Constraints and Opportunities for the Sustainable Aphid Pest Management in Leaf Cabbage

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ABSTRACT

During and post COVID 19 era, there has been an increase in the use and production of garlic (*Alium sativum L.*) the world-over for its medicinal value. Garlic has been used as a remedy to cure the pandemic flu-like ailment. Garlic has been used since 1550 B.C. as a remedy for a numerous ailments (So et al., 2021). In agriculture, garlic extracts are reported to have been used as pesticide or fungicides in crop protection against aphids, ants, soil bacteria, and fungi, particularly those in the class Oomycetes. Garlic is a relatively new crop in Zimbabwe. Farmers need demonstrable advantage of incorporating garlic as an inter-crop to facilitate growth of crops susceptible to aphid such as leaf vegetable in terms of Land Equivalent Ratio (LER) and Monetary Advantage Index (MAI). Land is predominantly a constraint in farming, so farmers seek to produce high yields per given area. High monetary return on the other hand, is the ultimate objective of farming since agriculture is a business. LER and MAI among other indices need to be considered for selection of an inter-crop crop.

INTRODUCTION

Intercropping is as a multiple cropping system, in which two or more crops species planted simultaneously in a field during a growing season (Blessing et al., 2022: Reddy et al., 2023). Intercropping is often perceived as a viable tool to increase on-farm biodiversity in organic agriculture and is a potentially important component of any sustainable cropping system. Apart from increasing total farm productivity, mixed species cropping can bring many important benefits such as improvement of soil fertility management and suppression of pests and/or diseases (Lizarazo et al., 2020). Scientists seem to believe natural chemicals are the panacea to insect control. Semiochemicals have great potential for use in integrated pest management (IPM) Programs, (Guerrero & Reddy, 2023). Garlic (*Allium sativum L.*) use is gaining momentum especially after the COVID-19 era. Garlic has been used as a protectant/cure against the flue-like viruses. The world garlic production stands at +4million tons and Lanling County account for 56.56 % (40 000tons) (Sui et al., 2022). In agriculture, garlic has been used to enhance plant protection against a variety of diseases and to stimulate plant growth (Mohammed and Akladious, 2014). The 21st century agronomist niche is to use biological methods to boost productivity as well as to ensure agricultural sustainability.

Biological method based on the sustainable use of pesticides is one of the main objective of 21st century agronomists, aimed at limiting the risks caused by the use of pesticides on environment and health. Plant extracts offer significant advantages in terms of sustainable agriculture and represent a feasible alternative against infestant weeds and pests for disease control of crops. Garlic is characterized as having several anti-bacterial, anti-fungal, nematocidal and several insecticidal properties which make it an established natural pesticide (Mukhia et al., 2023), hence can effectively control pests, makes an excellent economical,

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and non-toxic biological pesticide in agricultural use. Garlic *(Allium)* is known for its stimulating properties on plant growth and also protects plants due to its bactericidal and fungicidal activity (Fakhouri, et al., 2021). LER and MAI are two of the factors to be considered in selecting an inter-crop. Farming is a business and land is a constraint while money is the ultimate goal of a farming enterprise. There are no known studies on the effect of garlic- leaf vegetable inter-crop in Zimbabwe. High variability of garlic performance under differing climate conditions make it inevitable to carry out the garlic-leaf vegetable inter-cropping effect (So et al., 2021).

GARLIC TAXONOMY

Garlic is a species of bulbous flowering plant in the genus *Allium*. Its close relatives include the onion, shallot, leek, Clive, Welsh onion and Chinese onion. The scientific name for garlic is *Allium sativum which was* given by Carl Linnaeus in 1754 (Mukhia et al., 2023). Garlic belongs to the family Amaryllidaceae of the Plantae kingdom. Garlic is classified under the order Asparagales. The taxonomic position of garlic and related genera had been a matter of controversy for long period of time. The most recent classification scheme of garlic was class Liliopsida, subclass Liliidae, superorder Liliianae, order Amaryllidales, family Alliaceae, subfamily Allioideae, tribe Allieae and genus Allium which is mainly based on the sequences of nuclear ribosomal DNA (Friesen et al., 2006: Mukhia et al., 2023). The name "Allium sativum" is derived from the Celtic word "all", meaning burning or stinging, and the Latin "sativum" meaning planted or cultivated. The English word, garlic, is derived from the Anglo-Saxon "gar-leac" or spear plant, referring to its flowering stalk (Labu, 2015). Worldwide, the following names are used synonymously to refer to garlic Allium sativum: lasun (Hindi), Rasonam and Lahsuna (Sanskrit), Knoblauch (Ger), Knoblauchzweibel (Ger), da suan (Chin), taisan (Jap), inniku (Jap), taesan (Kor), tafanuwa (Hausa), ayo-ishi (Igbo), kitunguusumu (Swahili), ayu (Yoruba), lobha (Nepalese) (Labu, 2015).

Origins of Garlic

The origins of garlic date back from 1540 B.C. Garlic, a perennial bulb is thought to be indigenous to Central Asia, Siberia and west of the Himalayas and has been grown in England from before 1540 (Labu, 2015). The primary center of origin for garlic is Central Asia (Kazakhstan), and the secondary center is the Mediterranean and Caucasus zones

(Rahim et al., 2019: So et al., 2021). Garlic has been an important medicine to the ancient Egyptians. According to the Egyptian medical prescription record the Codex Ebers, garlic was listed as early as 1550 B.C. (Labu, 2015). Garlic has been used by ancient Egyptians as both a food flavoring and a traditional medicine since the 16^{th} century.

Benefits of Garlic

Garlic is a versatile crop. Garlic is a common food for flavor and spice. In India, garlic is important for foreign exchange, (Srivastava, 2020). Garlic is a high value crop in Zimbabwe due to its high demand for medicinal use. In Egypt, garlic has been prescribed as a remedy for a number ailments such as heart problems, headache, bites, worms and tumors since 1550 B.C. (So et al., 2021) Garlic is rich in chemicals such as Alliin, an odorless sulfur containing chemical derived from the amino acid cysteine. When garlic bulbs are crushed, Alliin is converted into another compound called Allicin. Allicin is further broken down to a compound called Ajoene, which may be the substance that inhibits blockage in blood vessels from clots and atherosclerosis (Nadeem et al.2021). Allicin, when crushed releases an amino acid which gives Garlic its strong odor and is responsible for the powerful pharmacological properties of the plant such as germanium, magnesium, selenium, Vitamin A, Vitamin C and volatile oil of which about 0.5% is composed of sulfur-containing compounds and zinc (Azmat et al., 2023).

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Garlic also contain 65% water, 28% carbohydrate, 2.3% organo-sulphur compound, 2% proteins, 1.2% Free amino acid (mainly arginine), 1.5% fiber, 0.15% lipids, 0.08% phytic acid and 0.07% saponins (Labu, 2015: Mukhia et al., 2023). Garlic is rich in protein, phosphorus, potassium, calcium, magnesium and carbohydrates. It helps in digestion of food, reduces cholesterol level in human blood and lowers blood sugar (Rahim et al., 2019; Azmat et al., 2023). Allicin present in garlic is useful for antimicrobial action. The volatile antimicrobial substance allicin (diallylthiosulphinate) is produced in garlic when the tissues are damaged and the substrate alliin (S-allyl-L-cysteine sulphoxide) mixes with the enzyme alliin-lyase (E.C.4.4.1.4) (Bhatwalkar, et al.,2021; Nadeem et al., 2021). Allicin's presence in the soil suppresses a range of pathogenic bacteria, fungi including some lower fungi in the class Oomycetes and present an opportunity for control of soil borne diseases caused by lternaria spp (Bhatwalkar, et al.,2021). Allicin's multiple antibacterial and antifungal exploits provide an excellent framework to develop them into novel antibiotics in organic farming (Bhatwalkar, et al.,2021).

Mechanisms of Action by Garlic Active Compounds in Plant Protection

Garlic as a plant protectant employs a variety of mechanisms. In arabidopsis, the reduction in disease was apparently due to a direct action against the pathogen since no accumulation of salicylic acid (a marker for systemic acquired resistance, SAR) was observed after treatment with garlic extract (Slusarenko, et al., 2007). Plant extracts are lethal or toxic and affect the physiological activities of insect pests like preventing feeding and decreasing oviposition (Aioub et al., 2024). Garlic is a natural protectant plant. The potential advantage offered by natural products is that their effectiveness has been optimised by evolution for their particular task. In terms of plant protection antimicrobial, insecticidal or anti-feedant activity, garlic employs the use of organosulfur that include allicin, ajoene and allyl sulphides (Bhatwalkar, et al.,2021). Several microorganisms produce antibiotics, and many preformed and induced antimicrobial substances are also known from plants. Allicin produced by garlic inhibit the pests, lower their feeding behavior, thus reduces their fecundity and the prevalence of resultant diseases. Garlic has been shown to inhibit growth of fungal elements equally along with the drug ketoconazole, when tested on the fungi. The strong aroma from garlic can mask normal host-finding or feeding cues in insects and provides an olfactory camouflage (Perrin and Phillips, 1978) against the insect like aphids, ants, termites, white flies, beetles, borers, caterpillars, slugs and army worms including *Spodorpthera frangipeda*, a moth that is a vector to FAW (Adorada et al., 2023). One other mechanism is that of being toxic and inhibiting other living things or organisms, which in this case pests. In a related study on the efficacy of garlic extracts on pests, crude an ethanolic extract and garlic oil were found to be toxic against 3rd stage of larvae of Culex pens, C. tarsalis, Acedes agypti, A. trisomiatus and A. migromaculis (Amonkar and Reeveres, 1970).

Physiology of Garlic

There are two types of garlic varieties, the hard neck and the soft neck. Within those two distinct varieties there are a variety of varieties. Climate has a significant impact on both taste and scape production, and a variety considered a soft neck in one location may produce a flower in another. This has led to the renaming of many strains that may instead be genetically the same plant (Labu, 2019).

1. Hard neck varieties (*Allium sativum var ophioscorodon*)

Hard neck varieties produce a flower stalk (scape) and are often termed as bolting or top setting varieties. Flowers, if they are produced, usually abort and form bulbils instead. These are small aerial cloves which are genetically the same as the parent plant. If the aerial cloves are used for propagation they will produce a bulb, which could be used for vegetative propagation. Use of bulbils however produces relatively smaller bulbs in comparison to use of cloves. The size of the vegetative propagules in garlic has a significant effect on the subsequent size of the cloves at maturity (Desta et al., 2021). Studies have seemed to conclude that,

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bulbils require at least one additional year to reach their full bulb size compared to seed cloves (Sopha et al., 2024) and take 2-3 years before the bulb reaches marketable size (Tyagi et al., 2013).

Typical hard neck varieties are including Killis, Mersin, Kahramanmaras, Araban and Yavuzeli (Akan et al., 2022). Hardneck garlic may be purple, purple striped, or white and is represented by varieties such as Roja, German Red, Valencia, Continental, and Creole. Creole garlic, a late variety covered with a deep purple skin, is the type grown in Mexico, South America, and the Imperial Valley of California (Ford et al., 2023).

2. Soft neck varieties (*Allium sativum var sativum*)

Soft neck varieties do not normally produce a flower stem. These are the most common varieties used for commercial cultivation, due to minimal flower stalk and bulb production which generally makes them more productive because all the energy goes to producing a bulb, while in hard necks it is diverted to scape production. All commercial cultivars of garlic are infertile and instead of seeds, garlic flowers contain numerous aerial bulbils that could be used as propagation materials, (Sopha et al., 2024). In some soft necks a partial flower stalk can be produced, and bulbils will form directly above the bulb. Soft neck varieties normally have a longer shelf life than hard necks and store for up to six to eight months. Soft necks are also easily braided and contain 10-40 cloves per plant. Soft neck varieties include taskopru, Nersehir, Ankara and Aksaray (Akan et al., 2022).

Factoring LER and MAI in Intercropping

LER refers to measures relative to land area required to grow the same quantity of both crop species in the mixture if they were grown as mono-cultures rather than as companions. FAO defines land equivalent ratio (LER) as:

the ratio of the area under sole cropping to the area under sole cropping needed to give equal amount of yield at the same management level. It is the sum of the fractions of inter-cropped yields divided by the sole crop yields.

Land Equivalent ratio is often used as an indicator to determine the efficacy of inter-cropping (Brintha and Seran, 2009(Крыжановский et al., 2021)). The LER is a standardized index that is defined as the relative area required by sole crops to produce the same yield as inter-crops (Mead and Willey, 1980). The LER is the ratio of land required by pure (sole) crop to produce the same yield as that of intercrop was determined according to the following formula:

LER was calculated using the formular:

$$LER=(Y12/Y11)+(Y21/Y22)$$

where Y12 is the yield of crop 1 intercropped with crop 2, Y21 is the yield of crop 2 intercropped with crop 1, Y11 is the yield of monocultured crop 1, and Y22 is the yield of monocultured crop 2. Thus, the LER expresses how much land in a monoculture system is needed to produce the same amount of food in intercropping system.

Monetary Advantage (MA)

Irrespective of the indices that are used to assess inter-cropping advantages, there may be need to indicate some monetary values for inter-cropping if at least one of the component crops is a cash crop as garlic is a high value crop. The economic evaluation is needed in addition to whatever analysis is carried out on straight yield (e.g. Willey, 1979; Willey, 1985). Willey (1985) stated monetary advantage (MA) can be calculated using:

$$MA=[TIV((LER-1)/LER)]$$

where TIV= total intercrop value, and LER is the land equivalent ratio.

Intercropping Metrics

Mixed cropping like crop rotation is perceived to facilitate growth of other crops through numerous mechanisms like nitrogen fixation in the case of legumes. Mixed species cropping is often perceived as a viable tool to increase on-farm biodiversity in organic agriculture and is a potentially important component of any sustainable cropping system (Zuza et al., 2024). Properly selected inter-crops with least competition between themselves and least allelophathy, complement each other for increased yield. Inter-cropping led to increased income from the product of inter-crop, greater use of environmental resources, reduction of pest, diseases and weed damage, stability and uniformity yield and improve soil fertility, lodging resistance and increase nitrogen, (Blessing et al., 2022)

Beside these advantages, the inter-crop should be investigated in the nutrient need, size, weather e.t.c. when grown under shade plant tend to display stem elongation, lodging reduced leaf size and subsequent reduced yield due to species cross- contamination (Blessing et al., 2022).

It can be expected that the adoption of inter-cropping demands more skill and knowledge of crop species when grown as mixtures, increased machinery costs for sowing, harvesting and grain separation; and costs of herbicide application can increase, as existing herbicides and application methods may not be applicable to crop mixtures.

CONCLUSION

There is a remarkable trend in garlic use and production the world over with China and India leading in terms of production and export. Garlic is known for its curative ability against numerous ailments. Garlic has been used since 1550 B.C. as a remedy against numerous ailments. In agriculture, garlic has been used as crop protectant precisely as a biopesticide and fungicide. The garlic active compounds allicin and ajone facilitate numerous natural mechanisms to effectively protect the crops from pests such as masking of normal host finding and feeding cues in insect pests.

The garlic allicin/ajone effect on pests offers an opportunity for garlic's selection as an intercrop to facilitate the growth and production of aphid pest susceptible crops such as leaf vegetables in the face of climate change. High variability of garlic behavior under different climatic conditions make the study on garlic effect inevitable. Moreover, demonstrable advantage of using garlic as an inter-crop such as LER and MA are needed to promote adoption and selection of garlic as an inter-crop. The response of aphid to the two types of garlic varieties found in Zimbabwe has to be determined.

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