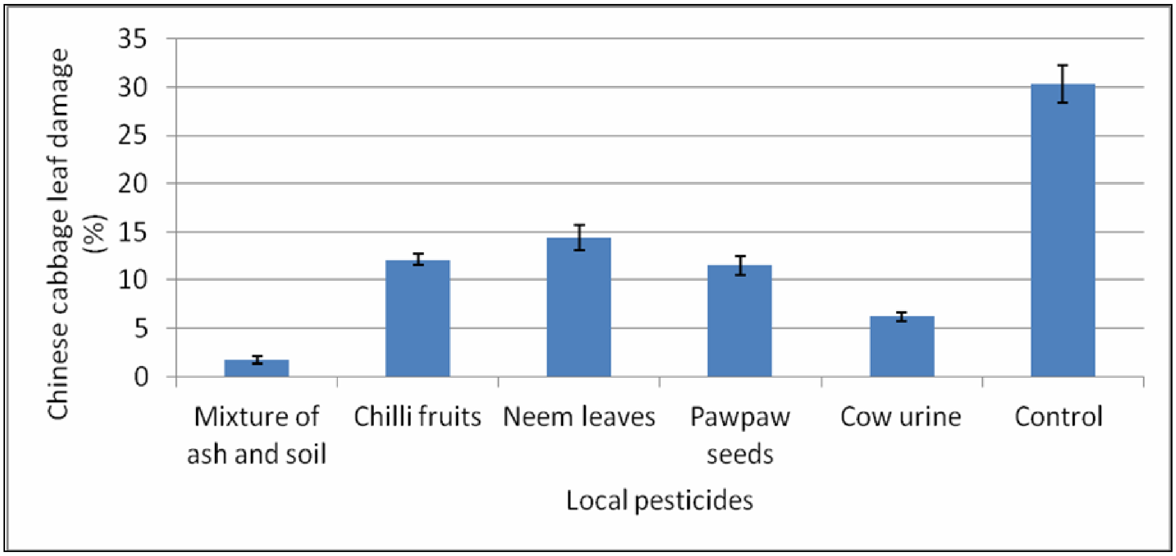

Figure 2: Chinese cabbage leaf damage under different treatments of local pesticides

Source: Field data

Table 1: Comparison of Chinese cabbage leaf damage under different treatments of local pesticides

Comparison	*Q*	*p*	Significance
Ash and soil vs chilli fruits	9.827	$p < 0.001$	***
Ash and soil vs neem leaves	11.983	$p < 0.001$	***
Ash and oil vs pawpaw seeds	9.194	$p < 0.001$	***
Ash and soil vs cow urine	4.224	$p > 0.05$	ns
Ash and soil vs control	26.930	$p < 0.001$	***
Chill fruits vs neem leaves	2.157	$p > 0.05$	ns
Chill fruits vs pawpaw seeds	0.633	$p > 0.05$	ns
Chill fruits vs cow urine	5.602	$p < 0.05$	*
Chill fruits vs control	17.104	$p < 0.001$	***
Neem leaves vs pawpaw seeds	2.789	$p > 0.05$	ns
Neem leaves vs cow urine	7.759	$p < 0.001$	***
Neem leaves vs control	14.947	$p < 0.001$	***
Pawpaw seeds vs cow urine	4.970	$p < 0.05$	*
Pawpaw seeds vs control	17.736	$p < 0.001$	***
Cow urine vs control	22.706	$p < 0.001$	***

3.2 Enhancement of Chinese cabbage yield on application of local pesticides

The results in Figure 3 show the yield of Chinese cabbage under different treatments of local pesticides. The means of Chinese cabbage yields (%) with ranges in brackets on application of a mixture of ash and soil, chilli fruits, neem leaves, pawpaw seeds, cow urine and control were 87.5 ± 1.02 (85 – 90), 42.5 ± 1.02 (40 – 45), 38.8 ± 0.72 (37.5 – 40), 65 ± 1.77 (62.5 – 70), 78.8 ± 1.6 (75 – 82) and 26.9 ± 1.2 (25 – 30), respectively (Figure 3). The increasing trend in the yield of Chinese cabbage treated with the local pesticides was ash/soil mixture > cow urine > pawpaw seeds > chill fruits > neem leaves > control. One Way ANOVA revealed significant difference in Chinese cabbage yield ($p < 0.05$). The results of Tukey's test revealed significant differences in all paired groups except for chill fruits vs neem leaves (Table 2).

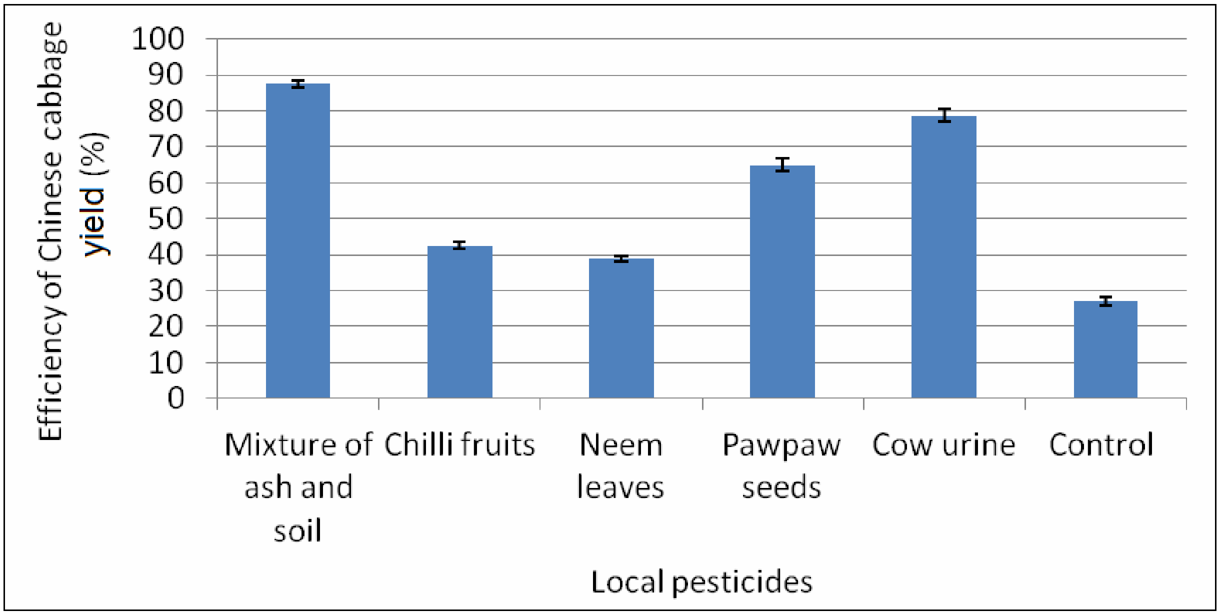

Figure 3: The efficiency of local pesticides on enhancing yield of Chinese cabbage

Source: Field data

Table 2: Comparison of Chinese cabbage yield under different treatments of the local pesticides

Comparison	*q*	*p*	Significance
Ash and soil vs chilli fruits	35.273	$p < 0.001$	***
Ash and soil vs neem leaves	38.212	$p < 0.001$	***
Ash and oil vs pawpaw seeds	17.636	$p < 0.001$	***
Ash and soil vs cow urine	6.859	$p < 0.01$	**
Ash and soil vs control	47.520	$p < 0.001$	***
Chill fruits vs neem leaves	2.939	$p > 0.05$	ns
Chill fruits vs pawpaw seeds	17.636	$p < 0.001$	***
Chill fruits vs cow urine	28.414	$p < 0.001$	***
Chill fruits vs control	12.247	$p < 0.001$	***
Neem leaves vs pawpaw seeds	20.576	$p < 0.001$	***
Neem leaves vs cow urine	31.353	$p < 0.001$	***
Neem leaves vs control	9.308	$p < 0.001$	***
Pawpaw seeds vs cow urine	10.778	$p < 0.001$	***
Pawpaw seeds vs control	29.884	$p < 0.001$	***
Cow urine vs control	40.662	$p < 0.001$	***

4. Discussion

The mixture of ash and soil ranked the first in protecting Chinese cabbage leaves against damage and subsequently improving the yield. These results suggest the presence of a potent substance(s) in the suspension formed after mixing kitchen ash and soil which worked against Chinese cabbage pests/pathogens. The substance(s) may be able to kill or deter pests and/or pathogens of Chinese cabbage. The result of this study is in conformity with Demissie *et al.* (2008) and Wahedi *et al.* (2017) who demonstrated the effectiveness of wood ash against pest infestation in okra, spinach, sorrel and maize in Ethiopia and Nigeria. Additionally wood ash was found to have repulsive property against vegetable pests (Mooya, 2016). But the efficiency of wood ash against pests may be site/regional specific; for example, in Ghana Babendreier *et al.* (2020) reported on the ineffectiveness of wood ash against maize pests.

Apart from pesticidal property, a mixture of wood ash and soil probably possesses an agent(s) useful in soil nourishment. Nourishment of the soil probably executed its effect and resulted in intactness of Chinese cabbage leaves with resultant improved yield. In Malaysia wood ashes were extensively used in soil amendments due their macro and micro element contents mainly Ca and P, also ability to increase soil pH and SiO_2 (Jeer *et al*., 2018; Goudoungou *et al*., 2018; Paramisparam *et al*., 2021; Batistič *et al*., 2023). Soil amendment by wood ash may make it suitable for vigorous growth of crops/plants ultimately limiting their vulnerability to pests (Bidein *et al*., 2016). In Kenya wood ash was linked to plant growth and development through enhancement of flowering and seed setting (Wiklund, 2017), which is why the material is widely used in forested areas (Pitman, 2006). However, the effectiveness of wood ash on vegetable may be crop specific; since it was observed that increased soil fertilisation due to wood ash application contributed to intensification of pests in cucumber (Bidein *et al*., 2016).

The results of this study revealed that cow urine was the second in protecting Chinese cabbage leaves and enhancing the yield of the horticultural crop. The effectiveness of cow urine could be contributed by the active chemical(s) therein. Cow urine contains 95% water, 2.5% urea, the remaining portion (2.5%) containing salts, hormones, enzymes, minerals (Ca, Cl, Mg, K, Na, SO_4^{2-}) and uric acid (Ramani *et al*., 2012). Also, cow urine is capable to fertilise the soil and improve microbial activities that consequently promote growth and development of crops (Kgasudi and Mantswe, 2020). Also, in Indonesia the effectiveness of cow urine was shown by its attractant effect for insect pests towards traps baited with the urine (Sujana *et al*., 2023). The finding of this study is in agreement with Jandaik *et al.* (2015) and Onunkun (2014) who reported on the effectiveness of cow urine against fungal diseases in vegetables named Meth (*Trigonella foenum-graecum*) and Bhindi (*Abelmoschus esculentus*), as well as sucking bugs on *Amaranthus cruentus* in India and Nigeria, respectively.

Furthermore, an average performance of pawpaw seeds suggests avoidance of Chinese cabbage leaves by pests/pathogens. Phytochemicals contained in papaya seeds include alkaloids, flavonoids, tannins, saponins, essential oils, anthraquinines and anthocyanins (Olivera *et al*., 2007). In the alkaloid there is karpain; a compound which is reported to have pesticidal property (Azizah and Fasya, 2019). Furthermore, in Indonesia *Carica papaya* seeds were reported to kill walang sangit; a noxious pest of vegetable (Ma'ruf *et al*., 2023). Likewise, in Thailand long pepper extract was able to kill beetles that invaded vegetable (Pumnuan *et al*., 2022). The result on pesticidal potential of papaya seeds is in agreement with Ogbonna *et al*. (2021) and Bahuwa *et al*. (2022).

The performance of chill fruits on Chinese cabbage was not so good indicating limitation of the local pesticide in prevention of the horticultural crop. The finding of this study is contrary to what was reported by other scholars. For example, in Nigeria spraying of chilli fruit extract on *Amaranthus* significantly reduced the number of damaged leaves and improved the yield (Lawan *et al.*, 2016). However, in that study only one local material (chilli) was used. Likewise, in the Philippines chilli fruit resulted in mortality of rice bugs and its effectiveness increased with concentration of the local pesticide (Diamante *et al*., 2022). The discrepancy between this study and the mentioned studies could be caused by the higher concentrations of the extracts (above 20 w/v) used in those studies.

In this study the treatment of dried neem leaves extract on Chinese cabbage was the least and not significantly different from chilli fruits in protecting leaves and improvement of the yield. It is likely that the leaves of neem are not so effective when compared with other plant parts. According to Gajalakshmi and Abbasi (2003) and Master Gardeners & Extension Specialists (2020) neem seeds contain two products called azadirachtin and clarified hydrophobic neem oil that are capable of killing and repelling pest insects, worms and fungi. Also, neem plant works better against juvenile vegetable pests than mature ones. Furthermore, neem is reported to kill both target and non-target organisms and therefore limiting the activities of beneficial organisms/insects in the soil; which indirectly interferes with crop growth and development. In this study it is possible that during earlier stage of Chinese cabbage development the leaves were moderately damaged but the problem increased later on (after attaining maturity). Furthermore, normal water (control) ranked the least in protecting leaves of Chinese cabbage in turn ending up with low yield. This result suggests limited contents of plant growth and yield enhancers in the water used. The result on the ineffectiveness of normal water (control) against Chinese cabbage pests is in conformity with Amoabeng *et al*. (2013).

5. Conclusions and recommendations

The most effective local pesticides in protecting Chinese cabbage leaves against damage with improved yield are a mixture of kitchen ash and soil, and cow urine. Spraying of the two substances resulted in intactness of Chinese cabbage leaves which ultimately improved the yield of the vegetable. The effectiveness of these substances is partly contributed by their ability to fight against pests/pathogens and but also nourishing the soils in which the plants are anchored. Also, moderate working of pawpaw seeds in Chinese cabbage growing was observed. The least performing local pesticides in growing Chinese cabbage were chilli fruit and neem leaves. For neem plant the selection of leaves for pesticidal testing limited the efficiency of the plant since many scholars report on seeds of neem being the most powerful against pests/pathogens. Chinese cabbages treated with normal water were the mostly affected in terms of leaves and yield. Apart from pesticides, performance and yield of Chinese cabbage is reported to be controlled by soil, climate, fertilizer and plant genotype (Liu, 2021), however, these factors were not covered in this study. Another limitation of this study is that pests/pathogens that invaded Chinese cabbage were not covered. We recommend on assessment of the studied local pesticides in other vegetables for the possibility of coming up with large scale formulations of the best performing materials for improved horticultural activities.

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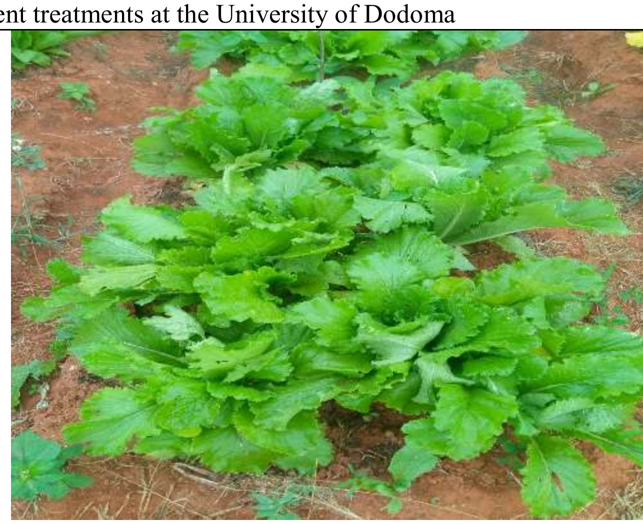
Appendix: Chinese cabbage under different treatments at the University of Dodoma


Mixture of wood ash and soil


Cow urine


Pawpaw seeds


Chilli fruits

 Neem leaves	 Control

Source: Field work