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Factors influencing income inequality among farming households of cassava producers, North Central, Nigeria

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ABSTRACT

This study focused on the factors influencing income inequality among farming households of cassava producers in North Central, Nigeria. A multi-stage sampling method was employed to select 160 cassava producers. The data were analyzed using descriptive statistics, Gini coefficient, and Probit model analysis. The results show that about 87% of cassava producers were male, while 13% were female. Approximate 92% of cassava producers were married. The mean age of cassava producers was 48 years. Averagely, the cassava producers had 13 years' experience in cassava farming. The cassava producers were literate with an average of 12 years of school education. The household sizes were large with an average of 8 people per household. Approximate 77% of cassava producers were member of cooperatives. The average farm size was 1.75 hectares which means that they are small-scale farmers. The estimates of Gini-coefficient show that 67 (41.88%) of cassava producers had values equal or less than 0.5 which means that they belong to low and moderate income inequality class. Similarly, approximate 93 (58.12%) of cassava producers had Gini-coefficient greater than 0.5, this implies that they belong to high income inequality class. The age, level of education, amount of credit accessed, farm experience, farm size, and extension contact were significantly different from zero in influencing the income inequality among farming households of cassava producers. The study recommends that single digit credit facilities should be provided to cassava farmers devoid of cumbersome administrative procedures. Also, mechanized farming using farm technologies with adequate provision of fertilizers, improved cuttings, agrochemicals, at appropriate time and affordable prices will increase productivity, income of cassava farmers.

Manyok üreticilerinin çiftçi haneleri arasında gelir eşitsizliğini etkileyen faktörler, Kuzey Orta, Nijerya

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ÖZET

Bu çalışma, Kuzey Merkez, Nijerya'daki manyok üreticilerinin çiftçi haneleri arasındaki gelir eşitsizliğini etkileyen faktörlere odaklandı. 160 manyok üreticisini seçmek için çok aşamalı bir örnekleme yöntemi kullanıldı. Birincil veriler kullanıldı. Veriler tanımlayıcı istatistikler, Gini katsayısı ve Probit model analizi kullanılarak analiz edildi. Sonuçlar manyok üreticilerinin yaklaşık %87'sinin erkek, %13'ünün ise kadın olduğunu göstermektedir. Manyok üreticilerinin yaklaşık %92'si evliydi. Manyok üreticilerinin ortalama yaşı 48'di. Manyok üreticilerinin manyok tarımında ortalama 13 yıllık deneyimi vardı. Manyok üreticileri okuryazardı ve ortalama 12 yıllık okul eğitimi aldılar. Hane halkı büyüklükleri oldukça büyük olup, hane başına ortalama 8 kişi düşmektedir.
Manyok üreticilerinin yaklaşık %77'si kooperatiflere üyedir. Ortalama çiftlik büyüklüğü 1,75 hektardı, bu da onların küçük ölçekli çiftçi olduğu anlamına geliyor. Gini katsayısı tahminleri, manyok üreticilerinin 67'sinin (%41,88) 0,5'e eşit veya daha düşük değerlere sahip olduğunu, yani düşük ve orta gelir eşitsizliği sınıfına ait olduklarını göstermektedir. Benzer şekilde, manyok üreticilerinin yaklaşık 93'ünün (%58,12) Gini katsayısının 0,5'ten büyük olması, onların yüksek gelir eşitsizliği sınıfına ait olduklarını göstermektedir. Yaş, eğitim düzeyi, erişilen kredi miktarı, çiftlik deneyimi, çiftlik büyüklüğü ve yayım sözleşmesi, manyok üreticilerinin çiftçi haneleri arasındaki gelir eşitsizliğini etkilemede sıfırdan önemli ölçüde farklıydı. Çalışma, manyok çiftçilerine hantal idari prosedürlerden arındırılmış tek haneli kredi olanaklarının sağlanmasını önermektedir. Ayrıca, yeterli miktarda gübre, iyileştirilmiş çelikler ve zirai kimyasalların uygun zamanda ve uygun fiyatlarla temin edildiği çiftlik teknolojilerini kullanan mekanize tarım, manyok çiftçilerinin verimliliğini ve gelirini artıracaktır.

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1. Introduction

Cassava (*Manihot spp*) is a food security crop, which can grow in low rainfall, minimal inputs, and poor soils (Gbigbi, 2021). The crop can withstand stress such as drought, cheap to cultivate, available all year round, and generate income for peasant farmers, hence providing household food security (Akerele et al., 2019). Cassava, apart from being used as a food crop for urban and rural communities, can also be used as bio-fuel, ethanol, to feed livestock, since it is a major source of income and employment for rural inhabitants in Nigeria. Nigeria, presently is the world's largest producer of cassava (60.8 million tons), second is Democratic Republic of Congo (48.8 million tons), third is Thailand (34.0 million tons), and fourth is Ghana (25.6 million tons) (FAO, 2024). Nigeria produced approximately 58,237, 500 tons and 60,835, 539.96 tons of cassava in 2021 and 2022, which represents 17.86% and 18.41% of world output, respectively (Figure 1). Similarly, in Nigeria, the cassava area in 2021 and 2022 approximated 9, 979, 330 hectares and 10, 029, 844 hectares, respectively (Figure 2). The world output of cassava in 2021 and 2022 approximated 326,015,871.5 tons and 330, 408,753.77 tons, respectively (Figure 1). The world area of cassava in 2021 and 2022 approximated 31, 461, 363 hectares and 320, 430, 055 hectares, respectively (Figure 2) (FAO, 2024). However, cassava farms faced low productivity and poor returns on investment (Itam et al., 2015). The sector is characterized by small-scale traditional farming methods with low modern technologies, and low levels of mechanization, leading to low levels of productivity (Abang et al., 2000).

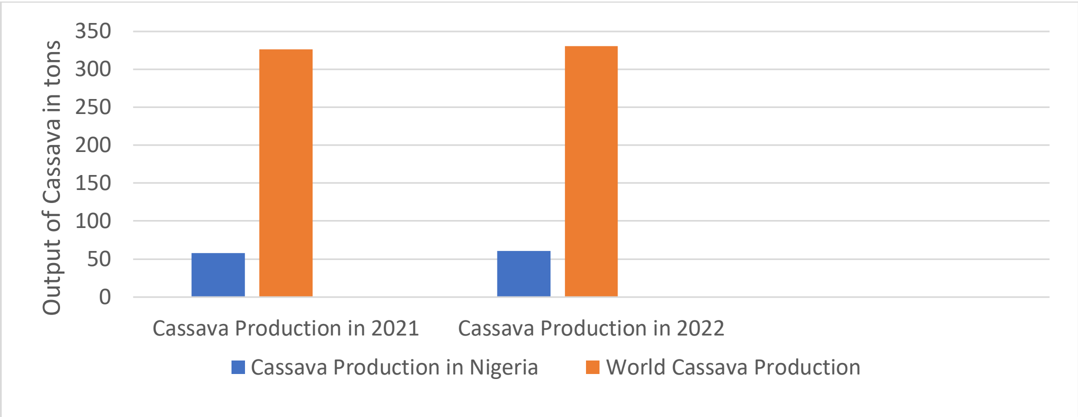

Figure 1. Cassava Production in Nigeria and the World

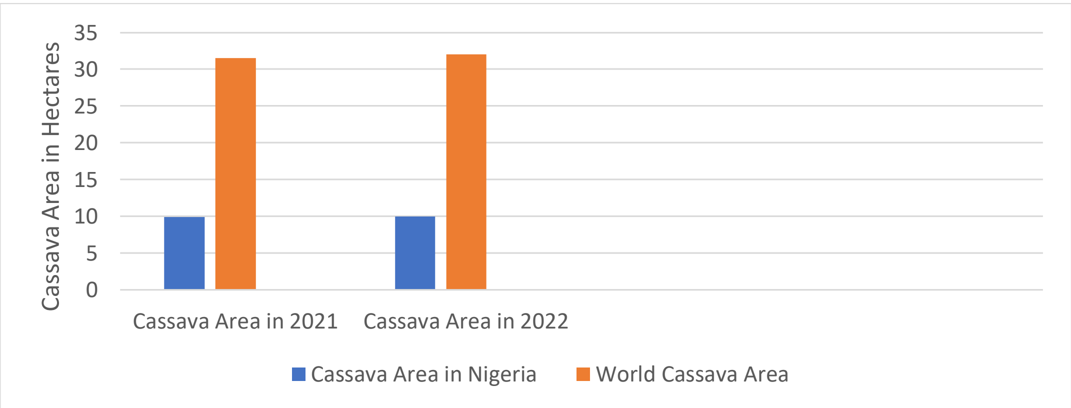

Figure 2. Cassava Area (Hectares) in Nigeria and the World

Income distribution pattern over the years has been a major problem in the determination of the level of economic development and growth (Agwu and Oteh, 2014). The gap between the lower income households and the upper income households has widened (Clarke et al., 2003). Income inequality was seen to be higher in the rural areas, when compared with the urban areas, the employment income increases inequality, while agricultural income decreases it (Addison and Cornia, 2001). Today, two out of five sub-Saharan Africans live in extreme poverty, and they do so among the worst income-wealth inequality (World Bank, 2019b). Economic inequality remains a matter of concern due to its link to extreme poverty, corruption, political stability, and social mobility (Bjornlund et al., 2020). The associations between income inequality, poverty, and growth are particularly important in rural areas, where poverty is most prevalent, typically above 70%, and where agriculture is the principal source of income (World Bank, 2019b). Agriculture-driven economic growth can become a vector of poverty reduction if it is not accompanied by extreme inequality in income and land (FAO, 2003). Economic inequality, whether in terms of income, expenditure, or wealth has long been recognized as a major obstacle to poverty reduction at global, national, and continental levels (Ravallion, 2014). The Gini-coefficient is the most popular inequality measure, given its relative ease of calculation and comparison across countries and population sizes (Manero, 2017). Gini -coefficient measure the degree to which the distribution of income differs from a perfectly equal distribution across all individuals in a group (World Bank, 2011). Its value ranges from zero (0) to one (1) (from total inequality to total equality).

The previous and related studies conducted by Donkor et al. (2022) on income inequality and distribution patterns in cassava value chain in the Oyo State, Nigeria was analyzed using descriptive statistics, Gini-Coefficient and multiple regression model. The result reported the estimated Gini coefficients of 0.44, 0.57, 0.79, and 0.73 among the small-scale cassava farmers, cassava medium scale farmers, cassava processors, and traders, respectively. The significant factors influencing profits of actors in the cassava value chains were age, primary education, secondary education, tertiary education, experience, farm size, labour, and membership of association.

Also, the studies conducted by Manero et al. (2020) on growth and inequality at the micro scale, an empirical analysis of farm incomes within smallholder irrigation systems in Zimbabwe, Tanzania, and Mozambique were analyzed by descriptive statistics, and Gini-coefficient. The estimated Gini-coefficients of 0.61, 0.57, 0.53, 0.61, 0.63 were reported for Mboka, Silalatchani, Kiwere, Magozi, and 25 Setembro among farmers in Zimbabwe, respectively.

The study conducted by Baruwadi et al. (2022) on inequality and income structure, a case study on maize farmer household in Gorontao Regency was analyzed using Gini-Coefficient, and z-test. The estimated Gini-coefficients of 0.61 and 0.35 were reported for Limboto and Tabongo. The previous study of Agwu and Oteh (2014) analyzed income inequalities and food security among farmers in Abia State, South Eastern, Nigeria, the data were analyzed using Gini-coefficient, food security formula, and multiple regression analysis. The result shows the Gini-coefficient was estimated at 0.67, which implies that there is high income inequality in the study area.

The research gap is that no available data on income inequality among cassava producers in North central, Nigeria, secondly, no available data on factors influencing income inequality among cassava producers in the North Central Nigeria utilizing Probit model.

1.1. Research questions

This study provided answers to the following research questions:
(i)What is the socio-economic profiles of cassava producers?
(ii) What is the income inequality among cassava producers?
(iii) What are factors influencing income inequality among cassava producers?

1.2 Objectives of the study

The main aim of the study is to evaluate factors influencing the income inequality among farming households of cassava producers in North West, Nigeria. The specific objectives include:
(i) description of the socio-economic profiles of cassava producers,
(ii)estimation the income inequality among cassava producers, and
(iii)evaluation the predictors influencing the income inequality among cassava producers in the study area.

2. Materials and Method

This study was carried out in North Central which is comprised of Federal Capital Territory and Niger State, Nigeria. They are predominantly known for cassava farming. The study employed a multi-stage sampling technique. The multi-stage sampling technique was chosen because of flexibility, time and cost-effective, the method helps cut down the population into smaller groups. The method is useful in collecting primary data from a geographically dispersed population, since it does not need a complete list of all members of the target population thereby reducing the sample preparation cost. In the first stage, Federal Capital Territory and Niger State were chosen using simple random sampling method. Second-Stage, two area councils were chosen in the Federal Capital Territory, and two local government areas were chosen in Niger State using simple random sampling method. Third-stage, two villages were chosen from each area council and local government area, respectively. The sample frame of cassava producers approximates 267 respondents. In the fourth and final stage, the total sample number of cassava producers was randomly selected from the villages which approximate 160 respondents comprising of 80 cassava producers each from Federal Capital Territory and Niger State, respectively. Primary sources of data were used based on a well-structured questionnaire that was passed through reliability and validity test. This sample number was calculated following the estimated formula of Slovin (1960) as follows:

$$n = \frac{N}{1+N(e^2)} = \frac{267}{1+267(0.05^2)} = 160 \quad (1)$$

Where,
n = The Sample Number
N = The Total Number of Cassava Producers (Number for the 2 States)
e = 5%
The data obtained were analyzed using both inferential and descriptive statistics:

2.1 Probit dichotomous regression model (PDRM)

The Probit model is chosen and well-suited for characterizing dichotomous (binary outcome variable) binomial response variable. The Probit model is based upon the normal distribution. The Probit model analysis ensures that your estimated probabilities are between 0 and 1. The Probit model also gives better results when the probabilities are small or large. The model following the work of Alabi et al. (2014) is explicitly stated as:

$$Y_i = P_i^* = \alpha_0 + \sum_{i=1}^{6} \alpha_i Z_i + \cdots \alpha_n Z_n + \mu_i \quad (2)$$

$$Y_i = P_i^* = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \mu_i \quad (3)$$

$$Y_i = \begin{cases} 1, & if \quad P_i^* > 0.5 \\ 0, & if \quad P_i^* \leq 0.5 \end{cases}$$

Where,
Y_i = The Dependent Variable, (1, Lower and Moderate Inequality; 0, Higher Inequality)
P_i^* = Gini Inequality
α_0 = Constant Term
α_1 - α_6 = Regression Coefficients
Z_1 = Age (Years)
Z_2 = Education Level in Years
Z_3 = Amount of Credit Accessed (Naira)
Z_4 = Farm Experience (Years)
Z_5 = Farm Size (Hectares)
Z_6 = Number of Extension Contact (Number per Month)
μ_i= Noise Term

2.2 The gini coefficient

The Gini-coefficient is used to calculate the income inequality among farming households of cassava producers. The Gini coefficient has values ranging between zero and one. The formula following the work of Taru and Lawal (2011) is stated as:

$$GC = 1 - \sum_{i=1}^{n} X_i Y_i \quad (4)$$

Where,
GC = Gini Coefficient
X_i =Percentage Share of Each Class or Producers
Y_i = Cumulative Percentage of their Sales
$0 \leq GC \leq 1$ **=** Gini coefficient varies between zero and one. According to Todaro (2011) the classification of income inequality using Gini Coefficient (GC) is as follows:
$0.20 \leq GC \leq 0.35$ = Low Inequality
$0.35 \leq GC \leq 0.50$ = Moderate Inequality
$GC > 0.50$ = High or Extreme Inequality
$GC = 0$ Perfect Equality
$GC = 1$ Perfect Inequality

3.Results and Discussion

3.1 Summary profiles of household head among smallholder Cassava producers

The summary profiles of household head among cassava producers are presented in Table 1. Approximate, 87% of cassava producers were male, while 13% of the respondents were female. The mean age of cassava producers is 47 years. This means that they are strong, young, energetic and resourceful. This result is supported with the findings of Donkor et al. (2022) who obtained and average age of 48 years among cassava farmers in Oyo State, Nigeria. Averagely, 92% (SD = 0.48) of cassava producers were married, while 8% of the respondents were not married. The producers had 12 years' experience in cassava farming. This result is in line with Gbigbi (2021) who reported that 5 1.7% of cassava farmers had between 6 – 10 years' experience in cassava farming in Delta State, Nigeria.

Table 1. Summary Profiles of Smallholder Cassava Producers

Variables	Unit of measurement	$\bar{X}_i$	SD
Sex	1, Male; 0, Otherwise	0.87	0.48
Age	Years	48	11.16
Marital Status	1, Married; 0, Otherwise	0.92	0.48
Cassava Farming Experience	Years	13	6.27
Formal Education	Years	12	3.74
Household Size	Number	8	2.45
Farm Size	Hectare	1.75	0.54
Membership of Cooperatives	1, Member; 0, Otherwise	0.77	0.47

Source: Field Survey (2024), SD = Standard Deviation

The more years of farming experience a farmers have, the higher farm output than those with lesser years of farming experience. Durojaiye and Ogunjimi (2015) reported that educated farmers are capable of understanding and evaluating innovations. The household sizes were large with an average of 8 people per household. This work is in line with Alabi and Safugha (2022), and Alabi et al. (2022). According to Idrisa et al. (2012) who documented that large household sizes provide adequate supply of family labour for activities of farm production. This outcome conforms to the findings of Oladeebo and Oluwaranti (2012) who reported an average of 8 persons per cassava farmers in South West, Nigeria. They are small-scale farmers who cultivated an average farm size of 1.75 hectares of cassava farms. Approximate 77% (SD = 0.47) of cassava producers belongs to cooperative organization, while 23% of the respondents do not belong to any cooperative organizations. Membership of cooperatives enables the cassava producers access credit, share ideas, information, and sell in bulk the cassava produce. This finding is supported with the outcomes of Bizikova et al. (2020), Manda et al. (2020), and Olagunju et al. (2021) who reported that the memberships of association are important social capital for the cassava value chain actors, enabling them to access to certain economic resources such as training, innovations, credit, and relevant market information. This study is supported with Donkor et al. (2022) who documented that membership of association enables the cassava actors to receive support in the form of training on innovations and finance from the non-governmental and government organizations. Moreso, members of association share information on available market, prices and innovations that enhance their productivity and profit. The collective action by cooperative members reduce transactions costs and enables cassava actors access to better markets.

3.2 Estimate of gini coefficient among farming household of cassava producers

Table 2 presents the values of Gini coefficient among farming households of cassava producers in the study area. Approximately 67 (41.88%) of cassava producers had Gini coefficient values less or equal to 0.5 this implies that they had low and moderate income inequality. Similarly, approximately 93 (58.12%) of cassava producers had Gini coefficient values greater than 0.5, this means that they had high income inequality. This study is similar to the findings of Taru and Lawal (2011) who obtained Gini coefficient of 0.52 for yam retailers and 0.5 for yam wholesalers in Taraba State, Nigeria. This finding is also in line with findings of Baruwadi et al. (2022) who obtained Gini coefficients of 0.61 and 0.35 for yam farming households in Limboto and Tabongo Gorontalo Regency, Indonesia. This result agrees with the findings of Donkor et al. (2022) who obtained the estimated Gini coefficients of 0.44, 0.57, 0.79 and 0.78 among small-scale cassava farmers, cassava medium-scale farmers, cassava processors, and traders in Oyo State, Nigeria. This result is supported with the findings of Agwu and Oteh (2014) who reported that there is a high income inequality for an estimated Gini-coefficient of 0.67 among farmers in Abia State, Nigeria.

Table 2. Estimates of Gini Coefficient among Farming Household of Cassava Producers

Gini Coefficient	Frequency	Percentage
≤ 0.5	67	41.88
> 0.5	93	58.12
Total	160	100.00

Source: Field Survey (2024)

3.3 Factors influencing income inequality among farming households of cassava producers

Table 3 presented the maximum likelihood estimates of factors influencing income inequality among farming households of cassava producers. The analysis was done using Probit model analysis. The log likelihood ratio statistics was estimated at -156.48 which was significant at 1% probability level, this signifies that the model has strong explanatory power. The Pseudo R^2 was evaluated at 0.8709, this means that 87.09% of the variations in the dependent variable was explained by the stated predictors in the model.

Table 3. The MLEs (Maximum Likelihood Estimates) of the Probit Regression Model

Variables	Parameters	Coefficient	Standard error	$P > \|Z\|$
Constant	α_0	0.4306***	0.1107	0.000
Age	α_1	0.2803***	0.1562	0.001
Level of Education	α_2	0.2168**	0.0852	0.026
Amount of Credit Accessed	α_3	0.2502*	0.1368	0.060
Farm Experience	α_4	0.2408**	0.1257	0.027
Farm Size	α_5	0.2209***	0.0561	0.000
Extension Contact	α_6	0.1309**	0.0578	0.028
Diagnostic Statistics				
LR_{χ^2} (6)	96.23***			
Pseudo R^2	0.8709			
LLF (Log Likelihood)	-156.48			
Prob $>_{\chi^2}$	0.00000***			

Source: Field Survey (2024),
*Significant at ($P < 0.10$)., **Significant at ($P < 0.05$), ***Significant at ($P < 0.01$).

Approximately six (6) predictors were included in the Probit model analysis. All the predictors had positive coefficient with income inequality of cassava producers. The significant predictors include age, level of education, amount of credit accessed, farm experience, farm size, and extension contact. The coefficient of age is positive (0.2803) and significantly different from zero at 1% probability level. This signifies that 1% increase in age, while keeping all other variables fixed will give rise to 28.03% increase in further lowering the income inequality among farming household of cassava producers. According to Donkor et al. (2022) who reported that the value addition activities from cassava production to trade in cassava products are labour intensive and require more energy, therefore, as actors advance in age, they become less active and their labour productivity tends to reduce. The low labour productivity leads to reduction in their total output and profit. The observation of the work is supported with the existing empirical study by Donkor et al. (2019) who reported that age of cassava farmers reduced their profits in Oyo State, Nigeria. The coefficient of level of education was 0.2168, and was significant at 5% probability level. This means a 1% increase in the level of education keeping all other variables constant will give rise to 21.68% increase in further lowering the income inequality among farming household of cassava producers. The coefficient of amount of credit accessed was positive (0.2502) and was significantly different from zero at 10% probability level. Thıs shows that a 1% increase in amount of credit accessed, while keeping all other factors constant will give rise to 25.02% increase in further lowering the income inequality among farming household of cassava producers. According to Oyibo et al. (2021) who reported that an increase in accessibility of credit will lead to a reduction in technical efficiency of the cassava farmers. Also, Mohammed and Falola (2016) who stated that access to credit affects input availability and efficiency and those producers who have access to credit tend to improve their income. The coefficient of farm experience is positive (0.2408) and significantly different from zero at 5% probability level. This signifies that a 1% increase in farm experience, while keeping all other factors fixed will give rise to 24.08 increase in further lowering the income inequality among farming households of cassava producers. According to Akerele et al. (2019) who reported that farming experience is used as a measure of management ability, the more experienced the farmers is, the more his ability to make farm decision. This study is supported with findings of Donkor et al. (2022) who documented that farm experience is another important human capital, most farmers develop agribusiness skills overtime through experience, therefore, farmers use the knowledge gained through experience to improve their productivity and profit.

Similarly, the coefficient of farm size was estimated at 0.2209 and was significant at 1% probability level. This signifies that a 1% increase in farm size of cassava producers keeping all other predictors fixed will give rise to 22.09% increase in further lowering the income inequality among farming households of cassava producers. This result is consistent with Obayelu et al. (2013) who reported that farm size was positively related to farm profit of cassava farmers in Ogun and Oyo States, Nigeria. The coefficient of extension contact is positive (0.1309) and statistically different from zero at 5% probability level. This means a 1% increase in extension contact, while keeping all other factors fixed will give rise to 13.09% increase in further lowering the income inequality among farming households of cassava producers. This study is supported with outcomes of Mohammed and Falola (2016) who documented that the contact with extension workers enables the cassava farmers to acquire the technical knowledge as well as to have access to improved production technology which will make them more efficient, productive with more profit. This work is also supported with Ofuoku et al. (2006) who reported that frequency of extension contacts enhanced adoption of improved technologies in Delta State, Nigeria.

4. Conclusion

This study focused on the factors influencing income inequality among farming household of cassava producers in North Central, Nigeria. A multi-stage sampling technique was employed to select 160 farming households of cassava producers. The sampling frame was 267 cassava producers. Primary data were used for this study. The data were analyzed using descriptive statistics, Gini coefficient, and Probit model analysis. The following conclusion were made based on the research questions:

What is the socio-economic profiles of cassava producers?

The cassava producers had a mean age of 48 years. They attended formal education with an average of 12 years of school education. The average farm size was 1.75 hectares, this shows that they are small-scale farmers based on the classification of farm holdings in Nigeria by Olayide (1980) who reported that small, medium, and large scale producers hold 0.1 – 5.99, 6.0 – 6.99, and above 10 ha, respectively.

What is the income inequality among cassava producers?

The estimates from Gini-coefficient revealed that approximately 67 (41.88%) of farming households among cassava producers had values less or equal to 0.5, this signifies that they belong to low and moderate income inequality class. Similarly, approximately 93 (58.12%) of farming households among cassava producers had Gini coefficient values greater than 0.5, this means that they belong to high income inequality class. The Gini coefficient is a value ranging from zero to one. The economic inequality remains a matter of concern due to its link to extreme poverty, corruption, political instability and social mobility (Rothman, 2015). Approximately two in five sub-Saharan

Africans live in extreme poverty, they do so amid some of the world severe wealth and income inequality (World Bank, 2019b). According to World Bank (2019b), the world most unequal countries by Gini coefficient are South Africa (0.63) (occupies 1st), Namibia (0.59) (occupies 2nd) heading the list, Nigeria (0.35) occupies 93rd position. These countries also score among the world's lowest on the Human Development Index, a composite of average life expectancy, education, and income (UNDP, 2017). The associations between inequality, poverty, and growth are particularly important in rural areas where poverty is prevalent, typically above 70%, and where agriculture is the principal source of income (World Bank, 2019b). Agriculture-driven economic growth can become a vector for poverty reduction if it is not accompanied by extreme inequality include in land and income (FAO, 2003).

(iii) What are factors influencing income inequality among cassava producers?

The significant predictors influencing income inequality among farming households of cassava producers include age, level of education, amount of credit accessed, farm experience, farm size, and extension contact. Based on the findings the following recommendations were made:

(i) Credit facilities at low interest rate should be giving to cassava producers to increase productivity and income. The credit facilities should be accessed devoid of cumbersome administrative procedures

(ii) The fertilizer input, agrochemicals, improved cuttings should be made available to cassava producers at affordable prices to increase productivity and income.

(iii) Extension contact should be employed to disseminate research findings and innovations to cassava farmers.

(iv) Farm land should be made available to youths, and farmers with appropriate farm technologies for mechanized farming to increase productivity should be presented concisely.

Author Contribution

The authors declare that they have contributed to the study on the subjects mentioned above.

Conflict of Interest Declaration Information

There is no conflict of interest.

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Topraktan izole edilen antagonist bakterilerin *Xanthomonas arboricola pv. juglandis L.*' e karşı biyolojik mücadelede kullanımının araştırılması

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ÖZET

Bu çalışmada, Düzce ilinin farklı ilçelerinde toprak örnekleri alınmış ve *Xanthomonas arboricola pv. juglandis L.*'e karşı *in-vitro* da biyolojik mücadele ajanı olarak kullanılmak üzere antagonist aktivite gösteren bakteriler taranmıştır. İzole edilen 10 adet aday antagonist bakteri morfolojik ve biyokimyasal özelliklerine yönelik farklı tanımlama testlerine tabi tutulmuştur. Antagonistik etkiye sahip olabileceği düşünülen bakteri izolatları saflaştırıldıktan sonra ikili kültür ortamında oluşturdukları inhibisyon zonları 3 tekerrürlü olacak şekilde ölçülmüştür. 10 adet izolatın farklı oranlarda (0,1- 2,1cm) engelleme zonları oluşturdukları tespit edilmiştir. İnhibisyon zonu oluşturmada en etkili izolat 2,1cm ile C1 olurken, G3-1 ve Cal2-1 izolatlarının inhibisyon zonu oluşturamadığı gözlemlenmiştir. Ancak Cal2-1 izolatı her ne kadar kültür ortamında gelişemese de ortama floresan madde salgılamıştır. Elde edilen sonuçlar *Xanthomonas arboricola pv. juglandis L.* ile mücadelede antagonist bakterilerin biyolojik mücadele etmeni olarak kullanılabileceğini göstermiştir. Çalışmada kullanılan izolatların tanımlanması ve *in-vivo* etkinliklerinin belirlenmesine yönelik daha çok çalışma yapılmalıdır.

Investigation of the possibilities of using antagonist bacteria isolated from soil in biological control against *Xanthomonas arboricola pv. juglandis L.*

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ABSTRACT

Soil samples were taken from different districts of Düzce province and bacteria that could be used as biological control agents against *Xantahomonas arboricola pv juglandis* were screened. The 10 isolated antagonist bacteria were subjected to different identification tests for their morphological and biochemical properties. After the bacterial isolates, which were thought to have an antagonistic effect, were purified, the inhibition zones they formed in the double culture medium were measured in 3 replicates. It was determined that 10 isolates formed inhibition zones at different rates (0.1-2.1 cm). While the most effective isolate in creating an inhibition zone was C1 with 2.1cm, it was observed that G3-1 and Cal2-1 isolates could not create an inhibition zone. Although the Cal2-1 isolate could not grow in the culture medium, it secreted a fluorescent substance into the medium. The results showed that the isolated bacteria could be used in biological control with *Xantahomonas arboricola pv juglandis*. More studies should be done to identify the isolates used and determine their *in-vivo* activities.

1.Giriş

Sert kabuklu meyveler arasında yer alan cevizin (*Juglans regia L.*) ticareti kabuklu ve kabuksuz olarak yapılmaktadır. Yaprakları, gövdesi, kökleri ve meyvesi çeşitli alanlarda kullanılan cevizin yüksek oranlarda yağ içermesi onu ilaç ve kozmetik sanayide sıkça

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tercih edilen bir ürün yapmıştır. FAO 2019 yılı verilerine göre ceviz sert kabuklu meyveler içerisinde dünyada alan olarak %9,3'lük pay ile ilk üç içerisinde yer almakta olup, üretim miktarı bakımından ise %25,8'lik pay ile birinci sırada yer alır. Dünyanın en büyük ceviz üreticisi olan Çin'in 2019 yılında ceviz üretimi %5,7 artış göstererek 2,5 milyon tona ulaşmıştır. Çin'den hemen sonra 592 bin ton ceviz üretimi ile ikinciliği ABD alır. Türkiye ise %5,0'lık pay ile ceviz üretiminde dördüncü sırada yer almaktadır. Ceviz üretim alanlarının %48,4'ü Çin, %11,3'ü ABD, %9,5'ini Türkiye oluşturmaktadır. 2020 yılında Türkiye'de ceviz üretim alanları 2019 yılına göre %13,8 oranında artarak 142 bin ha alanda gerçekleşmiştir. Ülkemizde ceviz üretim alanları incelendiğinde en fazla üretim alanı 110 bin dekar ile Denizli ilindedir. Denizli'yi 94 bin dekarla Manisa, 84 bin dekarla Bursa izlemektedir. En fazla meyve veren ağaca sahip il ise 643 bin adet ile Denizli ilidir. Denizli'yi 611 bin adetle Çorum, 582 bin adet Kahramanmaraş izlemektedir. Ülkemizde ceviz dış ticaretinde rekabet gücünün düşük olması, üretimin yurt içi tüketime yönelik olması, dünya piyasalarına kaliteli ceviz üretiminde yetersiz kalması, pazarlama karmasına göre faaliyet gösterecek birliklerin etkin olmaması gibi nedenlerle ithalatçı ülke konumunda olduğu görülmektedir ve ülkemizde yapılan ceviz üretimi ne yazık ki ülkemizin ceviz ihtiyacını karşılayamamaktadır (Anonim, FAO, 2019).

Ceviz üretiminde büyük zararlara yol açan etkenler incelendiğinde ana hastalıklar konumunda olan bakteriyel kökenli Ceviz Bakteriyel Yanıklığı (*Xanthomonas arboricola pv juglandis*) ve fungal kökenli Ceviz Antranknozu (*Gnomonia leptostyla*) liste başında yer alır. Bunun yanında ikincil zararlara veya doğrudan zarar neden olan *Armillaria sp., Phytophytora sp*, Külleme (*Phyllactinia guttata* ve *Erysiphe* (sect. *Microsphaera*) *sp*.) ve *Agrobacterium tumafaciens, Pseudomamanas syringae pv. syringae* gibi hastalıklarda gözlemlenebilir. Genel olarak çiçeklerin dökülmesi, genç sürgünlerin kuruması, yapraklarda nekrotik lekeler ve şekil bozuklukları gibi zararlara neden olurlar.

Xanthomonas arboricola pv. juglandis L. ülkemizde ceviz üretiminde ciddi ürün kayıplarına yol açan önemli bir bakteriyel hastalıktır ve etmenin tek konukçusu cevizdir. Hastalık başta Avustralya olmak üzere Yeni Zelanda, Kuzey ve Güney Amerika, Çin, Rusya, Irak, İran, Güney Afrika, Arjantin ve cevizin yetiştirildiği birçok Avrupa ülkesinde görülmektedir. Ülkemizde bilimsel bir kayıt olmamasına rağmen Karaca 1966 yılında Karadeniz Bölgesi'nde bu hastalığın belirtilerini gördüğünü belirtmiştir (Karaca, 1974). Özaktan ve arkadaşları tarafından yürütülen bir proje kapsamında 2007 yılında hastalık etmeni bakteri izole edilmiş ve kesin tanısı yapılmıştır (Özaktan ve ark, 2007). Özellikle Marmara Bölgesi'nde kapama ceviz bahçelerinin olduğu alanlarda hastalığın oldukça yıkıcı zararlara yol açtığı gözlemlenmiştir. Etkilenen ceviz bahçelerinde %50'nin üzerinde ürün kayıplarının olduğu bilinmektedir (Maragrega ve ark, 2007).

Cevizde çiçek, sürgün, meyve ve yaprak gibi çoğu aksamda zarar oluşturan bakteri başlangıçta yaprak dokuları (parankima, yaprak damarları ve yaprak sapı) içine yerleşir. İlk zamanlarda parankimada görülen küçük kahverengi- siyah lekeler zamanla gelişerek yaprak damarları ile sınırlandırılmış 2-3 mm'lik köşeli lekelere dönüşür. Lekeler çoğalarak yaprağın tüm yüzeyini kaplar ve fotosentetik yüzey kaybına neden olur. Yapraklarda şekil bozukluğu ve deformasyonlar gözlemlenir. Meyve oluşumunun ilk aşamalarında çiçek ve meyve hastalığa karşı oldukça hassastır. Yüzeyde küçük siyah yağ yeşili lekeler gözlemlenebilir. Bu safhalarda yaşanan enfeksiyonlar sonucu yüksek oranlarda meyve dökümü yaşanır. Yeşil meyve kabuğu üzerinde gözlemlenen siyah lekeler zamanla artarak çürüklükler meydana getirir. Kabukta bulunan lekeler ilerleyen aşamalarda cevizin içine doğru ilerleyerek cevizin renginde değişimlere ve tadında acılaşmalara neden olur. Ağaç üzerinde bulunan tüm erkek ve dişi çiçekler hastalığa karşı hassas yapılar olduklarından tamamen kuruyup kararır. Erken ilkbaharda yaşanan donlarda hastalığın sürgün ve yeşil tomurcuklarda oluşturduğu yanıklık hastalığın tipik bir belirtisidir. Fidanların henüz tam olarak gelişmeyen savunma yapılarını kolayca aşabilen patojen bu savunmasız dönemden faydalanarak şiddetli enfeksiyonlara ve ölümlere neden olur. Ağaçların bütün dönemlerinde hastalık oluşturabilme kabiliyeti ile patojen tüm dönemlerde zarar oluşturabilir. Özellikle fide dönemleri, meyvelerin ilk oluştuğu safhalar ve çiçek açma dönemleri gibi daha hassas dönemlerde patojenin oluşturduğu zarar daha fazladır. Çiçeklenme döneminde çiçeklerin kararıp kurumasına, yeni oluşan meyvelerde lekeler oluşturarak çürüklüklere, meyvede renk değişimi ve tadında acılaşma gibi zararlara neden olur. Tüm bu zararların sonucunda yüksek oranlarda meyve dökümü ve verim kaybı yaşanır. Ayrıca patojenin neden olduğu Bakteriyel Ceviz Yanıklığı Hastalığının, Marmara Bölgesi'nde uygun hava koşullarında şiddetli epidemi yapabildiği bildirilmiştir (Özaktan ve ark, 2007).

Ekonomik değeri yüksek olan ceviz üretiminde bu denli büyük ürün kayıplarına yol açan *Xanthomonas arboricola pv. juglandis* ile mutlaka zirai mücadele etmek gerekir. Hastalık etmeni kışı uyuyan gözlerde geçirmesinden dolayı yapılacak mücadele uygulamaları daha sınırlıdır. Etmenin mücadelesinde daha çok bakırlı preparatlar, hastalıklı dalların ve sürgünlerin kesilip uzaklaştırılması ve hastalığa karşı dayanıklı çeşitlerin kullanılması önerilmektedir. Kimyasal mücadelede kullanılan pestisitlerin neden olduğu kalıntı, dayanıklılık ve doğal kaynaklarının kirlenmesi göz önüne alındığında uzun yıllar kullanımı geri dönüşü olmayan sorunlara yol açmaktadır. Özellikle kullanılan geniş spektrumlu pestisitler ortadan kaldırılmak istenen patojenin yanısıra pek çok faydalı mikroorganizmayı yok etmektedir. Bilindiği kadarıyla kullanılan pestisitlerin genellikle %0,1'i hedef mikroorganizmaya ulaşır ve geri kalan kısmı toprak ve su gibi önemli kaynakların kirlenmesine yol açar (Sande vd., 2011 ve Mahmoud vd., 2016). Tüm bu zararlar göz önüne alındığında *Xaj* ile mücadelede alternatif yöntemler bulmak çok önemlidir. Bu aşamada kültürel ve biyolojik mücadelenin önemi artmaktadır.

Doğada karşılaştığımız sorunların çözümleri yine doğada yer almaktadır. Var olan sorunun çözümünü çok uzaklarda aramak yerine, asıl sorunun var olduğu yere odaklanmak çözüm bulmak için daha iyi bir yol olacaktır. Patojen ve antagonist mikroorganizmalar arasındaki ilişki bu durumun en güzel örneğidir (Bora ve Özaktan, 1998). Biyolojik mücadele esasen doğada bulunan zararlı popülasyonların yine doğada aynı ortamda bulunan doğal düşmanları ile kontrol altına alınabileceğini savunur ve bunu yaparken aynı ekosistem içerisinde bulunan tüm canlıların faydasını gözetir. Biyolojik mücadelenin tarihine şöyle bir bakacak olursak ilk uygulamaların Entomoloji bilim dalında yapıldığını görmüş oluruz. Bunun nedeni zararlı ve yararlı böceklerin etkileşimlerini görme kolaylığıdır. Fitopatolojide ise biyolojik mücadelenin dikkat çekmeye başlaması 1920'li yıllara dayanmaktadır. Yeşil gübre kullanımına başlanması ile patates uyuz hastalığı etmeni *Streptomyces scabies*'in baskılanması biyolojik mücadelede önemli bir başlangıç olmuştur. Yeşil gübre kullanımı sonucu ortamdaki mikroorganizma sayısından yaşanan artış ile patojenler çeşitli mikroorganizmalar tarafından baskılanmıştır. Patojen ve antagonist mikroorganizmalar arasındaki ilişkinin laboratuvar koşullarında araştırılmaya başlanması yaklaşık olarak 1940'lı yılları bulmuştur. *In-vitro* olarak başlayan çalışmalar imkanlar ve şartlar geliştikçe *in-vivo*'da saksı denemeleri ile devam etmiştir. Fitopatolojide her ne kadar bazı araştırmacılar bu konuyu 'bitmeyen senfoni' olarak değerlendirseler de günümüzde aktif olarak kullanılan biyopreparatların etkinliği biyolojik mücadelenin tarımsal mücadelede ne kadar etkili olabileceğinin kanıtını oluşturmuştur (Özaktan H. ve ark, 2010).

Ekolojik denge açısından daha doğa dostu bir mücadele yöntemi olan biyolojik mücadelenin geliştirilmesi ve kullanılacak ajanların alternatiflerinin çoğaltılması *Xaj* ile mücadelede oldukça önemlidir.

Literatür incelendiğinde yapılan birçok çalışmada biyolojik mücadelenin *Xaj*'a karşı etkinliği kanıtlanmıştır. Örneğin Yörük ve Mirik 2018 yılında yaptıkları bir çalışmada ceviz yapraklarından izole ettikleri aday antagonist bakterilerin *Xaj'*a karşı bakteriyel büyümeyi baskılayabilme yetenekleri ve antagonistik potansiyelleri araştırmışlardır. İzole edilen 109 adet bakteri izolatı ile *in-vitro* koşullarda ikili kültür denemesi yapılmıştır. Test sonucunda saptanan verilere göre 80 adet izolatın farklı boyutlarda (5-30mm) inhibisyon zonu oluşturduğu gözlenmiştir (Yörük ve Mirik, 2018). Özaktan 2012 yılında yaptığı bir çalışmada sağlıklı ceviz ağaçlarının filoplanından izole ettiği 35 aday antagonist bakterinin Xaj'a karşı *in-vitro* da biyolojik kontrol aktivitelerini araştırmıştır. Kullandığı antagonistik izolatların yaklaşık %60'ı patojeni %44 ila %77 oranında baskılamıştır. Çalışmanın devamında kurduğu bir *in-vivo* denemede ceviz fideleri kullanmış ve gözlemlerine dayanarak 4 antagonist izolatın patojeni önemli oranda (%41-%82) baskıladığını belirtmiştir. WH77/1, WH68 ve WH48/1A izolatları fide testinde en etkili izolatlar olup, birbirini izleyen iki yılda sırasıyla %55, %42 ve %82 hastalık azalması sağladı gözlemlenmiştir. Bu izolatlar, biyokimyasal ve fizyolojik testler temelinde geçici olarak *Pseudomonas fluorescen*s olarak tanımlamıştır. *P. vagans* izolatı C9/1 ajanı, yapraklardaki bakteriyel yanıklığın şiddetini %71 oranında azaltmıştır. Ceviz yapraklarına yapılan Prohexadione-Ca (Pro-Ca) uygulamaları sonucu yanıklık semptomlarını %66 oranında azalttığı gözlemlenmiştir (Özaktan ve ark, 2012). Başka bir çalışmada ise Fu ve ark, 2021 yılında *Xaj*'a karşı biyolojik mücadele ajanlarını araştırmak için 87 bitkiden 152 adet endofit bakteri izole etmişlerdir. Sırasıyla *Amaranthus tricolor, Bambusa multiplex, Canna indica ve Osmanthus fragrans* bitkilerinden 4 antagonist bakteri izole etmişlerdir bunlar ATE17, BME17, CIE17 ve OFE17'dir. İzolatların kültür ortamında *Xaj*'a karşı oluşturdukları inhibisyon zonları sırasıyla 1.5, 1.6, 1.3 ve 1.6 cm'dir. Başarılı buldukları izolatlar üzerinde yaptıkları tanımlama testleri sonucu izolatların *Bacillus spp*. olarak tanımlamışlardır ve aralarından iki izolatın (BME17-OFE17) çok sayıda bitki patojeni fungus ve bakteri üzerinde gelişmeyi baskılayıcı potansiyele sahip olduklarını belirtmişlerdir (Fu ve ark, 2021). Kültür ortamında oldukça etkili inhibisyon zonu oluşturan bakteriyel izolatların doğal koşullarda da aynı etkinliğe sahip olup olmadığını teyit etmek için yapılacak *in-vivo* denemeler, Xaj ile biyolojik mücadelede kullanılacak alternatif mikroorganizmaların bulunması adına çok önemlidir.

2. Materyal ve Metot

Çalışmada Düzce Üniversitesi Ziraat Fakültesi Bitki Koruma Bölümü laboratuvarlarına ait *Xanthomanas arboricola pv. juglandis* izolatı, otoklav, inkübatör, etüv, hassas terazi, manyetik karıştırıcı, steril kabin, effendorf, rock, öze, mikro pipet, mikrodalga, buzdolabı ve Düzce ilinin farklı ilçelerinden alınan (Çilimli, Gümüşova, Akçakoca, Kaynaşlı ve Merkez) toprak örnekleri kullanılmıştır. Toprak örneklerinden izole edilen antagonist bakterilerin saflaştırma işlemleri için King B (Litrede 20 g proteose pepton, 10 ml gliserin 1.5 g $K2HPO4$, 1.5 g $MgSO4$.- $7H2O$ ve 15 g agar) (King ve ark., 1954), SBC, ROSE ve ISP-2 gibi farklı besi yerleri kullanılmıştır. İzolatların +4 derecede uzun süreli muhafazası için LB besi yeri kullanılmıştır. Sağlıklı bitki köklerinden alınan toprak örnekleri polietilen torbalar içine doldurularak laboratuvara getirilmiştir. Her toprak örneğinden 10 g tartılarak 90 ml nutrient broth (NB) içerisinde 2-3 saat süreyle 150 rpm hızla orbital çalkalayıcıda çalkalanmıştır (Şekil 1.a). Her süspansiyondan 1 ml alınarak içerisinde 9 ml NB bulunan bulunan tüplere aktarılmıştır. Bu şekilde her bir örnekten ayrı ayrı seyreltme serileri oluşturulmuştur. Son üç seyreltme serisinden 100 er µl alınarak 3 tekerrürlü olacak şekilde NSA içeren petrilere steril baget ile yayılmıştır. Petriler 48 saat 26 °C de inkübe edilmiş ve farklı koloni morfolojisine sahip bakteriler saflaştırılmıştır (Şekil 1.b).

Şekil 1.(a) Toprak örnekleri.

Şekil 1.(b) Saflaştırma işlemi

Elde edilen izolatların çeşitli özelliklerini saptamak için bir dizi test uygulanmıştır. İzolatların patojen olabilme risklerine karşılık tütünde hipersensitif reaksiyon testi yapılmıştır. Koloni morfolojilerine göre antagonist olabileceği düşünülen izolatların hipersensitif reaksiyonu (HR) gözlemlemek için tütün (*Nicotiana tabacum cv. Samsun N*) bitkisinin yapraklarının alt yüzeyine damar aralarına aday antagonist bakterilerin 10^8 cfu/ml yoğunluğundaki süspansiyonu infiltre edilmiştir. 24-36 saat içerisinde bakteri infiltre edilen alanlarda nekrotik bir görünüm oluşturmayan izolatlar HR negatif olarak kabul edilmiş ve aday antagonist bakteri olarak değerlendirilmiştir (Şekil 2) (Klement ve

Goodman, 1967). 24-36 saat sonunda tütün bitkisi yaprakları üzerinde nekrotik alanlar oluşturan izolatlar HR pozitif olarak değerlendirilmiş ve bu izolatların biyolojik mücadelede kullanım olanakları araştırılmamıştır. Çalışmada pozitif kontrol olarak *Pseudomonas cichorii* kültürü kullanılmıştır. HR negatif olan izolatlar daha sonraki çalışmalarda kullanılmak üzere YDCA besi yerinde inkübe edilip +4 °C de buzdolabında muhafaza edilmiştir. İzolatların gram reaksiyonlarını belirlemek amacıyla Potasyum Hidroksit Testi (KOH) yapılmıştır. Taze hazırlanan %3'lük potasyum hidroksit solüsyonundan lam üzerine bir damla damlatıldıktan sonra 24-48 saatlik *X. arboricola pv. juglandis* izolatlarından steril özeyle alınan bakteri, solüsyona dairesel hareketlerle karıştırılmıştır. 15-20 saniye sonra özenin yukarı kaldırılmasıyla viskoz bir yapının oluşması bakterilerin Gram negatif olduğu sonucunu göstermiştir (Sands, 1990). Pozitif kontrol olarak *Clavibacter michiganensis subsp. michiganensis* kültürü kullanılmıştır. Daha sonra izolatların katalaz reaksiyonlarını gözlemlemek için lam üzerine 30 µl %3'lük H_2O_2 çözeltisi damlatılmıştır. Bakteri izolatlarının öze yardımıyla H_2O_2 çözeltisi ile karıştırılması sonucu gaz çıkışı olup olmadığı gözlenmiştir. Gaz çıkışı olması pozitif reaksiyon, olmaması ise negatif reaksiyon olarak değerlendirilmiştir (Klement ve ark., 1990). Bu test için *Xanthomonas campestris pv. vesicatoria* pozitif kontrol olarak kullanılmıştır.

Şekil 2. Tütün bitkisinde HR testi

Yapılan morfolojik tanı testlerden sonra antagonist bakteri izolatlarının patojen bakteriye karşı antimikrobiyal aktivitesini belirlemek için NSA besi yeri içeren petriler kullanılmıştır. Öncelikle NSA besi yeri içeren ortamda patojen bakteri 24 °C'de 1-2 gün süre ile geliştirilmiştir. Potansiyel antagonist adayı bakteriler de Nutrient Agar (NA) içeren petrilere ekilerek 24 °C'de inkübasyona bırakılarak 24 saatlik taze kültürleri elde edilmiştir. Gelişen taze bakteri kültürleri steril öze ile alınarak sdH_2O ile süspanse edilmiş ve bakteriyel hücre konsantrasyonu $1x10^8$ cfu/ml'ye ayarlanmıştır. Konsantrasyonları ayarlanan antagonist bakterilerden 20 µl pipet yardımı ile alınarak içerisinde NSA besi yeri bulunan petrilere nokta şeklinde üç kez olacak şekilde bırakılmıştır. Üç nokta bakteri inokulasyonu yapılan petrilere patojen bakterinin 10^6 cfu/ml konsantrasyonundan püskürtülmüştür. Petriler 24-36 saat süre ile 24 ºC'de inkübasyona bırakılmıştır. Bu süre sonunda aday antagonist bakterilerin oluşturduğu engelleme bölgesinin çapı ölçülmüştür. Her bakteri 3 tekerrür olarak test edilmiş ve elde edilen değerler yardımıyla antagonist bakterilerin oluşturduğu etkileri belirlenmiştir (Tekiner ve ark., 20).

3. Bulgular ve Tartışma

Çalışma sonucunda elde edilen veriler incelendiğinde izole edilen bakterilerin antagonistik etki gösterdiği gözlemlenmiş ve *Xaj* ile biyolojik mücadelede kullanılabilme potansiyeline sahip oldukları düşünülmektedir (Tablo 1).

Tablo 1. İzolatların tanı testleri tablosu

İzolat No	İzolasyon Tarihi	İzole Edildiği Materyal	Örneğin Lokasyonu	Gram Reaksiyon	Katalaz Testi	Hipersensitif Reaksiyon
G2-5	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
G2-2	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
G2-4	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
G2-3	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
M1-3	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
G4-2	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
G3-1	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
G4-1	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
C1	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif
Cal2-1	11/10/2022	Toprak	Düzce	Negatif	Pozitif	Negatif

Laboratuvarda yapılan *in-vitro* çalışmada kullanılan bakteri izolatları arasında en geniş inhibisyon zonu oluşturarak patojeni baskılamada en iyi sonuç veren izolat C1 (2,1cm) nolu izolat olmuştur. Bunun yanında kimi izolatlarda kültür ortamında antagonist bakterilerin hiç gelişmediği (Örneğin; G3-1, Cal2-1 gibi) gözlemlenmiştir. Diğer izolatlar da ise 0,1 ve 2,1 cm değerleri arasında değişen inhibisyon zonlar oluşmuştur (Tablo 2). İzolatlar arasında diğerlerinden farklı olarak Cal2-1 izolatı kültür ortamına floresan madde salgılamıştır. Literatürde yapılan benzer çalışmalar incelendiğinde alınan sonuçların bu çalışmadaki sonuçlar eşleştiği görülebilir. 2018 yılında yapılan bir çalışmada izole edilen 109 izolatın yaklaşık 80 tanesi 3,4-30mm arasında engelleme zonu oluşturmuştur (Yörük ve Mirik, 2018). Bu çalışmada ise ise ölçülen en büyük inhibisyon zonu 2,1cm olarak tespit edilmiştir. 2021 yılında yürütülen bir çalışmada ise 152 bakteri taradıktan sonra 4 farklı bitkiden, 4 antagonist bakteri elde edilmiştir. Bunlar ATE17, BME17, CIE17, OFE17. Sırasıyla oluştukları inhibisyon zonları ise 1.5, 1.6, 1.3, 1.6’cm olarak tespit edilmiştir (Fu ve ark, 2021).

Tablo 2. İnhibisyon zonu ölçümleri

İzolat no	*Zon Çapı 1(cm)*	*Zon Çapı 2(cm)*	*Zon Çapı* 3(cm)	Ortalama Zon Çapı
G2-5	0,1	0,1	0,1	0,1
G2-2	0,6	0,3	0,4	0,4
G2-4	0,5	0,4	0,1	0,3
G2-3	0,2	0,1	0,1	0,1
M1-3	0,2	0,4	0,6	0,4
G4-2	0,5	0,4	0,5	0,4
G3-1	-	-	-	-
G4-1	0,2	0,6	0,2	0,3
Cal2-1	-	-	-	-
C1-1	0,1	0,1	2,1	0,7

Yapılan bu çalışma ve önceki çalışmalar incelendiğinde sonuçların paralellik gösterdiği görülmektedir. Bu nedenle *Xaj*’a karşı yapılacak mücadelede alternatif yollar ararken antagonist bakterilerin kullanımı hastalığı baskılamada etkili olacaktır.

4. Sonuçlar

Çalışma kapsamında *Xaj* ile biyolojik mücadelede kullanılan antagonistlerin patojeni tamamen baskılayacak kadar etkili sonuçlar vermesi, umut veren mücadele yöntemlerinin olabileceğini ve bu konu üzerinde daha çok çalışma yapılması gerektiğini göstermiştir.

Çıkar Çatışması Beyanı

Herhangi bir çıkar çatışması yoktur.

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A case study on agricultural machinery variety and agricultural mechanisation level of Türkiye

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ABSTRACT

In this study, the varieties of machinery used in agricultural applications and the characteristics of the level of agricultural mechanisation in Türkiye were investigated. All data used in the study were taken from Turkish Statistical Institute (TUIK), National Tractor distributors and Turkish General Directorate of Security published database. The number of tractors, number of agricultural implements and machinery, variety of agricultural machinery used in Türkiye were examined and indicators such as the ratio of cultivated agricultural area to tractor power (kW/ha), the number of tractors per 1000 hectares of cultivated agricultural area (tractor/1000 ha) and the cultivated agricultural area per tractor were used to determine the level of agricultural mechanisation. In this study, the linkages between tractor power and tractor density were analysed and the number of tractors entering and leaving the farmers' agricultural machinery park over the years were taken into account. It is concluded that tractor economic life and park renewal rate is an important criterion as an indicator of the level of agricultural mechanisation in Türkiye and suggestions for solutions to tractor park problems are given respectively.

Türkiye'nin tarım makinaları çeşitliliği ve tarımsal mekanizasyon düzeyine ilişkin bir örnek çalışma

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ÖZET

Bu çalışmada, Türkiye'de tarımsal uygulamalarda kullanılan makine çeşitleri ve tarımsal mekanizasyon düzeyinin özellikleri araştırılmıştır. Çalışmada kullanılan tüm veriler Türkiye İstatistik Kurumu (TÜİK), Ulusal Traktör Bayiileri ve Emniyet Genel Müdürlüğü'nün yayınladığı veri tabanlarından alınmıştır. Türkiye'de kullanılan traktör sayısı, tarım alet ve makine sayısı, tarım makine çeşitleri incelenmiş ve ekili tarım alanının traktör gücüne oranı (kW/ha), 1000 hektar ekili tarım alanına düşen traktör sayısı (traktör/1000 ha) ve traktör başına düşen ekili tarım alanı gibi göstergeler tarımsal mekanizasyon düzeyini belirlemek için kullanılmıştır. Bu çalışmada, traktör gücü ile traktör yoğunluğu arasındaki bağlantılar incelenmiş ve çiftçilerin tarım makine parkına yıllar itibarıyla giren ve çıkan traktör sayıları dikkate alınmıştır. Türkiye'de tarımsal mekanizasyon düzeyinin bir göstergesi olarak traktör ekonomik ömrü ve park yenileme oranının önemli bir kriter olduğu sonucuna varılmış ve sırasıyla traktör parkı sorunlarına yönelik çözüm önerileri sunulmuştur.

1. Introduction

Agricultural machines are used for many different applications, such as tillage, sowing, irrigation, harvesting, storage and processing. For example, tractors are power

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machines which used to drive agricultural machines for performing the basic tasks of agriculture. The developments on agriculture and increased productivity is critical for the growth of the world's population and satisfy the need for food. Agricultural machines play important role in modernizing agriculture and making it more efficient. By reducing human labour, increased productivity and enable more field work time can be achieved with these machines.

Global population growth and limited natural resources pose a major threat to all countries. Nowadays, factors such as pandemics, wars, conflicts and climate changes have once again emphasized the critical role of food in human life. The fact that countries that are producers of food and agricultural products have given priority to their own citizens and restricted the sales of these products has had the effect of leading countries that are suppliers to search for new product types and productivity enhancers. Unfortunately, in a country where agricultural land is shrinking, increasing crop production efficiency is of vital importance. In this context, increasing agricultural productivity involves improvements in two main elements: product efficiency and input costs. Agricultural mechanization offers significant benefits in agricultural activities by saving time, reducing human labour and energy costs at every production stage. Furthermore, mechanization plays an influential role on product quality and productivity. Therefore, increasing the level of agricultural mechanization should be among the priority strategic objectives of all countries (Özgüven et.al 2010).

Agriculture contribute to employment, exporting and the all other industries in Türkiye. The utilization rate of Türkiye's land vary depending on the characteristics of climate and landforms. Although high mountainous areas have a large area, the utilization of the land here is quite limited due to the high number of steep slopes. While 36% of country's land consists of cultivated and planted areas, 32% consists of meadows and pastures, 26% of forests and 6% of settlements and bare rocks unsuitable for agriculture. Nowadays, due to high technological mechanization methods and machines in agriculture, meadow and pasture areas have shrunk, while agricultural areas continue to expand.

The agricultural sector occupies an important place in Türkiye's economic projection. According to 2011 data, the sector employs approximately 6.1 million people and generates an income of USD 62.7 billion. Moreover, in 2014, Türkiye has been exported 1707 different types of agricultural products to 190 countries and the total value of these exports amounted to 18.7 billion dollars (Turkish Agriculture and Forestry Ministry-2023).

The decline in the number of people working in the agricultural sector has been in line with the increase in the labour force in the service and industrial sectors. While agricultural employment rate was 50.6% in 1980 it continuously dropped to 34.3% in 2003, 25.5% in 2011 and men employment rate %15.5 and women employment % 30.7 (Turkish Agriculture and Forestry Ministry-2023). Although the agricultural sector had a 42.8% rate in GNP in the early years of the Republic, this rate has declined over time from 36% in 1970 to 25% in 1980, 16% in 1990, 13.5% in 2000, 12.6% in 2003 and finally 8.1% in 2011. The percentage rate of agricultural products in imports has also increased. Rate of change was 0.6% in 1980, 7.3% in 2011and %15.9 in 2023 (Turkish Exporter's Assembly-2023). In 2022, cereals and other vegetable crops (excluding fodder crops) increased by 14.6%, while fruits, beverages and spices increased by 7.7%. However, vegetables decreased by 0.5%. Thus, cereals and other crops produced 70.2 million tons, vegetables 31.6 million tons, and fruits, beverages and spices 26.8 million tons.

This study provides an overview of the types and importance of agricultural machinery. These machines contribute to the growth of the agricultural sector and increase food production. Agricultural machineries are indispensable tools to feed the world's population by ensuring that agricultural applications more efficient.

In this study, statistical sources for determining agricultural mechanisation levels compiled by the Turkish Statistical Institute (TurkStat) and relevant data provided by the Ministry of Agriculture and Forestry are included. These data contain information such as the values of cultivated area, number of tractors, harvesters and agricultural machinery throughout Türkiye and specific to geographical regions. Agricultural machinery types are analysed in detail under classification and their contribution to agricultural processes. A series of indicators were identified to assess the level of tractor-based mechanisation. These indicators include tractor power per unit area (kW/ha), number of tractors per unit area (number of tractors/1000 ha), agricultural area per tractor (ha/tractor) and average tractor power (kW). Among these indicators, tractor power per unit area (kW/ha) is the most widely used indicator to explain the current situation and to draw comparative conclusions. In addition, other criteria used to assess the level of tractor mechanisation include factors such as the number of agricultural machinery and implements per tractor, preferred energy sources in the agricultural sector, and the average duration of use of tractors.

2. Materials and Methods

In this study all materials supplied from public open governmental databases and related sector suppliers. Data are classified and then refined according to their trust ratios. Each data set analyzed and regroup according to sections which are used for determine mechanization level of Türkiye. Values according to tractor axle and horsepower distribution regrouped under some common ratios. Therefore tables are constructed according to these regrouped data set. Figures constructed for show relations mechanization parameter's variations among years.

3.Results and Discussion

3.1 Tractor park

A tractor park is an area where tractors, construction machinery or agricultural machinery used in industries such as agriculture or construction are stored and maintained. Such parks are used to carry out regular maintenance and repairs of tractors, refuelling and keeping machinery safe (Ağcı, 2002). Tractor parks are generally indispensable for agricultural enterprises, construction companies, forestry enterprises and similar industries. These parks play an important role in order to increase the efficiency and lifetime of construction machinery (Doğan, 2012) were given in Table 1.

Table 1. Türkiye Tractor Number Data for 2012-2022 period (TUIK, 2023).

Number of Tractors between 2012-2022										
		One axle Horse power		Two axle Horse power						
Year	Total	1-5	5 +	1-10	11-24	25-34	35-50	50+	51-70 (1)	70+(1)
2012	**1 178 253**	9 450	36 188	5 696	20 704	71 989	488 877	-	438 623	106 522
2013	**1 213 560**	10 889	42 476	5 937	20 153	71 165	493 462	-	451 292	118 000
2014	**1 243 300**	14 383	51 492	6 247	20 906	69 223	493 914	-	461 399	125 536
2015	**1 260 358**	14 856	54 604	6 252	21 181	68 074	491 828	-	468 060	135 297
2016	**1 273 531**	15 736	57 131	6 448	21 274	66 825	489 621	-	475 665	140 699
2017	**1 306 736**	16 589	59 061	6 432	20 527	65 866	492 343	-	493 660	152 133
2018	**1 332 139**	17 129	60 707	6 554	20 886	66 104	493 134	-	505 087	162 425
2019	**1 354 912**	17 512	62 178	6 589	20 513	65 496	495 375	-	513 035	174 105
2020	**1 442 909**	19 416	73 782	6 969	20 944	68 157	517 899	-	544 909	190 677
2021	**1 481 461**	20 517	79 658	6 853	20 841	68 730	523 718	-	555 536	205 488
2022	**1 526 769**	20 008	84 568	6 384	20 212	68 045	532 393	-	570 629	224 408

Analysing table 1 showed that, in 2012 total number of tractors was 1 178 253. This is summation of one axle and two axle tractors which are in diffrenet horsepower rates. Looking at one axle tractors according to horsepower distribution it is seen that highest interest locating at 5+ section and in two axle case highest interest seen on 35-50 horsepower section. When date comes to 2022 highest interests seen on 5+ horsepower section for one axle tractors and 51-70 horsepower section for two axle tractors while total tractor number was 1 526 769. Rate of change of tractor numbers is %29.5 in ten years. There was no significant change in one axle case but it is seen that highest interest section updated to 51-70 horsepower in two axle tractors. Tractor park renewed with higher powered tractors sothat power section upgraded (Işık (1988), Sümer et.al.(2004)).

3.2. *Quantitative and qualitative characteristics of tractor parks*

In order to compare the tractor data in Türkiye, it is very important to analyse 'Cumulative Tractor Sales Numbers', TURKSTAT statistics and National Police database records. According to the results of this comparison, TurkStat statistics and 'Cumulative Tractor Sales Numbers' data followed a harmonised course until 1988, but diverged in the following years.

On the other hand, a better agreement was observed between traffic records and 'Cumulative Tractor Sales Numbers'. it can be foreseen that traffic records may be a more reliable data source for the tractor park in Türkiye. At the end of 2020, the average age of Türkiye's tractor park, which was recorded as 1.946.806 units, was calculated as 25.3 years in Figure 1. Based on this data, it can be concluded that the mechanical life of tractors in Türkiye is 24 years at most. In the calculation of mechanical life, it is taken into consideration that according to the standards, the mechanical life of tractors is 10,000 hours until 2000 and 12,000 hours after 2000. It was also informed that tractors in Türkiye are used for an average of 500 hours per year and this average increases to 600 hours as the power level increases. It can be concluded that a large part of the tractor park in Türkiye consists of tractors that have completed their mechanical life. This information shows that the tractor park needs to be updated and modernised. Moreover, it is important to monitor the tractor park with more reliable and up-to-date data, so National Police database records may be a more suitable source for this purpose (Koçtürk and Avcıoğlu, 2007).

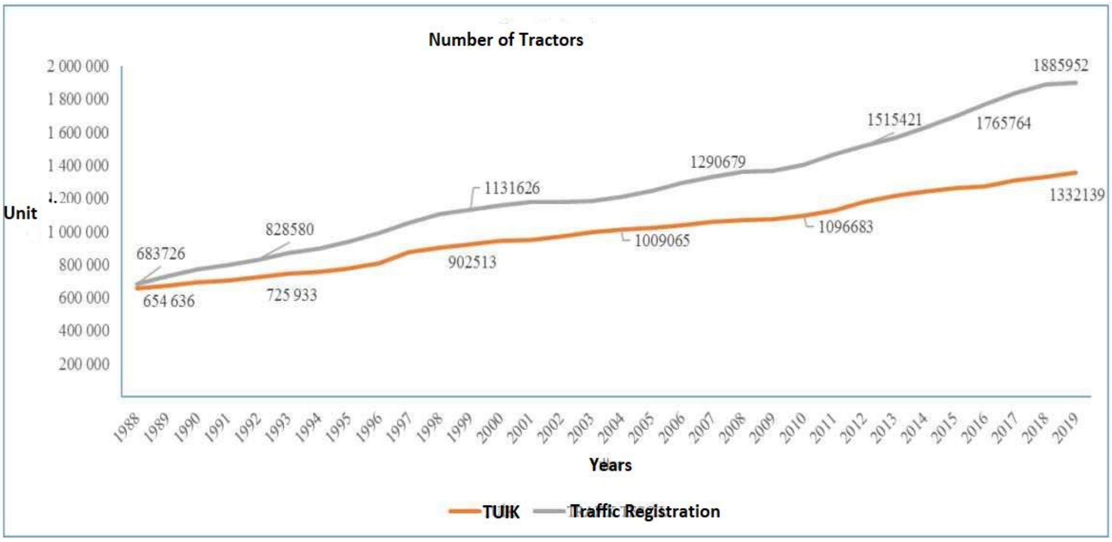

Figure 1. Development of Turkish Tractor park (TÜİK, 2020).

As seen in Figure 2, Although there are about 2 million tractors in Türkiye, about 500,000 of these tractors are over 40 years old. In addition, there are more than 150,000 tractors in the 35-39 age range. This situation further increases the importance of economic losses, environmental damage and safety deficiencies caused by the old tractor park. Moreover, in parallel with the development of the national economy and the agricultural sector, it is necessary to rapidly renew the old part of the existing tractor park. As of 2019, the average power of the tractor park in Türkiye was calculated as 39 kW (52.1 HP). This value is insufficient to utilise high production technologies and is far below the average of European countries (Tarmakbir, 2023).

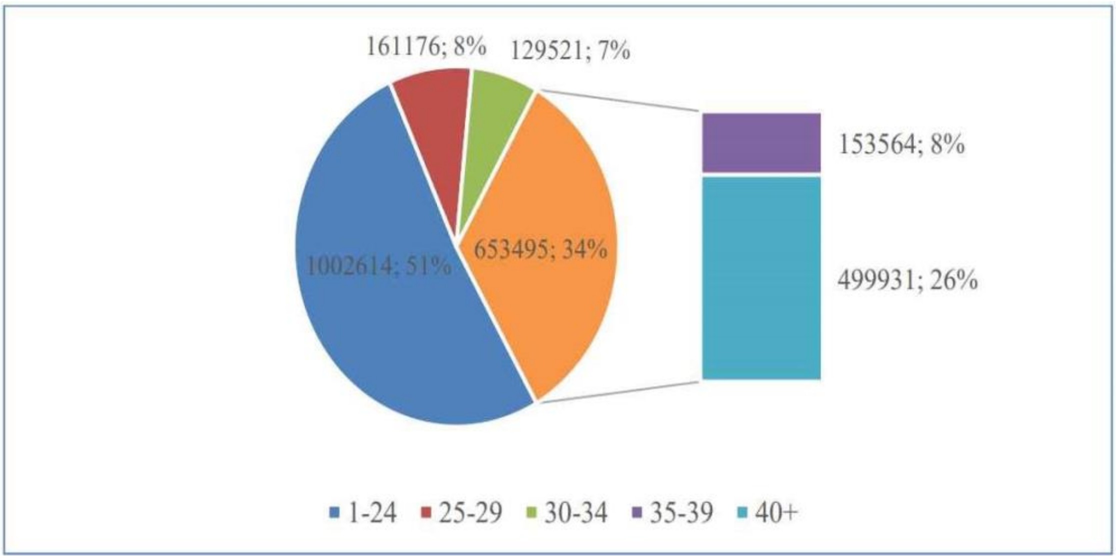

Figure 2. Distribution of tractor ages in Türkiye (TÜİK, 2020).

However, the difficulties of the agricultural enterprise structure appear to be the biggest barrier to this development. Therefore, both economic incentives for renewal and modernisation of the tractor park and policy changes may be needed to make the agricultural sector more efficient and competitive. In 2019, the majority of the tractor park in Türkiye consists of four-wheel tractors, which represent 94 per cent of the park. Single-axle tractors make up a very small part of the park (6 per cent). In the last five years, there has been a strong increase in the proportion of double-wheel drive tractors in tractor sales. This positive development indicates that the preference and use of double-wheel drive tractors are increasing. Double-wheel drive tractors can provide more ability to steering in agricultural work and may be more suitable for some applications. Continuation of this trend can increase agricultural productivity and contribute to the modernisation of the agricultural sector .(Evcim, et.al. 2010).

3.3. *Distribution of tractor parks by statistical regional units of Türkiye*

TurkStat's analysis of the number of tractors between 2016 and 2021 in Türkiye shows that the tractor park has increased in various regions of the country. However, in Table 2, this increase is more noticeable in regions where tractor density is already high, such as the Aegean, Western and Eastern Marmara, Western Black Sea and Mediterranean. These regions stand out as regions where agricultural machinery and tractor usage are more widespread. On the other hand, it is observed in Table 2 that the differences between Northeastern, Central Eastern and Southeastern Anatolia and other regions are increasing gradually. The rate of increase in the tractor park in these regions may be lower than in the western regions where tractor use is more intensive. This shows that agricultural mechanisation and tractor use differ regionally and some regions seem to be progressing faster in the increase of tractor park.

Table 2. Distribution of tractor park according to statistical regional units of Türkiye (TÜİK, 2020)

Statistical Regions	Number of Tractors (unit)									
	2015	**%**	**2016**	**%**	**2017**	**%**	**2018**	**%**	**2019**	**%**
TR1 İstanbul	4508	0.36	4483	0.35	4504	0.34	5132	0.39	5175	0.38
TR2 Batı Marmara	123189	9.77	125132	9.83	125759	9.62	126318	9.48	126562	9.34
TR3 Ege	259010	20.55	261512	20.53	274268	20.99	279812	21.00	286735	21.16
TR4 Doğu Marmara	131404	10.43	133147	10.45	134194	10.27	135392	10.16	136545	10.08
TR5 Batı Anadolu	113412	9.00	113590	8.92	116191	8.89	117312	8.81	118194	8.72
TR6 Akdeniz	159574	12.66	161771	12.70	165765	12.69	168420	12.64	171689	12.67
TR7 Orta Anadolu	129153	10.25	131757	10.35	134304	10.28	137218	10.30	138802	10.24
TR8 Batı Karadeniz	181652	14.41	181587	14.26	183673	14.06	186247	13.98	188823	13.94
TR9 Doğu Karadeniz	13506	1.07	14018	1.10	14899	1.14	15164	1.14	15402	1.14
TRA Kuzeydoğu Anadolu	42122	3.34	42759	3.36	46884	3.59	49025	3.68	51504	3.80
TRB Ortadoğu Anadolu	36634	2.91	37079	2.91	37960	2.91	42758	3.21	44002	3.25
TRC Güneydoğu Anadolu	66194	5.25	66696	5.24	68335	5.23	69341	5.21	71479	5.28
TÜRKİYE	**1260358**	**100**	**1273531**	**100**	**1306736**	**100**	**1332129**	**100**	**1354912**	**100**

Expanding the use of tractors and supporting agricultural mechanisation can contribute to making agriculture more sustainable and competitive (Korucu et. al.2015). When we analyse the tractor parks in Türkiye by region, the Aegean Region stands out as the region with the largest park with approximately 290,000 tractors. This region is followed by the Western Black Sea and Mediterranean regions with tractor parks ranging from 170,000 to 188,000. Eastern and Western Marmara and Western Anatolia regions have tractor assets ranging between 110,000 and 140,000. Among the other regions, Southeastern and Central Eastern Anatolia regions with less than 100,000 tractors are noteworthy. Although these regions have high agricultural potential, they have lower numbers of tractor parks.

When we look at the size and power groups of tractor parks in Table 2, it is seen that in regions with large parks, low power group tractors are in majority because of agricultural product patterns and enterprise structures of these regions. In high tractor intensed regions, product patterns such as fruit and vegetable farming, which generate higher income compared to field agriculture, are generally intensive. Also, smaller scale enterprises are common in these regions. Therefore, the majority of tractors are low-horse power, as they are sufficient for such enterprises. On the other hand, Istanbul, Western Marmara, Western and Northeastern Anatolia regions have more higher horse power tractors compared to other regions. The high number of high-powered tractors in Istanbul originates from a commercial practice rather than the characteristics of agriculture. High-powered tractors are mostly purchased through financial leasing and since financial leasing companies have their headquarters in Istanbul, their registration records are kept in this province. The high concentration of high-power tractors in the West Marmara, Western and Northeastern Anatolia regions can be explained by the fact that field agriculture is carried out more and there are relatively large-scale enterprises in these regions,. Enterprises may prefer high-powered tractors since they have larger lands. Such data shows that tractor utilisation and power levels may differ depending on the regional agricultural structure and enterprise types. Therefore, it is important that tractor parks are should be diversified and well adapted to the needs.

3.4. *Mechanisation level in Türkiye*

As seen in Table 3, Turkish agriculture has made significant progress between 2015-2018 in terms of mechanisation level. During this period, it was found that there were large differences in the level of mechanisation between the statistical regions of Türkiye.
<u>Tractor power per unit cultivated area (kW/ha):</u> Among the statistical regions, tractor power values per unit cultivated area vary between 0.38 and 4.56 kW/ha. This shows that agricultural lands differ according to tractor power.

<u>Number of tractors per 1000 ha cultivated area (Tractor/1000 ha):</u> This value varies between 20.24 and 129.61 tractors/1000 ha between regions. This shows that the number of tractors per thousand hectares of cultivated area is different according to the regions.

<u>Cultivated area per tractor (ha/tractor):</u> The area cultivated per tractor varies between 7.72 and 49.42 ha/tractor among the statistical regions. This shows that the size of the land cultivated by tractors is different according to the regions.

Table 3. Mechanization level data for Türkiye and geographical regions (TÜİK, 2019)

Geographical Regions	Kw/ha				Tractor/1000ha				Ha/Tractor				Equipment/Tractor		
	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017	2018	2015	2016	2017
Northeastern Anatolia	1.38	1.44	1.52	164	33.16	34.45	36.27	38.74	30.16	29.03	27.57	25.81	8.34	8.32	7.89
Middleeast Anatolia	1.02	1.04	1.10	1.29	28.36	28.94	30.57	34.90	35.27	34.55	32.71	28.65	10.31	7.85	8.06
Southerneast Anatolia	0.88	0.91	0.96	0.99	22.74	23.59	24.64	25.54	43.98	42.39	40.59	39.15	7.07	7.11	7.08
Istanbul	2.54	2.48	2.53	2.86	63.08	61.52	62.54	71.04	15.85	16.26	15.99	14.08	8.77	8.81	9.02
West Marmara	3.21	3.17	3.23	3.26	82.68	81.78	83.16	84.06	12.09	12.23	12.03	11.90	7.97	7.95	7.96
Egean	4.08	4.19	4.45	4.56	117.56	120.46	126.84	129.61	8.51	8.30	7.88	7.72	7.42	7.42	7.23
East Marmara	3.24	3.37	3.40	3.54	95.29	98.51	98.95	102.68	10.49	10.15	10.11	9.74	6.72	6.73	6.78
West Anatolia	1.29	1.29	1.37	1.38	32.72	32.61	34.38	34.63	30.57	30.66	29.08	28.88	7.69	7.72	7.80
Mediterrenian	2.64	2.68	2.80	2.89	75.84	77.02	79.90	82.32	13.19	12.98	12.52	12.15	7.98	8.16	8.20
Central Anatolia	1.33	1.38	1.45	1.50	34.64	35.76	37.49	38.43	28.87	27.97	26.67	26.02	7.08	7.03	7.02

Cultivated area per tractor (ha/tractor): The area cultivated per tractor varies between 7.72 and 49.42 ha/tractor among the statistical regions. This shows that the size of the land cultivated by tractors is different according to the regions.

Number of equipment per tractor (Equipment/Tractor): The number of equipment per tractor varies between 4.65 and 14.08 equipment/tractor across regions. This indicates that tractors have different equipment for the tasks they are used for.

Number of combine harvesters per 1000 ha cultivated area (Combine Harvester/1000 ha): This value varies between 0.02 and 2.62 harvester/1000 ha among the statistical regions.This shows that the number of harvesters per thousand hectares of cultivated area is different according to the regions.

These statistics show that agricultural mechanisation varies in different regions of Türkiye and these differences have significant effects on agricultural productivity. Therefore, it is necessary to formulate and develop mechanisation strategies according to the agricultural necessities and characteristics of each region (Altuntaş, 2016).

Developments in tractor intensity, when compared with some selected countries, show that Türkiye is ahead of countries such as Egypt, Pakistan and Mexico, but behind European countries (FAOSTAT, 2006). Moreover, when it is taken into consideration that the average power of the tractor parks of European countries is two times higher than that of Türkiye. This result is due to the fact that European countries have a high level of mechanisation in crop production as well as developed animal production and intensive use of tractors in this field. Therefore, when comparing tractor intensity, not only crop production but also animal production and tractor use in this field should be taken into consideration. The fact that the tractor intensity of the USA does not correspond to other data is the result of the high average tractor power in the country, and the enterprise structure and production technologies used also affect this situation.

3.5. *Problems of agricultural machinery in parks in Türkiye*

According to 2020 traffic records, there are a total of 1.958.727 tractors in Türkiye. The average age of these tractors is 25,3 years. There are approximately 945,000 tractors aged 25 years and older in the park and the average age of these tractors is 40.3 years. There are approximately 650,000 tractors over 35 years old. In addition, the average age of about 500,000 tractors over 40 years old is 47.8 years. Based on these data, we can say that half of the tractors in the park have completed their economic useful life. However, tractors should be evaluated not only according to their age, but also in terms of the technology and equipment they contain. Especially in tractors over a certain age, basic components such as PTO and hydraulic systems may be missing and there may be no four-wheel drive unit. Working with tractors that have completed their mechanical and economic life can lead to economic losses (Table 4). One of these losses is excessive fuel and oil consumption. In addition, it has a significant impact on product efficiency and quality in agricultural activities and may cause loss of working time (Toğa, 1994).

Such tractors also carry a high risk of accidents and a high risk to life safety. Moreover, end-of-life tractors can lead to high levels of environmental pollution (such as CO2 emissions). Therefore, the continued use of ageing and technologically outdated tractors can have various negative consequences.

Although many farmers are aware of the economic losses caused by working with end-of-life tractors, they may not have the means to renew or modernise these tractors due to economic difficulties. Furthermore, some farmers use their tractors as a debt instrument to meet their financial needs. This means renewing tractors that have not completed their economic life through trade-in and buying them with long-term debts. However, this practice can push second-hand tractor prices well above their real value. When tractors are reached the end of their economic life they will consume average 700 litres fuel per year excessively and cause 100-150 hours of lost work. In addition, when calculated based on the exhaust emission measurements of tractors over 25 years old, it is estimated that these old tractors generate an average of 1,816 kg of additional CO2 emissions per year (Evcim et.al.2007).

Table 4. Cost of a tractor that has completed its economic life (TÜİK, 2019)

Losts	Annual Cost (TL/Tractor)
Fuel	**4550**
Maintenance and Repair	**2000**
Work Loss	**9000**
Carbon Emission	**344,43**
Total	**15894,43**

The cost of losses caused by a tractor that has reached the end of its economic life is calculated as 16 thousand Turkish liras per tractor according to current data. According to 2019 data, there are 1.354.912 tractors in the tractor park in Türkiye and 664.000 of them are older than 25 years old. When calculate the annual economic losses caused by tractors reaches approximately 11 billion Turkish Liras. This shows an extra cost that old tractors impose on operating costs and the national economy annually (Gürsoy, 2012). When analysing combine harvester ages situation in park it is observed that most of the crop losses are in barley and wheat products, followed by maize, rye and oats, respectively. When the total production amounts are considered, it is determined that production losses constitute 5% of the total production amount and correspond to 1.687.150 tonnes of product loss. Especially when considered on a country-wide scale, the monetary equivalent of this crop loss is approximately 382,42 million Turkish Liras. In case of renewal of the combine harvester park, it is planned to gradually reduce this loss and contribute to the national economy.

4. Conclusion

In order to solve the problems of Türkiye's tractor and combine harvester park, the rejuvenation of this park should be urgently addressed. A Scrap Rebate program can be considered to support the country's resources rationally and efficiently. This program can be a framework for addressing and resolving long-term problems. For the Scrap Discount application, a commission must be formed to include all relevant stakeholders. This commission should include all relevant parties such as the Ministry of Industry and Technology, the Ministry of Agriculture and Forestry, the Ministry of Treasury and

Finance, the General Directorate of Police, HURDASAN, universities and relevant non-governmental organizations. This commission can generate the general principles regarding the Scrap Discount application. In addition, incentive regulations should be introduced so that those who will purchase a new tractor can benefit from low-interest or interest-free loan opportunities. The attractive scrap discount amount may be an incentive for farmers who want to renew the existing park. (Toga, 1994)

When planning a tractor or combine harvester replacement, the characteristics and requirements of the enterprise should be taken into account. These decisions should be based on the type of crops grown, the number of machines and operations used in agricultural production processes, technical and economic data, land size, future growth prospects and other factors. Additionally, all of these factors should be taken into account when choosing the optimal power range.

During the planning phase, realistic mechanization models should be created according to factors such as the size and geographical location of the enterprise. These models should be considered at different levels, starting from the business level to business groups, basins, regions and the country. It would be a correct approach to take into account especially smaller basins with similar characteristics. Existing machines should be tested and maintained at regular intervals to maintain their usability. This is important to support the long-term use of tractors and combine harvesters and minimize economic losses.

Encouraging domestic production can strengthen the domestic agricultural machinery industry and offer domestic producers the opportunity to increase capacity and create new job opportunities. This could also contribute to the revival of the economy. Local production also has the potential to better adapt to the needs of local agricultural machinery.

It is important to create data infrastructure for tractors and agricultural machinery. A system should be created where producers can record their machinery and tractor inventories and keep this information up-to-date. This allows machines to be rented, shared and managed more effectively. Additionally, digital platforms and applications that can be used for rentals and rapid communication should also be developed.

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Author Contribution

The authors' contributions to the study should be clearly stated as follows:.
S.A. (initials of the author's name. initials of the author's surname): writing the article, creating the experimental setup, and performing the experiments.
S.A.: Literature research and statistical calculations of the data.
B.P. : interpretation of the findings, literature research, and obtaining the necessary materials for the experiment.

The authors declare that they have contributed to the study on the subjects mentioned above.

Conflict of Interest Declaration Information (required field)

There is no conflict of interest.

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Comprehensive strategies for the integrated management of fall armyworm: a focus on biocontrol, cultural, and chemical methods

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ABSTRACT

Spodoptera frugiperda, are polyphagous agricultural pests that began in America and were ultimately discovered in West Africa in 2016.The larval stage of the pest's life cycle causes the most damage. It impacts 353 different crop types and leads to a 70% loss in crop yield, hurting the economy. Studies have shown that these pests do well in temperatures above 10°C, but moth wings become deformed when the temperature goes above 30°C.The cultural method is the most effective pest control approach, making up 56% of pest management efforts. The push and pull technique, meanwhile, controls 82.6% of larvae per plant. Research has found that Azadirachta indica (neem) seed powder can reduce larval mortality by 70%, while L. javanica and N. tobacum decrease larval toxicity by 66%. Spinosad causes over 90% of larval deaths, while a mixture of sawdust and chlorpyrifos controls 20% of the pests. This detailed review covers all types of biological control methods, including parasitoids, nematodes, predators, viruses, entomopathogenic fungi, biopesticide bacteria, as well as cultural, chemical, physical, and botanical controls. It focuses on how effective these methods are against the Fall Armyworm (FAW).

Güz tırtılının entegre yönetimi için kapsamlı stratejiler: biyokontrol, kültürel ve kimyasal yöntemlere odaklanma

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ÖZET

Spodoptera frugiperda, Amerika'da başlayan ve son olarak 2016'da Batı Afrika'da keşfedilen polifag tarım zararlısıdır ve zararlının yaşam döngüsünün larva aşaması en fazla zarara neden olur. 353 farklı ürün türünü etkilemekte ve ürün veriminde %70'lik bir kayba yol açarak ekonomiye zarar vermektedir. Çalışmalar, bu zararlıların 10°C'nin üzerindeki sıcaklıklarda iyi performans gösterdiğini, ancak sıcaklık 30°C'nin üzerine çıktığında güve kanatlarının deforme olduğunu göstermiştir.Kültürel yöntem, haşere yönetimi çabalarının %56'sını oluşturan en etkili haşere kontrol yaklaşımıdır. İtme ve çekme tekniği ise bitki başına larvaların %82,6'sını kontrol etmektedir. Araştırmalar, Azadirachta indica (neem) tohum tozunun larva ölümlerini %70 oranında azaltabildiğini, *L. javanica* ve *N. tobacum'un* ise larva toksisitesini %66 oranında azalttığını ortaya koymuştur. Spinosad larva ölümlerinin %90'ından fazlasına neden olurken, talaş ve klorpirifos karışımı zararlıların %20'sini kontrol etmektedir. Bu ayrıntılı inceleme, parazitoidler, nematodlar, predatörler, virüsler, entomopatojenik mantarlar, biyopestisit bakteriler ve kültürel, kimyasal, fiziksel ve botanik kontroller de dahil olmak üzere her türlü biyolojik kontrol yöntemini kapsamaktadır. Bu yöntemlerin Güz Ordusu Kurduna (FAW) karşı ne kadar etkili olduğuna odaklanmaktadır.

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1.Introduction

Fall armyworms (*Spodoptera frugiperda* (J.E. Smith) is one of the most damaging insect pests in the family Noctuidae. This pest has polyphagous which can damage a variety of vegetable crops as well as commercially valuable cereal crops like cotton, corn, sorghum, rice and eventually have an impact on food security (Barbosa et al., 2018). The FAW consumes plant species' stems, leaves and reproductive organs. It is common to the Americas' subtropical and tropical climates. One of the most prevalent pests of maize in North and South America is FAW, which first emerged in America. As of the end of 2017, it had spread to over 30 countries in tropical and southern Africa, including Cabo Verde, Madagascar, and the Seychelles, making it one of the most invasive pests on the continent. It was first documented in Africa in 2016 (Sisay et al., 2018). Almost 353 plants have been recognized as this pest's hosts. The first symptoms appear when the larval stage creates various-sized papery windows in the leaves, which causes significant plant defoliation and an accumulation of feces. Later on, the growth and growth of the plants is impacted (Reddy, 2019). The FAW is a harmful pest; if prevention strategies are not implemented, CABI (2017) estimates that the bug may cost African nations 6.1 billion US dollars in revenue loss. FAW travels about 500 miles before starting to place egg (Prasanna et al., 2018). Until they reach adulthood, a single generation of FAW moths can disperse over 500 kilometers from the site of emergence because of wind (Kumar et al., 2022). The assessment of crop varieties that can resist Fall Armyworm (FAW) should start. Over time, national policies should support safer pest control solutions by providing temporary subsidies, quickly evaluating and registering biotechnology, biological control products, and insecticides. For farmers without the financial means to buy costly crops and chemical insecticides, biological control methods are more appropriate (Ratto et al., 2022). There are microbial formulations on the market that are effective in agricultural systems and originate from illnesses and arthropod natural enemies. Since microbial formulations are mostly bulk produced in liquid media, their production costs have fallen significantly (Mahmoud et al., 2017). Control failures arise from the FAW caterpillar's larvae being firmly buried in the corn ears and leaf curls. But it only comes during the night or at dawn and twilight to eat on plants. The article covers vital information of the fall armyworm's introduction, identification, and possible control measures.

2. Taxonomy of Fall armyworm

There are two fall armyworm strains, such as the ones found in rice and corn strains (Nagoshi et al., 2018). As the corn strain consumes corn, cotton, and sorghum, the rice strain feeds on rice and other grazing grasses. Although sharing a similar morphology, these strains can be separated molecularly. In comparison to the fall armyworm present in America, which possess both strains, the invasion in Africa has greater diversity (Jacobs et al., 2018). The armyworm belongs to domain is Eukaryote, phylum Arthropoda, class Insecta, order Lepidoptera, family Noctuidae, genus *Spodoptera.*

3. The economic value of FAW

The most harmful and destructive stage of the fall armyworm life cycle for crops is the larval stage. FAW larvae infected maize plants can be observed on various plant components like leaf whorls, young leaves, cobs, and tassels depending on the plant's growth stage (Goergen et al., 2016). In estimating the loss resulting from FAW, several factors must be considered. In general, the quantity of pests, the timing of infestation, the pest's natural competitors and pathogens at that particular moment, and the crop's nutritional and moisture status together play a role in crop infestation (Sagar et al., 2020). There is an 11.57% reduction in yield in maize when the insect incidence varies from 26.4% to 55.9%. The yield decreases 58% by 25–50% damage to the leaf, silk, and tassel, whereas up to 73% of the crop's yield is lost by 55–100% severity during the mid–late whorl stage (Chimweta et al., 2019). During the reporting period, there was an output loss of 30.54 million tons in Ethiopia, 13.91 million tons in Uganda, and 3.2 million tons in Tanzania. Fall armyworm impacted 250,000 hectares of agricultural land in Kenya, which makes up 11% of the nation's total area under corn cultivation. In a similar vein, FAW estimated that maize loss in output in Zambia and Ghana was 40% and 45%, respectively. If control measures hadn't been implemented, losses from FAW in twelve African countries including Ghana and Zambia were estimated to be between 8.5 and 21 million tons, or approximately 250–630 million US dollars (Bateman et al., 2018). According to research, FAW has impacted 170,000 hectares of maize harvests across 10 states in India. This pest mostly affects Yunnan province in China, where it has been recorded to damage 80,000 hectares of land and crops comprising maize, ginger and sorghum. In China, 11,1992.17 ha of the total area have been harmed, maize covers 98.6% of the total area (FAO, 2019). FAW infestations are reported in Bangladesh, Indonesia, Myanmar, and Vietnam, affecting land areas ranging from 0.5% to 32%. Thailand is experiencing a 25-40% yield loss, resulting in a loss of 130-260 million dollars. The fatal pest can have an enormous effect on Nepalese farmers and the country's economy because of its constant appetite for crops like maize and others. Since the climate in Nepal is favorable to the formation of populations of this insect, crop loss in maize of up to 100% will be expected if this pest is not managed (Beshir et al., 2019).

4. Favorable environment for their developments

Climate impacts fall armyworms, and variations in weather conditions can have an effect on the armyworm's distribution over different geographical areas. According to reports, the state of the environment has an important effect on several traits, like death, growth, survival and abundance (Ramirez et al., 2017). The larger invasion of FAW is controlled by the pest overwintering mechanism. It grows best in cool, humid temperatures and during severe outbreaks following periods of heavy rain (Sharma et al., 2022). A warm, muggy growing season with lots of rain is ideal for the pest's growth and survival. At temperatures below ten degrees Celsius, the bugs stop growing. More than ten generations of fall armyworms occur annually in tropical and subtropical regions, compared to just two in temperate regions, suggesting that these regions are better suited for the species' efficient reproduction.

5. Distribution pattern

In an adult stage, it can fly longer and cover an area of about 300 miles. The movement of air in weather fronts could be the cause of this high migration rate. The most prevalent insect pest in tropical America is the fall armyworm, which is common in both tropical and subtropical areas of the nation. By the end of 2016, it initially emerged in West Africa and quickly spread to Sub-Saharan Africa (SSA), where it was subsequently confirmed in 44 African nations (Sisay et al., 2019). According to the research, both FAW strains invaded Africa from the Americas through cargo containers, commercial flights, or airplane holds. From there, they dispersed via wind (Day et al., 2018). Fall armyworm, first reported in Karnataka, India in 2018, has spread to various Asian regions including West Bengal, Odisha, Maharashtra, Gujrat, Bihar, and Chhattisgarh (CABI, 2020). The insect problem has been experienced by various Asian nations, including Japan, China, Cambodia, Bangladesh, Myanmar, Indonesia, Thailand, Korea, Sri Lanka, Vietnam, and China (FAO, 2019). Fall armyworm outbreaks in Nepal have been reported in 15 districts, posing a significant risk of rapid spread, despite not being reported globally.

6. Fall armyworm damage symptoms in maize

As soon as the eggs hatch, maize gets infected with Fall armyworm. The most common signs of FAW are papery windows on leaves that can range in size, have jagged edges, and seem oblong to spherical. These leaves can also become loose and separated from the plants. Due to the larval instars' ravenous feeding habits, major defoliation and an abundance of feces remaining on the plant are visible during the severe stage. Crop growth and development eventually stop, which prevents the development of cobs and tassels (Reddy, 2019). Larger, elongated holes appear from the third to the sixth instar of the infestation, while translucent patches are seen in the window glass during the first and second stars. In the end, the Fall armyworm feces appear on the leaves or in the maize funnels as sawdust-like particles (CABI, 2018). The crop's leaf damage can be evaluated using the methods (Table 1).

Table 1. Scale for evaluating crop leaf damage caused by fall armyworm (*S. frugiperda*)

Scale	Damage
0	No obvious damage to the leaves
1	Leaves with only tiny holes damaged
2	Leaf damage from pinholes and bullet wounds
3	1-3 leaves with tiny, elongated lesions (5–10 mm)
4	Lesion of a moderate size (10–30 mm) on 4–7 leaves
5	Large, elongated lesions (more than 30 mm) or little bits ingested on three to five leaves
6	Large parts consumed on 3-5 leaves and elongated lesions (>30 mm) are observed.
7	50% of the leaf eaten and elongated lesions (>30 cm).
8	Long (30 cm) lesions and significant eating pieces on 70% of the leaves.

7. Life Cycle Stages of Fall Armyworm

There are four distinct stages in *S. frugiperda*'s life cycle (Figure 1). The Fall armyworm can be identified by its physical characteristics, unique indications of damage on vulnerable crops, or molecular characteristics (FAO, 2019).

Egg Stage: The fall armyworm's egg is 0.4 mm in size and 0.3 mm in length, and it has a dome-like, flattened base. The creamy white eggs of the fall armyworm have reticulated ribs that are encased in abdominal hairs. The female lays a large batch of eggs, 100–200 at a time (Prasanna et al., 2018).

Larvae Stage: The fresh-hatched caterpillars are green during their first and second stars, then turn brown or black between their third and sixth instars (CABI, 2018). The mature larva has four dark elevated spots that create squares on its rough or granular epidermis, and it has a white inverted "Y"-shaped mark on the front. The head capsules of the 1-6 instar measure 0.35, 0.45, 0.75, 1.3, 2.0, and 2.6 mm in width, while the body lengths range around 1.7, 3.5, 6.4, 10.0, 17.2, and 34.2 mm, in that sequence.

Pupae Stage: Pupae are oval reddish brown and form a 20–30 mm long cocoon. They are typically found in soil that is 2–8 cm deep (CABI, 2018). Pupae are typically found in soil in cocoons that are 20–30 mm broad and 15 mm long (Silva et al., 2017).

Adult Stage: Adult Fall armyworm members display nocturnal behavior (CABI, 2017). The mature moths' range in size from 32 to 40 mm according to the color. The forewings of the male moths are dark and shaded, with triangular white patches near the center of the wing and at its tip (Assef & Ayalew, 2019). Because they are migratory, the moths can fly over long distances.

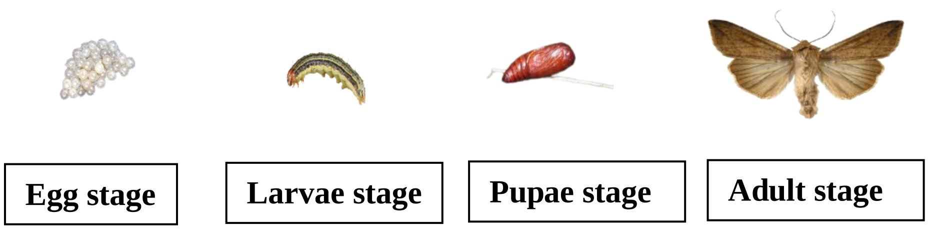

Figure 1. Life cycle stages of Fall armyworm

8. Integrated Management of Fall Armyworms

Fall armyworms pose economic threats to pets, and control techniques should be applied in maize only if 20% of whorls are infested or 5% of seedlings are clipped (Fernandez, 2002). The fall armyworm larval stage is the ideal period to properly control the pest; choosing an appropriate time of day to complete the management task is crucial (Assefa & Ayalew, 2019).

Consultancy services: A variety of methods of communication are needed in the private as well as public sectors, depending on the information that needs to be shared and the control strategies that are being maintained (Day et al., 2017; Azeem et al., 2020). The control of the fall armyworm starts with this, which is also the most important stage. Asian nations like Sri Lanka, Indonesia, Bangladesh, Myanmar, Japan and China are implementing this strategy to inform the public on the control of the destructive pest (FAO, 2019).

Mechanical and physical approach: Mechanical and Physical management is the most effective and rapid way to manage biological pests (Ali et al., 2021a). One method of controlling fall armyworms is the hand collecting and destruction of egg masses, as well as the mass crushing or soaking of neonate larvae in kerosene water (Firake, 2019). Another stated method of control is to apply dry sand into the whorl of afflicted maize plants as soon as FAW incidence appears in the field. Because the fall armyworm eggs and caterpillars are rare, hand-picking and smashing them can be a useful precaution for tiny gardens or a few impacted plants. 54% of insect control has been discovered to be accomplished by using mechanical management control (Assefa, 2018). To reduce the incidence of the fall armyworm, pheromone traps installed at a rate of five per acre at probable spreading areas are used throughout the crop season and off-season (Firake, 2019). For scaling, the pheromone traps that draw the male armyworm moths are suggested because of their ease of use (FAO, 2017). To catch fall armyworm moths, a traditional bucket trap featuring a yellow funnel, white bucket and green canopy has proven to be the most effective (Hardke et al., 2015).

Chemical approach: Chemical control is the best and fastest method to control biological pests and pathogens (Naqvi et al., 2024). The treatment of the fall armyworm greatly depends on the timing of the chemical application. The individual should be aware of the life cycle and the best times to administer pesticides, such as during the day when spraying is ineffective and when the larvae are deeply rooted in the maize whorls and ears because larvae only emerge at dusk, night or dawn to feed on plants (Day et al., 2017). It has been suggested to use a variety of pesticides to control fall armyworms. Various pesticides, including methyl parathion, methomyl, pyrethroids, organophosphate insecticide, and cyfluthrin can be employed to control fall armyworms (Badhai et al., 2019). It was discovered that the application of cyantraniliprole and chlorantraniliprole as a seed treatment was efficacious in mitigating the fall armyworm infestations in soy (Sharma et al., 2022). 20% control of the fall armyworm was observed when sawdust and chlorpyrifos were combined and applied as a therapy. In order to suppress the fall armyworm, chemicals such as beta cypermethrin, carbosulfan, emamectin benzoate, cartap hydrochloride, and chlorpyrifos have been applied extensively throughout Africa. Among these, using beta cypermethrin, cartap hydrochloride, and emamectin benzoate on vegetables is also recommended (IRAC South Africa, 2018). Since threshold levels are not being utilized to assess whether pesticides are necessary, there is the worry that using chemical controls improperly could result in the emergence of resistance in plants, harm to those plants, and hazards to the environment and public health. Foliar sprays against FAW in soya were not as necessary when seed treatments with chlorantraniliprole and cyantraniliprole were used (Sharma et al., 2022). FAW was not affected by soil treatment in Nicaraguan tests. Smallholder farmers in Ethiopia and Kenya use dry sand and trichlorfon mixtures, which are applied to the whorls using a plastic bottle and are thought to be effective (Kumela et al., 2017). In contrast, mixtures of sawdust and chlorpyrifos decreased the amount of pesticide required by 20% without sacrificing control. Spinosad and the novel insecticides spinetoram chlorantraniliprole and flubendiamide have been shown to outperform the conventional insecticides lambda-cyhalothrin and novaluron, resulting in over 90% decreases in larval morality (Hardke et al., 2015).

Cultural approach: Fall armyworm is frequently controlled by applying chemical or synthetic pesticides (Assefa et al., 2019). Using various cultural techniques, however, can lessen the amount of crop loss resulting from FAW. It is an effective pest management plan for FAW must include cultural control. Preventing ear damage caused by FAW and other insects involves growing maize hybrids with tight husk covers, balanced fertilizer use, and clean cultivation (Kumela et al., 2017). Applied as granules or powder into the whorls, the dry mixture of sand and trichlorfon has shown to be a popular and effective method among small-scale farmers in Ethiopia and Kenya. Crop leftovers that are left in the field can be destroyed by burning them, rotating the crop, selecting an appropriate variety, keeping high soil tilth, and regularly checking the field (Sharma et al., 2022). Systems that grow mainly maize provide a favorable setting for FAW to expand quickly. Chemical and cultural control techniques can be used to manage armyworms. Avoiding late planting is part of the cultural control since the ears of maize would be more severely damaged by a larger FAW infestation than those of the early plantings. In order to reduce the invasion of FAW, it may also be helpful to intercrop and rotate maize with non-host crops such as beans and sunflowers (FAO, 2018). The majority of subsistence farmers in Africa also don't use pesticides on their maize crops, but they do employ cultural control techniques that either kill or discourage pests, like hand-picking caterpillars and applying wood ashes and soils to leaf whorls (Ratto et al., 2022). According to a survey done in Ethiopia and Kenya, 14% and 39% of the farmers, respectively, used traditional techniques (such as handpicking) to manage FAW (Kumela et al., 2017). Up to 54% of farmers using a mechanical approach are able to control the pest.

9. Biological Approaches to control the FAW

Microorganism: Entomopathogens are pathogen-causing organisms that infect and cause diseases in insects. They include fungi (*Metarhizium anisopliae* and *Beauveria bassiana*), bacteria (*Bacillus thuringiensis*), protozoans, nematodes, viruses and other well-known recognized as being against FAW management.

Entomopathogenic fungus: Fungal antagonists play a significant role in controlling plant pathogens and destructive pests (Ali et al., 2021b; Tabbasum et al., 2022). Entomopathogenic fungi (EPF) can cause epizootics in particular natural habitats by infecting a range of insect species at different stages throughout a large range (da Silva et al., 2020). Fungal spores infect EPF species by first multiplying inside the insect's body through the integument. Certain poisons released by EPF cause tissue destruction, and the insect eventually perishes after multiplying. The climate and the frequency of insect contact dictate when the epizootics are introduced (da Silva et al., 2020). Insects with EPF infection turn green, cream, brown, or reddish in appearance, cease feeding, and eventually die as a hard, calcareous cadaver where the fungus starts to sporulate (Jaiswal et al., 2020). Moisture has a major impact on the biocontrol activity of mushrooms. *Metarhizium anisopliae*, *Nomuraea rileyi*, and *Beauveria bassiana* are utilized most frequently to control *Spodoptera* among the fungi that may be advantageous against insect pests (Jaiswal et al., 2020). When it comes to lepidopteran pests, FAW larvae are more susceptible to *B. bassiana*. Applying *M. anisopliae* to second instars and *B. bassiana* to eggs resulted in 87% and 30% mortality, respectively, according to in vitro investigations.

Entomopathogenic Bacteria: Bacillus genus members are commonly used as biopesticides to control plant diseases and insect pests (Ali et al., 2022; Ali et al., 2023b; Ali et al., 2024). *Bacillus thuringiensis* (Bt) Berliner is one of the most commonly used biopesticides for insect control (Kanedi et al., 2023). These bacteria as soil-dwelling, gram-positive bacteria that aid in the synthesis of crystal proteins called delta-endotoxins, which have an insecticidal impact. For controlling lepidopteran pests, only a small number of Bt treatments that are sold in the market are effective against FAW (Bortoli et al., 2019). In comparison to Bt *kurstaki*, which is efficient against a variety of lepidopteran pests, FAW is more susceptible to Bt *thuringiensis* and Bt *aizawai* (Silva et al., 2020). Its widespread adoption and application are occasionally limited by factors such as the endotoxin's UV sensitivity, the high cost of manufacture, and the inability to reach the pest to induce toxin intake (Silva et al., 2020). Several research teams are attempting to identify Bt strains that are more effective against FAW. Conversely, populations of FAW have been found to differ in their susceptibility to various Cyt toxins, which are also referred to as Cry toxins. Throughout the selection process in many places, biopesticides based on Bt must be taken into consideration in order to manage FAW. Lethal time mortality (LT50) with standard ranges of 2.33 ± 0.33 days and 6.50 ± 0.76 was caused by seven Bt strains that were highly effective against nineteen second-instar FAW larvae at ICIPE in Africa. These strains also caused 100% death within seven days of treatment. Large-scale manufacturing of Bt-based biopesticides has been explored through fermentation technology, employing either solid- or semi-solid fermentation processes (Thiviya et al., 2021). Vegetative insecticidal proteins, the majority of which are present in Bt culture supernatants, are likewise sensitive to cry toxins, as demonstrated by FAW.

Entomopathogenic Nematodes (EPNs): As effective biological control agents, entomopathogenic nematodes such as *Steinernema feltiae, Steinernema carpocapsae, Heterorhabditis bacteriophora,* and *Heterorhabditis indica* are employed. EPNs are beneficial to the ecosystem and play a significant role in managing pest insects that live in the soil, such as armyworms (Dillman et al., 2019). FAW has a 23,000 sensitivity rate to beneficial nematodes, targeting immature and adult larvae. Applying them early or late at night is optimal due to UV light sensitivity (Prasanna et al., 2018; Shapiro et al., 2018). In a petri dish, 400 infectious juveniles of *H. indica* kill 75% of FAW, but 280 infectious juveniles of *Steinernema* sp. can kill 100% of third-instar FAW (Shamseldean et al., 2024). Hydraulic spraying jets, which need 100 filtrating mesh elements, can reduce the concentration of infectious juveniles of *H. indica* and *Steinernema* sp. up to 28% and 53%, respectively. At the prepupal stage, *S. riobravis* and S*. carpocapsae* effectively control FAW. Several scientists claim that EPNs with resistant maize silk may increase FAW death during the prepupal phase. Under lab settings, these three nematode species, *S. glaseri*, *H. indica*, and *S. carpocapsae* have demonstrated compatibility with several pesticides. *H. indica* is more efficient against FAW when combined with lufenuron. Moreover, before advising the use of an IPM for FAW, a compatibility assessment of biopesticides with EPNs is necessary (Roby et al., 2023).

Botanicals: Plants are quite a safe and eco-friendly way to control the plants' pests (Ali et al. 2020). For the management of FAW, a few biocontrol agents have been proven to be successful. Multiple natural enemies can be built up through habitat management, which also protects natural enemies in-situ and increases plant diversity through intercropping with pulses and beautiful flowering plants (Firake, 2019). *Bacillus thuringiensis* var *kurstaki* can be applied at a rate of 2 g per liter (or 400 g per acre) to effectively manage FAW. It is advised to apply *Metarhizium anisopliae* (1x108 cfu/g) talc formulation at a rate of 5g/liter whorl 15–25 days after sowing. Similarly, it has been reported that 1or 2 sprays at the interim of 10 days apart, depending on the level of pest damage, effectively prevent the spread of the pest infection. The use of biopesticides particularly based on the fungi (such as *Beauveria bassiana*), and bacteria such as *Bacillus thuringiensis* (Bt) have been efficiently used for the management of FAW (FAO, 2018). To decrease leaf defoliation in crops these biotic agents also contribute. Arthropod bio-control agents and several microbial pathogens have been effectively used for the management of FAW (Pilkington et al., 2019). Fall armyworm can be effectively controlled by 53 species of parasites representing 43 genera and 10 families found worldwide (Assefa, 2018). The *Beauveria* isolate caused 30% of the mortality of second instar larvae, whereas the *Metarhizium* isolate was responsible for 87% of the mortality of egg and 96.5 % of the mortality neonate larvae in the assessment of the effectiveness of entomopathogenic fungus against and second instar larvae and eggs. Numerous lepidopteran insects of the noctuidae family can be effectively controlled by a variety of natural enemies (Aktuse et al., 2019). Several insect pests may be biologically managed by these natural enemies. Fall armyworm infestation was reported to be well controlled in Ethiopia by the larval parasitoid *Cotesia icipe*; in Kenya, the pest was found to be managed by *Plaexorista zonata* (Sisay et al., 2018). Numerous species of parasites from the Telenomus and Trichogramma families, which are easy to raise in a laboratory are widely used to control fall armyworms (Tefera, 2019). Regarding the management of FAW, the biological control agents were reported are *C. insularis*, *C. marginiventris*, *Telenomus remus* (Platygastridae), *Archytas*, earwigs (Dermaptera), *Lespesia* (Tachinidae), Ladybird beetles (Coccinellidae*), Trichogramma* spp., (Braconidae), *Podisus* (Pentatomidae), *Nabis* (Nabidae), Geocoris (Lygaeidae), Assassin and flower bugs like *Zelus* (Reduviidae), *Anthocoris* (Anthocoridae), ants, birds, batsand minute pirate bug (orius insidiosus) (FAO, 2018).

Plants Extracts: It is advised to utilize botanical pesticides instead of dangerous synthetic insecticides like pyrethroids and organophosphorus, which can cause environmental disruptions, increase user costs, pest resurgence, and pest resistance to insecticides (Ali et al., 2023a; Sowmiya et al., 2024). Farmers in developing nations have been using botanical pesticides for centuries to control insect pests of stored goods and field crops due to their affordability and availability (Schmutterer, 1985). These tools are safer and more environmentally friendly than other methods. *P. docendra*, *J. curcas*, *N. tabacum*, *M. ferruginea*, *A. indica*, *C. macrostachyus*, and *C. cinerariifollium* are just a few of the many botanicals that have been effectively employed to manage insect pests (Rizqullah et al., 2023). A*. indica* seed cake extract found significant larval mortality of FAW (Silva et al., 2020). Ethanolic extracts of *A. ochroleuca* (Papaveraceae) reduced feeding and retarded larval growth, which resulted in FAW larval death. Although many other plants have been commercially commercialized, only a small number of them exhibit insecticidal action against FAW in extracts (Junitor et al., 2021). In Latin America, azadirachtin (derived from neem) and pyrethrins (from pyrethrum) are the most commonly utilized products. Global product registrations have been made for a few items including rotenone, garlic, nicotine, rianodine, quassia, and other extracts (Kasoma et al., 2020). Neem-based sprays face challenges due to the high photosensitivity of azadirachtin and the lack of quality control. The short residual life of neem in field settings and lack of standardization impact insecticide effectiveness. Testing neem extracts may not be suitable for conventional pesticide efficacy due to low caterpillar mortality (Viana and Prates, 2003; Junitor et al., 2021).

Parasitoid and Predators: There are roughly 150 species of parasitoids known, originating from various parts of the Americas and the Caribbean (Table 2). The *S. frugiperda* larvae and eggs contain 53 distinct species of parasitoids, such as *Apanteles marginiventris, Chelonus insularis, Ophion spp,Campoletis grioti, Ternelucha spp., Rogus laphygmae, Meteorus autographae,* and *Ephisoma vitticole* (Adjaoke et al., 2023). Over 44% of naturally occurring parasites have been found in American non-sprayed fields (FAO, 2017). A level of 45.3% parasitism was shown by these species (Sisay et al., 2018). To manage *S. frugiperda*, three predator species and seven parasitoids' species were found in Ghana (Koffi et al., 2020). The three species of predators include *Pheidole megacephala F., Haematochares obscuripennis (Stal), Peprius nodulipes (Signoret)*. These seven parasitoid species are listed as *M. testacea, C. icipe, Bracon* sp.*, Anatrichus erinaceus (Loew), tachinid fly (Diptera: Tachinidae), C. luteum* and an uncertain *C. bifoveolatus* (Koffi et al., 2020). The degree of parasitism and species occurrence vary by region (Kenis et al., 2019). This finding is based on type changes crop stage, geographic regions, and agronomic methods (Hay-Roe et al., 2016). It has been observed that *Coccygidium luteum* from Tanzania and Kenya can cause up to 9 to 19% parasitism in *S. frugipera* (Sisay et al., 2018). In America, mass breeding and the introduction of parasitoids and predators have been employed to manage other pests to reduce the growing *S. frugiperda* pest population (Kumar et al., 2022). Sub-Saharan Africa's government uses classical biocontrol to manage *S. frugiperda* because it is a costly method (FAO, 2018). Native parasitoids with a greater level of parasitism have been found in many SSA communities (Agboyi et al., 2020). Releasing predators to combat the growing FAW pest population and utilizing augmentative biocontrol is the most effective approach to managing FAW (FAO, 2018). In America, *S. frugiperda* eggs have been effectively managed with the application of *trichogramma* parasitoids (Prasanna et al., 2018). *Telenomus* and *Trichogramma* are parasitoids that effectively enhance biocontrol against *S. frugiperda* (Agboyi et al., 2020). Parasites (*Trichogramma* and *Telenomus*) are inserted into maizefields before the FAW neonates emerge, to control the FAW population during the egg form. Upon finding FAW egg masses, these parasitoids lay their eggs on them (CIPE, 2018). Lepidopterous species found in Africa that have been parasitized by *C. luteum* include *Prophanti ssp. Spodoptera exempta* (Walker), *Condica capensis* (Guenée), *Crypsotidia mesosema* (Hampson), and *Spodoptera exigua* (Hübner) (Van et al., 2019). In Africa and many other countries *Coccygidium luteum* has been reported, such as Madagascar, Kenya, Guinea, Nigeria, Ethiopia, Namibia, Mauritius, Congo, Tanzania, Uganda, Somalia, South Africa, Cameroon, and Rodrigues Island (Agboyi et al., 2020). *Coccygidium luteum*, which has more than 46 species, is a solitary koinobiont parasitoid that is a member of the Braconid subfamily Agathidinae (Ganou et al., 2024). The efficiency of *Agathidinae* species in this subfamily as biocontrol agents against insect pests is poorly understood, and their effectiveness is rarely investigated (Abbas et al., 2022). In China, *C. luteum* regulates the eggs of numerous species of *Spodoptera* (Tang et al., 2019). Parasitoids may complete several generations in 90 days, which has caused early maturing maize types to proliferate in West Africa (Oluwaranti et al., 2018). Populations of natural enemies are affected by variations in parasitism (Abbas et al., 2022). Levels of parasitism were lower on average than previously reported levels in the United States i.e., 35%, 15.5%, 28.3%, 8.1%, 13.8% and 18.3%. From the several localities of Benin and Ghana 10 different species of parasitoids was reported (Agboyi et al., 2020). These species are *Charops spp, Drino quadrizonula* (Thomson), *Trichogramma spp. Meteoridea cf*, *Telenomus remus*, *Pristomerus pallidus* (Kriechbaumer), *Coccygidium luteum*, *Metopius discolour* (Tosquinet), *Cotesia icipe* and *Chelonus bifoveolatus* (Szpligeti) (Agboyi et al., 2020).

Table 2. Predators against FAW

Predator	Family	Description	Reference
Spined soldier bug	Pentatomidae	Nymphs and adults primarily prey on the larvae of lepidopterans. It punctures the spined soldier insect, *Podisus maculiventris Pentatomidae Heteroptera*, bites its victim and quickly impairs it with a toxin. The predator killed the prey by sucking its internal fluids.	Kneeland et al. (2020)
Pirate bug	Cimicoidea	A significant parasite. Aphids, tiny *Lepidoptera* larvae, and moth eggs are all food sources for *O. sauteri*.	Jaraleno et al. (2020)
Assassin bug	Reduviidae	In maize, the most prevalent killer insect genus is Zelus. Clusters of eggs are produced by females on plant leaves or even the ground. The nymphs resemble adults and lack feathers.	Grundy et al. (2019)
Ground beetle	Carabini	The females lay their eggs on the soil's surface or slightly below it after mating before the ground pupation. The immature stage has three instars.	Rukundo et al. (2020)
Flower bug	Anthocoridae	Most species utilized in biological control operations are extremely abundant ones. They feed on lepidopteran eggs, aphids, thrips.	Pathrose et al. (2023)

Use of plant-based Pesticides: Local farmers have stated that botanical extracts from plants grown nearby are advantageous (Prasanna et al., 2018). Botanical pesticides are a better substitute for synthetic insecticides, which may be more harmful to the environment, slow down recovery, and raise consumer costs (Shah et al., 2020). These chemicals are also to blame for the rise in insect resistance (Gul et al., 2019). A few botanical extracts include *Jatropha curcas*, *Nicotina tabacum*, *Milletia ferruginea*, *Chrysanthemum cinerariifollium*, *Croton macrostachyus*, *Phytolacea docendra*, which might be used as insect pest management (Rizqullah et al., 2023). About fifty botanical pesticides have been approved for the management of FAW in more than thirty countries; of these, twenty-three are recommended for field experiments and bioassays (Bateman et al., 2018). Under laboratory circumstances, botanical pesticides caused 80% of the deaths (Zaman et al., 2024). Neem extracts have demonstrated a 70% death rate in FAW (Silva et al., 2020). It was discovered that *Eucalyptus urograndis* was more beneficial in protecting maize from pests (Hruska, 2019). It was discovered that Carica's papaya seed powder worked well as a chemical pesticide (Sagar et al., 2020). When neem oil is applied at a concentration of 0.17–0.33%, maize is less affected by FAW (Babendreier et al., 2020). In contrast to chemical pesticides, botanical insecticides are ineffective for natural enemies, do not harm the environment, and are unique to a single target (Mora et al., 2018) (Table 3).

Table 3. Plant based pesticides to combat FAW

Extract uses	Action mode	Species	References
0.25 percent neem oil	Larvicidal with a laboratory death rate of up to 80%	Indian lilac	Zaman et al. (2024)
Wood-based dichloromethane extracts	Larvicidal and insect growth-regulating (IGR) with up to 95% mortality	Spanish-cedar	Paredes et al. (2021)
Extracts of roots and other aerial components in methanol	Controlling insect growth (IGR), larvicidal, and postponing pupation	Bilberry cactus	Paredes et al. (2021)
Ricinine and castor oil (seed extracts)	Suppression of growth and larvicidal	Castor Oil Bean	Kombieni et al. (2023)
Leaf ethanolic extracts	Synergistic with insecticide; antifeedant to larvae	Belly-ache Bush	Mendesil et al. (2023)

10. Conclusion and prospects

Spodoptera frugiperda, a harmful insect, necessitates the creation of FAW-tolerant/FAW-resistant germplasm in Africa and Asia. Conventional breeding faces challenges due to low resistant genotype frequency. Expanding the search for native genetic resistance and implementing genomic regions is crucial. There is a greater chance that this insect will spread globally, drastically reducing agricultural productivity and output. “Fall armyworm” control calls for an integrated management approach, wherein inspections in the field during the early stages of a pest assault and the discovery of the regulating mechanism are essential components. The high fertility rates and rapid spread of the pest made isolated management attempts ineffective in achieving the desired level of pest control. Frequent monitoring and scouting are required to identify pests and evaluate treatment choices. To address invasive pest species like FAW (*S. furgiperda*), it is advised to contact the Invasive Pest Study Center (IPSC) as well as Tuta absoluta Meyrick, the tomato leaf miner. The overall prevalence of the pest can be decreased by implementing an awareness program through advisory services that explains how to identify the pest, what damages it causes, and how to take effective control measures. By putting in place a campaign to raise awareness through advisory services that explain how to identify the pest, what damages it causes, and how to conduct effective control measures, the overall incidence of the pest can be decreased. The actions can promote international stability by reducing the frequency and damage caused by insect outbreaks. It can be recommended to take a collaborative approach, which is essential for controlling the fall armyworm.

Author Contributions

MAF, MI and ANA: Writing original draft and Figure preparations. **SB, EF, TK, HA and TS:** Conceptualization, Collecting literature, Software, Validation, Visualization, Writing– review & editing. **AA:** Conceptualization, writing– review & editing. **MT** and **ABA:** Finalization, Writing– review & editing.

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Domates sarı yaprak kıvırcıklık virüsü (*Tomato yellow leaf curl virus*, TYLCV): Güneydoğu Anadolu Bölgesi domates üretim alanlarında önemi artan bir virus

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ÖZET

Domates (*Solanum lycopersicum* L.) dünya genelinde en çok yetiştirilen sebzeler arasında yer almaktadır. İnsan beslenmesinde kullanılmasının yanı sıra çeşitli endüstri kollarında hammadde olarak kullanılmaktadır. Diğer kültür bitkilerinde olduğu gibi domates yetiştiriciliğinde de hastalıklar önemli ekonomik kayıplara yol açmaktadır. Bunlar içerisinde virüs hastalıkları, domates üretimini sınırlayan en önemli patojenler arasında kabul edilmekte olup, bugüne kadar domates bitkisiyle ilişkili 312 virüs ve viroid (22 familya ve 39 cinste) tespit edilmiştir. Önemli virüsler arasında Begomovirus, Tospovirus, Cucumovirus, Potyvirus ve Tobamovirus cinslerinde yer alan türler bulunmaktadır. Domates bitkisini enfekte eden *Begomovirus* türleri arasında, ekonomik açıdan en önemli ve yaygın olduğu bilinen virüs, *Tomato yellow leaf curl virus* (TYLCV) olarak tanımlanmaktadır. TYLCV ile enfekte olmuş duyarlı çeşitlerde, bodurluk, yaprakların yukarı doğru kıvrılması, kloroz ve yaprak boyutunda azalma gibi karakteristik belirtiler gözlemlenmekte ve %100'e varan ciddi verim kayıpları bildirilmiştir. TYLCV ilk olarak 1930'larda İsrail'in Ürdün Vadisi'nde tespit edilmesinden sonra uluslararası ticaretin artması, bu virüsün Türkiye ve Güneydoğu Anadolu Bölgesi dahil olmak üzere domates üretiminin yapıldığı tüm bölgelere yayılmasına neden olmuştur. Küresel ısınmanın neden olduğu iklim değişikliği ile birlikte, virüsün vektörü olan beyaz sinek (*Bemisia tabaci* Genn.) popülasyonlarındaki artış ve bilinçsiz insektisit kullanımı sonucunda beyaz sineklerde direnç oluşması, TYLCV'yi Güneydoğu Anadolu Bölgesi için giderek daha önemli bir viral etmen haline getirmiştir. Bu derlemede, domates yetiştiriciliği için en önemli viral patojen olarak kabul edilen TYLCV'nin ekonomik önemi, taşınma yolları ve oluşturduğu belirtiler hakkında bilgiler sunulmakta ve uygulanabilecek mücadele yöntemleri üzerinde durularak oluşabilecek verim kayıplarının önlenmesi hedeflenmektedir.

Tomato yellow leaf curl virus (TYLCV): A virus of increasing importance in tomato production areas of the Southeast Anatolian Region

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is one of the most widely grown vegetables in the world. In addition to human consumption, it is used as a raw material in various industries. As with other crops, diseases and pests cause significant economic losses in tomato production. Virus diseases are considered one of the most important pathogens limiting tomato production, and 312 viruses and viroids (in 22 families and 39 genera) associated with tomato plants have been identified to date. Important viruses include species in the *Begomovirus*, *Tospovirus*, *Cucumovirus*, *Potyvirus* and *Tobamovirus*. Among the *Begomovirus* species infecting tomato plants, *Tomato Yellow Leaf Curl Virus* (TYLCV) is known to be the most economically important and widespread virus. Characteristic symptoms such as stunting, leaf curling, chlorosis and leaf size reduction are observed in susceptible varieties infected with TYLCV, and severe yield losses of up to 100% have been reported. After TYLCV was first detected in the Jordan Valley of Israel in the 1930s, increased international trade has led to the spread of the virus to all tomato producing regions, including Turkey and the Southeast Anatolian Region. With the climate change caused by global warming, the increase in whitefly (*Bemisia tabaci* Genn.) populations, the vector of the virus, and the development of resistance in whiteflies as a result of inadvertent insecticide use, TYLCV has become an increasingly important viral agent for the Southeast Anatolian region. In this review, the economic importance, transmission routes and symptoms of TYLCV, which is considered to be the most important viral pathogen for tomato cultivation, are presented.

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1.Giriş

Domates (*Solanum lycopersicum* L.), biber, patlıcan ve patates gibi önemli kültür bitkilerini içeren *Solanaceae* familyasına ait bir bitki olup, dünya genelinde tarla ve sera şartlarında en yaygın şekilde yetiştirilen sebzeler arasında yer almaktadır (Hanson, 2022). Lezzetinin yanı sıra A ve C vitaminleri ile kalsiyum, potasyum ve fosfor gibi mineraller açısından zengin olması, domatesin hem doğrudan insan beslenmesinde kullanılmasını hem de ketçap, sos ve konserveler gibi endüstriyel ürünlerin ham maddesi olarak tercih edilmesini sağlamaktadır (Sainju ve Dris, 2006; Ayisha ve ark., 2017). FAO (2022) verilerine göre, dünyada 60.591.970 dekar alanda 254.449.772 ton domates üretilmiştir. Yine aynı veriler ışığında ülkemizde ise 1.587.190 dekar alanda 13.000.000 ton domates üretimi ile Çin ve Hindistan'ın ardından üçüncü sırada yer almaktadır.

Domates yetiştiriciliğinde, diğer kültür bitkilerinde olduğu gibi, hastalıklar ve zararlılar önemli ekonomik kayıplara yol açmaktadır. Bu hastalıklar içerisinde viral etmenler, domates üretimini sınırlayan en önemli patojenler arasında kabul edilmekte olup, domates bitkisiyle ilişkili 312 virüs, satellite virüs ve viroid (22 familya ve 39 cinste) tespit edilmiştir (Ong ve ark., 2020; Rivarez ve ark., 2021). Önemli virüsler arasında *Begomovirus*, *Tospovirus*, *Cucumovirus*, *Potyvirus* ve *Tobamovirus* cinslerinde yer alan türler bulunmaktadır (Pico ve ark., 1996). *Begomovirus* (*Geminiviridae*), domatesi enfekte eden 162 türü ile bitki virüslerinin en büyük ve en çok çalışılan cinslerinden biridir (Rivarez ve ark., 2021). Domates bitkisini enfekte eden *Begomovirus* türleri arasında, ekonomik açıdan en önemli ve yaygın olarak bilinen virüs, *Tomato yellow leaf curl virus* (TYLCV) olarak tanımlanmaktadır. TYLCV, küresel domates üretimine en fazla zarar veren virüslerden biri olması nedeniyle üzerine en fazla araştırma yapılan bitki viral patojenlerinden biridir (Mabvakure ve ark., 2016). TYLCV ile enfekte olmuş duyarlı çeşitlerde, bodurluk, yaprakların yukarı doğru kıvrılması, kloroz ve yaprak boyutunda azalma gibi karakteristik belirtiler gözlemlenmekte ve %100'e varan ciddi verim kayıpları bildirilmiştir (Levy ve Lapidot, 2008; Prasad ve ark., 2020).

TYLCV ilk olarak 1930'larda İsrail'in Ürdün Vadisi'nde tespit edilmiştir ve uluslararası ticaretin artması ile tarımsal kaynakların paylaşımına yönelik artan eğilim, bu virüsün domates üretiminin yapıldığı tüm bölgelere yayılmasına neden olmuştur (Cohen ve Harpez, 1964; Ramos ve ark., 2019). Daha önce yapılan araştırmalarda, TYLCV'nin ülkemizin farklı illerinde varlığı tespit edilmiştir (Sertkaya ve ark., 2017; Erdoğan ve ark., 2022). Küresel ısınmanın neden olduğu iklim değişikliği ile birlikte, virüsün vektörü olan beyaz sinek (*Bemisia tabaci* Genn.) popülasyonlarındaki artış, üreticiler tarafından beyaz sineğe karşı insektisitlerin bilinçsiz kullanımı sonucunda beyaz sineklerde insektisit direncinin oluşması ve virüsün hızlı yayılma özelliği, TYLCV'yi Güneydoğu Anadolu Bölgesi için giderek daha önemli bir viral etmen haline getirmiştir.

Bu derlemede, domates yetiştiriciliği için en önemli viral patojen olarak kabul edilen TYLCV'nin ekonomik önemi, taşınma yolları ve oluşturduğu belirtiler hakkında bilgiler sunulmakta; ayrıca, uygulanabilecek mücadele yöntemleri üzerinde durularak oluşabilecek verim kayıplarının önlenmesi hedeflenmektedir. Aktarılan mücadele yöntemleri, sadece TYLCV için değil, diğer virüslerle mücadelede de geçerlilik taşımaktadır.

2. Domates Sarı Yaprak Kıvırcıklık Virüsü (*Tomato yellow leaf curl virus*, TYLCV) Hakkında Genel Bilgiler

2.1. Taksonomisi

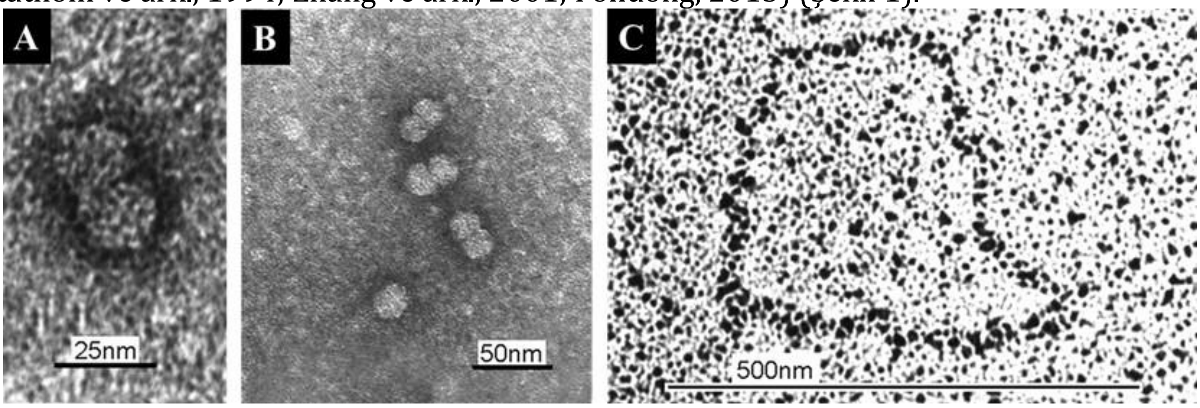
Domates sarı yaprak kıvırcıklığı virüsü (*Tomato yellow leaf curl virus*, TYLCV), *Geminiviridae* familyasının *Begomovirus* cinsi içinde yer almaktadır (ICTV, 2023) (Tablo 1). *Geminiviridae* familyası konukçu dizini, vektör, filogenetik ilişki ve genom organizasyonuna dayalı olarak 15 cinse bölünmüş ve yaklaşık 522 virüs türü içermektedir (Zerbini ve ark., 2017; ICTV, 2024). Bunlardan *Begomovirus* cinsi TYLCV ve birçok önemli tür dahil olmak üzere 445 virüs türü barındıran en büyük cinstir ve bilinen türlerden 162 tanesinin domatesi enfekte edebildiği bilinmektedir (Rivarez ve ark., 2021; ICTV, 2024).

Tablo 1. TYLCV'nin taksonomisi (ICTV, 2023)

Takson		Virüsün bulunduğu takson adı
Realm (Alan)		*Monodnaviria*
Kingdom (Alem)		*Shotokuvirae*
Phylum (Şube)		*Cressdnaviricota*
Class (Sınıf)		*Repensiviricetes*
Order (Takım)		*Geplafuvirales*
Family (Familya)		*Geminiviridae*
Genus (Cins)		*Begomovirus*
	Binominal adı	*Begomovirus coheni*
Species (Tür)	İngilizce adı	*Tomato yellow leaf curl virus*
	Türkçe adı	Domates sarı yaprak kıvırcıklık virüsü

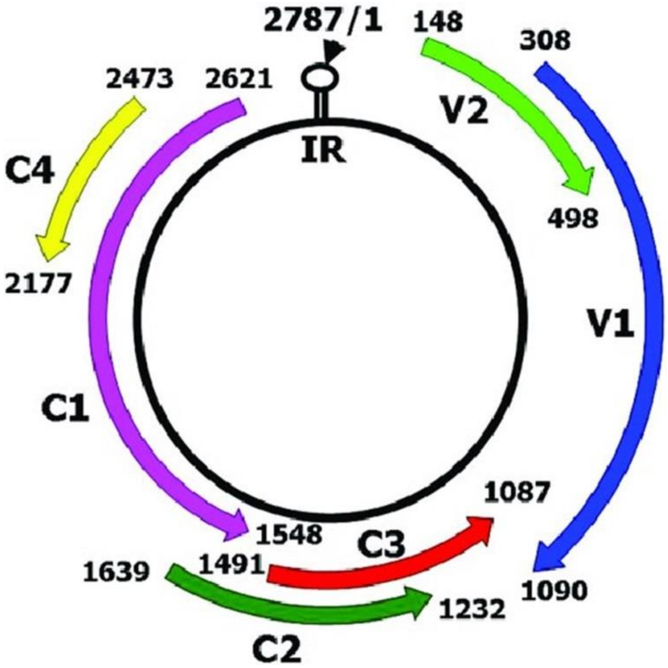
2.2. Virion Yapısı ve Genom Organizasyonu

TYLCV, *Geminivirus* cinsi virüslerin karakteristik ikiz morfolojisine sahiptir. Diğer *Geminivirus* türlerinde olduğu gibi kapsid T=1 yüzey simetrisine sahip iki ikozahedral yapıdan oluşmaktadır. Her biri, 30,3 kDa'lık 260 amino asitlik bir kaplama proteininin (CP) beş birimini içeren toplam 22 kapsomer içermektedir. Virüs, 2787 nükleotitlik dairesel ssDNA (single strand deoxyribonucleic acid)'dan oluşan tek parçalı bir genoma (DNA-A) sahiptir ve DNA-B'den yoksundur (Czosnek ve ark., 1988; Navot ve ark., 1991; Attathom ve ark., 1994; Zhang ve ark., 2001; Fondong, 2013) (Şekil 1).



Şekil 1. TYLCV'nin morfolojisini ve DNA'sını gösteren büyütülmüş elektron mikrografı. A, B: Domates bitkisinden saflaştırılan TYLCV'nin ikiz partikülleri, C: TYLCV partiküllerinden izole edilen dairesel tek sarmallı DNA molekülü (Attathom ve ark., 1994).

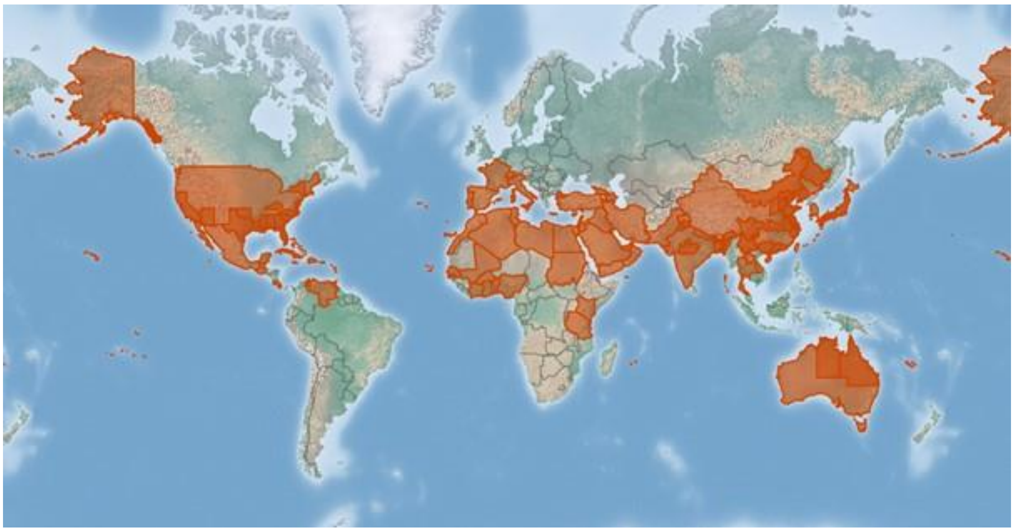
TYLCV'nin genomu üzerinde V1, V2, C1, C2, C3 ve C4 ORF (Open Reading Frame) bölgeleri bulunmaktadır (Fondong, 2013). V1'de genomun enkapsidasyonu ve vektör/konukçu içinde hareketten sorumlu kılıf proteini (Coat Protein, CP), V2'de RNA susturmayı baskılayıcı özelliğe sahip ön kaplama proteini (Precoat), C1'de replikasyonla ilişkili protein (Rep), C2'de transkripsiyonel aktivatör proteini (TrAP), C3'te replikasyon arttırıcı proteini (REn) ve C4'te hareket ve belirti belirleyici proteinler kodlanmıştır. Ayrıca, yuvarlanan daire modeline göre viral genomun replikasyonu sırasında ayrılma bölgesi olarak görev yapan ve V1, V2, C1 ve C4 genlerinin ifadesi için çift yönlü bir promotör görevi yapan 314 nükleotitlik bir intergenik bölge (Intergenic Region, IR) bulunmaktadır (Laufs ve ark., 1995; Gronenborn, 2007; Díaz-Pendón ve ark., 2010; Scholthof ve ark., 2011; Prasad ve ark., 2020) (Şekil 2).



Şekil 2. TYLCV'nin genom organizasyonu (Czosnek, 2021)

2.3. TYLCV'nin Ortaya Çıkışı ve Yayılımı

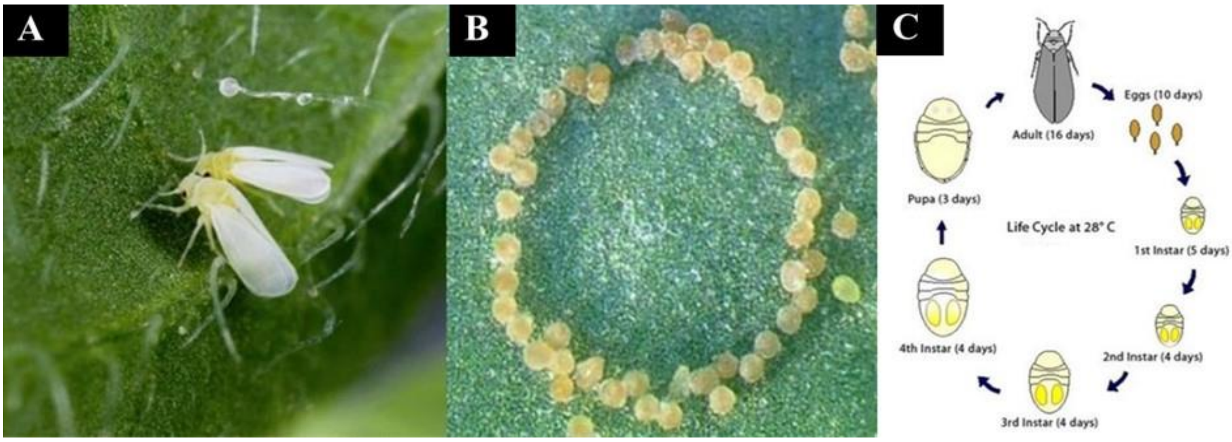
TYLCV ilk olarak 1930'larda İsrail'in Ürdün Vadisi'nde fark edilmiş, ancak 1960'ların başına kadar tanımlanamamıştır (Cohen ve Nitzany, 1966). Virüs daha sonra *Tomato yellow leaf curl virus* (TYLCV) olarak adlandırılmıştır (Cohen ve Harpaz, 1964). Virüs 1988 yılında izole edilmiş, tek parçalı olduğu kanıtlanmış ve 1991 yılında nükleotit dizilimi yapılmıştır (Czosnek ve ark., 1988; Navot ve ark., 1991). TYLCV 1960'ların başından itibaren hızla tüm Orta Doğu'ya yayılmış ve kısa bir süre içerisinde Kuzey Amerika, Afrika, Avrupa ve Uzak Doğu Asya'ya da ulaşmıştır (Czosnek, 2010). Türkiye'de ise ilk olarak 1980 yılında Çukurova bölgesinde (Adana) ve sonrasında 1993 yılında Ege bölgesinde tespit edilmiştir (Yılmaz ve ark., 1980). Virüsün yeni bölgelere girişi, yeni konukçulara uyum sağlamasına ve rekombinasyon ilemutasyon yoluyla yeni ırklar geliştirmesine neden olmuştur (Péréfarres ve ark., 2012). Virüsün şimdiye kadar yedi ırkı belirlenmiş olup, ülkemizde mevcut ırkların TYLCV-IL ve TYLCV- Mild ırkları olduğu tespit edilmiştir (Morris, 1997) (Şekil 3).



Şekil 3. TYLCV’nin dünyadaki yayılımı (CABI, 2012)

2.4. Taşınma Şekli

TYLCV’nin taşınma ve bulaşmasının en önemli yolu, hastalık etmeni taşıyanbitki üretim materyallerinin dağıtımı ve birçok ürünü istila edebilen, şu anda küresel olarak yaygın kriptik bir tür olan beyaz sineklerin (*Bemisia tabaci* Genn.) yayılmasıdır (Lefeuvre ve ark., 2010; Stansly ve ark., 2010; Alemandri ve ark., 2015; Fiallo-Olivé ve ark., 2020). *B. tabaci* yaklaşık 130 yıl önce tanımlanmış ve o zamandan beri dünya çapında en önemli zararlılardan biri haline gelmiştir. Şu ana kadar kadar 600 bitki türünde zarar oluşturduğu bildirilmiş ve henüz resmi olarak belgelenmemiş çok sayıda konukçusu olduğu tahmin edilmektedir (Oliveira ve ark., 2001; Czosnek ve ark., 2017). Kültür bitkilerinde önemli bir zararlı olmasının yanı sıra virüs vektörü olması bu zararlıyı daha da önemli hale getirmektedir (Şekil 4). TYLCV beyaz sinekle persistent (transovaryal) olarak taşınabilmektedir (Ghanim ve ark., 1998). Beyaz sinek enfekteli bitkiyle 15-30 dakika beslendikten sonra virüsü edinmekte ve 8-24 saat latent dönemden sonra virüsü başarılı bir şekilde bulaştırabilmektedir (Ghanim ve ark., 2001). Ayrıca TYLCV’nin bitki çeşidine göre değişmekle birlikte, %20-100 arasında tohumla taşınabildiği bildirilmiştir (Kil ve ark., 2016).



Şekil 4. Beyaz sinek (*Bemisia tabaci*). A: Bir yaprak üzerinde beslenen erkek (daha küçük) ve dişi yetişkinler, B: *B. tabaci* tarafından bırakılan dairesel desenli yumurtalar, C: *B. tabaci*’nin yaşam döngüsü (Prota, 2015).

2.5. Konukçuları

Domates (*Solanum lycopersicum* L.) TYLCV'nin ana konukçusu olup, *S. chilense*, *S. habrochaites*, *S. peruvianum* ve *S. pimpinellifolium* gibi yabani domates türlerinin belirti göstermeden virüs taşıyıcısı olduğu veya virüse karşı dayanıklı olan aksesyonlarının bulunduğu bilinmektedir (Zakay ve ark., 1991; Vidavsky ve Czosnek, 1998). Daha önce yapılan çalışmalarda *Amaranthaceae*, *Chenopodiaceae*, *Compositae*, *Convolvulaceae*, *Cruciferae*, *Euphorbiaceae*, *Geraniaceae*, *Leguminosae*, *Malvaceae*, *Orobanchaceae*, *Plantaginaceae*, *Primulaceae*, *Solanaceae*, *Umbelliferae* ve *Urticaceae* familyalarına ait 49 farklı kültür bitkisi ve yabani ot türünün TYLCV'ye konukçu olduğu bildirilmiştir (Papayiannis ve ark., 2011; Hančinský ve ark., 2020).

2.6. Domates Bitkisinde Oluşturduğu Belirtiler

Domates bitkileri fide döneminde enfekte olduğunda hastalık kolayca tanımlanabilmektedir. TYLCV ile enfekte olan bitkilerde yaprak kenarlarında yukarı ve içe doğru kıvrılma, damarlar arası sararma ve bodurluk belirtileri oluşmaktadır. Çiçeklenme öncesi gerçekleşen enfeksiyonlarda meyve tutumunda önemli ölçüde azalma meydana gelmektedir. Enfekteli bitkilerden elde edilen meyvelerde gözle görülür bir belirti oluşmamaktadır (Thongrit ve ark., 1986) (Şekil 5).

Şekil 5. TYLCV'nin domates bitkisinde oluşturduğu belirtiler. A; Bitkinin üst (genç) yapraklarında sararma ve kıvrılma, B; Yaprakların damar aralarında ve kenarlarında kloroz, C; Bitkide bodurlaşma ve çalılaşma belirtileri (Murray ve ark., 2023).

3. MÜCADELE YÖNTEMLERİ

Domates sarı yaprak kıvırcıklığı virüsü (*Tomato yellow leaf curl virus*, TYLCV), dünya genelinde yaygınlığı ve geniş konukçu dizisi nedeniyle mücadelesi zor bir patojendir. Diğer virüs hastalıklarında olduğu gibi doğrudan mücadele yöntemlerinin olmaması, "Önlem almak tedavi etmekten daha iyidir" anlayışını öne çıkarmaktadır. Bu bağlamda, TYLCV ile mücadelenin başarısı, üretim sezonu öncesinde, sırasında ve sonrasında virüsün girişini ve yayılmasını engellemeye yönelik önlemlerin uygulanmasına bağlıdır. Entegre hastalık yönetimi kapsamında, karantina önlemlerinden kimyasal mücadeleye kadar geleneksel yöntemler ile birlikte son yıllarda kullanılan transgenik yöntemler, gen düzenleme ve RNA interferans (RNAi) teknolojisi gibi modern yöntemlerin bir arada kullanılması, TYLCV ve diğer bitki hastalıklarının kontrolünde büyük önem taşımaktadır.

Hastalığın mücadelesinde ilk ve en önemli adım, hastalığa neden olan etmenin doğru bir şekilde teşhis edilmesi ve ardından uygun mücadele stratejilerinin belirlenmesidir. TYLCV'nin neden olduğu belirtiler ve beyaz sineklerin gözlemlenmesi teşhis için yararlı olabilse de bu yöntem tek başına yeterli değildir. Zira birçok hastalık etmeni benzer virüs belirtileri oluşturabilmekte ve beyaz sinekler farklı virüslere vektörlük yapabilmektedir. Bu nedenle, kesin teşhis için serolojik ve moleküler yöntemlerin kullanılması gerekmektedir (Rojas ve ark., 1993).

TYLCV salgınlarının önlenmesi amacıyla üretim sezonu başlamadan önce doğru planlama yapılması önemlidir. Virüs hastalıkları gibi mücadele edilmesi güç olan etmenlere karşı en etkili yöntemlerden biri dayanıklı çeşitlerin kullanımıdır. Geleneksel ıslah yöntemleri ile yabani domates türlerinden (*Solanum pimpinellifolium*, *S. peruvianum*, *S. chilense*, *S. habrochaites* ve *S. cheesmaniae*) ıslah edilmiş, TYLCV'ye karşı dayanıklılık genleri taşıyan birçok çeşit mevcuttur. Güvenilir kaynaklardan temin edilen virüsten ari ve vektör bulunmayan dayanıklı üretim materyallerinin (tohum/fide) kullanılması önemlidir (Gill ve ark., 2019).

TYLCV'nin yayılmasında en etkili faktörlerden biri beyaz sineklerdir. Bu nedenle, beyaz sinek popülasyonlarını kontrol etmeye yönelik önlemler, salgınların engellenmesinde etkili olabilmektedir. Fideliklerde ağ kullanımı ve kimyasal mücadele, beyaz sineklerin virüsü bulaştırmasını ve salgın oluşturmasını önleyebilir. Ancak, insektisitlerin bilinçsiz kullanımı çevre ve insan sağlığı üzerinde olumsuz etkilere yol açmakta ve beyaz sineklerde insektisit direncinin gelişmesine neden olmaktadır (Antignus ve ark., 2004; Horowitz ve ark., 2007; Rojas ve ark., 2018).

Erken dönemde tarlada belirtiler gösteren ve virüsle enfekte olduğundan şüphelenilen bitkilerin üretim alanından uzaklaştırılması, primer inokulum kaynaklarının ortadan kaldırılması açısından kritik bir öneme sahiptir. Ayrıca, bitkilerin beslenme ve sulama durumu, hastalığın şiddeti üzerinde etkili olabilmektedir. Bu nedenle gübreleme ve sulama işlemlerinin dengeli ve düzenli bir şekilde yapılması, bitkilerin hastalığa karşı dirençli olmasını sağlamaktadır. Üretim sezonu sona erdiğinde, sonraki sezon için olası inokulum kaynaklarının ortadan kaldırılması da gereklidir. Bu amaçla, TYLCV konukçusu yabancı otlara karşı mücadele edilmelidir (Papayiannis ve ark., 2011; Prasad ve ark., 2020).

Sonuç olarak, erken teşhis ve hastalığın oluşumunu etkileyen faktörlerin dikkate alındığı doğru tarım uygulamaları, TYLCV mücadelesinde etkili sonuçlar elde edilmesine olanak tanımaktadır.

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