https://doi.org/10.46344/JBINO.2023.v12i01.18

EVALUATION OF FUNGICIDES, BOTANICALS AND BIO-AGENTS AGAINST CABBAGE BLACK ROT (*Xanthomonas campestris pv. campestris*) IN GUDAR, WEST SHEWA ZONE, ETHIOPIA.

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ABSTRACT

Cabbage (*Brassica oleracea* L.) is the second most important vegetable crop in Ethiopia in area coverage as well as level of production next to red pepper. Black rot (*Xanthomonas campestris pv. campestris*) is a major disease constraint for cabbage production everywhere in Ethiopia. The aim of this study was to identify the most effective management practices against cabbage black rot. *In vitro* evaluation of efficacy of fungicides, botanicals and bio-agents against *Xanthomonas campestris pv. campestris* was carried out in Plant Pathology laboratory of the Department of Plant Sciences and the field experiment was conducted on the research farm of Gudar Mamo Mezimer Campus, Ambo University from mid-May to mid-September 2021. Based on *in vitro* evaluation results, Vitra 50 WP at 2000 ppm were superior over the other treatments in inhibiting *Xanthomonas campestris pv. campestris* with an inhibition zone value of 71.37mm which was followed by Funguran OH 50WP treatment with the mean value of 66.96mm. Of the 15 treatments evaluated under field study, Funguran OH 50WP was scored superior over the other treatments in reducing the severity of cabbage black rot disease by 42.70% and resulting in high yield which was followed by Vitra 50WP with the mean disease reduction value of 41.40%. Moreover, *Trichoderma harzianum* and *Moringa* seed extracts performed considerable reductions in disease severity (31.41% and 29.42%), respectively over the control. Overall, the present study was concluded that the two fungicides, Funguran OH 50 WP and Vitra 50 WP were performed well and utilized as the effective management strategies against cabbage black rot in this study area in particular and over the cabbage production areas of the country in general. The current study result is also recorded that *Moringa* seed extracts and the bio-agents showed promising performance in black rot disease reduction which can be incorporated as component of integrated management of cabbage black rot disease. Based on the present findings, it is concluded that Funguran OH 50WP and Vitra 50 WP are the best remedy to manage black rot of Cabbage.

Keywords: Cabbage, Black rot, *Xanthomonas campestris pv. campestris*, Efficacy, Fungicides, Bio- agents, Botanicals.

INTRODUCTION

Cabbage (*Brassica oleracea var. capitata L.*) is an important Cole crops belongs to the family Cruciferae or Brassicaceae with 2n=2x=18 chromosome number. It is a native of Western Europe and Northern Shore of Mediterranean Region. The cabbage was originated from the wild, leafy, non-heading types 'Cole wart' (*Brassica oleracea var. sylvestris)* (Grubben *et al*., 2004; Moamogwe, 2005). The leading cabbage producing countries in the world are China, India, Russian Federation, Japan and Republic of Korea, respectively. According to FAOSTAT (2017/18), the total area cultivated under cabbages in the world is about 2,416,885 hectares with a production of about 70,644,191 metric tons with the average productivity of about 29.23 metric tons/ha. In Africa, headed cabbage is cultivated in tropical and subtropical areas as commercial cultivation and is still mostly restricted to the cooler climates of the highlands or to the mild cool seasons at higher latitudes. Cabbage production is estimated 100,000 ha in Africa (FAOSTAT, 2017/18; Kumar *et al.,* 2014) and the reliable data on areas planted annually with headed cabbage are lacking for most countries in tropical Africa. Cabbage is the second most important vegetable crop in Ethiopia both in area coverage as well as level of production next to red pepper (MoA, 2019). In Ethiopia, cabbage is cultivated on 38,000 hectares of land with mean average production of 395,000 tons in irrigation and rain fed with very low productivity (10.4 t/ha) (FAOSTAT, 2018) as compared to the world average (29.23 t/ha). The cabbage is used commonly as vegetables and also used for salad mixed in tomato, green chillies and beetroot. It is a rich source of sulphur containing amino acids, minerals, carotenes, ascorbic acid, anti-carcinogenic property and antioxidants (Singh *et al*., 2009). Due to its antioxidant, anti-inflammatory and antibacterial properties, cabbage has widespread used in traditional medicine, in alleviation of symptoms associated with gastrointestinal disorders as well as in treatment of minor cuts and wounds and mastitis (Samec *et al.,* 2011). The cabbage is also an excellent source of vitamins A, C, K, B_1, B_2 and B_6, calcium, dietary fiber and proteins when it is eaten raw as salad and boiled or cooked as stew or soup (Naher *et al*., 2014).

However, the production and productivity of cabbage in Ethiopia is very low due to different biotic and abiotic factors. Several diseases are affecting and causing high losses in cabbage production and productivity. Among different diseases that inflicted tremendous problems on cabbage production, black rot, *Xanthomonas campestris pv. campestris* is one of the major constraints in the production and productivity of cabbage, causing quality and quantity losses reaching as high as total failure under favourable environmental conditions to the disease (Shimelis and Swart, 2004). It

attacks all the cultivated varieties of crucifers like Brassicas, radishes, and cruciferous weeds. *Xanthomonas campestris* pathogen thrives in warm, humid climates; therefore, it is the most destructive pathogen in tropical, subtropical and humid continental regions. This bacterium can be transmitted either by being seed borne, or at times the infection can be principally spread through wounds caused by insects, natural openings/hydathodes (significant port of entry), through fluid filled stomata openings or even via irrigation water (Singh *et al.,* 2016). However, seed is the main effective and most important vehicle of transmission for this pathogen because the bacterium attaches itself to the seed before plant establishment (Berthier *et al.,* 1993). *Xanthomonas campestris* pathovars exhibit a wide host range, with each pathovars being specific and exceptionally distinctive to particular host plants (Mansfield *et al.,* 2012). The black rot disease mainly affects the above ground parts of the plant and proceeds fast in plots with multi-focal inoculation than in those with uni-focal inoculation. Plants are susceptible to black rot at any stage of their growth, with the initial, usual and characteristic symptom being the V-shaped, small, wilted lesions which appear on the leaf margins. The lesion patch usually has small black veins and in severe cases, vein discoloration sometimes even reaches the stems. After reaching the stem the bacteria moves systemically to other healthy uninfected plant parts (Jensen *et al.,* 2010). The infected areas will eventually enlarge progress towards the leaf base, turn yellow to dark and then dry out. Diseased leaves may become stunted on one side and then drop prematurely (Kocks *et al.,* 1998).

Despite its importance and increased production, numerous and prominent production problems accounted for the low yield of cabbage in Ethiopia include lack of proper planting material, inappropriate agronomic practices, absence of proper pest and disease management practices, lack of marketing facilities, lack of infrastructures and improper postharvest handling practices (Melkamu Alemayehu, 2015). This bacterium is reported to have developed resistance to antibiotics and also against different fungicides such as Equation pro WDG, Opera Max 147.5 SE and Revus 250 SC and therefore poses a challenge in their control (Culver *et al.,* 2012). As plant-based bactericides has not yet been developed and the need to work on these has of huge importance (Alshia *et al.,* 2013). However, many researchers were exploring naturally occurring compounds constrain the pathogen attack as an alternative management systems to reduce fungicides dependence which is an increasing public concern on environmental issues (Bhardwaj and Sahu 2014; Cuthbert son and Murchie 2005; Singh, 2003; Singh *et al.,* 2014). In recent years, a large number of natural and biologically active compounds from different plants and bio-agents have been investigated for their antimicrobial properties against plant pathogenic bacterial diseases of vegetables including

black rot (Kokoskova and Pavela, 2006; Tripathi and Shukla, 2015).

Indiscriminate use of chemical fungicides to control various pathogenic microorganisms of crop plants is causing health hazard both in terrestrial and aquatic lives through their residual toxicity (Ambridge and Haines, 1987). Considering the adverse and alarming effects of synthetic fungicides on environment and natural habitats, this study was undertaken to find out an alternative control of black rot of cabbage pathogen through biological control agents and botanical extracts. Plant extracts are a huge reservoir of various effective chemotherapeutics and could serve as an environmentally friendly natural alternative to the toxic chemical fungicides (Hostettmann and Wolfender, 1997). Many plant species have also been reported to exhibit inhibitory activities against *X. campestris pv. campestris*. Lirio *et al.,* (1998) reported the extracts of twenty plant species showed antibacterial activity against *X. campestris pv. campestris* under laboratory conditions. *Terminalia chebula* and neem extracts were found effective in reducing the disease incidence (Bora and Bhattacharyya, 2000). In spite of the importance of black rot and its frequent epidemics in the study area in Ethiopia, no attempt has been made to evaluate fungicides, botanicals and bio-agents as component strategies against the disease. Therefore, the current study was conducted to evaluate and determines the efficacy of fungicides, botanicals and bio-agents against cabbage black rot, *Xanthomonas campestris pv. campestris* in Gudar, Toke Kutaye district of West Shewa Zone, Ethiopia.

MATERIALS AND METHODS

Description of the study area

This study was conducted to check the efficacy of fungicides, botanicals and bio-agents against cabbage black rot pathogen *Xanthomonas campestris pv. campestris* under *in vitro* and *in vivo* conditions at Guder Mamo Mezemir campus in Plant Pathology Laboratory and the campus experimental field, Ambo University. Guder is an administrative town of Toke kutaye district located in the West Shewa Zone of Oromia Regional state which is 126 km far from Addis Ababa, the capital city of Ethiopia, and 12 km from Ambo town. It is located between 8° 59' 00''N latitude and 37°46'0''E longitude. The elevation of the study area ranges from 1580.3-1900 m.a.s.l. The agro ecology of the district includes 23% highland, 60% mid attitude, and 17% low land which generally lies in the sub-tropical zone with annual temperature ranging between 10-29°C. The district has bi-model rain fall distributions; main rainy season during June-August and short rainy season between May-April and the district is dominantly covered by a clay soil slightly acidic pH of 5.5 – 6.0 with an average rainfall of 800-1100 mm (TKDANO, 2020).

Experimental materials used.

Three fungicides (Funguran OH 50 WP, Vitra 50 WP and Electis 75 WG), six botanicals (Ginger rhizome, *Moringa* seed, *Parthenium* root, *Xanthium* leaf, *Croton* bark and leaves) and three fungal (*Trichoderma harzianum, T. virens* and *T.*

viride) and two bacterial (*Pseudomonas fluorescens* and *Bacillus subtilis)* bio-agents were used to check the efficacy of fungicides, botanicals and bio-agents against cabbage black rot pathogen *Xanthomonas campestris pv. campestris*. All the fungicides were obtained from Chemtex Company, Addis Ababa, Ethiopia. The botanicals were collected from the Gudar and Toke Kutaye district farmer's area and the bio-agents were obtained from Ethiopian Biodiversity Institute (EBI) Laboratory; Addis Ababa, Ethiopia.. The susceptible variety, cabbage (*Brassica oleracea var. capitata* L) seeds were used for the purpose of yield potential, early maturity and its susceptibility to black rot disease which is obtained from Gudar market.

Isolation and purification of *Xanthomonas campestris pv. campestris*

Naturally infested cabbage leaves showing typical symptoms of black rot disease were collected from farmer's field around Guder. The sampled leaves were washed thoroughly with distilled water and surface sterilized with 1% sodium hypochlorite for 30 sec followed by 70% ethanol for 30 sec and rinsed trice with sterile distilled water and inoculated on the solidified cooled Nutrient agar (NA) medium in Petri plates under aseptic conditions (Rademaker *et al.,* 2006). Inoculated plates were then incubated at 28±1°C. After 3 days of incubation, following streak technique, the bacterial colony was sub-cultured aseptically on the NA. Purified bacterial colonies were characterized based on crop pathogen indexing, the symptom and growth characteristic and confirmed as *Xanthomonas campestris* pv. *campestris*. The bacterial cell suspensions were stored in Nutrient broth medium in culture tubes for further studies (Malik, 1984).

Preparation of plant extracts (Botanicals)

The botanicals tested in this study were collected from Ambo-Guder road side and urban agricultural field of Toke Kutaye district. Plant tissue samples were dried under shade in the laboratory and ground to powder using a mortar and pestle. The powders of all the samples were carefully stored at 4°C. Water-soluble extracts were prepared as described by Rivillas-Acevedo and Soriano-Garcia (2007). The powdered material of all plants were extracted for 24 h at 25°C with water at a ratio of 2:10 w/v under rotary shaker and left to settle overnight. The homogenate was filtered through double-layered muslin cloth. The filtrates obtained were further filtered through Whatman No.1 filter paper using funnel and volumetric flasks (1000 ml) and stored until further usage. The resulting aqueous solution was used for the microbial growth inhibition assay.

Preparation of Bio-agents (Bio-control agents)

The pure culture of three fungal (*Trichoderma harzianum, T. virens* and *T. viride)* and two bacterial (*Pseudomonas fluorescens* and *Bacillus subtilis)* putative antagonists against to Xcc were used for sub-culturing in YDCA and NA media, respectively and the cultures were incubated at 27±1°C and 28±1°C for 7days and 3days, respectively. On each cultured plate, spores and bacterial

colonies were harvested by flooding 10 ml of sterilized distilled water. The spore and colony suspensions were again filtered through cheese cloth and diluted (1:10) in sterile water. The suspensions were vortexes for eight minutes to avoid clumping of the spores and colonies. Spores of *Trichoderma* and colonies of bacterial species were adjusted to 1×10^7conidia/ml and cfu/ml, respectively (Valdez and Picolo, 2006; Abril *et al*., 2008). Then to make it ready for *in vitro* evaluation, mass multiplication of *Trichoderma* spp. and bacterial spp. were done on Molasses yeast medium and King's B medium, respectively (Pramod Kumar and Palakshappa, 2009).

***In vitro* Evaluation of Efficacy of Fungicides, Botanicals and Bio-agents**

***In vitro* evaluation of fungicides and botanicals**

In-vitro evaluation of three fungicides (Funguran OH 50 WP, Vitra 50 WP and Electis 75 WG) and six plant materials (Ginger rhizome, *Moringa* seed, *Parthenium* root, *Xanthium* leaf, Croton bark and leaves) extracts were carried out against Xcc using disc diffusion method and bacterial zone of inhibition. A young culture of 48 to 72 hr old of the test bacterium was used for the preparation of bacterial lawn. Bacterial culture lawns were prepared by spreading the bacterial culture from 10^7cfu/ml on the NA growth medium using sterile spreader. A preliminarily concentration test for fungicides solution at dose of 1000 ppm, 1500 ppm and 2000 ppm and for plant extracts at dose of 10%, 15% and 20% have been evaluated and the concentration with 2000ppm of fungicides and 20% crude extract showed potential bacterial inhibition and used for final efficacy test. The above mentioned concentration of each treatment were applied to 5mm filter paper disc in Petri plates and soaked overnight. Each of the soaked disc were placed at the centre of a bacterial lawn. A discs soaked in SDW were used as control. Each treatment replicated thrice and the inoculated plates were incubated at 28±1°C for 72 hr in CRD arrangement. The susceptibility of the test pathogen to the fungicides and plant extracts were recorded after 72 h by measuring the average diameter of the clear zone of inhibition with digital caliper in milli meters (mm) around the discs (Ray *et al.,* 2019).

***In vitro* efficacy of bio-agents**

Three fungal antagonists viz., *Trichoderma harzianum, T. virens* and *T. viride* and two bacterial antagonists viz., *Pseudomonas fluorescens* and *Bacillus subtilis* were evaluated *in vitro* against the test pathogen (Xcc) by applying dual culture technique (Dennis and Webster, 1971). Five (5mm) diameter discs of agar media along with culture growth of the test bacteria and bio-agents were cut out with sterilized cork borer. Then the two culture discs, one each of the test bacteria and bio-agents were placed aseptically at equidistance and exactly opposite with each other on solidified YDCA medium in Petri plates. YDCA plates inoculated only with culture disc of test bacteria were maintained as untreated control. Each treatment was replicated thrice and the plates were incubated at 28±1°C in CRD arrangement. Observations on growth

inhibition of the test bacteria and bio-agents were recorded until untreated control plate was fully covered with colonies growth of the test bacteria (Pandey *et al.*, 2000).

Experimental Design and Procedures for field experiment

Evaluation of the efficacy of fungicides, botanicals and bio-agents against Xcc were conducted at the Research farm of Plant Science Department, Guder Mamo Mezemir Campus, Ambo University, Ethiopia during mid-May to mid-September, 2021 under field conditions. Foliar application of the treatments (Labelled dose of chemicals and 30kg/ha of botanicals and 1×10^7conidia/ml and cfu/ml bio-agents solutions) were applied with 200 L/ha of water for spray. The treatments were applied three times with ten days interval by starting at the appearance of first disease symptoms. One plot per replication was maintained as unsprayed control. All the recommended agronomic practices for cabbage production were applied during the growing stages. The experiment was laid out in a Randomized Complete Block Design **(RCBD)** with three replications. Fifteen treatments, including a control were assigned randomly to the plot of 2.5m × 1.6m= 4m^2 in size. Distances between plots and blocks were 0.5m and 1m, respectively. The seedlings were planted with 40 cm intra and 50 cm inter row spacing.

Data collection

Disease parameters

Disease incidence and severity were recorded before each spray of the treatments and lastly 10 days after last spraying. Disease incidence and severity was taken according to Miedaner *et al.*, (1996) and Morocko (2006).

Disease Incidence (DI) is the number of infected plant as a percentage of total number of plants. It was calculated by using the following formula.

$$\mathbf{DI} = \left(\frac{\text{Number of infected plants in the sampling unit}}{\text{Total number of plants in the sampling unit}}\right)$$

Disease Severity (DS) is defined as the affected leaf area, including the lesion as a percentage of total leaf area. Severity data was taken from six pre tagged entire row plants.

It was calculated by using the following formula.

$$\mathbf{DS} = \left(\frac{\text{Infected area of the sample plant}}{\text{Total area of a sample plant}}\right) \times 10$$

Percent Severity Index (PSI)

The numerical values of the severity were further used for the calculation of the mean Percent Severity Index (PSI) using the formula suggested by Morocko (2006) as presented below:

$$\mathbf{PSI} = \frac{\text{Sum of numerical ratings}}{\text{No. of plants scored } x \text{ Maximum score on scale}}$$

Further, Percent Severity Reduction (PSR) was worked out by applying the formula:

$$\mathbf{PSR} = \frac{\text{PSI in control plots} - \text{PSI in treated plots}}{\text{PSI in control plots}} x10$$

Table-1: Severity scale used for recording black rot disease of cabbage under field conditions:

Grade	Description	Diseased plants (%)
0	No symptom observed (no visible attack)	0
1	Small necrosis or chlorosis surrounding the infection point;	1-5
2	Marginal chlorotic, necrotic lesions and 0.5–3.0 cm in diameter;	6-10
3	Typical small V-shaped lesion with black veins;	11-20
4	Medium V-shaped lesions extending to the midrib with distinct marginal chlorosis and blackened veins within the lesion;	21-30
5	Large V-shaped lesions coalescing and expanding beyond the midrib, leaves appear scorched with coalescing lesions,	31-40
6	Many of wrapper leaves exhibit symptoms, and a few are necrotic	41-50
7	Typical lesion progressing to the middle vein and many wrapper leaves are necrotic,	51-60
8	All wrapper leaves exhibit symptoms, many are necrotic,	61-80
9	Lesion reaching the middle vein and all wrapper leaves are necrotic	>80

Source: Anjorin *et al.* (2013).

Area under Disease Progress Curve (AUDPC)

Disease progress curve is a curved line representing progress of disease over time. AUDPC used to quantify and summarize the severity of the disease over time. The disease severity indexes obtained from five assessment periods were used to calculate the AUDPC of the recording period. It was calculated from the severity data following the method proposed by Shaner and Finney (1977).

$$\text{AUDPC} = \sum_{i=1}^{n-1} 0.5(Xi + Xi+1)(ti+1 - ti)$$

Where: AUDPC= area under disease progress curve, *n*= total number of observations, x_i= is percentage of disease severity at i^{th} observations, t_i= time (days) after transplanting at the i^{th} observation, ∑= is the sum of areas of all the individual areas from *i* to *n* –1, *i* and *i* + 1 represent observations from 1 to n. AUDPC values were then used in different analysis packages in the study to compare amount of disease among plots with different treatments.

Agronomic parameters

Both vegetative and yield parameters of cabbages were collected in this study. Data on the following agronomic parameters were collected from six plants of entire rows per net plot area: Plant height, leaf length, plant spread, plant height, number of leaves per plant, number of unfolded leaves per plant, days to first head formation, days to 50% heading, days to 90% maturity, head diameter, head weight above ground fresh biomass, above ground dry biomass,

harvest index, marketable yield per hectare, unmarketable yield per hectare and total yield per hectare were recorded. Relative yield loss per hectare was determined as percentage of the yield difference from maximum protected plots was calculated based on the formula RYL (%) = $\frac{Y1-Y2}{Y1} X\ 100$

Where, RYLH = Relative yield loss per hectare, Y1 = mean value of the yield parameter for protected plots (maximum protected plot) and Y2 = mean value of yield parameter in less protected plots.

Data analysis

Laboratory and field experiment data were arranged for Completely Randomized Design (CRD) and Randomized Completely Block Design (RCBD) respectively, were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS) Version 9.4 procedure. When treatment means show significant difference and least significant difference (LSD) test at 5% or 1% values were used to separate the treatment means. For field experiment, correlation analysis was carried out to determine the association of disease and agronomic parameters of cabbage.

RESULTS AND DISCUSSION

***In vitro* evaluation of fungicides, botanicals and bio-agents against Xcc**

The analysis of variance revealed that all the treatments tested (fungicides @ 2000ppm, botanical @ 20% and bio-agents) were significantly inhibited the colony growth of Xcc at P ≤ 0.01 over untreated control. Maximum inhibition zone (71.37mm) was recorded in plate treated with Vitra 50WP followed by Funguran OH 50WP (66.96mm). This was because of Vitra 50 WP and Funguran OH 50WP are copper based contact fungicides and bactericide, with fine particles to ensure better disease control. Plates treated with *Trichoderma harzianum* and Electis were also exhibited better inhibition zone next to Vitra 50WP and Funguran OH 50WP with the mean values of 58.91 and 56.87 mm, respectively. Minimum inhibition zone was recorded in plate treated with Ginger rhizome extract and *Croton* bark extract with the mean values of 28.60mm and 29.58mm, respectively (Table 2; Fig.1). The results indicated that the preventative copper fungicides have a capacity to inhibit bacterial growth. Copper compound fungicides experienced for control of bacterial blight in cabbages/ Brassicas. Similar results were also observed by Sarkar *et al., (*2010), who reported that Copper oxychloride and Copper hydroxide were effective in controlling black rot disease of tea. Sarkar *et al.* (2010) also reported copper oxychloride and copper hydroxide to be highly compatible with *T. harzianum* in controlling black rot disease of tea. Cheng *et al.,* (2015) also reported that three species including *Trichoderma hamatum, T. harzianum and T. virens* had the greatest antimicrobial activity against the bacterial wilt pathogen, in agreement with the present study results. The probable reason for such findings may be due the antagonistic properties exhibited by *Trichoderma* species such as antibiosis, mycoparasitism, aggressive competitors, grow very fast and rapidly colonize

substrates to exclude pathogens (Ghildyal and Pandey, 2008).

Table 2. *In vitro* efficacy of fungicides, botanicals and bio-agents against black rot

Treatments	IZ(mm)
T1. Funguran OH 50 WP	66.957[b]
T2. Vitra 50 WP	71.37[a]
T3. Electis 75 WG	56.867[d]
T4. Ginger rhizome extract	28.60[j]
T5. *Moringa* seed extract	53.88[e]
T6. *Parthenium* root extract	35.327[i]
T7. *Xanthium* leaf extract	36.32[i]
T8. *Croton* bark extract	29.580[j]
T9. *Croton* leaf extract	36.477[i]
T10. T. harzianum	58.907[c]
T11. T. viride	49.357[g]
T12. T. virens	51.747[f]
T13. B. subtilis	46.907[h]
T14. P. fluorescens	50.367[fg]
T15. Control	0.00[k]
Mean	44.84
CV (%)	2.04
LSD	1.81

**Means followed by similar letters across column were not significantly different
IZ =inhibition zone, CV=Coefficient of variation and LSD=Least significant difference.

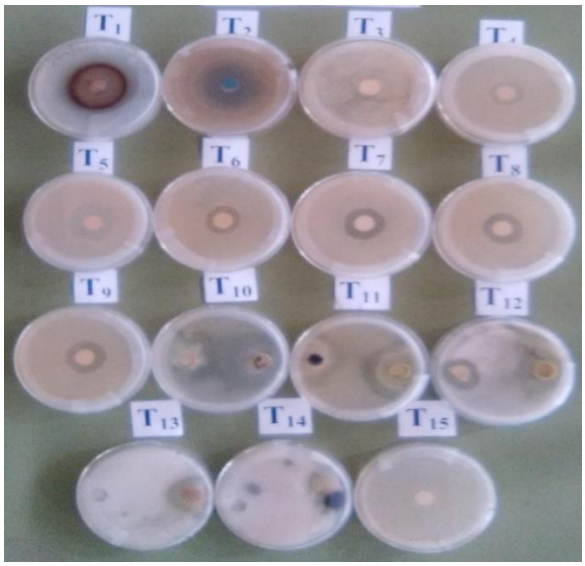

Figure-1:- *In vitro* evaluation of fungicides, botanicals and bio-agents against Xcc; T1 – T 15 treatment details as shown in Table 2

Evaluation of fungicides, botanicals and bio-agents against black rot under field conditions

Disease parameters

The analysis of variance revealed that the tested treatments were significantly different (P ≤ 0.01) for all disease parameters such as Area under Disease progress Curve (AUDPC), Percent Severity Index (PSI), Percent Severity Reduction (PSR) and Disease incidence (DI) of black rot. The black rot symptoms appeared to start in treated and untreated plots at the same time with uneven distribution of the pathogen. However, gradually the disease severity varied among treatments. Funguran OH 50WP and Vitra 50 WP fungicide treatments resulted in significantly better foliar black rot control and their difference was statistically significant at P≤ 0.01 in residual Area under Disease Progress Curve (rAUDPC). The maximum rAUDPC of 66.98% days was recorded on untreated plot (control) whereas; the minimum rAUDPC was recorded on plots treated with Funguran OH 50WP and Vitra 50 WP with the mean values of 38.19 and 39.81% days, respectively (Table 3). This implies that more rAUDPC was related to more disease severity and duration. It is directly proportional to disease severity. This study agreed with the findings of Behlau *et al.* (2008), who studied the effect of various treatments on disease severity and AUDPC of a citrus orchard caused by *Xanthomonas axonopodis pv. citri* and reported that there was decrease in disease severity and rAUDPC on treated plants over untreated. The result of the present study also indicated that the lower mean percent severity indexes, 33.49 and 33.95%, were recorded for Funguran OH 50WP and Vitra 50 WP, respectively and their difference was statistically similar at P≤ 0.01. Likewise, plots treated with *Trichoderma harzianum* and *Moringa* seed extracts also showed lower mean percent severity index next to Vitra 50 WP and Funguran OH 50WP with mean values of 40.12 and 40.74%, respectively. On the other hand, the maximum mean percent severity index of black rot (58.33%) was recorded on unsprayed (control) plots (Table 3). Different scholars reported that *Trichoderma harzianum* and *Moringa* seed offers resistance to the invasion of disease-causing pathogen and have great potential antimicrobial properties as an alternative means to manage black rot disease (Al-askar *et al.,* 2010). In addition, *Moringa* seed extracts in this study exhibited high antibacterial properties next to Funguran OH 50WP, Vitra 50WP and Trichoderma harzianum. This was in support of studies carried out in screening of *Moringa* extracts for their antibacterial potential against enteric pathogenic bacteria such as *Xanthomonas campestris* of crucifers, *Staphylococcus aureus, Pseudomonas aeruginosa, Salmonella typhi, E. coli* and *Vibrio cholera*, and the results revealed that the strong antibacterial potency of Moringa against several gram-negative and gram-positive bacteria (Malliga *et al.,* 2014).

The ANOVA revealed that there were also significant differences (P≤ 0.01) among treatments for disease incidence. In addition to Black rot; Fusarium wilt *(Fusarium oxysporum f.sp. conglutinans*) and *Alternaria* leaf spot *(Alternaria brassicae)* was occurred on the unfolded leaves of the crops after the completion of days to 50% heading. But as the infections occurred on the unfolded leaves, it couldn't affect the yield produced. The lower mean Disease Incidence of 46.68 and 52.08% were recorded on treatments treated by Funguran OH 50WP and Vitra 50 WP respectively, however, the maximum mean disease incidence of black rot (100%) was recorded on unsprayed plots (Table 3). The reason for this finding was most probably due to the fact that copper compounds are well known and have been commonly used for over 100 years as fungicides shown protective activity against bacterial diseases. Various copper formulations (copper hydroxide, copper oxychloride and copper sulphate) are the only means registered in many countries for the protective control of such bacterial diseases including black rot of cabbage (Buchner *et al.,* 2001). Vitra 50 WP and Funguran OH 50 WP are composed of copper hydroxide which is contact fungicide characterized by a very good capacity of penetration in plants and high protection. It has great preventive action by inhibiting germination and blocking the development of the fungal spores and bacterial colony in plants. Upon application on the leaves, a Copper ion is released. The copper ions are absorbed by fungal and bacterial spores. Once absorbed, copper disrupts the enzyme system of the pathogenic organisms. Copper ion found in Vitra 50 WP and Funguran OH 50 WP kills bacteria, thus stops infection. It is a protectant fungicide/ bactericide therefore it must be deposited on the leaves before infection. Furthermore, copper compounds are not easily washed from leaves by rain since they are relatively insoluble in water. Therefore, they give longer protection against diseases than other organic materials. In agreement with the present findings, Ravikumar *et al.* (2001) reported that copper hydroxide sprayed in combination with Streptomycin sulfate was very effective in reducing the disease severity of bacterial citrus disease caused by *Xanthomonas spp*. Similarly, a study to control walnut bacterial blight also showed the significant efficacy with application of copper fungicides and Mancozeb (Buchner *et al.,* 2001).

Table 3. Evaluation of fungicides, botanicals and bio-agents against black rot under field conditions

Treatments	Parameters			
	rAUDPC	PSI	PSR	DI
Funguran OH 50 WP	38.91^{g}	33.49^{g}	42.70^{a}	46.68^{f}
Vitra 50 WP	39.81^{fg}	33.95^{fg}	41.40^{ab}	52.08^{f}
Electis 75 WG	48.46^{de}	42.59^{de}	27.11^{cd}	60.87^{e}
Ginger rhizome extract	59.72^{b}	53.40^{ab}	7.87^{fg}	77.63^{b}
Moringa seed extract	47.38^{de}	40.74^{efg}	29.42^{abc}	64.45^{de}
Parthenium root extract	51.85^{cde}	44.75^{cde}	22.85^{cde}	69.76^{cd}
Xanthium leaf extract	58.02^{bc}	52.16^{abc}	10.32^{efg}	66.14^{cde}
Croton bark extract	53.47^{bcd}	46.76^{bcde}	18.84^{cdef}	71.67^{bc}
Croton leaf extract	52.78^{bcde}	46.91^{bcde}	19.47^{cdef}	64.94^{cde}
T. harzianum	45.83^{ef}	40.12^{efg}	31.41^{abc}	61.67^{e}
T. viride	51.31^{cde}	44.91^{cde}	22.32^{cde}	65.03^{cde}
T. virens	47.84^{de}	41.67^{ef}	28.63^{bc}	64.95^{cde}
B. subtilis	55.86^{bc}	50.00^{bcd}	14.06^{def}	71.54^{bc}
P. fluorescens	47.84^{de}	41.98^{e}	28.22^{bc}	59.17^{e}
Control	66.98^{a}	58.33^{a}	0.00^{g}	100^{a}
Mean	51.02	44.78	22.97	66.44
CV (%)	8.41	10.45	34.6	6.29
LSD	7.18	7.83	13.3	6.99

**Means followed by similar letters across the column were not significantly different. rAUDPC= Residual Area under Disease Progress Curve, PSI= Percent severity index, PSR= Percent Severity Reduction and DI= Disease Incidence.

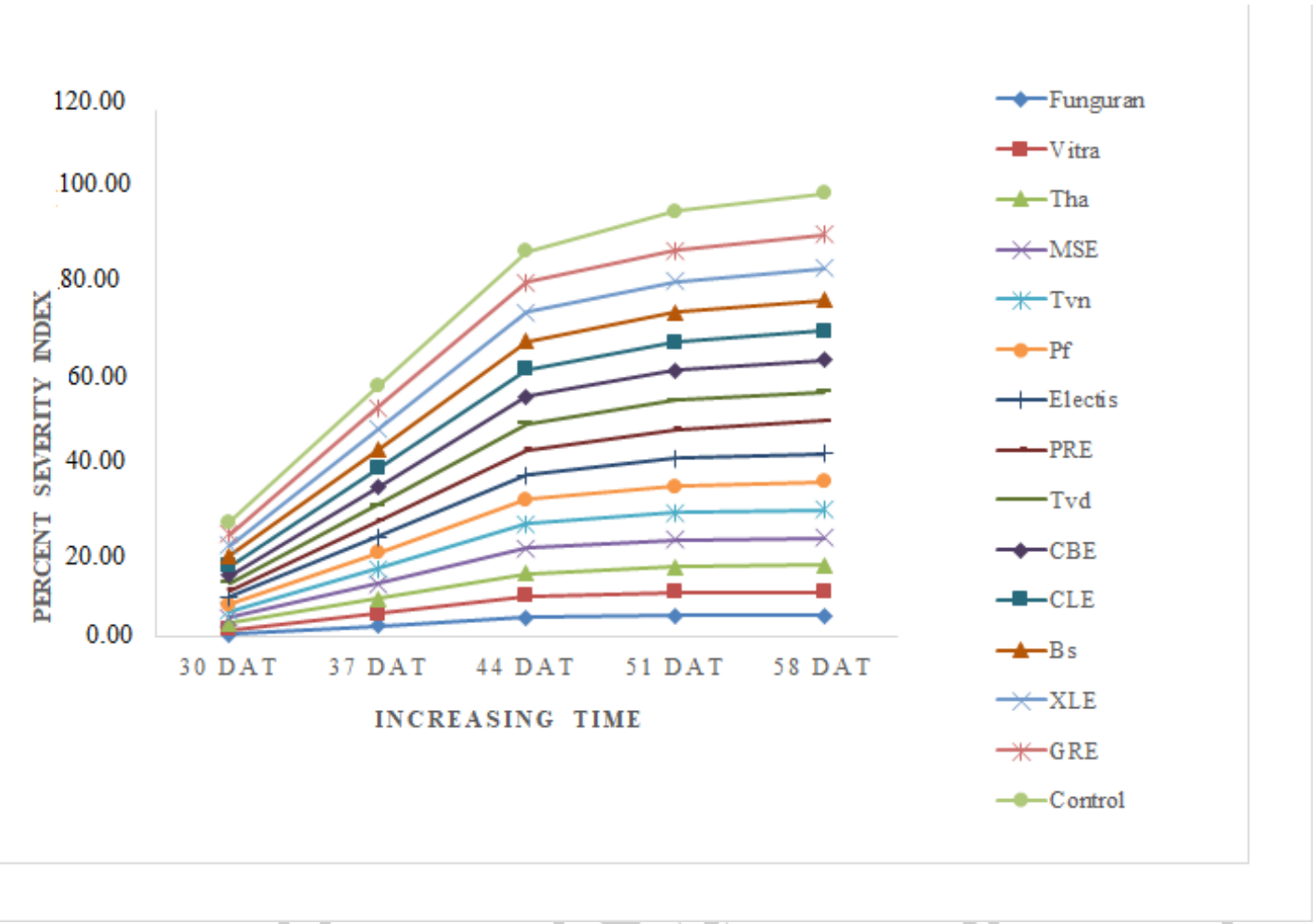

Figure -3: Disease progress curve of cabbage black rot.

Key: - DAT= Days after transplanting

The comparisons of the disease development rate among treatments using the logistic model showed that disease progress rates significantly differed between treatments ($p< 0.05$). The acceptable regression equation which produced by a linearized final black rot severity over time, in days after transplanting shows the coefficient of determination (R2) ranging from 0.75 to 0.902. The lowest disease progress rate (0.75) was recorded from plots treated with Funguran OH 50WP while the highest disease progress rate was observed from untreated plot with a value of 0.902, which exceeds Funguran OH 50WP by 0.151 units per day (Fig. 3).

Growth parameters of cabbage

The analysis of variance indicated that disease management treatments were significantly different at $P < 0.05$ for all growth parameters of cabbage like plant height, leaf length, plant spread, number of leaf per plant and number of unfolded leaf per plant. The tallest plant height (33.17cm and 32.62cm) were obtained from the treatments received *Trichoderma viride* and *Pseudomonas fluorescens,* respectively,

whereas the shortest plant height (18.99 cm) was recorded from untreated control plot (Table 4). The present results also exhibited the maximum plant spread (21.38cm and 20.84cm) were also obtained from treatments receiving *Pseudomonas fluorescens* and *Trichoderma viride*. Similarly the highest average leaf length (27.80cm) was also recorded on plots that received *Pseudomonas fluorescens* and this was statistically similar with plots which received *Trichoderma viride* and Parthenium root extract having average leaf length of 27.70cm and 27.49cm, respectively, while the shortest leaf length (16.31cm) was recorded on untreated control plot (Table 4).

The probable reason for this result may be due to the ability of *Trichoderma spp.* to colonize roots and stimulate plant growth and suppress plant diseases (Van Wees *et al.,* 2008; Mastouri *et al.,* 2010). Further, the application of *Pseudomonas fluorescens* combined with Azotobacter chroococcum led to enhancing of growth performance, nutrition and increment in broccoli and cabbage yield (Salim *et al.,* 2018a and 2018b). Many strains of Trichoderma spp., Bacillus spp. and Pseudomonas spp. were also reported as potential plant growth promoters and disease resistance inducers in a wide range of crops (Nandakumar *et al.,* 2001; Ramamoorthy *et al.,* 2002; Harman *et al.,* 2004; Udayashankar *et al.,* 2011 and Chowdappa *et al.,* 2013). Furthermore, minimum ratio of unfolded leaves to number of leaves per plants were recorded from plots treated with Vitra 50WP and Funguran OH 50WP with the mean values of 0.38 and 0.40, respectively, which was followed by *Trichoderma harzianum* with average value of 0.45 whereas the maximum ratio of unfolded leaves to number of leaves per plants were found in control plots (Table 4). This results were in agreement with the findings of many scholars who reported that plant growth promoters (PGP) encourage plant growth directly though increasing nutrition uptake excited by producing growth regulators (Idris *et al.,* 2007; Gravel *et al.,* 2007; Harman, 2011; Shoresh *et al.,* 2010; Kloepper *et al.,* 2004; Chen *et al.,* 2009).

Table 4. Effect of management option on growth parameters of cabbage under cabbage black rot disease.

Treatments	Parameters					
	PH	**LL**	**PS**	**NLPP**	**NULPP**	**RULNL**
Funguran OH 50 WP	30.64^{ab}	25.82 ^{ab}	19.03^{abc}	25.01 ^{ab}	11.24^{ab}	0.40^{c}
Vitra 50 WP	28.63 ^{ab}	24.06^{ab}	18.27^{abc}	25.31^{ab}	9.80^{b}	0.38^{c}
Electis 75 WG	28.03 ^{ab}	24.82^{ab}	18.09^{abc}	24.39^{ab}	12.55^{a}	0.50^{b}
Ginger rhizome extract	30.69 ^{ab}	25.74 ^{ab}	19.69^{abc}	23.29^{b}	12.32^{a}	0.56^{ab}
Moringa seed extract	27.88 ^{ab}	23.39 ^{ab}	17.58^{abc}	24.17^{ab}	12.22^{a}	0.47^{bc}
Parthenium root extract	31.53 ^{ab}	27.49^{a}	19.79^{abc}	24.31^{ab}	12.07^{a}	0.50^{b}
Xanthium leaf extract	30.72 ^{ab}	25.87 ^{ab}	19.01^{abc}	23.89^{ab}	13.16^{a}	0.53^{b}
Croton bark extract	31.08 ^{ab}	26.09^{ab}	19.78^{abc}	24.70^{ab}	12.49^{a}	0.51^{b}
Croton leaf extract	31.58 ^{ab}	26.12^{ab}	20.42^{ab}	25.14^{ab}	13.22^{a}	0.53^{b}
T. harzianum	26.37^{b}	22.32^{b}	16.40^{cd}	24.25^{ab}	11.41^{ab}	0.45^{bc}
T. viride	33.17^{a}	27.70^{a}	20.87^{a}	23.37^{b}	12.27^{a}	0.52^{b}
T. virens	26.72^{b}	22.14^{b}	16.46^{bcd}	23.92^{ab}	12.28^{a}	0.52^{b}
B. subtilis	28.97 ^{ab}	24.40^{ab}	19.07^{abc}	23.72^{b}	12.89^{a}	0.53^{b}
P. fluorescens	32.62^{a}	27.80^{a}	21.38^{a}	26.89^{a}	12.86^{a}	0.46^{bc}
Control	18.99^{c}	16.31^{c}	12.82^{d}	14.24^{c}	8.61^{c}	0.60^{a}
Mean	29.18	24.67	18.58	23.77	11.83	0.51
CV (%)	11.48	11.32	12.93	7.88	10.34	15.65
LSD	5.6	4.67	4.02	3.13	2.04	0.13

**Means followed by similar letters across the column were not significantly different. PH= Plant height, LL= Leaf length, PS= Plant spread, NLPPl= Number of leaves per plant and NULPPl= Number of unfolded leaves per plant, RULNL=Ratio of unfolded leaves to number of leaves per plants, *T .ha= Trichoderma harzianum, T.vd= Trichoderma viride, T.vn= Trichoderma virens, Bs= Bacillus subtilis and Pf= Pseudomonas fluorescens.*

Phenological parameters

The analysis of variance indicated that different treatments were significantly different at P ≤ 0.01 for phonological parameters of cabbage like days to 50% heading and days to 90% maturity; but non-significant for days to first head formation or head initiation. Earlier 50% head formation was observed in plots received Funguran followed by treatment treated with Moringa seed extract and *Pseudomonas fluorescens* which 50% of their plant population headed after about 52 days after transplanting. Whereas treatment plots which were not supplied with any treatments required relatively longer time (61.00 days) to heading. These treatments also assure early head maturity over the control (Table 5). The probable reasons for this result may be due to the ability of copper fungicides used as a broad-spectrum fungicide and bactericide favoring the plant growth soon after treatment (Miotto *et al.*, 2014). The current study also validated the finding of Price (1985) who reported that Juice from fresh Moringa leaves and seeds used to produce a good and effective plant growth hormone, which in turn increased vegetative growth in a variety of crops including onions, cabbage, maize, sorghum, soya, coffee and melon. The same results were presented by Fuglie (2000), who stated that leaf and seed extracts of Moringa oleifera accelerated growth of young plants, strengthened plants as a whole, improved plants resistance to pests and diseases, increased leaf area duration and number of roots, produced more and larger fruits and generally increased yield by 20 to 35%. This fact was further justified by Fuglie (2001) stating that Moringa leaf and seed contain substances that promoted the vegetative growth and grain yield of many crops. Different researchers also showed that application of *P. fluorescens* stimulates vegetative growth and growth contributing characters of cabbage. Vegetables, like cabbage, cauliflower and tomato respond well to plant growth enhancer by *P. fluorescens* in minimizing the transplanting shock and being encouraged to a quick growth (Karungi *et al.,* 2010). Similarly, result was found by Wani *et al.* (2007) who reported Pseudomonas spp. secrete organic acids and enzymes that act to mineralize immobile form of phosphates. It also produces amino acids, vitamins and growth-promoting substances which promote plants growth.

Table 5. Effects of management option on phenological parameters of cabbage under cabbage black rot disease.

	Phenological Parameters		
Treatments	**DFHF**	**DFH**	**DNM**
Funguran OH 50 WP	41.67	52.00^{c}	75.33^{de}
Vitra 50 WP	42.67	53.00^{bc}	74.33^{e}
Electis 75 WG	43.00	53.67^{bc}	76.33^{cde}
Ginger rhizome extract	44.67	54.67^{b}	78.33^{bcd}
Moringa seed extract	42.33	52.67^{bc}	78.33^{bcd}
Parthenium root extract	42.33	54.00^{bc}	79.00^{bc}
Xanthium leaf extract	42.67	53.00^{bc}	79.00^{bc}
Croton bark extract	43.33	54.33^{b}	78.67^{bc}
Croton leaf extract	42.33	53.00^{bc}	79.00^{bc}
Trichoderma harzianum	43.67	53.67^{bc}	77.67^{bcd}
Trichoderma viride	41.33	53.67^{bc}	79.00^{bc}
Trichoderma virens	43.00	54.67^{b}	78.33^{bcd}
Bacillus subtilis	43.33	53.33^{bc}	79.67^{b}
Pseudomonas fluorescens	41.67	52.67^{bc}	80.00^{b}
Control	44.00	61.00^{a}	95.67^{a}
Mean	42.8^{ns}	53.96	79.24
Cv (%)	3.70	2.25	2.29
LSD	2.65	2.03	3.03

**Means followed by similar letters across the column were not significantly different. DFHF= Days to first head formation, DFH= Days to 50% heading, DNM= Days to 90% maturity.

Yield and yield component parameters

From the analysis of variance, it is observed that the tested treatments were significantly different at P ≤ 0.01 for all yield and yield component parameters of cabbage except harvest index (Table 6). The maximum average head diameter (15.24 cm) was obtained in plots received Vitra 50WP while the average minimum head diameter (6.57 cm) was recorded in control plot Cabbage plants supplied with Funguran OH 50WP produced significantly (P ≤ 0.05) maximum (10.93kg) aboveground fresh biomass whereas the minimum aboveground fresh biomass (3.95Kg) was obtained from control plots (Table 6).

Similarly the maximum aboveground dry biomass of cabbage was also recorded from treated plots while the minimum aboveground dry biomass of cabbage was found from control plots (Table 6).The results of the cabbage yields also indicated that cabbage plants supplied with Funguran OH 50WP and Vitra 50 WP were produced significantly the highest total yield of cabbage (68.33 and 67.89 t ha-1) respectively. More over cabbage plots supplied with Funguran OH 50WP produced significantly ($P \leq 0.01$) the highest marketable yield (65.03 t ha-1) which was followed by Vitra 50 WP with a mean value of 64.17 t ha-1 and the lowest marketable yield (10.56 t ha-1) and the highest unmarketable yield (16.67 t ha-1) were obtained from control plants. Indeed the treatments result in better yield and yield attributes also significantly reduce the unmarketable yield and yield loss of the crop (Table 6). The positive reason for these results were related to the properties of copper fungicides as it contains active ingredient of different important chemicals which is effective against numerous plant diseases and promoting plant growth and yield components (He *et al.,* 2005). Dias (2012) also reported that Inorganic Cu compounds with fungicidal and bactericidal properties used as fertilizer additives are very popular in crop production due to their low cost and those bacteria and fungi cannot build up resistance against it as they do with antibiotics and synthetic fungicides that are organic in origin.

Table 6. Effect of management option on yield and yield components of cabbage under cabbage black rot disease.

Treatments	Parameters								
	HD	HW	AFB	ADB	HI	MYH	UMYH	TYH	YLH
Funguran OH 50 WP	14.45^{ab}	1.61^{a}	10.93^{a}	1.02^{a}	14.66	65.03^{a}	3.31^{g}	68.33^{a}	0.00^{f}
Vitra 50 WP	15.24^{a}	1.60^{a}	9.83^{ab}	0.78^{ab}	16.64	64.17^{b}	3.72^{fg}	67.89^{a}	0.32^{f}
Electis 75 WG	14.11^{abc}	1.49^{a}	9.59^{ab}	1.02^{a}	15.65	53.11^{def}	5.06^{defg}	58.17^{d}	14.87^{d}
Ginger rhizome extract	12.62^{cd}	1.32^{a}	8.94^{abc}	0.98^{ab}	14.77	43.28^{i}	9.72^{b}	53.00^{ef}	23.93^{b}
Moringa seed extract	12.96^{bcd}	1.27^{a}	8.37^{bc}	0.78^{ab}	15.73	52.28^{efg}	5.00^{defg}	57.28^{d}	16.03^{d}
Parthenium root extract	13.04^{bcd}	1.43^{a}	8.93^{abc}	0.64^{abc}	16.08	56.08^{cde}	7.81^{c}	63.89^{bc}	6.45^{e}
Xanthium leaf extract	12.58^{d}	1.52^{a}	9.17^{abc}	0.87^{ab}	17.29	58.53^{bc}	6.47^{cd}	65.00^{abc}	4.79^{ef}
Croton bark extract	12.83^{cd}	1.34^{a}	9.83^{ab}	0.98^{ab}	13.71	59.75^{bc}	6.53^{cd}	66.28^{ab}	1.54^{f}
Croton leaf extract	13.27^{bcd}	1.31^{a}	8.77^{bc}	0.87^{ab}	15.06	56.5^{cd}	5.61^{de}	62.11^{c}	8.98e
T. harzianum	13.83^{abcd}	1.37^{a}	7.74^{bc}	0.57^{bc}	18.37	48.88^{gh}	4.44^{efg}	53.32^{ef}	21.96^{bc}
T. viride	12.95^{bcd}	1.50^{a}	9.45^{ab}	0.84^{ab}	16.12	58.72^{bc}	3.94^{efg}	62.66^{c}	8.62^{e}
T. virens	12.82^{cd}	1.34^{a}	7.17^{c}	0.80^{ab}	19.99	45.89^{hi}	4.83^{defg}	50.72^{f}	25.65^{b}
B. subtilis	13.62^{bcd}	1.23^{a}	8.41^{bc}	1.01^{a}	14.89	44.33^{i}	5.67^{de}	50.00^{f}	26.77^{b}
P. fluorescens	14.03^{abcd}	1.83^{a}	9.28^{abc}	1.02^{a}	14.87	51.05^{fg}	5.34^{def}	56.39^{de}	17.49^{cd}
Control	6.57^{e}	0.44^{b}	3.95^{d}	0.22^{c}	11.72	10.56^{j}	16.67^{a}	27.22^{g}	60.13^{a}
Mean	12.99	1.34	8.69	0.83	15.7^{ns}	51.21	6.34	57.55	15.84
CV (%)	6.92	23.63	14.6	31.87	21.29	4.58	17.39	3.61	18.54
LSD	1.5	0.53	2.12	0.44	5.59	3.93	1.84	3.47	4.91

**Means followed by similar letters across the column were not significantly different. HD= Head diameter, HW= Head weight, AFB= Aboveground fresh biomass, ADB= Aboveground dry biomass, HI= Harvest index, MYH= Marketable yield per hectare, UMYH= Unmarketable yield per hectare, TYH= Total yield per hectare, YLH= Yield loss per hectare, GRE= Ginger rhizome extract, MSE= Moringa seed extract, PRE= Parthenium root extract, XLE= Xanthium leaf extract, CBE= Croton bark extract, CLE= Croton leaf extract, Tha= Trichoderma harzianum, Tvd= Trichoderma viride, Tvn= Trichoderma virens, Bs= Bacillus subtilis and Pf= pseudomonas fluorescens.

Correlation of agronomic traits and disease parameters

The Pearson's correlation coefficients results showed that, all yield and yield components of cabbage were positive and significant at p≤0.05 (Table 7). Total yield per hectare (TYH) had significant positive association with all paired yield component traits except unmarketable yield and yield losses. The result revealed that treatments with longer in plant height were better in their yield and the plants producing better leaf length, wide spread of plant and more number of leaves per plant leads to produce better and healthier head yield. Indeed plots treated with Vitra 50WP, Funguran OH 50WP and *pseudomonas fluorescens* performed better head diameter and head weight and had maximum above ground fresh biomass and marketable yield per hectare. Thus, selection for better yield component traits would bring about a definite improvement in above ground biomass and this gave more total yield per hectare. On the other hands, the result indicate that both days to 50% heading (DFH) and days to 90% maturity (DNM) had significant negative association with all agronomic and yield traits parameters except unmarketable yield (UMYH) and relative yield losses per hectare (RYL).

All growth parameters had non-significant negative association with rAUDPC and percent severity index (PSI) except number of leaf per plant (NLPPI) which had significant negative association with them. The result revealed that relative yield losses per hectare had significant negative association with plant height, leaf length, plant spread, and number of leaf per plant, head diameter, head weight, aboveground fresh biomass, marketable yield per hectare and total yield per hectare. But it had significant positive association with days to 50% heading, days to 90% maturity, unmarketable yield per hectare at P≤0.01(Table 7). This showed that yield loss had related to poor performance of agronomic traits.The correlation analysis showed that, rAUDPC and percent severity index (PSI) had significant negative association with number of leaf per plant, head diameter, head weight, aboveground fresh biomass, marketable yield per hectare and total yield per hectare. However, it had significant positive association with days to 50% heading, days to 90% maturity and relative yield losses per hectare at P≤0.05. Thus, it indicated that as disease infection increase agronomic traits had been decrease in their performance and directly contributes to reduce yield responses. Generally, this investigation revealed that efficacy of treatments evaluated in this study were significantly reducing the disease parameters and result high yield.

Table 7. Correlation between different agronomic traits of cabbage and their final disease reaction to black rot.

	PH	LL	PS	NLPl	DFH	DNM	HD	HW	AFM	MYH	UMYH	TYH	RYL	rAUDPC	PSI	PSR
PH	1															
LL	0.97**	1														
PS	0.94**	0.93**	1													
NLPl	0.68**	0.66**	0.68**	1												
DFH	-0.51**	-0.56**	-0.48**	-0.51**	1											
DNM	-0.47**	-0.48**	-0.41**	-0.63**	0.81**	1										
HD	0.56**	0.61**	0.48**	0.61**	-0.85**	-0.89**	1									
HW	0.68**	0.71**	0.59**	0.60**	-0.64**	-0.63**	0.72**	1								
AFM	0.59**	0.61**	0.55**	0.54**	-0.61**	-0.67**	0.68**	0.69**	1							
MYH	0.61**	0.611**	0.53**	0.60**	-0.73**	-0.75**	0.69**	0.63**	0.79**	1						
UMYH	-0.33*	-0.31*	-0.29*	-0.45**	0.53**	0.51**	-0.49**	-0.32*	-0.33*	-0.56**	1					
TYH	0.67**	0.68**	0.58**	0.56**	-0.72**	-0.73**	0.69**	0.72**	0.81**	0.90**	-0.32*	1				
RYL	-0.62**	-0.63**	-0.52**	-0.57**	0.73**	0.76**	-0.70**	-0.65**	-0.78**	-0.97**	0.67**	-0.99**	1			
rAUDPC	-0.17^{ns}	-0.19^{ns}	-0.10^{ns}	-0.44**	0.57**	0.67**	-0.68**	-0.40**	-0.39**	-0.39**	0.14^{ns}	-0.44**	0.51**	1		
PSI	-0.11^{ns}	-0.15ns	-0.04^{ns}	-0.38**	0.54**	0.62**	-0.63**	-0.35*	-0.34*	-0.33*	0.08^{ns}	-0.40**	0.46**	0.99**	1	
PSR	0.24^{ns}	0.24^{ns}	0.17^{ns}	0.51**	-0.42**	-0.57**	0.57**	0.36*	0.36*	0.51**	-0.61**	0.43**	-0.94**	-0.93**	-0.45**	1

PH= Plant height, LL= Leaf length, PS= Plant spread, NLPl= Number of leaves per plant, DFH= Days to 50% heading, DNM= Days to 90% maturity, HD= Head diameter, HW= Head weight, AFM= Aboveground fresh biomass, MYH= Marketable yield per hectare, UMYH= Unmarketable yield per hectare, TYH= Total yield per hectare, RYL= Relative yield losses per hectare, rAUDPC= Residual area under disease progressive curve, PSI= Percent severity index, PSR= Percent severity reduction, *= significant @ p<0.05; **= significant @ P<0.01and ns= non-significant

CONCLUSIONS

The laboratory and field evaluation results of management option tested in this experiment revealed that Vitra 50 WP and Funguran OH 50WP at 2000PPm concentration superiorly inhibited the growth of the bacteria *Xanthomonas campestris pv. campestris* that cause black rot of cabbage and reduce the disease in the field. From the bio-agent evaluated *Trichoderma harzianum* and mong the evaluated plant extracts moringa seed extract also show promising result in inhibiting the bacterial growth and reducing the disease it cause in the field. Indeed the superior above stated treatments also show enhanced growth parameters such as plant height, leaf length, plant spread, number of leaf per plant, number of unfolded leaf per plant, head diameter and improve yield per hectare and reduce unmarketable yield per hectare. Generally, from the present investigations, it can be concluded that Funguran OH 50WP and Vitra 50 WP were effective to control cabbage black rot, so can be utilized as management strategies in the study area in particular and the cabbage production areas of the country in general. The current result is also in a conclusion that Moringa seed extract and the bio-agents *Trichoderma* showed promising performance in black rot disease reduction can be incorporated as component of integrated management of cabbage black rot disease.

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