Volume 9, Issue 9, September – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP888

# Effect of Different Concentrations of Tomato Leaf Extract on Aphid Control in Rape Production in Zimbabwe

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**Abstract:- Rape (*Brassica napus*) is an important vegetable crop grown by smallholder farmers in Zimbabwe to achieve food and nutritional security. However, productivity and quality of rape are greatly dampened by aphids which reduce its palatability and quality. Chemical pesticides, while effective, pose environmental risks and can lead to pest resistance and resurgence, besides residual effects and bioaccumulation along the food chain. Tomato leaves are rich in phenolic and flavonoid compounds, that have shown promise as a botanical pesticide against aphids in other crops. This research aimed to establish the aphicidal components in tomato leaf extract using TLC and UV-Vis Spectroscopy; establish toxicity of the extract using laboratory bioassay, investigate the potential of different concentrations of tomato leaf extracts as a natural, environmentally friendly and sustainable approach to pest management against aphids in rape production at Kushinga Phikelela Agricultural College in Zimbabwe. A CRD with four treatments (0%, 20%, 40% and 60% of tomato leaf extract) and distilled water (negative control) replicated five times each was used. Aphid infestation (scored on a scale of 0-9), yield, leaf size, and plant height were measured fortnightly. Data was analysed for statistical significance using ANOVA while separation of significant means was done by Fisher's Protected Least Significant Difference Test (LSD (5%). The results from combined analysis using TLC and UV-Vis Spectroscopy indicated that tomato leaf extract used in this research contained compounds (Solanine, Tomatine, Chaconine) which are known to be toxic to pests. There was a highly significant ($p<0.001$) difference among treatments on aphid mortality. The highest aphid mortality (95.57%) while the lowest (4%) was observed in 60% and 0% leaf extract respectively. Aphid infestation, leaf size and plant height were highly significant ($P<0.001$) during weeks 4, 6, 8 and 10 after transplanting. Aphid infestation in week 10 mean score was 8.8, 6.2, 3.8 and 0.8 for 0%, 20%, 40% and 60% tomato leaf extract respectively. Other parameters such as yield and leaf size were highest in the plots that received 60% tomato leaf extract sprays. Highly significant difference ($P<0.001$) in yield was observed in weeks 8 and 10, while significant difference ($P<0.05$) in yield was noted in weeks 4 and 6. However, in week two there were no significant differences among the treatments in yield and aphid infestation. Tomato leaf extracts contain secondary metabolites toxic to aphids and this can be used by resource constrained farmers. We recommend the use 60% tomato leaf extracts to control aphids in rape to sustainably achieve high yields.**

***Keywords:-*** *TLC, Tomato Leaf Extract, Nutritional Security, Botanical Pesticide, Sustainable Pest Management, UV-Vis Spectroscopy.*

## I. INTRODUCTION

Rape (*Brassica napus*) is a valuable crop widely cultivated by many smallholder farmers for its nutrient and mineral-endowed fresh and dry leaves in Zimbabwe. The crop reaches harvesting maturity within a very short period of time (20-30 days) after transplanting, making it very attractive to cultivate for many rural farmers as it offers food and nutritional security as well as surplus for sale to get income to elevate livelihoods. However, aphid infestation can significantly impact crop yield and quality reducing nutritional security and profitability among households. In the case of rape, aphids can cause damage by feeding on plant sap, transmitting viruses, and reducing overall plant health. According to Mhazo, et al. (2021), aphids vector more than thirty viral diseases reducing yields and quality of harvested leaves and brassica heads directly through feeding. Chemical pesticides, while effective, pose environmental risks and can lead to pesticide resistance in pests, residual effects and bioaccumulation along the food chain. Silbert, et al. (2012) reported that chemical control tactics have been employed as the primary method of managing pests, but this strategy has become less effective due to the development of insecticide-resistant populations. The dense and uncontrolled use of synthetic agrochemicals is, therefore, unsustainable as it is deleterious to humans and agroecological diversity. Regnault-Rogder et al. (2012) noted that synthetic pesticides, unlike botanicals, cause mutagenic effects on non-targets and cross-multi-resistance in pests. Ngeba, et al. (2022) weighed in reporting that the non-target, residual consequence and challenging bio-degradability of synthetic pesticides have become a huge setback, which urgently requires the alternative and pushes the need for the adoption of sustainable and cost-effective pest management strategies. Rape is harvested at short intervals for consumption or value addition and is more prone to toxic chemical residues. Tomato (*Lycopersicon esculentum* M.) leaf extracts are known to be rich in

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP888

secondary metabolites including phenolic and flavonoid compounds, and have shown promise as a botanical pesticide against a broad range of insect pests (Kanyange, et al., 2022, Friedman, et al. 2013). Solanine, tomatine and chaconine are major steroidal glycoalkaloids (SGAs) found in members of the nightshade family accounting for 95% of the steroidal glycoalkaloids (Ha et al. 2012, Friedman and Levin, 2016, Royta et al. 2023). According to Lin et al. (2018), solanine and chaconine are established to be toxic to bacteria, fungi, viruses as well as insects and therefore aid in plant protection. Mature tomato leaves are readily locally available and are a by-product of tomato production among smallholder farmers. The extract is, therefore, cheap, and sustainable in protecting brassicas from pest attacks. This study will extend this approach to rape production, aligning with integrated pest management principles by determining the concentration of tomato leaf extract that provides optimum aphid control in rape production for recommendation to smallholder farmers.

## II. MATERIALS AND METHODS

### *A. Site Description*

The experiment was carried out at Kushinga Phikelela Agricultural College (18.1550S; 31.6670E) in the Horticultural Production Section garden during the 2023-2024 summer season. Kushinga Phikelela Agricultural College is 16 km from Marondera town towards and along Mutare road and it has clay loam soils with a pH range of 5.5-6.5. The district lies in Natural Region IIb, with an annual rainfall of 750 mm-1000 mm and a temperature range of 20°C – 30°C. The district's altitude is 1688m.


**Fig 1; Location of Kushinga Phikelela Agricultural College. Google Imagery@ 2024 Terra Metrica. Map data @2024.**

### *B. Experimental Design and Treatments*

The experiment was laid out in a randomized complete block design (RCBD). There were four treatments, and each treatment was replicated five times. The treatments were 20%, 40%, 60% tomato leaf extracts and a control (0% tomato leaf extract). The land slope was used as a blocking factor. The size of land used for the investigation was 10.5m x 29.6m (310.8 $m^2$). The gross plot measured 1.6m x 5.0m ($8.0m^{2)}$ while the net plot was 1.6m x 4.4m ($7.04m^{2)}$ including 0.8m border rows. Plots were separated by 0.5m pathways while 1m was left between blocks. Each plot had five crop rows at a spacing of 0.15m in row and 0.4m interrow. At the periphery of each plot were two border rows to exclude the border row effect. The plots were maintained weed-free to reduce alternative hosts to harbour potential pathogens and pests including the aphids. The 3m of field borders were also kept free of weeds to avoid the influence of the external environment.

**Table 1. Treatments Used in the Study**

| Treatment Number | Tomato Leaf Extract Concentration(%) |
|---|---|
| 1 | 20 |
| 2 | 40 |
| 3 | 60 |
| 4 | 0 (plain water/negative control) |

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP888

C. *Experimental Procedure*

➢ *Preparation of Tomato Leaf Sample and Extraction*

Leaves of tomatoes were collected from an unsprayed plot at the college horticulture production garden. The leaves were left to dry at room temperature for two months. They were then ground into very fine powder. The powder was then soaked in distilled water for four weeks with regular agitation. After four weeks the contents were shaken and filtered through a sieve with a 2mm aperture size. The filtrate was kept in a deep freezer until use (Ghada et al., 2017).

➢ *Preparation of Stock Solution of the Tomato Leaf Extract*

The filtrate from the deep freezer was used as the stock solution and was kept in glass stoppered bottles and stored under refrigeration.

➢ *Method of Tomato Leaf Extract Application and Rape Establishment*

Land preparation, trial establishment, fertiliser management and other agronomic practices were executed as per recommendations for rape production requirements. İrrigation was done using the drip method to ensure a uniform moisture supply. Rape seedlings were transplanted into the plots after one week of hardening off. The concentrations of tomato leaf extracts were prepared by adding 200 ml, 400 ml and 600 ml of stock solution to a 1L volumetric flask separately and topped to the mark to make 20 %, 40 % and 60 % respectively. A 1L hand sprayer was used to spray the rape with the appropriate application rate of tomato leaf extract from week two to ten after transplanting to allow the establishment of aphids. Tomato leaf extracts (20%, 40% and 60%) were then sprayed in their respective treatment plots. İn the control, distilled water was sprayed, representing negative control. Liquid soap of 0.2% (v/v) was added to the mixture before spraying as a sticking agent. Each treatment was replicated five times. Full leaf coverage with tomato leaf extracts was done. Different 1L hand sprayers were used for each treatment to avoid cross-contamination. Border rows were included to manage the drift of botanical insecticides from one plot to the next.

➢ *Determination of Toxic Compounds in Tomato Leaf Extract*

Toxic compounds in tomato leaf extract were determined using Thin Layer Chromatography (TLC) and UV-Vis Spectroscopy. The compounds were extracted using ethanol and then filtered and concentrated by a Buchner funnel and filter paper. TLC was performed using TLC plates, organic solvents and a UV lamp. UV-Vis Spectroscopy to measure different absorbance of the compounds. Literature values were used to identify the toxic compounds in the tomato leaf extract. Retardation factor (Rf) values and spot colour on the TLC plate were compared for the different toxic compounds. Thereafter, peak absorbances and wavelengths on the UV-Vis Spectrum were compared. The combination of the TLC and UV-Vis data was then used to identify the toxic compounds in tomato leaf extract.

➢ *Determination of Effects of Tomato Leaf Extract Concentration in the Laboratory*

Petri dishes were used as experimental units in the laboratory. Tomato leaf extract was prepared from dried tomato powder. Aphids were collected from the rape in the control plots. Separate spray bottles were used for the application of the leaf extract. Cotton wool was used to support the aphids in the experimental units. The experiment was done under laboratory conditions.

*D. Experimental Setup*

Petri dishes were labelled (0% (negative control), 20%, 40%, 60%) showing the concentration of tomato leaf extract. Each treatment was replicated 3 times. Cotton wool was placed at the bottom of each petri dish. Respective tomato leaf extract concentration was appropriately applied to the cotton wool in each petri dish.

➢ *Aphid Introduction*

Fifty aphids were introduced in each petri dish to ensure equal initial aphid infestation.

*E. Monitoring and Data Collection:*

The set-up was left for 72 hours, but daily observations of the aphids were done. After 72 hours the number of dead and live aphids in each dish was recorded and transformed to percentages.

➢ *Field Data Collection*

Two outer rows from each plot were spared as border rows and the three center rows represented the net plot. Sampling of plants from the net plot was done using a systematic sampling method with the sampled plants tagged using a string attached to a label. İn the 2$^{nd}$, 3$^{rd}$ and 4$^{th}$ rows plants numbered 4, 8, 12, 16, 20, 24 and 28 were selected giving a total of 21 plants per net plot. Data collection for aphid infestation and yield commenced two weeks after transplanting and continued at fortnight intervals up to ten weeks. Aphid infestation scoring scale of 0-9 was used. Equal numbers of leaves were harvested from each plot and weghed using a digital balance to determine yield. Plant height and leaf area were measured at week ten after transplanting. Leaf area was determined using the formula; length x width x 0.75 (Montgomery, 1911). Rape yield was harvested from the second week after transplanting at two weeks intervals up to week ten. An equal number of leaves were harvested from each randomly selected plant in each plot. The aphid mortality rate (%) was calculated using the formula:

Mortality rate = (Number of dead aphids / Total initial aphids) × 100

**Table 2. Aphid Abundance/Infestation Scale**

| Rating | Appearance |
|---|---|
| 0-1 | No infestation |
| 2-3 | A few individual aphids |
| 4-5 | A few isolated colonies |
| 6-7 | Several small colonies |
| 8-9 | Large isolated/continuous colonies |

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP888

➢ *Data Analysis*

Analysis of variance (ANOVA) was done using Genstat version 18th (2016). Separation of significant treatment means at α=5% was done using Fisher's Least Significance Difference (LSD).

## III. RESULTS

Tomato leaf extract contained three organic compounds, solanine, tomatine and chaconine distinguished by different colours on the TLC plate, Rf values and UV-Vis absorbance peak wavelengths. The absorbance peaks were 210-220 nm, 230-240 nm and 250-260 nm for Solanine, tomatine and Chacotine respectively (Table 3).

**Table 3. Results of Test for the Presence of Toxic Compounds of Aphids in Tomato Leaf Extract**

| Toxic Compound | Observations | | |
|---|---|---|---|
| | Colour on TLC Plate | (Retardation Refractory Factor (Rf) Value | Uv-Vis Absorbance Peak Wavelength (nm) |
| Solanine | Yellowish spot | 0.5-0.6 | 210-220 |
| Tomatine | Brownish spot | 0.7-0.8 | 230-240 |
| Chaconine | Dark brown spot | 0.9-1.0 | 250-260 |

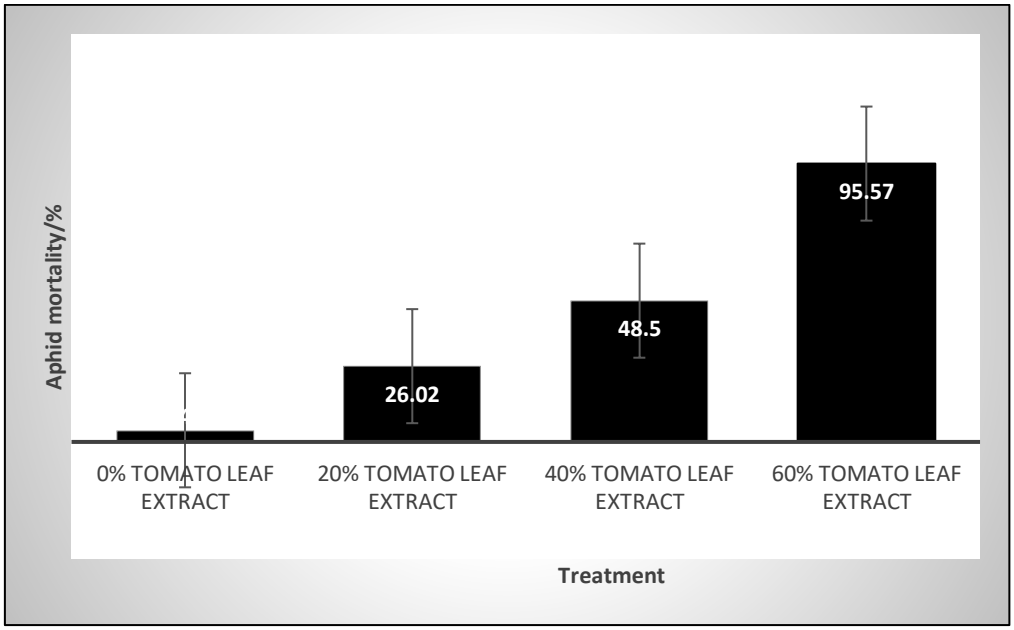


Fig 2. Effect of Different Tomato Leaf Extract Concentrations on Aphids in the Laboratory.

There was a highly significant difference ($p<0.001$) in aphid mortality among the treatments in the laboratory bioassays. Aphid mortality increased with an increase in tomato leaf extract concentration. The tomato leaf extract was 6.51, 12.13 and 22.62 times more lethal to aphids at 20%, 40% and 60% respectively than the control (Figure 2).

**Table 4. Rape Aphid Infestation Score at Two Weeks Interval after Transplanting Rape**

| | Weeks after transplanting | | | |
|---|---|---|---|---|
| | 4 | 6 | 8 | 10 |
| **Minimum** | **0.00** | **0.00** | **0.00** | **0.00** |
| **Maximum** | **6.00** | **7.00** | **9.10** | **9.00** |
| **Mean** | **2.70** | **3.55** | **4.65** | **4.90** |
| **60%** | **0.40$^{a}$** | **0.00$^{a}$** | **0.80$^{a}$** | **0.80$^{a}$** |
| **40%** | **0.24$^{b}$** | **3.00$^{b}$** | **3.40$^{b}$** | **3.80$^{b}$** |
| **20%** | **0.32$^{b}$** | **4.80$^{c}$** | **6.00$^{c}$** | **6.20$^{c}$** |
| **0%** | **4.80$^{c}$** | **6.40$^{d}$** | **8.40$^{d}$** | **8.80$^{d}$** |
| **L.S.D** | **0.916** | **0.723** | **0.733** | **0.966** |
| **C.V (%)** | **24.6** | **14.8** | **11.4** | **14.3** |
| **S.e.d** | **0.665** | **0.33** | **0.337** | **0.443** |
| **Sig.** | **<0.001** | **<0.001** | **<0.001** | **<0.001** |

**Key:** Means that do not share a letter are significantly different, **, *** = significance at P<0.05 and P<0.01 respectively.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP888

The results indicated that tomato leaf extract had a highly significant ($p<0.001$) effect on aphid infestation on rape from week four after transplanting through to week ten (Table 4). There was a general reduction in aphid score with an increase in the concentration of tomato leaf extract. Generally, the negative treatment showed the highest aphid infestation from the fourth week after transplanting. Aphid infestation on rape was reduced by 1100%, 950% and 1000% in the 4th, 8th and 10th weeks respectively after transplanting when 60% tomato extract concentration was used. İn week six the rape crop was clean with a mean aphid score of 0.00 at 60% tomato extract concentration. The score of the aphid population continued to increase with time in the control. İt increased by 83.3% in the tenth week when compared to week four after transplanting. İn week 10 aphid score was 29.55%, 56.82% and 90.91% higher for 20%, 40% and 60 % tomato leaf extract than the control.

**Table 5. Effect of Tomato Leaf Extract Concentration on Leaf Area and Plant Height**

| Tomato Leaf Extract Concentration/% | Mean Leaf Area/cm$^2$ | Mean Plant Height/cm |
|---|---|---|
| 0% (control) | 93.4$^a$ | 19.00$^a$ |
| 20% tomato leaf extract | 174.3$^b$ | 28.80$^b$ |
| 40% tomato leaf extract | 228.3$^c$ | 34.40$^b$ |
| 60% tomato leaf extract | 276.4$^d$ | 43.60$^c$ |
| **L.s.d** | 20.89 | 5.34 |
| **CV/%** | 3.3 | 9.60 |
| **S.e.d** | 9.59 | 2.45 |
| **Sig.** | <0.001 | <0.001 |

**Key:** Means that do not share a letter are significantly different, **, *** = significance at P<0.05 and P<0.01 respectively.

The results in Table 5 indicated that tomato leaf extract had an influence on leaf area and plant height. The concentration of tomato leaf extract had a highly significant ($p<0.001$) effect on leaf area and plant height. Tomato leaf extracts of 20% and 40% had the same effect on plant height but were significantly different from the effect of 60% concentration. The plants which received 20%, 40% and 60% tomato leaf extract were 86.62%, 144.44% and 195.93% respectively greater in leaf area compared to those which received no tomato leaf extract, while the difference in plant height was 145.26%. The effect of 20% and 40% tomato leaf extract was the same on plant height.

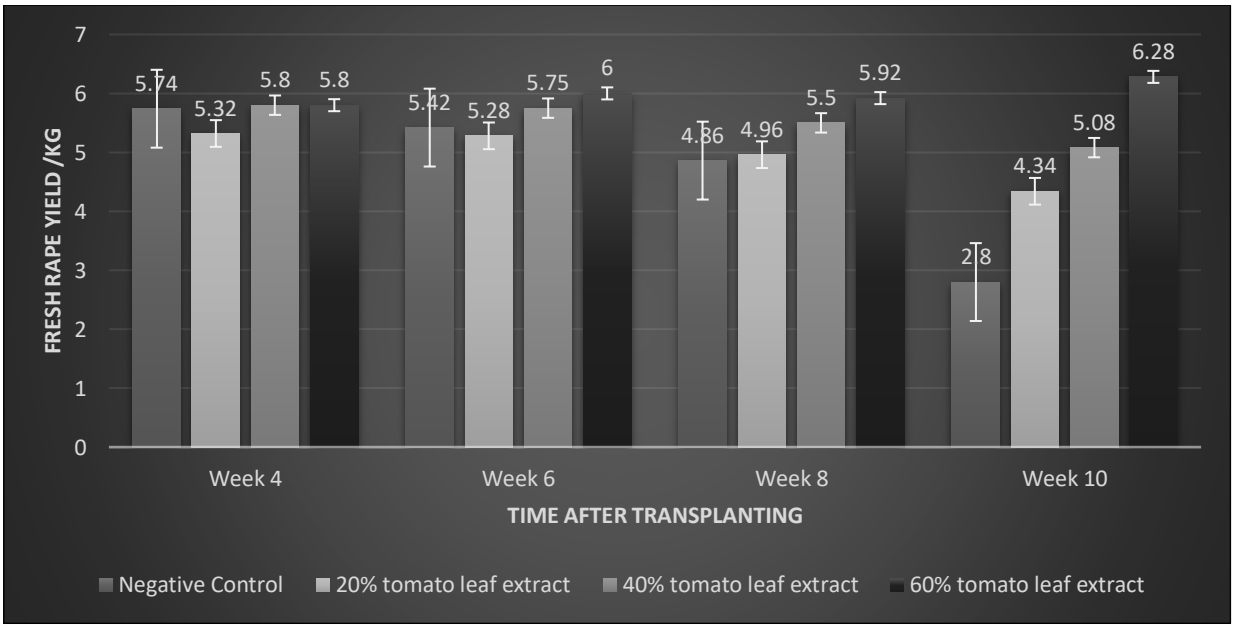


**Fig 3. Effects of Concentration of Tomato Leaf Extract on Fresh Yield of Rape from Two Weeks after Transplanting**

The data on harvested fresh rape weight from the fourth to the tenth week after transplanting is shown in Figure 3. The results showed a significant difference ($p<0.05$) in weeks four and six, and a highly significant difference ($p<0.001$) in weeks eight and ten after transplanting in treatment on yield of fresh rape. There was a general increase in rape yield as the concentration of tomato leaf extract increased.

The yield of rape increased by 2.09%, 10.7%, 21.8% and 124.3% at 4, 6, 8 and 10 weeks after transplanting respectively in treatments that received 60% tomato leaf extract concentration. The 60% tomato extract induced a consistently higher yield performance in rape with time compared to all the other treatments. The yield was, however, the same for the negative control, 40% and 60% tomato leaf extract but was 7.3% lower in the 20% leaf extract treatment two weeks after transplanting.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP888

## IV. DISCUSSION

Tomato leaf extract contained three organic compounds showing different spot colours on the TLC plate with different Rf values and characteristic absorbance peaks. These laboratory results confirmed the presence of solanine, tomatine and chaconine compounds which are known to have insecticidal properties. This is in agreement with Gupta et al., (2020) who reported that studies suggested that plant parts have immense potential as sources of biologically active compounds (alkaloids) that have a promising role in the management of various pests. Rattan (2010) also concurred that alkaloids are among the most important natural compounds with insecticidal properties. Gupta et al., (2020) further noted that *Carica papaya* aqueous leaf extracts proved to be effective against rose aphids (*Macrosiphum roseformid* D.). Additionally, Hamadah (2017) pointed out that Azadaractin which is a prominent constituent of neem is well known insecticidal ingredient which acts as an antifeedant, repellent, repugnant agent and induces sterility in insects by preventing oviposition and interrupting sperm production in male insects. This implies that botanicals can starve insects and make them fail to multiply on treated crops. Acheuk, et al. (2013) noted that flavonoids play an important role in the protection of plants against plant-feeding insects and herbivores. The observation affirms the huge potential role of botanical extracts in integrated pest management as an integral component to sustainable crop production.

Laboratory bioassays showed that the more the concentration of tomato leaf extract increased the more lethal the leaf extract became to the aphids. This could be attributed to the increase in alkaloids which are toxic to aphids with an increase in tomato leaf extract. Ahmad, et al., (2018) reported the presence of alkaloids, tepenoids, flavonoids and non-protein amino acids in botanicals which are deleterious to plant-sucking insect pests. The observation is in line with the report by Padim, et al. (2013) who pointed out that botanical extracts are toxic and cause death to insects. The laboratory results suggest that the same lethality of the botanicals on aphids provides potential protection of crops from aphids in the field.

During the first two weeks after transplanting, there were no significant differences in aphid infestation on rape between the control and those sprayed with different tomato leaf extract concentrations. This could have been because the aphids had not yet established since the experimental site was planted to maize and not brassicas which could have provided an innoculum of aphids. However, from 4 weeks after transplanting and afterwards, aphids invaded the experimental site and the control plots. The application of tomato leaf extract significantly reduced aphid population and infestation onwards, with the 60% rate of tomato leaf extract offering the highest protection of rape from aphids. This could be attributed to the repellent and aphicidal effect of tomato leaf extract. Tomato leaf extract is known to produce a distinctive odour that repels insects (Santoso et al., 2018). The aphicidal effect of tomato leaf extract could be due to the presence of alkaloids. The alkaloids are known to be toxic to insects and inhibit the process of metamorphosis (EndaE et al., 2023). Thus tomato leaf extract kills the aphids and disrupts their life cycle reducing their population on rape. The components of tomato leaf extract have the potential to deter feeding, and oviposition and interfere with metabolic processes (Laxmishree and Nandita, 2017). The strong smell produced by tomato leaf extract could have prevented aphids from finding their potential host plant especially as the concentration increased. The control recorded the highest score of the aphids population with time, rising by 83.3% in week 10 after transplanting. This could have been due to the repulsion of aphids from the tomato extract sprayed treatments. İn addition, the aphid life cycle is approximately two weeks (Sibanda et al., 2000, Pahla et al. 2014) hence the jump in aphid score in the tenth week. Rajashekar, et al. (2012) summed that the components of various botanical insecticidal extracts can be classified into six groups namely; repellents, feeding deterrents, antifeedants, toxicants, growth retardants, chemosterilants and attractants. Treulter (2005) highlighted that the presence of flavonoids in plants makes them unpalatable, decreases digestibility, acts as toxins or even reduces their nutritive value. As the concentration of the tomato extract increased the six groups of chemicals also increased, each contributing to the steep reduction in aphid population in rape.

Plant leaf area and height were significantly influenced by the concentration of tomato leaf extract because as the concentration increased to 60% the leaf area of rape escalated by 195.93% while plant height rose by 145.26%. The observation could be attributed to the higher efficacy of the tomato leaf extract in controlling aphids as well as the addition of nutrients which stimulate the growth of rape plants. As the tomato leaf extract concentration increased the insecticidal constituents concentration also increased keeping aphids at bay. Aphids, if in huge populations on rape leaves extract sap to decelerate the growth of leaves and effectively slow down the rate of photosynthesis as well as transmitting diseases. According to Pahla et al. (2014) infected seedlings of rape become stunted and distorted; continual feeding on mature plants causes wilting, yellowing and general plant stunting, curling and subsequent drying up of leaves, hence reducing the overall performance of the crop.

The yield of rape remained significantly lowest in the control with time while significantly highest for rape that received 60% tomato leaf extract spray suggesting that there was still room to further increase higher dosage for more effective control of aphids. İncrease in the concentration of tomato leaf extract was generally directly linked to an increase in the yield of fresh rape. The observation could be attributed to the reduction of the aphids population through repulsion, toxicity, failure to oviposit, failure of eggs to hatch and deterrent to feeding particularly at the highest tomato leaf extract concentration. With increasing doses of tomato leaf extract on rape the rape grew faster and established larger leaves. Larger leaves have a higher surface area for photosynthesis. The observation agrees with

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24SEP888

Li, et al., 2019 who reported that an increase in leaf size results in a larger increase in dry mass accumulation per unit leaf area.

## V. CONCLUSION

Tomato leaf extract contained organic compounds: solanine, tomatine, and chaconine which exhibited different spot colours on the TLC plate, distinct Rf values, and characteristic UV-Vis absorbance peaks. Solanine, tomatine, and chaconine are known for their insecticidal properties. The aphid infestation on rape was significantly influenced by tomato leaf extract sprays. The effectiveness of tomato leaf extract significantly depended on concentration as increasing concentration resulted in a steep reduction in the aphid population with time. A high concentration of tomato leaf extract not only dampened aphid score on rape but increase leaf size, plant height and fortnightly yield of rape. Tomato leaf extract is a promising botanical aphicide which is effective, easy to use, readily available, renewable, safe for the environment and humans and therefore, sustainable to control pests of economic importance in rape production among smallholder farmers in developing nations. However, the optimum concentration to be used needs to be established as it is still at a rudumentary level. The bio-aphicide is a promising low-hanging fruit for resource-constrained farmers because the source is a by-product of a common fruit vegetable grown by most smallholder farmers.

## RECOMMENDATIONS

Preliminary results suggest that tomato leaf extract contains lethal chemicals to aphids and we recommend rape farmers to use tomato leaf extract as a bio-aphicide. The farmers are recommended to use 60% tomato leaf extract concentration for effective control of aphids and to enhance growth rate of rape. To get large leaves and a high yield of fresh rape farmers are recommended to use the highest concentration of 60%, as tomato leaf extract has the potential to also control diverse pests, and provide nutrients for growth and development of the crop. More studies are recommended across seasons, agroecological zones and varieties of tomatoes as sources of extract to fully appreciate the effect of concentration of tomato leaf extract in the control of aphids in rape. We also recommend the effective utilization and development of botanical pesticides to aid the sustainable production of rape by farmers.

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