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# TARIM ve DOĞA DERGİSİ

# JOURNAL of AGRICULTURE and NATURE

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Hampton, S., Rabagliati, H., Sorace, A., & Fletcher-Watson, S. (2017). *Autism and bilingualism: A qualitative interview study of parents' perspectives and experiences*. PsyArXiv, *Preprint*. https://doi.org/10.31234/osf.io/76xfs

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While the peer-reviewed journal literature should be accessible online without cost to readers, it is not costless to produce. However, experiments show that the overall costs of providing open access to this literature are far lower than the costs of traditional forms of dissemination. With such an opportunity to save money and expand the scope of dissemination at the same time, there is today a strong incentive for professional associations, universities, libraries, foundations, and others to embrace open access as a means of advancing their missions. Achieving open access will require new cost recovery models and financing mechanisms, but the significantly lower overall cost of dissemination is a reason to be confident that the goal is attainable and not merely preferable or utopian.

To achieve open access to scholarly journal literature, we recommend two complementary strategies.

**I. Self-Archiving:** First, scholars need the tools and assistance to deposit their refereed journal articles in open electronic archives, a practice commonly called, self-archiving. When these archives conform to standards created by the Open Archives Initiative, then search engines and other tools can treat the separate archives as one. Users then need not know which archives exist or where they are located in order to find and make use of their contents.

**II. Open-access Journals:** Second, scholars need the means to launch a new generation of journals committed to open access, and to help existing journals that elect to make the transition to open access. Because journal articles should be disseminated as widely as possible, these new journals will no longer invoke copyright to restrict access to and use of the material they publish. Instead, they will use copyright and other tools to ensure permanent open access to all the articles they publish. Because the price is a barrier to access, these new journals will not charge subscription or access fees and will turn to other methods for covering their expenses. There are many alternative sources of funds for this purpose, including the foundations and governments that fund research, the universities and laboratories that employ researchers, endowments set up by discipline or institution, friends of the cause of open access, profits from the sale of add-ons to the basic texts, funds freed up by the demise or cancellation of journals charging traditional subscription or access fees, or even contributions from the researchers themselves. There is no need to favor one of these solutions over the others for all disciplines or nations, and no need to stop looking for other, creative alternatives.

Open access to peer-reviewed journal literature is the goal. Self-archiving (I.) and a new generation of open-access journals (II.) are the ways to attain this goal. They are not only direct and effective means to this end, but they are also within the reach of scholars themselves, immediately, and need not wait on changes brought about by markets or legislation. While we endorse the two strategies just outlined, we also encourage experimentation with further ways to make the transition from the present methods of dissemination to open access. Flexibility, experimentation, and adaptation to local circumstances are the best ways to assure that progress in diverse settings will be rapid, secure, and long-lived.

The Open Society Institute, the foundation network founded by philanthropist George Soros, is committed to providing initial help and funding to realize this goal. It will use its resources and influence to extend and promote institutional self-archiving, to launch new open-access journals, and to help an open-access journal system become economically self-sustaining. While the Open Society Institute's commitment and resources are substantial, this initiative is very much in need of other organizations to lend their effort and resources.

We invite governments, universities, libraries, journal editors, publishers, foundations, learned societies, professional associations, and individual scholars who share our vision to join us in the task of removing the barriers to open access and building a future in which research and education in every part of the world are that much more free to flourish.

For various reasons, this kind of free and unrestricted online availability, which we will call open access, has so far been limited to small portions of the journal literature. But even in these limited collections, many different initiatives have shown that open access is economically feasible, that it gives readers extraordinary power to find and make use of relevant literature, and that it gives authors and their works vast and measurable new visibility, readership, and impact. To secure these benefits for all, we call on all interested institutions and individuals to help open up access to the rest of this literature and remove the barriers, especially the price barriers, that stand in the way. The more who join the effort to advance this cause, the sooner we will all enjoy the benefits of open access.

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### *3. Referee Process*

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MUŞ ALPARSLAN ÜNİVERSİTESİ TARIM VE DOĞA DERGİSİ
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# Labour-use efficiency of rice farmers in Nigeria's north-central region

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**A B S T R A C T**

A cross-sectional data collected through structured questionnaire coupled with an interview schedule from 360 rice farmers selected *via* a multi-stage sampling technique was used to determine the labour efficiency of rice farmers in Nigeria's North-Central region. Both descriptive and inferential statistics were used to analyze the 2020 cropping season data. The empirical evidences showed a farming population that is gender biased due to gender stereotype, thus affected women's access to and control over productive resources. Besides, economic-productive people that explored pecuniary advantages to achieve economies of scale engaged in cultivation of thinly uneconomic holding. The poor economic status of the farm families made most of the farmers to rely on family labour for farm operations, thus keeping most of their children and young ones out of school. Furthermore, most of the farmers were fairly efficient in the use of labour with little technical support required to enable them to achieve optimum labour efficiency level (frontier point). However, the empirical evidences showed competition for labour demand between farm and off-farm activities, and, conservative and complacency attitudes due to longevity in the enterprise to be the factors that affected labour efficiency. Therefore, the study calls for gender mainstreaming in the agricultural budget to overcome women's challenge on productive resources; incentivized the enterprise *viz.* credit provision; and, adoption of a bottom-to-top approach in research and practical demonstration approach in the transfer of innovative rice technologies.

## 1. INTRODUCTION

The socio-economic developments in Africa are primarily agrarian and about 70% of its workforce directly or indirectly involved in agriculture live in rural areas and rely on agriculture for their livelihoods (Ugorji, 2013). In the staple food crop sub-sector of Nigeria, rice production occupies an important position, especially among cereal crops (Sadiq et al., 2020a). Rice is one of the world's most important grains and staple food for millions of individuals in South Asia, America and Africa (FAO, 2017). Presently, the average Nigerians consume 21 kg of rice per year, comprising 9% of the total caloric intake and 23% of the total consumption of cereals, with the population consuming approximately 2.1 million tons of rice annually (Sadiq et al., 2020a).

Nigerian farmers complain of unavailability and high labour costs, long propagation periods, and high use of crude rice processing technologies. There is a need to make effective use of basic production factors, including labour, land and resources, in order to have sustainable agricultural growth. Human labour stimulates other factors of production and converts other farm inputs into the outputs needed. The lack of farm labour has had a negative effect on planting accuracy, improved weed control, timely harvesting and crop processing (Oluyole et al., 2011; Kadurumba et al., 2020). Akanni & Dada (2012), Anyiro et al. (2013) and Kadurumba et al. (2020) have noted the inadequacy of farm labour to promote the expansion of rice farms and to intensify the already chosen area for rice production in Nigeria.

In Nigeria, smallholder farmers contribute more than 85 percent of domestic agricultural production (Akanni & Dada, 2012). Empirical evidence has shown that the labour force available consisted primarily of elderly farmers, excluding men and women in the active working age, thus had a negative effect on the production of rice. Drudgery in farm activities, rural-urban migration and lack of social infrastructure in rural areas, as well as low farm income and low life expectancy in rural areas, could be due to the growing absence of people under the productive/active age. The only main source of labour available to small-scale rice farmers in Nigeria is human labour (Kadurumba et al., 2020). Thus, there is a need to continue to supply the ever-growing Nigerian population with food, which is rooted in the productivity of human labour.

Some studies confirm that the supply of farm labour by humans on the farm is not homogeneous and that the content of work varies. In general, these studies showed that men carried out heavy farm operations such as land preparation, staking and harvesting while women and children carried out lighter operations such as planting, application of fertilizers and weeding (Akanni & Dada, 2012; Kadurumba et al., 2020). Farm labour supply researchers have observed that total labour supply depends on factors such as population size, age composition and certain institutional factors (Anyiro et al., 2013).

The seasonal relationship between the periodic shifts in the patterns of labour usage and the various labour operations expected to be carried out in a timely manner exercises a limit on the proportion of household labour on which to rely upon. Almost all farm activities are concentrated in the wet season, thus, slight delays, particularly in the very short wet season, can be costly. At such times, labour demand is becoming the most worrying issue. The conspicuously scarce factor of production is labour supply. In the farming communities, the responsiveness of the labour supply of both family and hired to prospective profitable alternative job opportunities among smallholder farmers poses barriers to the extended use of labour in agricultural production.

Increasing the production of rice requires increased productivity in the use of labour, increased land use and the expansion of indigenous technology. It is in view of the foregoing that the research themed “labour-use efficiency among rice farmers of North-Central Nigeria” was conceptualized so as to provide a roadmap that will guide policymakers and farmers on productive labour-use enhancement in rice production. To the best of our knowledge literature showed no information of related study in the Northern region of the country. Thus, the outcome of this research will add to the existing literature of related studies that covered the southern part of the country. Therefore, the research ought to determine the labour-use efficiency of rice farmers in Nigeria’s North-central region. The specific objectives were to describe the socio-economic characteristics of the respondents; to describe the labour-use pattern for the different farm activities in the study area; and, to determine the labour-use efficiency among the respondents in the study area.

## 2. RESEARCH METHODOLOGY

The North-Central region is geographically located in the middle belt of Nigeria and consists of six states *viz*. Benue, Nasarawa, Niger, Plateau, Kogi and Kwara;

and a federal unity territory called Abuja. The region spanned from the west to around the serenity of the confluence of two major rivers- River Niger and River Benue. The geographical co-ordinates of the region are latitude 10° 20′ N and longitude 7° 45′ E, and its vegetation cover is largely guinea savannah alongside mountainous and tropical vegetations. The mean cumulative annual and monthly rainfall of the region are 1247.52 ± 166.68 mm and 103.96 mm, respectively; while the annual mean temperatures hovered around minimum and maximum values of 22.55 ± 0.42°C and 33.54 ± 0.23°C. The mean is slightly above 50 percent for the relative humidity and varied between the small range of 50.08 and 52.75 percent. The distribution of monthly rainfall ranges from May to October, with a uni-modal peak in August (274.23 mm) (Olayemi et al., 2014). The months of January and February are completely dry season (no rainfall) while the months of April and November witnessed little spring, thus referenced as pre- and post-rainy season transition periods respectively. The inhabitants of the region majorly engaged in arable crop production alongside tree cropping, fishing, hunting, artisanal, civil service and *Ayurvedic* medicines. In achieving a representative sampling size, a multi-stage sampling technique was adopted. Except Benue state, all the state units and the Federal unity territory are suitable for the cultivation of rice. Thus, three out of the seven units *viz*. Niger and Kogi States; and FCT Abuja were conveniently selected. Given the preponderance of rice cultivation across the chosen units, two Local Government Areas (LGAs)/Municipal Area Councils (MAC) were randomly selected from each of the selected units using Microsoft's inbuilt sampling analytical tool. Furthermore, using the same Microsoft's sampling analytical tool, two villages were randomly selected from each of the chosen LGAs/MAC. Based on the sampling frame sourced from the States' Agricultural agencies and reconnaissance survey, a scale ratio of 18% was used to determine the representative sample size (Table 1). Thus, a total of 376 active rice farmers that made the sample size were drawn through the simple random sampling technique. However, 16 out of the 376 questionnaires retrieved contained outliers, thus were eliminated. Therefore, a total of 360 valid questionnaires were subjected to the analysis. Using an easy cost-route approach, a structured questionnaire complemented with an interview schedule is the instrument used to elicit cross-sectional data of 2020 rice cropping seasons from the farmers. Both descriptive and inferential statistics were the tools used for data analysis. The first and second objectives were achieved using descriptive statistics while the last objective was achieved using the Cob-Douglas stochastic labour-use frontier function.

**Empirical Model**

Following Masso & Heshmati (2003); Akanni & Dada (2012); Kadurumba et al. (2020), the imposed Cobb-Douglas Stochastic Labour-use frontier function approach is given below:

$$L_i = f(X_{ij,}Y_{ij,};\beta) + (V_i - U_i)\ (i = 1,2 \ldots\ldots, n) \quad (3)$$

$L_i = Labour\ of\ the\ i^{th} farmer;$

$X_i = Vector\ of\ the\ actual\ j^{th}\ inputs\ used\ by\ the\ i^{th} farmer;$

$Y_i = Vector\ of\ the\ actual\ j^{th}\ output\ of\ the\ i^{th} farmer;$

$\beta_i = parameter\ to\ be\ estimated;$

$V_i = Uncertainty\ which\ is\ beyound\ the\ control\ of\ the\ i^{th} farmer;$

$U_i = Risk\ which\ is\ attributed\ to\ the\ error\ of\ the\ i^{th} farmer;$

Given the level of technology at the disposal of a technical unit, the labour-use efficiency is expressed as the ratio of the observed labour-use ($L^b$) to the corresponding optimum labour requirement ($L^{opt}$), and it is given below:

$$L_e = \frac{L^b}{L^{opt}} = \frac{f(X_{ij,}Y_{ij,};\beta)+(V_i-U_i)}{f(X_{ij,}Y_{ij,};\beta)+V_i} = \exp\ (U_i) \quad (4)$$

Where $L_e$ is the labour efficiency, and it takes the value of $\leq 1$ with 1 defining labour-use efficient technical unit. The observed labour-use($L^b$) represents the actual labour-use while the potential labour requirement ($C^{opt}$) represents the frontier labour requirement level.

The explicit form of the Cob-Douglas functional form of the LCF function is as follow:

$$lnL_i = ln\beta_0 + \sum \beta_k lnX_{ij} + \beta_l lnY_{ij} + (V_i - U_i) \quad (5)$$

Where $L_i$ = total human labour-use of $i^{th}$farmer (man-day); $X_i$ = vector of farm inputs used:

$X_1$ = inorganic fertilizer (kg), $X_2$ = seeds (kg), $X_3$ = herbicides (litre), $X_4$ = pesticides (kg), $X_5$ = depreciation on capital items (N), and $X_6$ = farm size (hectare); $Y_i$ = farm output (kg) from $i^{th}$ farmer; $V_i$ = random variability in the production that cannot be influenced by the $i^{th}$ farmer also known as uncertainty; $U_i$ = deviation from potential labour requirement attributable to labour-use inefficiency and also known as risk. $\beta_0$ = intercept; $\beta_k$ = vector of input parameters to be estimated; $\beta_l$ = vector of output parameter to be estimated; $i = 1,2,3 \ldots\ldots, n\ farmers$; $j = 1,2,3 \ldots\ldots\ldots, m\ inputs$.

The inefficiency model is:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 \ldots\ldots\ldots. + \delta_n Z_n \quad (6)$$

Where $Z_1$ = age (year); $Z_2$ = gender (male = 1, female = 0); $Z_3$ = marital status (married = 1, otherwise = 0); $Z_4$ = educational level (year); $Z_5$ = dependent household member (number); $Z_6$ = independent household member (number); $Z_7$ = farming experience (year); $Z_8$ = mode of land acquisition (inheritance = 1, otherwise = 0); $Z_9$ = distance from home to farm (kilometre); $Z_{10}$= distance from home to market (kilometre); $Z_{11}$= co-operative membership (yes = 1, no = 0); $\delta_0$ = intercept; and, $\delta_{1-n}$ = parameters to be estimated.

Using the generalized likelihood function, the test for the presence of labour-use inefficiency is defined by:

$$\lambda = -2ln(\frac{H_0}{H_a}) \quad (7)$$

Where $H_0$ is the value of the likelihood function for the unrestricted frontier (OLS) while $H_a$ is the value of the likelihood function for the restricted Cobb-Douglas frontier model. Thus, if the calculated Chi² is greater than the tabulated Chi² at 5% degree of freedom, then the null hypothesis is rejected in favour of the alternative hypothesis. The alternative hypothesis has approximately a mixed Chi² distribution with a degree of freedom equal to the number of parameters omitted in the unrestricted model, if the null hypothesis is true (Sadiq & Singh, 2016).

**Table 1.** Sampling frame of rice farmers

| States | LGAs/MACs | Villages | Sample frame | Sample size |
|---|---|---|---|---|
| FCT Abuja | Kwali | Dabi | 85 | 15 |
| | | Gada-biu | 109 | 20 |
| | Abaji | Yaba | 100 | 18 |
| | | Pandagi | 90 | 16 |
| Kogi State | Yagba West | Omi | 198 | 36 |
| | | Ejiba | 220 | 40 |
| | Kogi | Giryan | 250 | 45 |
| | | Panda | 180 | 32 |
| Niger State | Borgu | Swashi | 208 | 37 |
| | | Saminaka | 170 | 31 |
| | Katcha | Katcha | 238 | 43 |
| | | Badeggi | 242 | 43 |
| **Total** | **6** | **12** | **2090** | **376** |

***Source:*** States' Agricultural Agencies, 2020

***Note:*** District unit is called Municipal Area Council (MAC) and Local Government area (LGA) in FCT Abuja and State, respectively.

## 3. RESULTS AND DISCUSSION

### Socio-Economic Profile of the Farmers

A perusal of Table 2 revealed an economically active (41 years) farming population with capacity to achieve high labour productivity that will ensure rice food security in the studied area. Besides, the value of standard deviation being ± 10.8 depicts that most of the farmers fall within the age bracket of 30 to 50 years; an age bracket recommended by FAO to be viable and productive. Most of the farmers are married (84.44%) with family obligations to meet-up, thus indicating sustainable rice production for the purpose of achieving sustainable earnings-income inflow: making ends meet- keeping the body and soul together. However, the enterprise is gender biased (81.11% of male farmers) and this may be attributed to gender stereotype which hinders women from access to and control over productive resources. Women face many constraints despite playing a pivotal role in food production, the chief being landless with no assets in their name. Even if they have land, they are constrained by money and other resources needed for cultivation (inputs and technical know-how). This depicts that the studied area did not recognize farm women as 'farmers' but rather 'wives' of the farmers. Thus, it can be suggested that women folk are very vulnerable or susceptible to the vicious cycle of poverty as they have little or no title of economic ownership. This scenario depicts a threat to development as gender equity is more than a goal itself because it is a pre-condition for reducing poverty, promoting sustainable development and building good governance (Sadiq et al., 2020b). When male farmers earn cash from crop sales, they either re-invest it for more agricultural productivity or use it on personal things. Their income does not increase the quality of food accessible to their families, but it is likely to be spent on family food when female farmers earn cash, albeit comparatively less (Sadiq et al., 2020b). Thus, the studied area needs to revise its chasm narrative about farm women so as to achieve growth and development. Most of the farmers had post-primary school education (8.1 years), thus depicting a farming population that will be receptive to farm skills capacity building acquisition programs on rice production. In addition, the studied area has been populated by literate farmers, the reception of rice innovations/technologies and managerial efficiency is likely to be high. Most of the farmers maintained a sustainable household size (4 persons) that is recommended by FAO for a sustainable livelihood, thus with little or no consequence on the enterprise going concern. Most of the farmers have been in rice production for many years with an average experience of 9.7 years. Thus, adequate experience plays a key role in enhancing the quality of farm decision-making in the allocation of resources, products supply and adoption of rice technologies. The mode of farm acquisition is majorly through inheritance (73.61%), thus indicating the susceptibility of the thinly uneconomic holdings to fragmentation as any adult family member will want to have his own portion of the parcel. This form of land ownership mostly does not permit the use of land for mechanized agricultural practices as land is viewed from the perspective of cultural, political and economic and not solely an economic good. The average distances from the farmers' house to farm and house to market are 4.34 and 5.68 km respectively, thus indicating a quite distance of the economic activity units from farmers' abode. The farther the farmers' houses from their technical units the better, as the farmers will spend much of their valuable time on farm operations with little or no social disturbances that may emanate from their families. Likewise, the farther the farmers' homes from the market units the better as the farmers will less frequent the market for non-farm and off-farm activities, thus makes them to concentrate and spend adequate time on farm operations during the production season. Most of the farmers belong to a co-operative association, indicating that the farmers explore their social capital so as to benefit from pecuniary advantages *viz*. bulk input discount, timely access to credit-kind and cash, bargaining output market power, technical advices; that are inherent in a co-operative organization. Most of the farmers are small-scale farmers cultivating rice on an average farmer size of 2.8 hectares. Therefore, it can be suggested that the farmers produced rice on subsistence level, a thinly uneconomic holdings which majorly improvise for household consumption with little or no output to serve the non-farming population. Most of the farmers cultivated rice under the rainfed condition i.e., during the Kharif season (85%) while 15% cultivated rice during the Rabi (hay) season. Under the rainfed condition, 81.05% cultivated rice on the lowland while 18.95% grow rice on the upland.

**Labour-use Pattern for Different Farm Activities**

A perusal of the results showed that for a hectare of rice farm a total of 216.73 labour man-hours were utilized in the production of rice output (Table 3). Gender-wise, it was observed that adult male farmers provided 142.24 labour man-hours used in the farm operation while the adult female and children accounted for 55.22 and 19.27 labour man-hours respectively. Furthermore, it was observed that labour requirements were high during land preparation, planting and harvest in the following average proportion of 19.25, 16.76 and 16.75% respectively. Thus, this outcome conforms to *a prior* expectation as these operations are intensive farm operations that required high labour engagement. The farm operations that utilized low labour man-hours were winnowing (2.49%), transportation of farm produce (2.21%), third weeding (1.95%) and second weeding (1.77%). However, the use of labour was found to be moderate in fertilizer application (14.21%), threshing (13.54%) and first weeding (11.07%). Most of the labour used for the farm operations was sourced from family labour (93.64%) which is cheap and almost free while hired labour contribution was marginal (6.36%). Thus, high reliance on family labour revealed the poor economic position of the farmers as most of them are resource-poor cultivating rice on a thinly uneconomic holding. In addition, farm families spend most of their time during the cropping season on farm activities. This suffices those children spend valuable school hours on farm activities all in an effort to supplement family labour due to the poor capital position of the farmers to improvise for paid labour.

**Table 2.** Socio-economic profile of the farmers

| Variables | Mean | Standard deviation | CV |
|---|---|---|---|
| Age | 41.49 | 10.83 | 0.261 |
| Gender | 0.8111 | 0.391 | 0.483 |
| Marital status | 0.8444 | 0.362 | 0.429 |
| Education | 8.083 | 4.97 | 0.614 |
| Child composition | 1 | 1.22 | 1.103 |
| Adult composition | 3 | 1.88 | 0.588 |
| Total household size | 4 | 2.62 | 0.606 |
| Experience | 9.68 | 7.112 | 0.734 |
| Land acquisition | 0.7361 | 0.441 | 0.599 |
| DHF | 4.34 | 3.390 | 0.780 |
| DHM | 5.68 | 4.166 | 0.733 |
| Co-operative memb. | 0.7278 | 0.464 | 0.637 |
| Farm size | 2.79 | 1.448 | 0.519 |
| Seasonal cultivation | 0.8500 | 0.357 | 0.4206 |
| Kharif season cultiv. | 0.8105 | 0.392 | 0.4843 |

***Source:*** Field survey, 2020

***Note:*** DHF and DHM are Distance from House to Farm and Distance from House to Market, respectively.

**Table 3.** Labour-use distribution pattern per hectare (man-hour per hectare)

| Operations | Family labour (FLAB) | | | Hired labour (HLAB) | | |
|---|---|---|---|---|---|---|
| | **AM** | **AF** | **Children** | **AM** | **AF** | **Children** |
| Land preparation | 18.57058 | 18.53538 | 0.067689 | 4.53912 | 0 | 0 |
| Planting | 31.65439 | 3.628111 | 0.103524 | 0.939677 | 0 | 0 |
| 1st weeding | 6.872387 | 13.44535 | 0.238901 | 3.440175 | 0 | 0 |
| 2nd weeding | 0 | 3.073223 | 0.123432 | 0.621143 | 0.021342 | 0 |
| 3rd weeding | 4.093171 | 0.133386 | 0 | 0 | 0 | 0 |
| Fertilizer appl. | 29.44854 | 0.698945 | 0.314553 | 0.310571 | 0 | 0.027872 |
| Harvesting | 24.03345 | 9.870595 | 0.298626 | 2.078439 | 0.005335 | 0.003982 |
| Threshing | 10.09755 | 2.662393 | 15.61617 | 0.73263 | 0.085367 | 0.167231 |
| Winnowing | 0.055744 | 2.529007 | 2.102329 | 0.605216 | 0 | 0.099542 |
| Transportation | 4.093171 | 0.533546 | 0.051762 | 0.055744 | 0 | 0.051762 |
| **Total** | **128.919** | **55.10993** | **18.91698** | **13.32272** | **0.112045** | **0.350388** |
| **Operations** | **FLAB** | **HLAB** | **AM** | **AF** | **Children** | **Total labour** |
| Land preparation | 37.17364 | 4.53912 | 23.1097 | 18.53538 | 0.067689 | 41.71276 (19.25) |
| Planting | 35.38602 | 0.939677 | 32.59407 | 3.628111 | 0.103524 | 36.3257 (16.76) |
| 1st weeding | 20.55664 | 3.440175 | 10.31256 | 13.44535 | 0.238901 | 23.99681 (11.07) |
| 2nd weeding | 3.196655 | 0.642485 | 0.621143 | 3.094565 | 0.123432 | 3.83914 (1.77) |
| 3rd weeding | 4.226558 | 0 | 4.093171 | 0.133386 | 0 | 4.226558 (1.95) |
| Fertilizer appl. | 30.46203 | 0.338443 | 29.75911 | 0.698945 | 0.342425 | 30.80048 (14.21) |
| Harvesting | 34.20267 | 2.087756 | 26.11189 | 9.875931 | 0.302608 | 36.29042 (16.74) |
| Threshing | 28.37611 | 0.985228 | 10.83018 | 2.74776 | 15.7834 | 29.36134 (13.55) |
| Winnowing | 4.687079 | 0.704758 | 0.66096 | 2.529007 | 2.201871 | 5.391838 (2.49) |
| Transportation | 4.678479 | 0.107505 | 4.148915 | 0.533546 | 0.103524 | 4.785984 (2.21) |
| **Total** | **202.9459 (93.64)** | **13.78515 (6.36)** | **142.2417 (65.63)** | **55.22198 (25.48)** | **19.26737 (8.89)** | **216.731** |

***Source:*** Field survey, 2020
***Note:*** AM = Adult male; AF= Adult female; values in ( ) are percentage.

**Maximum Likelihood Estimates of Stochastic Labour-Use Frontier Function**

A cursory review of the MLE of the stochastic frontier function showed the variance parameters *viz.* sigma square and gamma to be within the plausible margin of 10% probability level. Thus, the former implies that the distribution assumed for the composite error term is correct and fit while the latter indicates that the dominant sources of random error are systematic influences that are unexplained by the labour-use function (Table 4). Besides, there is presence of inefficiency effect in the labour efficiency that owes to differences in farmers idiosyncratic characteristics.

The gamma coefficient of 0.4184 depicts that 41.84% of the variation in the total labour-use among the farmers is due to the disparities in their labour efficiencies. The calculated LR $chi^2$ being greater than the tabulated as evidenced by the generalized likelihood ratio test, implies that inefficiency effect is present, thus the traditional response (OLS) model is not an adequate representation for the data (Table 5).

Furthermore, the significant variables that influenced labour requirements are seed, depreciation on capital item and farm size while labour inefficiency is affected by age, gender, marital status, independent household ratio and experience as evidenced by the plausibility of their respective parameter estimates at 10% significant level. The positive significant of the seed coefficient implies that a high labour requirement was used during seed sowing and the possible reason is that local and fourth filial generation seed varieties were used. Therefore, the marginal and elasticity implications of a unit increase in seed quantity will lead to an increase in labour-use by 0.08 man-days and 0.08% respectively. The positive significant of depreciation on capital items coefficient indicated that obsolesce of the farm implements due to wear and tear resulted in high labour quantity utilization in rice production. Thus, the marginal and elasticity implications of a unit increase in wear and tear of the capital will lead to an increase in labour-use by 0.003 man-days and 0.13%, respectively. The positive significant of the farm size coefficient indicated that the unit of cultivation was large, thus utilization of high labour quantity as most of these farmers lack economic capital. Because of the farmers in ability to procure or lease labour saving implements, a high quantity of manual labour is deployed in rice production. Therefore, the marginal and elasticity implications of an increase in a farm size by 1 hectare will lead to an increase in labour-use by 6.46 man-days and 0.18%, respectively.

However, the agrochemicals *viz*. inorganic fertilizer, herbicides and pesticides were not used in sufficient quantity, thus the reason for the non-significant of their estimated coefficients. The negative coefficient of inorganic fertilizer showed that the farmers used synthetic liquid form which required less man-day as compared to the granulated form due to the use of sprayer implements. In the same vein, the weed suppressant-repellent effect of herbicides made the farmers to utilize little labour during land preparation and weeding as evidenced by the negative sign of herbicides coefficient. On the other hand, use of pesticides, a powdery substance required much labour in order to ensure adequate spray in the field against the use of few hands, thus the positive sign associated with the pesticide's coefficient. The non-significant of the output coefficient depicts diseconomies of size which did not come as a surprise because most of the farmers cultivate rice on a small-scale basis. Thus, an increase in output implies an increase in labour utilization for post-harvest operations.

The negative significant of the age coefficient implied that old farmers are more labour efficient; since they are not energetic enough, they are conscious in labour utilization and are less likely to embark on futile labour exercise that has a consequence on judicious use of their labour workforce. Besides, coupled with experience in the rational allocation of resources, they are likely to be more efficient that the young farmers who are mostly novice in the rice farming enterprise. Therefore, for a unit increase in a farmer's age, his/her labour inefficiency will decrease by 0.04%. The negative significant of the gender coefficient depicted that gender stereotype due to cultural barrier hinders women's folk access to and control of production resources, thus affected their labour efficiency. In addition, most of the farm implements used are designed to suit men and not women, thus increasing the drudgery and ergonomic challenges faced by women farmers. Thus, access to and control of productive resources and less ergonomic hazard encountered by the male farmers play a crucial role in decreasing their labour inefficiency by 0.99%. The negative significant of the marital status coefficient implied that married farmers are more labour efficient that their single counterparts. Apart from the twin capital benefits *viz*. social and economic capitals associated with marriage; the need to carter for household forced married farmers to take to sustainable rice farming. Therefore, the need to achieve sustainable income inflow makes married farmers to be rational in resource allocation, thus achieving efficiency in farm labour utilization.

Therefore, being married will lead to a decrease in labour inefficiency by 0.45%. The positive significant of the household coefficient implied that less of the able-bodied household members are involved in the rice farm operation, thus affected farmers' labour efficiency. This is true as able-bodied household members take to white-collar jobs with little or no money remittances to the household to substitute for hired labour. Also, on the other hand, it depicts a household composed of vulnerable people *viz*. old people and women; thus affected the labour-use efficiency. Thus, an increase in a farmer's household by one adult person will lead to an increase in his/her labour inefficiency by 0.15%. However, though not significant, there is an exploitation of dependent household members-children below 18 years as evident by the negative sign associated with the dependent household member coefficient which implied an increase in labour efficiency. The positive significant of the experience coefficient implied that longevity in the rice farming makes experienced farmers to develop complacency to innovative labour-saving technologies, thus affected their labour efficiency. Therefore, an increase in the farmers' experience by one year will lead to an increase in their labour inefficiency by 0.04%.

**Table 4.** MLE of the stochastic labour-use frontier

| Variable | Coefficient | Standard error | t-statistic |
|---|---|---|---|
| ***Deterministic model*** | | | |
| Constant | 2.9618 | 0.5603 | 5.285*** |
| Inorganic fertilizer (kg) | -0.0183 | 0.0522 | 0.350NS |
| Seed (kg) | 0.0792 | 0.0460 | 1.722* |
| Herbicides (litre) | -0.0538 | 0.0462 | 1.164NS |
| Pesticides (kg) | 0.0423 | 0.0487 | 0.868NS |
| Capital item Deprec. (N) | 0.1307 | 0.0470 | 2.777*** |
| Farm size (hectare) | 0.1821 | 0.0607 | 2.995*** |
| Output (kg) | 0.0279 | 0.0566 | 0.493NS |
| ***Inefficiency model*** | | | |
| Constant | 1.0326 | 0.4804 | 2.149** |
| Age | -0.0395 | 0.0240 | 1.648* |
| Gender | -0.9876 | 0.4871 | 2.027** |
| Marital status | -0.4496 | 0.2057 | 2.185** |
| Education | 0.0270 | 0.0201 | 1.350NS |
| Children composition | -0.0283 | 0.0648 | 0.436NS |
| Adult composition | 0.1530 | 0.0902 | 1.695* |
| Experience | 0.0413 | 0.0214 | 1.925* |
| Mode of land acquisition | -0.4356 | 0.3601 | 1.209NS |
| DHF | 0.0089 | 0.0117 | 0.751NS |
| DHM | 0.0209 | 0.0166 | 1.254NS |
| Co-operative membership | -0.1703 | 0.1524 | 1.117NS |
| ***Variance parameters*** | | | |
| Sigma-squared($\sigma^2$) | 0.4039 | 0.0700 | 5.766*** |
| Gamma ($\gamma$) | 0.4184 | 0.1217 | 3.437*** |

***Source:*** Field survey, 2020

***Note:*** *, **, *** and NS means significance at 10%, 5%, 1% and non-significant respectively

**Table 5.** Generalized Likelihood ratio test of hypothesis for parameters of SLFF

| $H_0$ | Log likelihood function | $\lambda$ | Critical | Decision |
|---|---|---|---|---|
| $\gamma = 0$ | -265.89 | 168 | 77.92 | $\gamma \neq 0$ |

*Source:* Field survey, 2020

*Note:* $\lambda = -2(47 - 131) = 168$

Though, non-significant, the signs associated with inheritance, the distance of farm from home, the distance of home from market and the co-operative membership coefficients convey useful information. The negative sign of the inheritance coefficient implies that the ability to enhance land productivity *viz.* reclamation among farmers that inherited their farmlands enhanced their labour efficiency. Farmers with farmland far away from their homes are more labour efficient as there is little or no distraction that are likely to emanate from their abodes, thus more valuable time is spent on the farm. However, farmers that have their homes close to the markets spent most of their valuable time in non-farm and off-farm market activities than on-farm activities; thus affected their farm labour efficiency. The pecuniary advantages benefited by farmers that belong to the co-operative associations made them to be more labour efficient than their counterparts who had no co-operative membership.

**Labour-use Efficiency Scores**

On average, the mean labour efficiency is 0.866, implying that an average farmer achieved a labour efficiency of 86.6% that is below the defined frontier level (Table 5). Besides, an average farmer's labour efficiency fell short of the maximum defined frontier level by 13.4%. Thus, it can be inferred that an average farmer lost a potential labour-use of 13.4% in the production of rice. In other words, 13.4% of labour man-days utilized in rice production of average farmers were wasted relative to the best practiced farms facing the same technology and producing the same output. Furthermore, the frequencies of occurrences of the predicted labour efficiency above the average score represents 84.5% of the sampled farmers, thus indicating that most of the farmers are fairly efficient in labour utilization at a given level of output using available technology at their disposal in the studied area. However, approximately 15.6% of the sampled population had their labour efficiency in the range of 30-70%, indicating that at least 30% of their potential labour input is lost to inefficiency. The worst and best labour efficient farmers achieved efficiency scores of 0.398 and 0.954 respectively; while the most frequent efficiency score is 0.89. Therefore, it can be inferred that the worst and best practiced farmers lost potential labour inputs of 60.16 and 4.57% in rice output due to factors that are within their control. For the worst, average and best practiced farmers to be on the frontier level they need to increase their labour efficiency by 39.8, 13.4 and 4.57%, respectively. However, for the worst and the average farmers to be on the same level as the best practiced farmers they need to increase their labour efficiencies by 9.22% {[1-(0.866/0.954)]×100} and 58.24% {[1-(0.398/0.954)]×100}, respectively. Generally, most of the farmers were relatively efficient but there still exists an opportunity for them to increase their labour efficiency so as to optimize allocation of labour resource in rice production.

**Table 6.** Frequency distribution of labour-use efficiency scores

| Efficiency level | Frequency | Relative frequency % |
|---|---|---|
| 0.30-0.39 | 1 | 0.277778 |
| 0.40-0.49 | 4 | 1.111111 |
| 0.50-0.59 | 0 | 0 |
| 0.60-0.69 | 11 | 3.055556 |
| 0.70-0.79 | 40 | 11.11111 |
| 0.80-0.89 | 158 | 43.88889 |
| 0.90-0.99 | 146 | 40.55556 |
| 1.00 | 0 | 0 |
| Total | 360 | 100 |
| **Mean** | 0.865712 | |
| **Maximum** | 0.954285 | |
| **Minimum** | 0.398376 | |
| **Standard deviation** | 0.080365 | |

*Source:* Field survey, 2020

## 4. CONCLUSION

Based on the findings, it was suggested that the enterprise is not gender sensitive as gender stereotype hindered women's access to and control over productive resources. Besides, the enterprise is dominated by a low level literate people that engaged in sustainable production so as to earn a sustainable income that will guarantee sustainable households' livelihood. Most of the farmers had adequate experience in the production of rice and benefited from pecuniary advantages that wade-off diseconomies of scale due to the cultivation of thinly uneconomic holdings. The poor economic capital status of the farmers made them to deploy labour majorly from families, thus keeping their wards out of schools. Furthermore, the empirical evidence showed that most of the farmers were fairly efficient in the utilization of labour input with little effort needed by them to achieve optimum labour efficiency. It was observed that labour inefficiency owes majorly to search for white collar jobs that affect farm labour supply by the able-bodied household members; and, conservative attitudes and complacency against the adoption of innovative rice technologies due to many years of experience in the enterprise. Therefore, based on the foregoing the following recommendations were proffered:

- Policymakers should introduce gender budget mainstream into agricultural sector so that women farmers can have access to and control over productive resources. This will help in reducing poverty-escape from a vicious cycle of poverty, enhance growth, promote sustainable development and build good governance.
- Given that most of the farmers need little push to achieve optimum labour efficiency, more technical support from policymakers-governmental and non-governmental organizations should be given to the farmers.
- The enterprise should be made more attractive through the provision of credit-kind and cash so as to attract and encourage the teeming population that rushed for white-collar jobs, thus enhancing rice food security in the studied area.
- Besides, advisories services should adopt more of practical demonstrations so as to change farmers' attitudes, especially the experienced ones, towards improved rice technologies.
- Also, farmers should be sensitized on the importance of child education to the immediate environment and the society at large by providing them with light labour substitute technologies at subsidized rates with a fair amortization time frame for repayment.

## COMPLIANCE WITH ETHICAL STANDARDS

### Authors' Contributions

All authors have contributed equally to the work. All authors read and approved the final manuscript.

### Conflict of Interest

The authors declare that there is no conflict of interest.

### Ethical Approval

For this type of study, formal consent is not required.

### Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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MUŞ ALPARSLAN ÜNİVERSİTESİ TARIM VE DOĞA DERGİSİ

MUŞ ALPARSLAN UNIVERSITY JOURNAL OF AGRICULTURE AND NATURE

# Characterization of shell, spine and Aristotle's lanterns of the invasive *Diadema setosum* in Iskenderun Bay

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**A B S T R A C T**

The invasive sea urchin Aristotle's lanterns, shell and spines describe as biological materials. In order to confirm this suggestion, the physical and chemical properties of Aristotle lantern, shell and spine of the invasive *Diadema setosum* distributed in the Iskenderun Bay were explained for the first time in this study. This species was prepared for the Fourier transform infrared spectroscopy (FT-IR), X-ray diffraction (XRD), energy dispersive X-ray spectroscopy (EDS) and scanning electron microscope (SEM) evaluation of Aristotle's lantern, shell and spine. The results showed that the shell, spine and Aristotle's lantern are composed of rough, microporous, multilayered, rough and fiber-like structures. According to XRD results, Aristotle's lantern, shell and spine were found to be similar to calcite. As a result, the shell, spine and Aristotle's lantern of *D. setosum* are qualified biological materials that can be used in many areas such as biosorption, biocatalyst, medicine, biomedical applications and lime welding.

## 1. INTRODUCTION

*Diadema* sp. sea urchin is a widely distributed, abundant and ecologically important tropical sea urchin genus (Muthiga & McClanahan, 2020). *Diadema setosum* (Leske, 1778) (Echinodermata: Echinoidea: Diadematidae) is one of echinoderm species distributed in the Indo-West Pacific Ocean. This invasive sea urchin species is distributed in the Red Sea (Gulf of Suez, Gulf of Aqaba, Northern and Southern Red Sea) and from the east coast of Africa to Japan and Australia (Lessios et al., 2001). *D. setosum* was first reported in 2006 in the Mediterranean Sea, the southwestern coast of Türkiye (Yokes, 2006). It has also been reported in Türkiye's Mediterranean coast, Hatay (Turan et al., 2011), Aegean Sea (Yapıcı, 2018), and Marmara Sea (Artüz & Artüz, 2019). *D. setosum* is defined by its long dark spines, five white spots around the shell, and an orange colour around the anal cone (Clark, 1925; Lessios et al., 2001). *D. setosum* is an omnivorous digger that eats free substrate and feeds on detritus. The invasive sea urchin lives in the shallow sublittoral region (0-20 m) and mostly congregates at 1-6 m depth.

Found in rocky habitats and biogenic reefs, where it hides in crevices and under ledges, especially due to intense lighting, *D. setosum* has also been reported to be distributed in sediment and seagrass meadows (Muthiga & McClanahan, 2020). The species exhibits variable reproductive patterns in altered geographic regions that are influenced by local environmental factors such as temperature, moon phases, and congener and adult densities. Because of their high densities, species can turn rocky shores into barren (Muthiga & McClanahan, 2020) and coral reefs, in particular, can erode biogenic substrates (Bronstein & Loya, 2014). Studies on echinoids are generally very limited with studies such as determination of heavy metal accumulation levels, biology, population density, distribution, chitin and chitosan production (Downs et al., 1993; Flammang et al., 1997; Al Najjar et al., 2018; Çağiltay et al., 2022; Öndes et al., 2022; Uğurlu & Duysak, 2022a, 2022b).

The aim of this study is to determine the microstructure characterization of the shell, spine and Aristotle's lanterns (teeth) of *D. setosum*. In this context, surface morphology, chemical contents and crystal structures will be determined by Fourier Transform Infrared Spectroscopy (FT-IR), X-Ray Diffraction (XRD), Energy Dispersive X-ray Spectroscopy (EDS) and Scanning Electron Microscope (SEM) analyses of sea urchin shell, spine and Aristotle structures.

## 2. MATERIAL AND METHOD

The sea urchin (*D. setosum*) was collected (n=5) in February 2023 from the Iskenderun station located on the northeast coast of the Iskenderun Bay (Figure 1). Sea urchins collected from the stations were transported to the laboratory in a bucket. Then the shells, spines and Aristotle's lanterns were washed abundantly with distilled water. The washed samples were left to dry separately in an oven at 70°C for one day. Dried shells, spines and Aristotle's lanterns were pulverized with the help of a mixer mill and passed through a 300 μ filter. All samples were stored in the freezer (-20°C) until analysis.

### XRD Analysis

X-Ray diffraction microstructural measurements (XRD) were made in Iskenderun Technical University Central Research Laboratory. With this analysis, it was aimed to determine the crystalline structures of sea urchin shell (testa), spine (spin) and tooth (Aristotle lantern) samples. In this study, Malvern Panalytical EMPYREAN 3rd generation (UK) device was used. XRD analysis was recorded with CuK$\alpha$ radiation at 45 kV and 30 mA. Scanning speed was 0.033° and scanning range was between 2θ=5° and 80°.

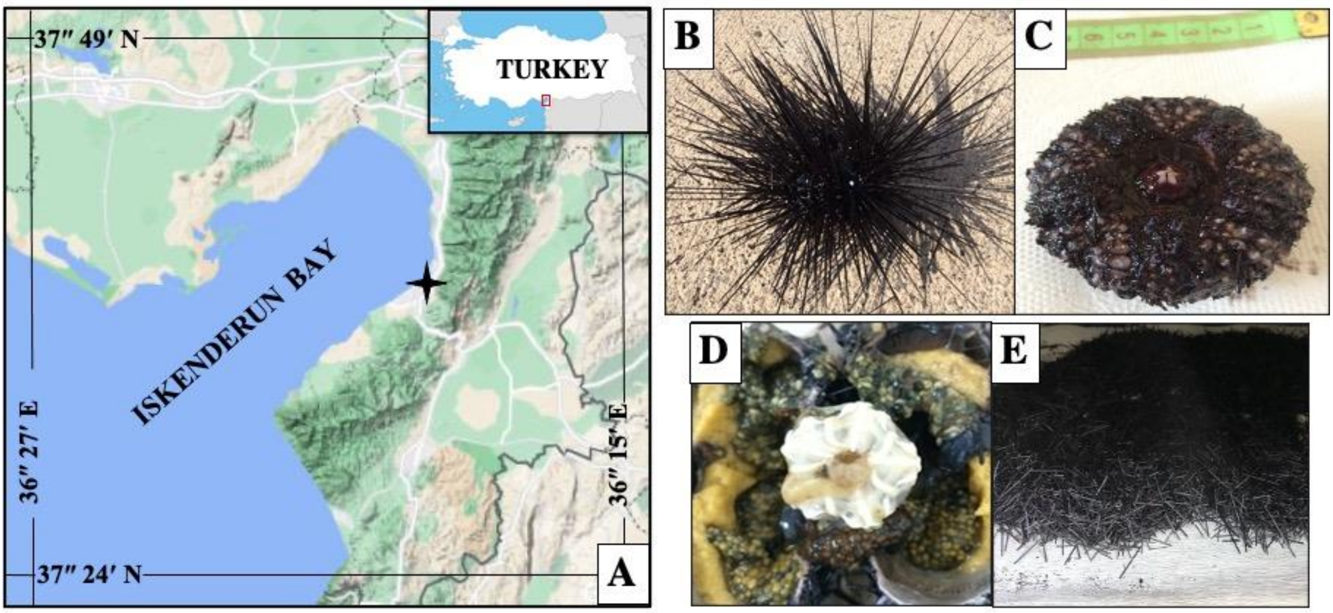


**Figure 1.** A) Study area (Anonymous, 2023; GM, 2023), B) *Diadema setosum*, C) Shell D) Aristotle's lantern and E) Spine

**FT-IR Analysis**

Fourier Transform Infrared (FT-IR) Spectroscopy measurements were made in Iskenderun Technical University Central Research Laboratory. It was determined by FT-IR spectrophotometer (Jasco/FT/IR-6700) device at 400-4000 $cm^{-1}$ wavelength using ATR (Attenuated Total Reflectance) technique for shell, spine and Aristotle's lanterns analysis.

**SEM-EDS Analysis**

The obtained powder samples were coated with gold-palladium (Au-Pd) using POLARON SC7620 spray coating device before being displayed in the Central Research Laboratory of Iskenderun Technical University. Different sizes of images were taken under SEM (Scanning Electron Microscopy) (JEOL JSM-638OLA) using samples at 10-15 kV. In addition, to determine the chemical contents of these samples, energy dispersive X-ray spectroscopy (EDS) connected to the SEM device was used.

## 3. RESULTS AND DISCUSSION

The surface morphology, chemical components and crystal structures of the hard structures (shell, spines and teeth) of the sea urchin *D. setosum* taken from the Iskenderun Bay were investigated. In this context, XRD, FTIR, SEM and EDS analyses of *D. setosum* shell, spines and Aristotle's lanterns are presented in Figures 2-5.

**XRD**

Crystal structures of sea urchin shell, spine and Aristotle's lanterns raw powders were determined by XRD analysis (Figure 2). In Figure 2, the peaks obtained from the XRD patterns of 3 different powders of sea urchin represent the calcite phases. The most severe peaks seen in the XRD pattern are calcite of $CaCO_3$ at 2θ = 23.08°, 29.41°, 31.43°, 36.02°, 39.41°, 43.19°, 47.55° and 48.53°. It has been found to be related to its structure (Downs et al., 1993).

As can be seen in Figure 2, it has been determined that the majority of the structure belongs to the calcite phase. It is important that components such as shell and spines of *D. setosum*, which is an invasive species in Turkish waters, contain calcite in terms of providing an economic benefit for this species. Because calcite is one of the main ingredients used in plastic, rubber, paint, sticky, pigments, toothpaste, cosmetics, paper, feed, pharmaceutical and food industries (Yener, 2015).

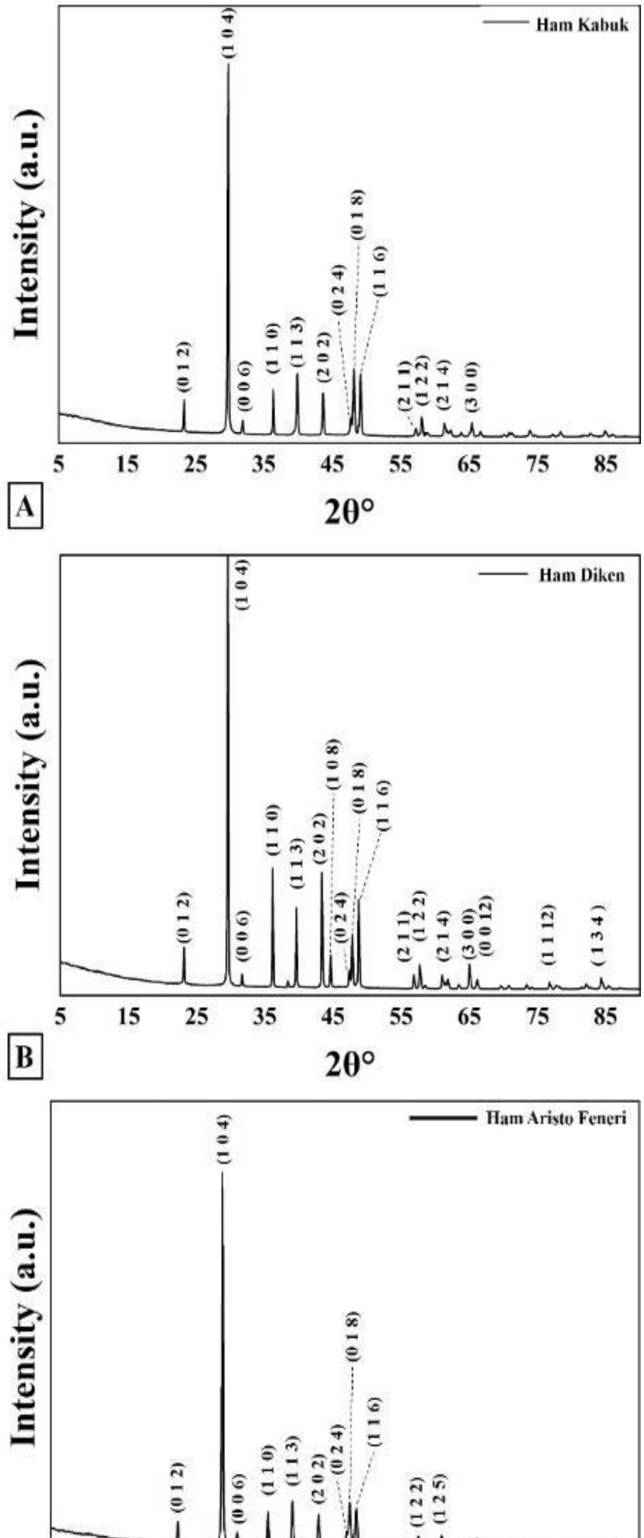


**Figure 2.** X-ray diffraction of sea urchins (*D. setosum*) shell (A), spines (B) and Aristotle's lanterns (C) samples.

**FT-IR**

Infrared characterization of the samples was performed to examine their spectral properties indicative of chemical bonding in sea urchin shells, spines and Aristotle's lanterns. Infrared spectra *D. setosum* shells, spines and Aristotle's lanterns powder is shown in Figure 3.

In Figure 3, the FT-IR spectrum of the sea urchin shell, spine and Aristotle's lanterns was determined between 4000-400 $cm^{-1}$ wavelengths. The absorption band of the $CO_3$ group at 874.56–1403.92 $cm^{-1}$. Accordingly, it can be characterized as O-H stretching of the peak around 3270 $cm^{-1}$, C=O stretching of the peak around 1400 $cm^{-1}$, O-H bending of the peak around 1370 $cm^{-1}$, C-C stretching of the peaks around 1000 and 710 $cm^{-1}$. An important absorption peak of carbonate was observed at 1403.9 $cm^{-1}$, 1412.8 $cm^{-1}$ and 1421.1 $cm^{-1}$ in sea urchin shells, spine and Aristotle's lanterns, respectively. Amide I functional groups represented by smaller absorption bands in sea urchin shells, spine and Aristotle's lantern powders are 1645.95, 1644.81 and 1642.76, respectively.

The band representing Amide I functional groups has been reported between 1639 $cm^{-1}$ and 1646 $cm^{-1}$ (Yang et al., 2005; Li et al., 2005). The FT-IR results also showed the absorption peak of calcite at 874.56 $cm^{-1}$, 874.43 $cm^{-1}$ and 874.12 $cm^{-1}$ of $CO_3^{-2}$ in the sea urchin shells, spine and Aristotle's lantern, respectively (Figure 3). Jung et al. (2000) reported that they observed the absorption peaks of calcite at 875 $cm^{-1}$ in their study. These results supported that the sea urchin shell, spine and Aristotle's lantern were calcite.

**SEM-EDS**

The SEM and EDS analysis results of the shell (Figure 4A), spine (Figure 4B) and Aristotle's lanterns (Figure 4C) of the pulverized sea urchin *D. setosum* are given in Figure 4 and Figure 5, respectively. The surface morphologies of shell, spine and Aristotle's lantern samples of sea urchin are shown in Figure 4. Although the surface of the sea urchin shell (Figure 4A), viewed at 5 μ and 1 μ magnification, appears straight at first glance, it was determined that its structure was rough and consisted of micro-pore and fibre-like structures. As a result of the SEM analysis of the sea urchin spines (Figure 4B), it was determined that there were vertical and transverse overlapping structures, and at the same time, each layer had a surface area as if it were made up of very dense fibres. Finally, in the SEM image of the tooth structure of the sea urchin, which is called Aristotle's lantern (Figure 4C), it was understood that it was gathered from vertical columns of dense fibrous and regionally different thicknesses. In addition, it was observed that the surface structure was multi-layered and rough.

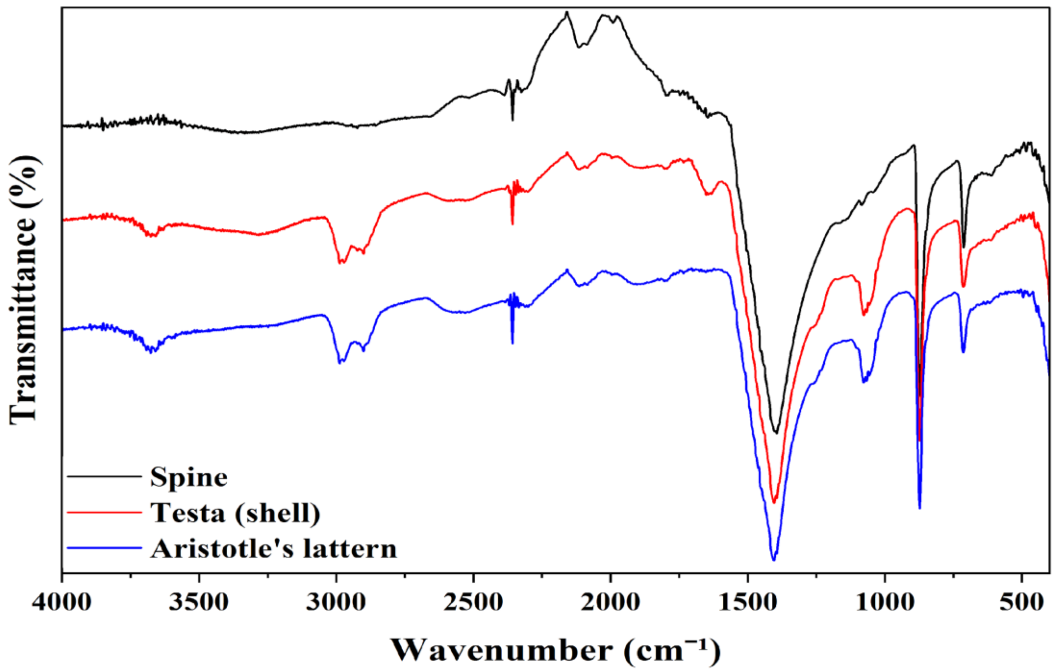


**Figure 3.** FT-IR spectrum of *D. setosum* shell, spine and Aristotle's lantern

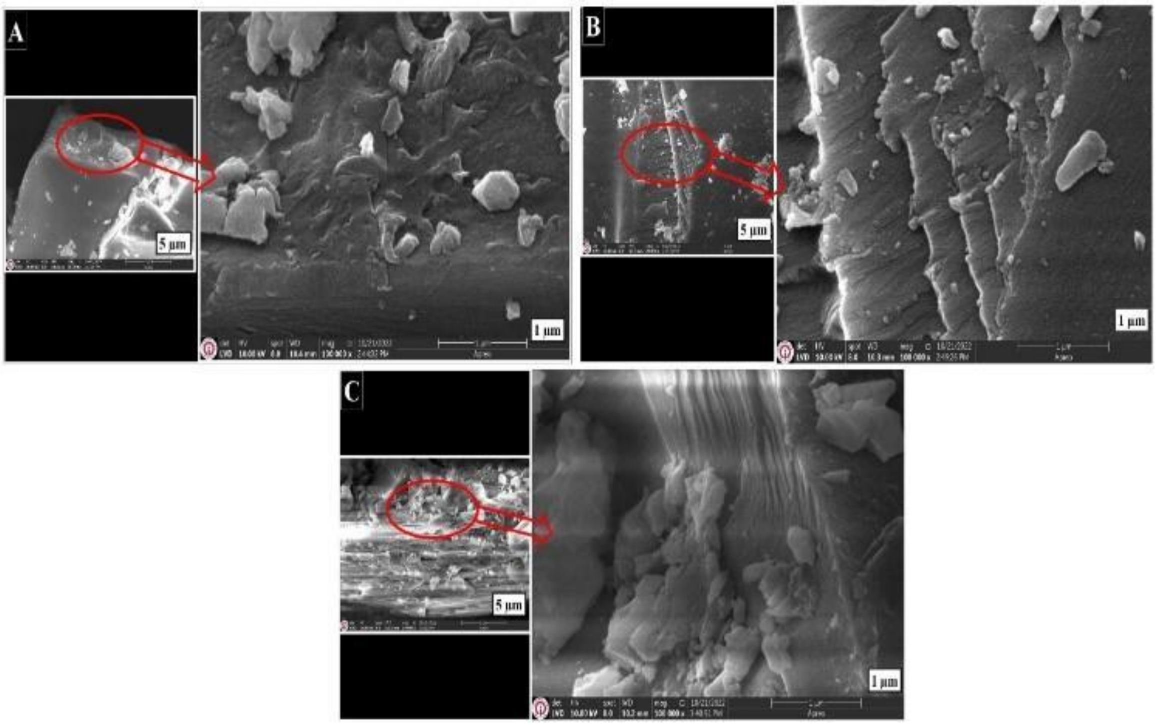

**Figure 4.** Structure of the *D. setosum* **(A)** Raw shell, **(B)** Raw spine **(C)** Raw Aristotle's lantern.

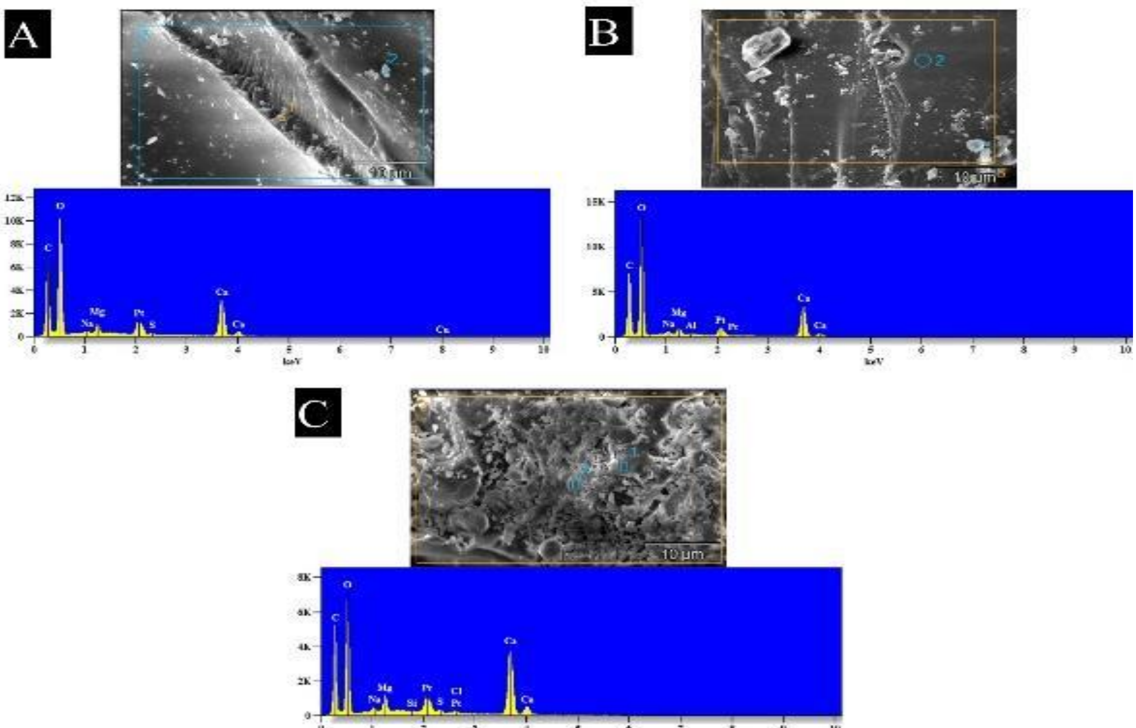

**Figure 5.** *Diadema setosum*: **A)** Raw shell **B)** Raw spine **C)** Raw Aristotle's lantern

The microstructure of the shell, spines and Aristotle's lantern of *D. setosum* has not been studied, except for investigations on the heavy metals, biomaterials or distribution (Flammang et al., 1997; Al Najjar et al., 2018; Öndes et al., 2022; Uğurlu & Duysak, 2022a, 2022b). The present study contributes new data on the morphology and the crystalline characterization of calcium carbonate structures in a shell, spines and Aristotle's lantern of *D. setosum*.

**Table 1.** EDS results of sea urchin shell, spines and Aristotle's lantern (Wt: weight and at: atom)

| Elements | Shell | | Spine | | Aristotle's lantern | |
|---|---|---|---|---|---|---|
| | *Wt %* | *At %* | *Wt %* | *At %* | *Wt %* | *At %* |
| C | 13.19 | 23.04 | 11.92 | 19.66 | 11.27 | 20.92 |
| O | 45.22 | 59.27 | 51.87 | 64.24 | 39.24 | 54.67 |
| Mg | 1.79 | 1.54 | 1.48 | 1.20 | 2.17 | 1.99 |
| Cl | - | - | 0.16 | 0.09 | 0.58 | 0.37 |
| Ca | 26.79 | 14.02 | 27.44 | 13.57 | 35.78 | 19.90 |
| Pt | 11.87 | 1.28 | 6.48 | 0.66 | 9.69 | 1.11 |

In the element analysis of the outer shell of the sea urchin, its spine and the Aristotle's lantern with the EDS device, oxygen (O), calcium (Ca), carbon (C) and platinum (Pt) elements were determined, from largest to smallest, respectively, according to their weight percent ratio (Figure 5). The results of EDS analyses are shown in Figure 5 indicating that shell, spine and Aristotle's lantern powders own similar elements such as Ca, C, Mg (magnesium) and O.

It is thought that the platinum element detected as a result of the EDS analysis of sea urchin shell, spines and Aristotle's lantern is due to the coating of the samples with gold platinum before imaging (Table 1). Similar results were reported by Saharudin et al. (2018), Jones et al. (2011), Suteu et al. (2012) and Kamba et al. (2013) where the elements of raw powders detected through EDS were Ca, C, Mg and O.

## 4. CONCLUSION

The surface morphology, chemical contents and crystal structures of the shell, spine and Aristotle's lantern materials of the invasive *D. setosum* sea urchin distributed in the Iskenderun Bay were revealed for the first time in this study. SEM, FT-IR and XRD analyzes have been made to bring the hard structures of this species, consisting of calcium carbonate, into the economy, which reach dense populations in the bay and are not consumed as human food, in various fields. The shell, spine and Aristotle's lantern of *D. setosum* is qualified biological materials that can be used in many areas such as biosorption, biocatalyst, pharmaceutical, biomedical applications and lime source. The use of hard structures of this invasive species, which is distributed along the Turkish coasts, will ecologically reduce the pressure on the endemic species and thus provide economic support.

## COMPLIANCE WITH ETHICAL STANDARDS

### Conflict of Interest

The author declares that there is no conflict of interest.

### Ethical Approval

For this type of study, formal consent is not required.

### Data Availability Statement

The data that support the findings of this study are available from the author upon reasonable request.

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# Germination Physiology and Optimum Values in Cereals

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**Review Article**

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**A B S T R A C T**

Seed germination is the first important stage of plant growth. It is also a critical step for plant productivity. The morphological changes during germination, followed by physiological and biochemical changes, are strongly correlated with vegetative growth, which affects seedling survival and ultimately yields and quality. Seed germination is the process by which a seedling develops from a seed. It is described as the process by which a seed maintains its viability until it reaches optimum conditions, at which point germination is initiated by water absorption through the seed coat. Optimum conditions are generally different for each species. Germination physiology in cereals is an important area of study that controls the growth and development of the plant throughout its life from the seedling stage and has many implications. At the same time, germination stages in cereals are effective in determining seedling persistence and also affect the chemical composition of the seedling. Healthy seedlings can only be obtained through a healthy germination process. This study aims to provide information on seed germination metabolism, germination physiology of cereals and optimum germination values.

## 1. INTRODUCTION

Seed germination is a vital process for all plants. It is also the most important step in agricultural production. In agricultural production practices, it is desirable for seeds to germinate uniformly, as this allows simultaneous cultural practices for product quality. It also helps to ensure that competition between plants is at an equal level. For this reason, it is important to study seed germination physiology in detail and to improve germination parameters, especially for crops.

Germination physiology in cereals is an important basic science with many practical implications, ranging from grain quality assessment to storage and preservation. Germination is the metabolic process that can lead to reduced nutrient content and increased seedling susceptibility in cereals (Rodriguez et al., 2015).

Germination physiology involves highly complex procedures. Endogenous and exogenous factors play an important role in the germination of a seed. Some of the endogenous factors are phytohormones and endosperm degradation. Exogenous factors are environmental influences such as light and temperature (Carrera-Castaño et al., 2020). Seed germination is the first and most important step the plant must take to meet its basic needs. Many biochemical events take place during this important step. It is therefore essential that the seed is (optimally) compatible with internal and external factors during germination.

The germination of the seed depends primarily on the completion of its physiological development and its viability. If it has completed its physiological development and is found to be viable after the relevant viability tests are carried out, the next stage is the dormancy phase of the seed (Yılmaz, 2016). Dormancy can be observed in the seed for many different reasons and this situation should be corrected first (Roman et al., 2022). Otherwise, the seed may not germinate even under optimal conditions. A healthy seed, with or without dormancy, should be in optimal environmental conditions for germination (Notarnicola et al., 2023). Optimum germination conditions may vary from one plant species to another. It is therefore necessary to provide optimum germination conditions specific to each plant species or variety.

Germination literally begins when the seed absorbs water and culminates in the elongation and emergence of the embryo axis (Hernández Cortés, 2022). It is well known that physiological events in living cells depend on the presence of water. Germination is not possible unless water is absorbed from the environment (Küpe, 2023). The absorption of water leads to the initiation of a series of physical and chemical events in the seed and thus to germination. Nutrients stored in the embryo or endosperm of the seed begin to move in the presence of water (Muhie, 2019). A significant amount of water enters the seed in contact with water through swelling and osmosis (Zengin & Sarıbaş, 2020). This is because the osmotic or swelling pressure in the seed is exceptionally high. Therefore, the seed often does not need to be in direct contact to absorb water. In order to germinate, the seed can also absorb the water it needs from the humidity of the air (Sumiahadi, 2020). Germination in cereals is the process by which the ovary wall of the seed dissolves and the rootlet or seed root and shoot emerge. The seed coat expands as it releases stored food reserves from the endosperm. In this context, germination of a grain can be explained as the production of an active form of grain called a seed, and germination involves a wide range of biological processes. Among them, the most prominent common feature is the change in the appearance and chemical structure (nutritional values, antinutritional factors, toxic components) of the seed (Mohammed, 2016). Based on the given information, this study attempted to reveal germination physiology and optimum germination values of cereals from different literature.

### 1.1. Germination Physiology in Cereals

All living things benefit directly or indirectly from cereals, while maintaining their vital activities. While cereal grains are evaluated in terms of carbohydrate, protein and fat (Figure 1.), they are also at the forefront in terms of antioxidant substances in their composition. Oxygen is the basic element found in units such as carbohydrates, proteins and fats, which form the basic structure for vital activities. Cereals are divided into two groups in terms of climatic requirements: warm climate cereals and cool climate cereals. The cool climate cereals are wheat, barley, rye and oats, while the warm climate cereals are maize, paddy, birdseed and sorghum (millet) (Zülkadir, 2022). When the seed morphology of these cereals is examined, it is found that they generally consist of micropyle, radicle, coleoptile, scutellum, pericarp, seed coat, aleurone, endosperm and brush (Figure 2). Although it is the most stored food component, it is approximately 70-80% starch, about 15% protein, and less than 5% lipids, minerals and vitamins (Ali & Elozeiri, 2017) (Figure 1).

Germination in cereals begins with the uptake of water by the seed coat. Contact with water or absorption of moisture from the air softens the seed coat. While water uptake is initially rapid, it slows over the next 5 hours. In addition, the low water content in the seed tissue leads to rapid water uptake in the initial period (Rathjen et al., 2009). As the seed absorbs water, it also absorbs water-soluble substances.

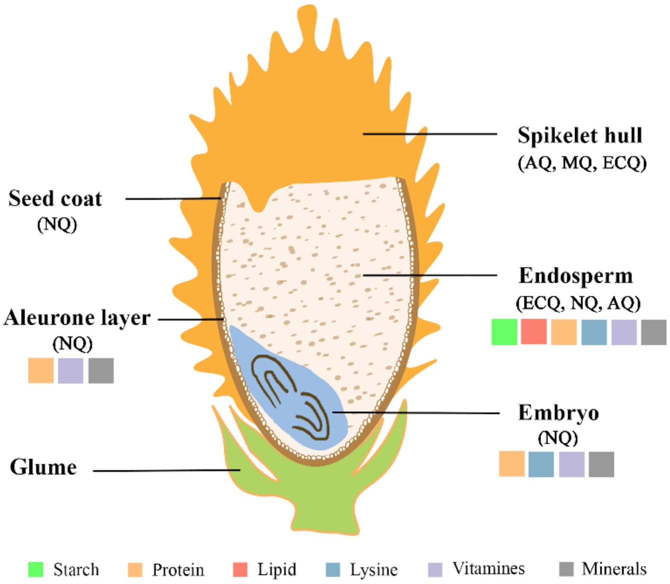


**Figure 1.** Overview of the main structure and components based on a longitudinal section of a mature rice seed (Li et al., 2022)

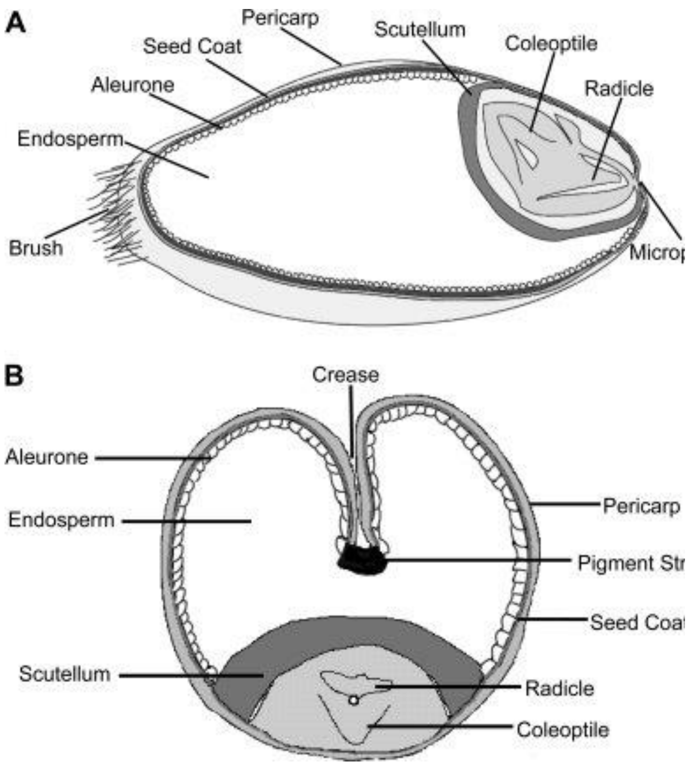


**Figure 2.** Main structure of wheat seed with longitudinal (A) and transverse (B) sections (Rathjen et al., 2019)

After water uptake, the carbohydrates, proteins, lipids and phosphates stored in the seed act as energy sources and carbon skeletons. In order for these storage substances to be taken up by the embryo, they are hydrolysed into a usable form (Figure 4.). In this way, the metabolic pathway activates hydrolytic enzymes. This is accompanied by a high level of oxygen consumption. In cereals, most hydrolytic enzymes are produced in the aleurone or scutellum in response to germination signals (Ali & Elozeiri, 2017). During germination, starch reserves are hydrolysed into simple sugars (Figure 3.), oligosaccharides and polysaccharides by $\alpha$-amylase, nitrogen-containing fractions into oligopeptides and amino acids by proteolytic enzymes, and triacylglycerols into fatty acids by lipase. While the amount of anti-nutritional factors (phytate, trypsin inhibitor, tannin, etc.) decreases, the amount of bioactive components (phenolic acids, flavonoids, GABA, etc.), which have many benefits for human health, increases significantly. The increase in bioactive compounds increases the antioxidant capacity of the grain. This increases the functionality of cereal sprouts (Şenlik & Alkan, 2021). Seed imbibition triggers many biochemical and cellular processes associated with germination, including reactivation of metabolism, resumption of cellular respiration and mitochondrial biogenesis, translation and/or degradation of stored mRNAs, DNA repair, transcription and translation of new mRNAs. These processes are followed by the accumulation of ROS (mainly $H_2O_2$), which is the result of a marked increase in intracellular and extracellular production in the early stages (El-Maarouf-Bouteau & Bailly, 2008; Kubala et al., 2015).

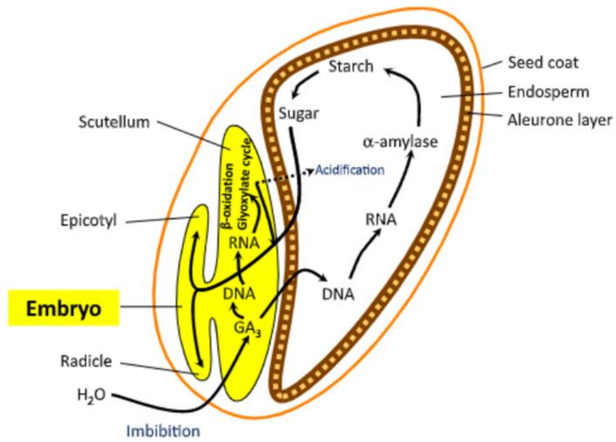


**Figure 3.** Metabolic processes in embryo and endosperm during germination of barley (Ma et al., 2017)

According to Majeed et al. (2012), some of the physiology of germination in cereals include: a) water uptake and its effect on water-soluble substances and growth processes, b) the role of hydrogen peroxide in enzyme activation, c) the effect of temperature on various metabolic activities, and d) micronutrients derived from reserves (Majeed et al., 2012). Cereal germination is closely related to the content and structure of the embryo. Germinating cereal proteins contribute to the functionality of cereal products, such as improving nutritional value through bioavailability or functional properties (Majeed et al., 2012). Germination is the first stage of development that takes place in the cereal grain. At this stage, the processes of water uptake, loss and entry through the grain embryo that cause changes in the volume and morphology of each organ (i.e., endosperm, seed coat and aleurone layer) are interrelated to initiate the process of emergence from dormancy (Kumar & Kalita, 2017). In cereals, it is estimated that more than 50% of the energy invested in growth is used to break down the hard seed coat, which is usually multilayered. After germination, the seedling emerges from the seed coat, roots grow from the embryo and leaves develop from the embryonic leaf primordia (González Carretero et al., 2017).

### 1.2. Optimum Growth Conditions of Cereals Germination Values

Cereals in cool climates can germinate at temperatures as low as 1-4°C (Balşen 2022). They require a total temperature of 1750-2250°C during a growing season (Taner & Bayram, 2005). For this reason, cool climate cereals are generally grown in the winter belt. Wheat and barley are cool climate cereals. Cool climate cereals, which are mostly grown successfully in temperate and cold climates, cannot be grown in tropical climates where it is very hot and rainfall exceeds 1500 mm (Taner & Bayram, 2005).

Cold climate grasses show optimal development in the range of 15-21°C. Originating from the cooler regions of Europe and Asia, the seeds of these plants are highly resistant to cold and are used in areas with continental climates (Kıldış, 2021).

Some wheat genotypes require a certain amount of chilling and light for emergence and germination. Wheat genotypes that do not require chilling or require very little chilling for emergence are called "summer wheats" and those that require chilling are called "winter wheats". The need for chilling is recognized as a mechanism to protect wheat from cold (Okhan, 2022). For this reason, winter wheat is sown in autumn in our country.

The optimum growth temperature of wheat growing areas is 25 degrees Celsius, while the minimum and maximum growth temperatures are between 3-4˚C and 30-32˚C, respectively. In our country, wheat cultivation is mostly carried out in arid and semi-arid areas depending on rainfall, and exposure to dry and high temperatures, especially during the grain growth period, causes a significant decrease in yield (Sayılğan, 2016).

The lowest germination and photosynthetic temperatures of cool-climate cereals, including wheat, barley, oats, rye, triticale and spelt, are 1-4°C and 5-7°C, respectively. They can be grown in regions where the total temperature during the growing season is 1750-2250°C, which can meet the vernalization requirement between germination and stem emergence, with low temperature, cloudy and wet days in the vegetative period and abundant sunny days in the generative period. Cool-climate cereals, which are the most adaptable group of crops to different climatic and soil conditions, can be grown in almost all regions of our country. In our coastal regions, they are generally cultivated under higher rainfall or irrigated conditions, while in our other geographical regions and inland regions, they are mostly cultivated under dry conditions (Kün, 2004).

The responses of cereal germination to environmental factors are important in understanding the limits under which a crop can grow and produce maximum yield. Knowledge of grain germination is of primary importance not only to seed technologists, but also to agronomists, plant physiologists, plant biologists and soil scientists involved in field management (Fowler, 2003).

For warm-climate cereals (such as maize and rice), temperature requirements are quite high. The minimum germination temperature is 9-12°C and the optimum germination temperature is 18-20°C. Low temperatures after emergence will arrest growth, while conditions that prolong the initial growing season will slow growth, facilitate disease infection and reduce yield. It is very important to decide on the sowing date according to the region, taking these values into account. The average daily temperature during the growing season should be above 20°C. Optimum growth temperatures are between 25 and 30°C. Early sowing of the main crop causes cold damage during germination and initial development. The desired early sowing of the second crop depends on the drainage of the field by the preceding crop, while late sowing results in high moisture content in the crop and cold damage in the autumn. During flowering, excessively hot and dry weather damages the inflorescences and disrupts fertilization. Plant reproductive organs are severely damaged by temperatures above 45°C during the flowering period. This problem is particularly important in the production areas of south-east Anatolia and the Mediterranean coast of our country. Variety and sowing time should be chosen correctly so that the flowering period does not coincide with the extremely hot period. The opposite practice increases the rate of infertile spikelets in paddy. Similarly, grain attachment in maize cobs is disturbed and gaps increase (Kün, 2004).

## 2. CONCLUSION

Germination has been described as a process involving complex interactions between a number of factors, including genotype, environment and physiology. It is believed that the knowledge gained from research will lead to advances in breeding and improve the yield and quality of cereals.

Germination is one of the most important steps in crop production. It involves the physiological changes of seeds in water and darkness, including biochemical, morphological and physiological changes that lead to the production of roots and shoots.

By understanding the physiology of cereal germination, growers can improve the quality of their seed and increase yields.

## COMPLIANCE WITH ETHICAL STANDARDS

### Authors' Contributions

The authors declare that they have contributed equally to the manuscript.

### Conflict of Interest

The author declares that there is no conflict of interest.

### Ethical Approval

For this type of study, formal consent is not required.

### Data Availability Statement

Data availability is not applicable to this article as no new data were created or analysed in this study.

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MUŞ ALPARSLAN ÜNİVERSİTESİ TARIM VE DOĞA DERGİSİ

MUŞ ALPARSLAN UNIVERSITY JOURNAL OF AGRICULTURE AND NATURE

# Labour Preferences Among Small-Scale Arable Crop Farmers in Akwa Ibom State, Southern Nigeria

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**A B S T R A C T**

Human labour is critical in the survival and sustainability of the small-scale farm production system in developing countries. Following the imperfection in the rural labour market and the mounting rural poverty, labour demand among resource-poor small-scale farmers has shifted from its traditional surplus supply market pattern to a more competitive labour market. In Nigeria for instance, human labour is not readily available to farmers in most rural farming communities compared to the previous decades. Considering the fact that more than 60% of agricultural production is done by small-scale farmers in the country; there is an overwhelming need to identify ways of increasing labour utilization by the small-scale farmers in the southern region of Nigeria. Premised on these facts, the study primarily examined the prominent labour sources available to small-scale cassava-based farmers and identified determinants of their demand or adoption. The study was conducted in Akwa Ibom State in the southern region of Nigeria. A total of two hundred (200) cassava-based farmers were randomly sampled using a structured questionnaire. Descriptive and multinomial Logit models were employed to analyse the data and objectives of the study. The findings revealed hired labour, family labour and group labour as the major human labour sources for the small-scale farmers in the region. Also, farmers' age, educational attainment, farm income, farming experience, non-farm income, farm size and social capital formation were identified as factors that increase the probability of adopting hired labour relative to the family labour in the region. Similarly, farmers' age, education attainment, social capital formation, farmers' sex and non-farm income were found to increase the probability of using group labour relative to the family labour source. However, household size impacted negatively on the probability of using both hired and group labour relative to family labour. It is recommended that farmers' formal education, farm income and social capital formation should be enhanced to help them in making efficient choices on labour demand in the rural labour market.

## 1. INTRODUCTION

The small-scale farmers in sub-Saharan region of Africa produced the bulk of the food consumed in the region (Chiaka et al., 2022; Okou et al., 2022; Baptista et al., 2022; Akpan & Effiong, 2022). The technique of production used by these farmers in the region is far remoted compared to the methods of production employed in other regions of the World (Ogunkoya et al., 2015; Baptista et al., 2022). The farm resources of these small-scale farmers are often being inefficiently utilized resulting in low outputs. In most instances, the small-scale farmers have poor resource endowments, which often affected factors-combination leading to inefficiency in resource allocation (FAO, 2017; Akpan et al., 2019a, 2022; Ariom et al., 2022). Hence, for sustainable agricultural production in the sub-Saharan Africa region, being dominated by small-scale farmers, production must be anchored on efficient farm resources management (Akpan et al., 2019a, 2022). Preset on these assertions, many government programmes on agriculture in Nigeria have been developed on the framework of small-scale production to improve farm resources management (Okuneye & Ayinde, 2011; Lokpobiri, 2011). This is necessary because previously available farm resources for small-scale farmers to utilize are becoming relatively difficult to access even in rural areas (Adebo & Falowo, 2015; Mgbenka & Mbah, 2016; Edohen & Ikelegbe, 2018).

In some parts of Africa, farm labour has become relatively difficult to access, and the farmers have to choose among the few available forms (Jean-Claude, 2011; Obasi & Kanu, 2014; Jayne et al., 2017). For instance, the scarcity of rural farm labour is a serious challenge in the south-south region of Nigeria, because family labour dominancy has been threatened due to the improvement in human capacity development of most farm households (Udoh & Akpan, 2017). Again, the progressive growth of the urban areas through urbanization and the general perceptions of the youths concerning agriculture in the rural areas as well as the risk component of the agricultural system have further changed the framework and composition of the rural labour market in the region (Akpan, 2010, Akpan et al., 2017c, 2019b; Umoren et al., 2021). As observed by Bedemo et al. (2013), farm labour is seen as a fundamental asset for resource-poor farmers in developing societies. In Nigeria, farm labour composition for small-scale producers majorly revolved around the family labour source, hired labour and group labour sources. Group labour is one of the social capitals that involves the gathering of two or more common-minded people (common among women) with a common goal and identity bound in a formal relationship and are engaged in rotational farming among members (Francis et al., 2000; Saliu & Ojandage, 2008; Edoka et al., 2014). The use of machines and animal power as sources of labour are not widespread among small-scale or peasants' farmers in the south-south region of Nigeria. This is because small-scale farmers are resource-poor and still rely heavily on less efficient techniques of production (Udoh & Akpan, 2007, Salami et al., 2010, Akpan et al., 2017a, 2017b, 2019a; Akpan & John, 2020).

The small-scale farmers' preference for labour sources is conditioned by several factors including economic, social and cultural factors among others. Following the assertions of Ogbalubi & Wokocha (2013) and Gocowski & Oduwole (2003), scarcity of farm labour has posed a serious challenge to the efficiency of small-scale farmers during all farm operations in Nigeria. According to the report of Yeboah & Jayne (2016), human labour constitutes the main source of labour for small-scale farmers in areas of high population. In addition, Yusuf (2018) noted that small-scale farmers have resorted to the use of family labour following the presence of asymmetric information flow in the labour market. However, with the persistent change in needs and perceptions of most farm households, family labour would not provide sustainable farm power to farmers now and in future (Sakho-Jimbira & Hathie, 2020). As figured by Omotesho et al. (2014), farm households' need for a complementary labour source to family labour is awesomely important and is a prerequisite for the attainment of food security in the present and in future generation. The hired labour, which is the closest substitute to family labour among peasant farmers has its problems. As noted by Akpan (2020), the wage rate for hired labour is rising progressively in some rural farming communities in the southern region of Nigeria; while Deotti & Estruch (2016) and John (2019) attributed the rise in wage rate to an increase in rural-urban migration and improvement in farm household human capacity development. As observed by Akpan (2020), the average rural wage rate is competitive, following inelastic demand for labour.

The choice of human labour by the peasant or small-scale farmers in the southern region of Nigeria cannot be over-emphasized. It is documented that human labour accounted for more than 80% of the total farm power and constituted between 80% to 90% of the total variable cost (TVC) of production, hence a major determinant of the gross margins and the sustainability of the small-scale farming system in the region (Udoh & Akpan, 2007, Anyiro, 2013, Nmadu & Akinola, 2015, Akpan et al., 2017a, 2017b). Hence, small-scale agricultural production in Nigeria is particularly labour-intensive in nature (Olayide, 2002; Edohen & Ikelegbe, 2018). Since the farmers' choice of human labour is guided by several categories of factors, it is absolutely important to identify these attributes, especially farmers-specific characteristics. The identification of these factors would enhance efficient resource allocation and management. The overall farm productivity of factors of production will be enhanced while an evidence-based farm labour policy framework can be efficiently enunciated and implemented. Another important justification to identify the factors that model small-scale farmers' choice of human labour stem from the fact that arable crop outputs from the region have been persistently low for years now. These have aggravated poverty, food insecurity, poor revenue and farm income diversification drives among small-scale arable crop farmers in the region. The sustainability of the small-scale arable crop production system in the southern region cannot be guaranteed if labour is not readily available.

Only a few pieces of literature have explored factors that influence farm labour choices among small-scale arable farmers. For instance, in Ethiopia, Bedemo et al. (2013) reported that the probability of farm households choosing hired labour source was significantly and positively determined by farmers' education, dependent ratio, farm size, credit availability, and farm income. Otherwise, the negative determinant was family size. In Nigeria, Bassey et al. (2014) revealed that the probability of farm households using borrowed labour was determined by the household size and wage rate. The report also showed that the probability of farm households demanding hired labour was significantly influenced by farmers' farming experience, educational level, income and age. Moreover, the coefficient of farm size was positive and significantly related to the probability of using both borrowed and hired labour. In a similar vein, Omotesho et al. (2014) revealed that the household dependency ratio, age and years of formal education of the family head, family size and income significantly influenced the use of hired labour among farm households in Kwara State, Nigeria. In South Africa, Anim (2011) reported that farmers' experience, land size, number of farm machineries, agricultural extension services, and farm inputs positively influenced labour supply; while years of formal education of household head, household size, household members engaged in off-farm activities, real wage rate and farm exerted inverse relationship with farm labour supply. As noted by Echebiri & Mbanasor (2003), the household labour constitutes about 97.65% of the total labour source among farmers in Abia State. The findings further revealed variables such as farmer's sex, household size, household marital status, and education of the household head as factors influencing labour supply in the area. Furthermore, Nmadu & Akinola (2015) reported that family and hired labour constitutes the major sources of labour to farmers in Niger State, Nigeria. The study identified farmers' income, household size, wage rate, farm size, and sex as factor that influenced the labour utilization in the area.

The literature available on this critical issue needs to be updated and new variables tested to develop workable policies on labour market in the region. Again, the need to have sufficient, timely delivered and efficient human labour for sustainable arable crop production is inevitably given the high headcount poverty rate of 28.82%, poverty gap index of 7.25 and youth unemployment rate of 40% in the region (NBS, 2022). The region needs an urgent policy direction based on sound empirical research to develop a sustainable policy framework to tackle the prevalent issues of farm labour information asymmetric or imbalances in the farm communities of the State and region. Anchored on these facts, the research was primarily designed to identify factors that modelled the labour choices of arable crop farmers in the southern region of Nigeria.

## 2. MATERIAL AND METHOD

### 2.1. Study Area

The research was carried out in Uyo and Etinan agricultural development programme (ADP) zones in Akwa Ibom State, the southern region of Nigeria. The Uyo ADP zone comprises Uyo, Ibesikpo Asutan, Itu, Uruan and Ibiono Ibom Local Government Areas. The Etinan Agricultural Development Programme (ADP) zone consists of Nsit Ibom, Nsit Ubium, Etinan and Nsit Atai local governments. The similarities in the climatic and soil factors as well as the presence of the large population of cassava-based farmers in these zones were the factors considered for the purposive selection of these zones out of the six zones in the State. Agricultural production is the major occupation of the inhabitants of the region. Varieties of crops and animals are being cultivated and reared respectively in the region. Common crops are cassava, waterleaf, fluted pumpkin and yam, pepper, maize, plantain, banana and cucumber. Some of the cash crops available in the region include oil palm, rubber and cocoa. The average rainfall in the zones ranges from 2000 mm to 3000 mm per annum. Two distinct seasons namely; rainy and dry seasons are noticeable while the annual average temperature and relative humidity in the region range from 26°C to 27°C and 75% to 95%, respectively (NiMet, 2023; cited in Akpan et al., 2019a).

### 2.2. Data Source, The Instrument for Data Collection and the Type of Respondents

Cross sectional information was sourced from the respondents using a well-designed structured questionnaire. The study also conducted interviews with selected key informants (consisting of farmers' groups and community leaders) in the selected farming communities to authenticate and compared the consistency and accuracy of information provided by the respondents. The respondents were arable crop farmers that cultivate majorly cassava crop and a combination of other crops. The choice of respondents was based on the fact that the cassava crop is the most popular food crop in terms of cultivation and consumption in the region (FGN, 2006; Wossen et al., 2017). In the region, almost 100% of food crop farmers cultivate cassava crops either as a major or supporting crop. It is the most proficient food crop that can be used as an indicator for measuring growth in the crop-sub sector in the region.

### 2.3. Sample Size Selection

Using a Cochran (1963) sample size selection formula, the study derived the required sample size from a large population of cassava-based farmers (mixed crop farmers with cassava as a major crop) using the Equation (1):

$$S_x = \frac{z^2\rho(1-\rho)}{D^2} \quad (1)$$

where $S_x$ is the estimated representative sample population; $Z$ connotes the 95% confidence interval (1.96); "$\rho$"; is the percentage of cassava-based farmers in the total population of arable food crop farmers (about 85%) in the two agricultural zones; D represents the absolute error at 5% probability level of type 1 error. The representative population for the study was obtained as shown in Equation (2):

$$S_n = \frac{(1.96)^2 0.85(1-0.85)}{(0.05)^2} = 196 \quad (2)$$

For ease of sampling, the calculated sample population was scaled up to two hundred (200) respondents.

### 2.4. The Sampling Procedure

The study utilized a multi-stage sampling method to pick the required population. The first process was the purposive selection of two agricultural zones in the State. That is Uyo and Etinan agricultural zones were selected because of the high number of cassava mixed crop farmers. The second process was the random selection of two local government areas with a high population of cassava farmers from each of the agricultural zones. A total of four (4) local government areas were selected for data collection. The local government areas selected were; Uyo and Itu, in Uyo ADP zone, while Etinan and Nsit Ibom were selected from Etinan ADP zone. The third stage is based on the random selection of two (2) villages from each of the local government areas earlier selected. Hence, a total of eight (8) villages were selected for the study. The villages contain farm families that cultivate mixed crops with cassava crop as a dominant crop. The fourth stage was the random selection of twenty-five (25) farm families from each of the villages. A total of 200 cassava-based farm families were randomly sampled and used to obtain the needed information for the study.

### 2.5. The Conceptual Framework

From the economic theory, a rational farmer will choose a particular technology only if it maximizes utility relative to the other alternatives available. This suggests that given a set of options or technologies, a rational farmer will always prefer an option that yields higher utility among a set of options on the condition that the farmers' budget constraint is minimized. However, since the options are assumed to be latent variables, the utility gain from the options preferences is not observable but is reflected in the choice of the option adopted by the farmer. Hence, the utility can be exemplified by the probability of choosing an option with higher utility among a set of options as shown in Equation 3. According to Zegeye et al. (2022), farmers' behaviour towards multiple choices of technology could be shown also in their risk-bearing capacity or behaviour. A small-scale farmer is assumed to be rational in his farm decision and is risk averse because he is a resource–poor entrepreneur. Hence, a risk-averse farmer would always seek to maximize farm profit or output by choosing a discrete option of technology that minimizes risk and cost of production. Alternatively, such an option is tended to maximize profit or output subject to the farmers' budget constraints.

$$V_i = \begin{Bmatrix} 1\ if\ U_{max}(V_1) > U_{max}(V_2) > U_{max}(V_3) \\ 2if\ U_{max}(V_2) > U_{max}(V_1) > U_{max}(V_3) \\ 3if\ U_{max}(V_3) > U_{max}(V_1) > U_{max}(V_2) \end{Bmatrix} \quad (3)$$

The adoption of an option among a set of options can be represented in Equation 4. The $M_i$ represents the latent variable or a probability which explains the farmer's behaviour in choosing different forms of labour available to him. The $Z$ is the explanatory variable which conditioned the farmers on the choice of alternative labour. The $\delta$ are the coefficients of the explanatory variables while the $\varepsilon$ is the random error term or the unexplained explanatory variables.

$$\begin{Bmatrix} M_1 = \beta_1 + \delta_1 Z_1 + \varepsilon_1 \\ M_2 = \beta_2 + \delta_2 Z_2 + \varepsilon_2 \\ M_3 = \beta_3 + \delta_3 Z_3 + \varepsilon_3 \end{Bmatrix} \quad (4)$$

It is assumed that the specified explanatory variables ($Z_i$) are uncorrelated with the error term ε's for each of the labour option equation. The error is assumed to be independently distributed in each of the alternatives, hence, the independence of irrelevant alternatives (IIA) hypothesis. The above structural form is the resemblance of the structure of the multinomial Logit because of the different options available to the farmer, hence the justification for selecting the multinomial Logit model.

### 2.6. The Determinants of Farm Labour Choices

Rural households are often confronted with different choices of labour and the use of the multinomial Logit model is appropriate in this case. The Multinomial Logit Model has error terms for each of the choice equations which are independent and identically distributed. The model is proved to produce more stable results when the Independent of Irrelevant Alternatives (IIA) assumption is fulfilled. According to Kropko (2008), the multinomial Logit model is found to provide nearly more accurate and realistic results than other models even when the Independent of Irrelevant Alternatives (IIA) assumption is severely violated. In the specified model, the family labour is considered the base category and all the other Logits are made relative to the base category. A multinomial Logit regression was used to estimate the determinants of farm labour choices of a cassava-based farmer in the study area. According to Gujarati & Porter (2009), a generalised multinomial Logit model is specified as thus in Equation 5:

$$\pi_{ij} = P_r(Y_{ij} = 1) = \frac{e^{\alpha j + \beta_j X_i}}{\sum_{j=1}^{n} e^{\alpha j + \beta_j X_i}} \quad (5)$$

The family labour is used as the base category and all the other Logits are made relative to the base category. Then the estimated multinomial Logit model is specified as follows in Equation 6:

$$\pi_{ij} = P_r(Y_{ij} = j/x) = \frac{exp(x_i \alpha_j)}{1+\sum_{k=1}^{n} exp(x_i \alpha_k)} \quad for\ j = 1, 2. \ldots, k-1 \tag{6}$$

$$\pi_{i1} + \pi_{i2} + \pi_{i3} = 1 \tag{7}$$

$$\pi_i = \emptyset_0 + \emptyset_1 AGE + \emptyset_1 HHS + \emptyset_1 EDU + \emptyset_1 SOC + \emptyset_1 FAS + \emptyset_1 FIN + \emptyset_1 NFI + \emptyset_1 GEN + \emptyset_1 EXP + \mu_i \tag{8}$$

$Y_{ij} = 1$, If a farmer chooses alternative j (j =1, 2, and 3). Where j = 1(family labour); j = 2 (hired labour); j = 3 (group labour). The β's are a set of coefficients attached to each alternative; while X's are a set of explanatory variables that determined the respective probability. The dependent variable ($\pi_{ij}$) represents the probabilities that a farmer chooses alternative 1, 2 or 3 respectively. If there are three alternatives available to a farmer, then the summation of their probability is equal to unity as exemplified in Equation 7.

For an $i^{th}$ option, the explicit model is expressed as shown in Equation 8.

The set of explanatory (X's) variables that defined Equation 8 are given below;

AGE: Age of a cassava-based farmer (years)

HHS: Household size of a cassava-based farmer (number)

EDU: Educational qualification of a cassava-based farmer (year)

SOC: Membership of a social organization by a cassava-based farmer (years)

FAS: Farm size of a cassava-based farmer (ha)

FIN: Farm income of a cassava-based farmer (naira)

NFI: Non-farm income of a cassava-based farmer (naira)

GEN: Sex of a cassava-based farmer (a dummy; where 1: female and 0: male)

EXP: Farming experience of a cassava-based farmer (years)

## 3. RESULTS AND DISCUSSION

### 3.1. The Social and Economic Characteristics of Cassava-Based farmers

The socio-economic features of cassava-based farmers are shown in Table 1. The findings revealed that more than 90.00% of the farmers are in their active age with a mean age of about 43 years. This finding showed the fact that youths (aged 18-35 years) are not actively involved in cassava production in the region. Only 4.00% of the farmers are in the youthful stage. Another implication of this finding is that cassava production in the region might not be attractive enough to command the involvement of the youthful population. Since farmers are mostly resource-poor and the wage rate does not commensurate with the capacity of most youths, the region witnessed disguised unemployment among the youths. Currently, the southern region of Nigeria has a youth unemployment rate of over 40.00% (NBS, 2022).

The result on the pattern of the farmers' household distribution revealed that about 60.00% of the farmers have 4 – 6 children with an average of four (4) members. This reflects the fact that farm households in the region are yielding to the family planning programme implemented in the region by having a smaller number of household members. This has continued to have a deteriorating impact on the availability of family labour as a form of farm labour in the region and thus opens up farmers to other options for farm labour. Alternatively, the contribution of family labour is decreasing with the emphasis being shifted to alternative sources of labour.

Formal education is seen as a motivational and a change factor that can inculcate the habits of entrepreneurship and change attitudes in farmers. The finding indicated about 89.00% literacy rate with an average of 7.00 years of formal education among cassava-based farmers in the region. The social capital acquisition or socialization among small-scale cassava-based farmers in the region is very low with an average of about 1.80 years. The result has a deteriorating effect on trust and social bonding among farmers in the region. Perhaps the issues of increasing insecurity and incessant kidnappings including high poverty rates and other social vices might be responsible for the low capital build-up among cassava-based farmers in the region. Also, the cost implication of being a member of a social group can help to explain the low capital formation among farmers in the region. The majority of the farmers are resource-poor and cannot afford financial obligations inform of levies and charges in a social group.

**Table 1.** The socioeconomic feature of cassava farmers

| Feature | Freq. | % | Feature | Freq. | % |
|---|---|---|---|---|---|
| **Age (Year)** | | | **Household size (number)** | | |
| Less than 35 | 4 | 2.00 | <4 | 70 | 35.00 |
| 36 – 50 | 190 | 95.00 | 4-6 | 120 | 60.00 |
| Greater than 50 | 6 | 3.00 | >6 | 10 | 5.00 |
| Total | **200** | **100.00** | Total | **200** | **100.00** |
| Mean | **45.12** | | Mean | **4.00** | |
| **Educational level (year)** | | | **Membership of social organization (years** | | |
| No schooling | 22 | 11.00 | 0 – 5 | 186 | 93.00 |
| Primary school level | 128 | 64.00 | 6 – 10 | 10 | 5.00 |
| Secondary school level | 38 | 19.00 | >10 | 4 | 2.00 |
| Tertiary school | 12 | 6.00 | Total | 200 | 100.00 |
| Total | 200 | | Mean | 0.95 | |
| Mean | **7.70** | | | | |
| **Farm size (ha)** | | | **Farm income (Naira) per annum** | | |
| <0.50 | 170 | 70.00 | ≤ 50,000 | 40 | 20.00 |
| >0.50 | 30 | 30.00 | 50,001 – 150,000 | 138 | 69.00 |
| Total | 200 | 100.00 | > 150,000 | 22 | 11.00 |
| Mean | 0.3125 | | Total | 200 | 100.00 |
| | | | Mean | 242,865.00 | |
| **Non-farm income (Naira) per annum** | | | **Marital status (dummy)** | | |
| 0.00 | 4 | 2.00 | Married | 184 | 84.0 |
| ≤25,000 | 144 | 72.00 | Others | 16 | 14.0 |
| 25,001 - 150,000 | 18 | 9.00 | Total | 200 | |
| 150,001 - 275,000 | 14 | 7.00 | **Sex composition (dummy)** | | |
| >275,000 | 20 | 10.00 | Male | 66 | 33.00 |
| Total | 200 | 100.00 | Female | 134 | 67.00 |
| Mean | 398,200.00 | | Total | 200.00 | |
| **Access to credit (dummy)** | | | **Access to Agricultural extension services** | | |
| Yes | 6 | 3.00 | Yes | 10 | 20.00 |
| No | 194 | 97.00 | No | 190 | 70.00 |
| Total | 200 | | | | |

***Note:*** Source: From field survey, 2021 and 2022 planting season.

The finding further revealed predominantly small size farm land owned and cultivated by cassava-based farmers in the State. A mean farm size of about 0.31ha was obtained for farmers in the region. The study area is noted for excessive land fragmentation due to the high population density. The population density of the State stood at 463 persons/m$^2$ in 2020 (NBS, 2022). The region needs to plan for land conserving or saving technology in its agricultural system in the future to guarantee food security for future generations.

An average farm income of N242, 865.00 per annum in absolute terms is reported for cassava-based farmers in the region. However, the majority of the farmers were partly commercialized. The bulk of their products was used for domestic consumption with a handful of outputs sold for household revenue. Besides, the limited and insatiable farm income earned by cassava-based farmers triggered income diversification. For instance, an average non-farm income of N398, 200.00 was recorded for cassava-based farmers in the region. The diversification drives are mostly propelled by increasing poverty and declining farm income in real terms. For instance, the country's double-digit inflation rate was reported at 21.34% in December 2022. Currently, the country is witnessing a food price increase of more than 100% with a corresponding negative effect on farm income, hence justifying the need for farm income diversification.

The finding revealed that only 2.00% of the farmers relied solely on farm income, while 98.00% were engaged in non-farm income-generating activities. The sex composition of the farmers showed that females are the dominant sex (67.00%) who are majorly married. The analyses also revealed that about 70.00% and 97.00% of the farmers do not have access to agricultural extension services and farm credit respectively. The agricultural extension delivery system is inefficient while farm credit is a major issue that needs urgent policy intervention.

### 3.2. The Composition of Human Labour

From the pooled information collected, the study identified three major sources of human labour available to the arable crop farmers in the southern region of Nigeria. The sources are: Family labour source, hired labour source and group labour source. The breakdown of the result is presented in Figure 1. The finding revealed that family labour is the most available human labour accessible by small-scale farmers in the region. This source makes up about 43.00% of the total human labour available to the farmers in the region.

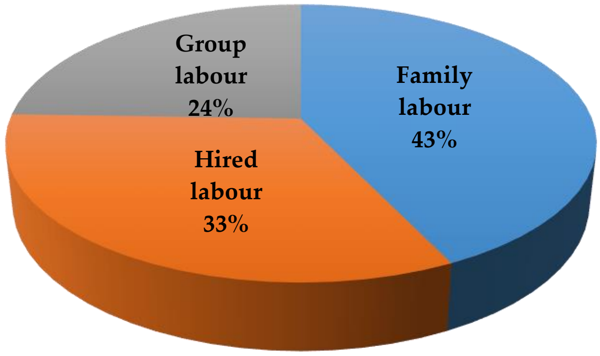


**Figure 1.** Share of farm labour sources (Source: From field survey, 2022)

The second most predominant human labour source is hired labour. This source constitutes about 33% of the total human labour source available to cassava-based farmers. The result connotes that the probability of a cassava-based farmer utilizing hired labour relative to family and group labour is about 0.33. Besides the group labour source is 24.00% of the total labour source.

However, the findings revealed the declining roles of family labour in farm labour contributions among small-scale arable farmers in the southern region of Nigeria. Previously family labour was contributing up to 80% to 90% of the total labour in small-scale farm production (Echebiri & Mbanasor, 2003). Following the structural changes in the rural area labour market, other alternative labour sources are gaining momentum in terms of preference or demand by the small-scale farmers (Nmadu & Akinola, 2015).

### 3.3. Determinants of Labour Preferences

The results in Table 2 showed the multinomial Logit coefficients for the specified labour choice equation. The Chi-square estimates revealed that the likelihood ratio is highly significant ($p < 0.0000$), indicating that the specified models have the power to explain the behaviour of the cassava-based farmers' choice of labour preference. The diagnostic statistics also revealed the pseudo $R^2$ of 0.4609, suggesting that 46.09% of the variability in the probability of occurrences of the dependent variables is due to the explanatory variables. The estimated Chi-square model (413.07) is significant at 1% probability level. This implies that the effects (including the signs) of the explanatory variables in the specified models are statistically significant at a 1% level, hence justifying the reliability of the estimated model. Note, the coefficients of each explanatory variable in the multinomial Logit do not represent the marginal effect of the explanatory variable on the dependent variable (the probability of choosing any labour choice). Hence, the estimated marginal effects or the slope coefficients which represent the change in the probability due to a change in the explanatory variable were used to interpret the multinomial logit model.

### 3.4. Determinants of Hired and Group Labour (Using family labour as reference category)

The empirical results revealed that farmers' age has a significant positive relationship with the probability of farmers preferring hired and group labour relative to the reference category (family labour). The finding implies that a unit increase in the farmers' age would likely result in a 1.06% and 3.33% increase in the probability of farmers preferring hired and group labour respectively relative to the base category. The findings imply that older or aged farmers would have higher possibilities of using hired and group labour relative to family labour. The finding could likely be attributed to the fact that most farm households to avert the scourge of poverty choose to invest in human capacity development thereby exposing some members to formal education and entrepreneurial skill acquisition programmes. Hence, at the old age of a farmer, household members might have acquired higher training and leave the farm household for an anticipated better job offer and opportunities elsewhere. The gap created at the farm household would force the aged members to go for alternative labour sources such as group or hired labour. The issue of rural-urban youth migration is another possible cause of the result. The result corroborates Echebiri & Mbanasor (2003), Omotesho et al. (2014) and Bassey et al. (2014).

**Table 2.** Estimates of the multinomial logit regression on farm labour choices (Family labour as reference category)

| Variable | Hired labour | | | Group labour | | |
|---|---|---|---|---|---|---|
| | *Coefficient* | *Z-value* | *dy/dx* | *Coefficient* | *Z-value* | *dy/dx* |
| Constant | 1.4802 | 0.38 | - | 8.4626 | 1.71* | - |
| Farmers' age | 0.0982 | 2.01** | 0.0106 | 0.2304 | 1.88* | 0.0333 |
| Household size | -0.1757 | -2.16** | -0.0332 | -0.0071 | -2.04** | -0.0127 |
| Formal education | 0.1001 | 3.44*** | 0.0219 | 0.0158 | 3.21*** | 0.0051 |
| Social capital | 0.0463 | 2.55** | 0.0010 | 0.0117 | 2.11** | 0.0016 |
| Farm size | 1.3345 | 2.82*** | 0.1312 | 0.3507 | 0.20 | 0.0431 |
| Farm income | 3.2e-05 | 3.59*** | 5.34e-06 | 2.6e-05 | 0.71 | 3.98e-07 |
| Farmers' sex | -0.2869 | -0.48 | -0.0979 | 0.1309 | 2.19** | 5.48e-07 |
| Farming experience | 0.0532 | 2.81*** | 0.0019 | 0.0288 | 1.78* | 0.0009 |
| Non-farm income | 2.21e-06 | 2.23** | 1.34e-07 | 1.5e-07 | 2.01** | 2.01e-07 |

***Note:*** Source: computed from field survey data, 2022 season. Note, *, **, and *** denote significance levels at 10%, 5%, and 1%, respectively; Number of observations = 200; LR $Chi^2$ (18) = 413.07; Prob. > chi2 = 0.0000. Log likelihood = -100.829; Pseudo $R^2$ = 0.4609.

The slope coefficient of cassava farmers' household size is negative and significantly correlated with the probability of selecting hired and group labour, relative to the base category. A unit increase in the household size would reduce the probability of choosing hired and group labour by 3.32% and 1.27%, respectively relative to the base category. An increase in household size is an incentive to reduce the probability of using hired and group labour. Family labour is an important source of farm labour, especially in rural areas where farmers are resource-poor and youth migration is prominent. Most often rural farm households rely heavily on family labour instead of hired labour because of the mounting wage rate. However, the importance of family labour depends on many factors such as the state of development of the household and the sex composition among others. Besides, the availability of group labour depends on the size of the social capital of farm households. Most rural farm households do not belong to a social organization for reasons linked to their inability of them to keep to the financial obligations of being a member, religious reasons and other criteria. The finding agrees with the reports of Echebiri & Mbanasor (2003), Omotesho et al. (2014), Nmadu & Akinola (2015), and Anim (2011).

The slope coefficient of formal education is found to be significant and positively associated with the hired and group labour at a 1% probability level relative to the base category. A unit increase in years of formal education of cassava-based farmers would, in turn, upsurge the chances of choosing hired and group labour by 2.19% and 0.51%, respectively, relative to the base category. This means that the probability of using hired and group labour increase with an increase in the educational qualification of cassava-based farmers compared to the use of family labour. An increase in farmers' educational qualification implies that the farm household members will likely be educated as well, this will generate opportunities for farm household members to diversify to an alternative source of income. The situation may likely create a labour shortage that will prompt household heads to go for alternative labour sources. The finding is substantiated by Echebiri & Mbanasor (2003), Anim (2011); Bassey et al., (2014) and Omotesho et al. (2014); but is contrary to the submission of Bedemo et al. (2013).

The coefficient of social capital has a positive significant relationship with the probability of cassava-based farmers preferring hired and group labour relative to the base category. This connotes that as the social capital accumulation increase among cassava-based farmers, the probability of choosing hired and group labour increases relative to the choice of family labour. A year increase in social capital will lead to 0.001 and 0.0016 increases in the probability of choosing hired and group labour respectively relative to the base category. Mounting social capital is known to stimulate farmers' information exchange, especially in areas of labour availability, prevalent wage rate, market access, farm inputs, farm management and issues related to families etc.

The farmers' farm size is positively and significantly correlated with the hired labour preference at $p < 0.01$, relative to the base category. A unit increase in farm size would increase the probability of adopting hired labour choice by 13.12% relative to the base category. The finding satisfies a priori expectation as a large farm size would attract more labour beyond those provided by the family. Bedemo et al. (2013), Anim (2011) and Nmadu & Akinola (2015) have reported a similar result.

Farm income has a positive and significant correlation with the probability of preferring hired labour relative to the base category at $p < 0.01$. Farmers with a larger farm income would have a greater capacity to pay for wage rate and this would encourage hired labour utilization relative to family labour. Bassey et al. (2014) and Nmadu & Akinola (2015) have reported a similar result.

The female composition (sex of farmers) of farmers has a positive significant relationship with the probability of group labour choice relative to the base category. This implies that female cassava-based farmers are likely attracted to the choice of group labour compared to the family labour choice. The possible reason could be the fact that female cassava-based farmers are more likely interested in social formation such as church/religious membership, age grade and other social gatherings thereby deriving benefits in form of labour input.

The coefficients of farming experience have a positive significant correlation with the choice of hired and group labour relative to the base category. A unit increase in farming experience will lead to a 0.19% and 0.09% increase in the probability of preferring hired and group labour relative to the choice of family labour. The increase in the farming experience is very important in determining the optimal resource use and the best combination of farm inputs taking into consideration several endogenous and exogenous factors in the farm. The result aligned with the reports of Bassey et al. (2014), Bedemo et al. (2013) and Anim (2011).

The non-farm income coefficient is positively and significantly correlated with the likelihood of choosing hired and group labour sources at $p < 0.05$ respectively, relative to the base category. An increase in the non-farm income is likely to increase the probability of the farmers' choice of hired and group labour relative to the choice of family labour. An increase in non-farm income would likely upsurge the financial capacity of a farmer to pay for wages and fulfilled the requirement to utilize group labour. Anim (2011) has reported similar findings.

## 4. CONCLUSION

The farm environment is changing and small-scale farmers ought to prepare to change with the dynamics that engulf the current farming system. Therefore, small-scale farmers should be ready to shift from the usual traditional sources of farm labour to other alternatives conditioned by certain characteristics specific to farmers and exogenous factors alike. The study has identified three major sources of farm labour available to cassava-based farmers in the southern region of Nigeria. These are family labour, the hired and group labour. Each of these labour source options has a set of exogenous variables that influence its adoption by a small-scale cassava-based farmer in the southern region of Nigeria. The major issue the study dealt with, was to identify these exogenous factors that influence the probability of adopting each of the labour options available to the small-scale farmer in the region. The empirical results revealed that the farmer's age, education, social capital formation, sex of a farmer, farming experience and non-farm income are significant positive determinants of the choice of hired labour relative to the family labour by the small-scale arable crop farmers in the southern region of Nigeria. Besides, household size has a negative correlation with the probability of preferring hired labour instead of family labour. Also, the farmers' age, years of formal education, social capital formation, sex and farming experience were identified as factors that influence the probability of adopting group labour source relative to the family labour source by cassava-based farmers in the region. Again, the household size negatively affected the choice of group labour relative to family labour.

Following the empirical results, it is recommended that concerted efforts should be developed to increase the formal education attainments of small-scale farmers, scale-up social capital formation, and increase non-farm income sources and farm income sources as a prerequisite to upsurge the use of hired labour among small-scale cassava-based farmers in the region. In addition, to encourage the use of group labour by smallholder farmers, emphasis should be placed on experienced women farmers. Also, efforts should focus on improving levels of education and increasing farmers' social capital formation or social interactions as well as boosting off-farm sources of income.

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## COMPLIANCE WITH ETHICAL STANDARDS

### Authors' Contributions

Authors contributed equally in all aspects of the paper.

### Conflict of Interest

The author declares that there is no conflict of interest.

### Ethical Approval

For this type of study, formal consent is not required.

**Data Availability Statement**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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# Alternate Bearing and Chemical Thinning Applications in Olives

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**Review Article**

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## A B S T R A C T

In this review, in which the subject of alternance in olives is discussed, the effect of alternance on olive cultivation and the methods of coping with alternans are examined in line with the latest literature. The latest developments in chemical dilution, which is the most effective and most practical among alternative methods of combating alternance, are brought together. Chemical dilution studies on olives conducted in 2021 and before were searched for and presented in this review using various databases. As a result of the literature review, access to 20 scientific research articles directly related to the subject was provided. Because of the alternate bearing discussed in the study, olive production follows a cyclical pattern. Despite the fact that the olive is genetically predisposed to alternate bearing, it can be managed and controlled through horticultural practices; in this regard, chemical fruit thinning is the most commonly used method in olives. NAA, NAAm, Ethephon, Urea and $GA_3$ are among the most preferred chemicals used for chemical dilution in olives. Chemicals used, their doses, application times and many factors related to them affect the success of chemical applications. These factors include the tree's age, variety, physiological condition and climatic conditions (particularly temperature), full flowering time, and young fruiting period. When we look at the publications on chemical dilution, it is striking that the studies in our country are fewer in number than the studies abroad. This situation can be associated with the fact that there are still some concerns about chemical dilution in our country. The availability of "environmentally friendly" chemicals will be beneficial in reducing these concerns and protecting the environment, and producers will not suffer economically. As a result, there has been an increase in the use of chemicals all over the world in recent years, with an increasing reputation for environmentally friendly chemicals.

# 1. INTRODUCTION

Olive, an evergreen plant, produces the majority of its flowers and fruits on one-year-old shoots. As with some other fruit species, it produces a large amount of fruit in one year and little or no fruit in the following year or years. Due to this event called 'periodicity' or 'alternate bearing', Olive production shows a fluctuating course based on yield, which changes over the years. The physiological and biochemical mechanism of alternate bearing has not yet been fully elucidated**.** Alternans are a type of genetic trait that are affected by environmental variables including temperature, water availability, and nutrient availability that impact vegetative and generative development processes (flower bud stimulation, differentiation, fruit set, fruit growth and ripening). It is known that alternance is also controlled by intrinsic factors such as carbohydrates, mineral nutrients and hormones (Marino & Greene, 1981**;** Monselise & Goldschmidt, 1982; Dağ et al, 2009).

The primary cause of alternate bearing is thought to be the inhibition of flower bud stimulation and differentiation by some hormones synthesized and transported by the developing seed. According to other perspectives on the subject, it is the inhibition of flower bud stimulation by developing seed due to nutrient competition, the cessation of vegetative development due to competition from fruits, which are high carbohydrate consumers, and the emergence of alternans as a result. Basically, the fruit yield of the olive tree that year is determined by the vegetative development level of the previous year. The factor affecting vegetative development is the amount of fruit on the tree at that time. Alternate bearing can also be exacerbated by insufficient or excessive winter cooling in hot climates. From an economic point of view, alternate bearing reduces the producer's income per unit product in the 'on' year, while increasing the cost of harvesting, as well as leading to the marketing of large quantities of poor quality products. The relative price increase in the 'off' year, on the other hand, cannot cover the loss of the producer, and it also causes two important problems such as insufficient supply of goods and insufficient employment. In this context, the control of alternate bearing gains importance (Kailis & Haris, 2000; Krueger et al., 2005; Lavee, 2007; Dağ et al, 2009; Therios, 2009).

In the control of alternate bearing; It is important to cultivate olive varieties that do not show severe alternate bearing and to carry out the cultural processes (irrigation, pruning, fertilization) that will cause a balanced flower bud stimulation**.** In order to alleviate the alternate bearing first of all, it is necessary to reduce the excessive fruit load of the olive tree**.** Control of fruit load; consists of chemical thinning, manual thinning and pruning (Krueger et al., 2005; Lavee, 2007; Therios, 2009).

The most often used strategy to manage olive tree fruiting and, as a result, lower the output of alternate fruits, is chemical fruit thinning**.** In addition, chemical thinning increases fruit size in table varieties; By increasing the leaf/fruit ratio, it provides more nutrients to the fruit; It ensures earlier ripening and harvesting of the fruit, increasing the fruit pulp/seed ratio, increasing the amount of oil in oily varieties, and positively affecting flower bud differentiation (Dağ et al., 2009).

The aim of this review is to review the dilution studies in the national and international literature in recent years and to shed light on our breeders and the studies to be done on this subject.

# 2. ALTERNATE BEARING

## 2.1. Alternate Bearing in Olives

Alternans is found in a variety of fruit species. Olive trees are known to yield products in varying cycles throughout the year. Periodicity is a two-year rotation of 'on' and 'off' seasons. initially, some trees in the same orchard may be in a "on" cycle, while others may be in a severe "off" season. Strong vegetative growth occurs during the "off" season, resulting in large fruiting areas for the following season's crop. Abundant flowers, large fruit set, small fruit size, delayed fruit ripening, and little vegetative growth are observed in the following "on" seasons. Thus, for the next season's crop, the "off" season is characterized by fewer fruit and low flower formation. Even if olives are genetically prone to replication, climatic conditions may still play a large role in explaining reversibility in olives. Cultural practices that reduce olive tree vigor, such as nutrient deficiency and drought stress, suggest secondary causes of alternative transportation (Hackett & Hartmann, 1967; Lavee, 1996; Martin et al., 2005).

## 2.2. Factors Affecting Alternance

### *2.2.1. Environmental Impacts*

Alternative bedding may develop gradually as trees enter production or may begin abruptly with a climatic trigger. Initially, some trees in the same orchard may be in an "on" cycle, while others may be in a severe "off" season. On the other hand, if alternate bearing is induced by environmental events, the change in trees is usually evenly observed throughout the orchard (Goldschmidt, 2005).

In some areas, climatic factors can increase alternate bearing. Because successful reproductive development (differentiation) occurs as a result of winter cooling, a "off" season can occur when conditions are unfavorable for flower development (Briccoli Bari et al., 2002).

Pinney & Polito (1990) and Rallo & Martin (1991) claimed that trees subjected to insufficient cooling bloom, but the flowers that open have poor quality and low fruit set. They also claimed that winter cooling is extremely important for identifying high quality flower buds. They found that olive fruit set decreased with increasing time spent above 27°C in winter.

Fruit set in olives is largely dependent on the climate. Usually only one fruit is kept per inflorescence. While the fruit is on the tree, any environmental stress can cause the fruit to drop. In addition, cool spring conditions can increase fruit set to five to seven fruits per bloom. Moreover, this increased starting set will not significantly increase the final fruit per tree due to increased natural fruit shedding that may occur at a later stage. High temperatures during flowering do not necessarily prevent fruit set. With this, the combination of low humidity and high temperature can result in high embryo drop and dryness of young fruit (Lavee, 1986).

### *2.2.2. Carbohydrates*

Sugar and starch levels are significantly higher at the start of the 'on' season than during the 'off' season. Even more importantly, after the "off" year, the sugar and starch levels in olive leaves increase from year to year. The high crop load of the "on" season is due to the tree's carbohydrate reserves. As a result, large crops reduce the carbohydrate levels available for distinguishing flower buds, flowers, and young fruit. Apples' high fruit set and low fruit drop are due to adequate carbohydrate reserves and citrus fruits. The presence of carbohydrates appears to be less important for flower formation in olives compared to other parameters. Therefore, after the "on" season, low carbohydrate levels are not a direct cause of alternans in olives. It is seen that reproductive organs in olive have higher sink power than vegetative organs. It was also concluded that heavy crops use carbohydrate sources to induce shoot growth. Since the olive tree bears fruit from its one-year-old shoots, reduced shoot growth will reduce fruiting capacity in the next season (Fahmy, 1958; Hartmann, 1964; Stutte & Martin, 1986; Rallo & Suarez, 1989; Goldschmidt, 1999; Stopar et al., 2000).

### *2.2.3. Phenolic Acids*

Chlorogenic acid (CGA) accumulated in olive leaves in 'on' seasons is higher than in 'off' seasons. Dilution of young fruit after fruit set, prevents CGA accumulation in leaves, resulting in positive flower differentiation and flowering in the following season. Spraying olive trees with CGA before winter significantly reduces flower bud differentiation. On the other hand, it was observed that flower differentiation and fruit set were not affected when CGA was applied after mid-winter. We can deduct from this observation that CGA exerts a direct, non-toxic effect on flower formation in olives (Lavee & Avidan, 1981; Lavee et al., 1986).

### *2.2.4. Hormones*

#### 2.2.4.1. Overall effect on alternate bearing of hormones

The most effective way to neutralize alternans or produce fruit in the 'off' season has to do with its ability to control flower formation. As mentioned earlier, besides the role of carbohydrates, plant hormones also play an important role in controlling the transition from vegetative to generative bud development. Plant hormones, one of the endogenous substances investigated so far, have been found to be most effectively associated with flower formation (Bernier et al., 1993; Bangerth, 2006; Dağ et al., 2009).

#### 2.2.4.2. The importance of the seed for alternans

Flower induction with the aid of gibberellic acids (GAs) released by developing seeds is suppressed by high fruit loads. The importance of the seed for alternans is also emphasized for many other tree species. Demonstrated in their study that the effect of seedless apple fruit on flower induction of nearby shoot meristems did not have the same inhibitory effect as seedless fruit. An inhibitory signal emerges from the seeds and is then carried over to attract meristems where it inhibits flower formation (Chan & Cain, 1967; Ebert & Bangerth, 1981; Stutte & Martin, 1986; Bangerth, 1997; Fabbri & Benelli, 2000).

#### 2.2.4.3. Hormonal interactions

GAs are thought to have an effect on the flower development of seeds which are a rich source. Exogenous application of GAs may additionally inhibit flower formation, which may turn hormones into optimal candidates for seed signaling. GAs are known to be persistent in shoot tips and seeds, where they stimulate auxin (IAA) synthesis/transport as primary messengers involved in flower induction. IAA suppresses flower induction as a secondary messenger, and the application of GAs stimulates polar IAA transport from fruit and shoot tips (Kuraiski & Muir, 1962; Bangerth, 1997; Stopar et al., 2000).

Concentration and/or transport of IAA in annual plants may be associated with inhibition of flower formation. This could be related to other effects as well, such as apical bud dominance. The observed increase in a tree's apical bud dominance indicates that the inhibitory organ's IAA flux increases at the expense of the inhibited organs' IAA fluxes. A smaller overall transport system for assimilates, minerals, water, and other substances required for floral induction results from the creation of a reduced IAA flow. Application of IAA-transport inhibitors such as 2,3,5-triiodobenzoic acid has been observed to stimulate flower formation in both annual and perennial plants. In addition, more compelling evidence has been found that IAA is a signal that inhibits flower formation (Daie, 1985; Bangerth, 1989; Tsujikawa et al., 1990; Bernier et al., 1993).

Numerous GA biosynthesis inhibitors also lessen IAA export from fruit and shoot tips. It has been discovered that paclobutrazol prevents the oxidation of caurene to caurenic acid, interfering with the production of GA. In doing so, it works by inhibiting GA biosynthesis in the secondary-apical bud meristem. As a result of foliar applications of this inhibitor, it was observed that fruit bud differentiation and yield increased more than 50% in apples in the second year. Conversely, in the Manzanillo olive, spraying of paclobutrazol from the tree no longer had a significant effect on flowering, fruit set or fruit size (Dalziel & Lawrence, 1984; Ebert & Bangerth, 1981; Sansavini et al., 1986; Fernandez-Escobar et al., 1992).

Cytokinins stimulate flower induction in both annual and perennial plants. These hormones have been shown to play a positive role in flower induction. According to molecular biologists, high IAA concentrations typically lower the cytokinin concentration of a specific organ. IAA concentration has an impact on cytokinin concentration as well as IAA transport. He emphasized that an optimal cytokinin concentration is required for the meristem to produce flowers, most likely due to cytokinins' stimulatory effect on meristematic activity (cell division). Low activity usually results in drowsiness, whereas high activity can cause new vegetative reddening. In light of this information, it seems that a critical cytokinin concentration is required for flower induction in a resting but not dormant meristem (Bernier et al., 1993; Muday & DeLong, 2001; Akça Uçkun, 2017).

### *2.2.5. Factors Affecting Alternate Bearing: General Inference*

The factors involved in both vegetative and reproductive development of olive buds are the continuous and complex interaction between temperature and other environmental factors as a result of the factors discussed in this section. The increase in fruit number and thus seeds will increase

GAs, exacerbating IAA's negative effect on flower induction. IAA either directly inhibits flower formation through a signal or indirectly through a negative effect on cytokinins. Crop potential for the following season can be guaranteed up to a certain point by removing fruit before seed-produced GAs come into play (Lavee, 2006; Crous, 2012).

Although olives are genetically predisposed to periodicity, horticultural practices can manage and control it. Controlling the interaction of fruit load and vegetative growth are the two most important parameters in the alternate bed. Because the olive tree produces fruit on one-year-old shoots, shoot development is required to create enough flowering areas. As a result, it is critical to maintain a healthy balance between fruit load and shoot/vegetative growth. Under favorable climatic conditions, horticultural practices such as pruning, thinning, covering, and other cultural and nutritional means can reduce or even eliminate periodicity; however, keep in mind that alternans are extremely difficult to control under changing environmental conditions (Crous, 2012).

## 3. FRUIT THINNING IN OLIVES

### 3.1. What Is Fruit Thinning?

Fruit thinning is the process of removing buds, flowers or fruits that are more than normal on the tree by different methods. Fruit thinning, which has a significant effect on fruit quality in the 'on' year and fruit yield in the next season. It is a method applied to increase fruit quality and reduce periodicity, and its application is common in fruit trees (Bangerth & Quinlan, 2000; Link, 2000; Wertheim, 2000; Webster, 2002).

### 3.2. Methods Used to Control Fruit Load

In the control of fruit load; pruning and thinning methods are used. The thinning methods used are in the literature as manual, mechanical and chemical thinning. In this section, the methods are discussed in order.

#### *3.2.1. Pruning*

One of the oldest methods applied to control the fruit load in olive orchards is pruning. Pruning; it is used because it provides benefits in forming the crown of the tree, controlling vegetative growth, increasing light, stimulating flower bud differentiation, spraying applications, and mechanization of harvest. Olive pruning (especially hard pruning) should be applied before the year of "on". The amount of fruit on the tree is limited by pruning before the year of "on year". It causes the elongation of vegetative shoots on pruned branches. Pruning provides only light penetration in the "off year", where the growing crown is very dense. In regions with stable climatic conditions, alternans can be controlled quite successfully by pruning. However, in regions with very unstable climatic conditions, especially in slow growing varieties, the expected benefit from pruning may not be obtained and therefore additional methods such as fruit thinning may be required (Lavee, 2007).

Compared to thinning and pruning, fruit thinning is more effective. This is because pruning removes both fruit and leaves, so applying fruit thinning will result in an increased leaf-to-fruit ratio. It has been determined that fruit thinning performed two weeks after full flowering in olives increases vegetative development, flower bud differentiation, fruit size and yield. In fruit growing, a certain proportion of the flowers formed are required to set fruit. Crop load affects the fruit quality and physiological condition of the tree, as well as the next year's crop. Thinning does not reduce the amount of product obtained from the unit area, on the contrary, it improves the fruit quality and increases the rate of salable product (Westwood, 1995; Tromp, 2000; Dağ et al., 2009; Kaçal, 2011)

#### *3.2.2. Thinning Methods*

Control of fruit load; It can be achieved by manual thinning, mechanical thinning and chemical thinning. Fruit thinning in olive trees aims to reduce branch breakage due to next year's fruit load, increase fruit size, increase fruit yield and promote flower bud induction. Advantages of chemical thinning are: increase in fruit size, regular fruiting, early ripening of the fruit, increase in meat/seed ratio, increase in olive fruit quality, flower bud differentiation is in the form (Krueger et al., 2005; Therios, 2009). These methods are listed in Table 1.

**Table 1.** Comparison of thinning methods

| Thinning methods | How is it applied? | Advantages and Disadvantages |
|---|---|---|
| Manual Thinning | *Manual thinning of fruit is the process of removing fruit or flowers from branches by hand.<br>*Delay in thinning time should be avoided. Otherwise, there will be no decrease in alternate bearing and no increase in fruit size. | *It causes excessive increase in labor cost.<br><br>*Thinning in the early period has a greater effect on the size of the fruits. |
| Mechanical Thinning | *During flowering, high pressure water spraying on the trees can cause the flowers to fall or the fruit to fall with the shakers used in fruit harvest. | Disadvantages:<br>*Leads to uneven product distribution.<br>*Shedding of larger fruits,<br>*Damage to long-stemmed fruits by hitting each other.<br>*Shedding more of the fruits at the shaking point is in the form. |
| Chemical Thinning | *With the help of chemicals, thinning is done in 2 different periods, namely the thinning of flowers or small fruits. *Sometimes these two methods are used together. | *Also, prices for chemicals used in thinning applications have increased significantly in recent years. |

**3.2.2.1. Chemical thinning**

Chemical thinning studies are carried out in many fruit species such as apple, peach, apricot and pear. Chemical thinning of fruits was first realized in 1939 with the use of DNOC (Dinitro-ortho-cresol). In the studies, it is seen that the chemical thinning studies in apples and peaches are more than in other fruits, but the chemical thinning studies in olive are relatively less compared to the studies in other fruits. Chemical fruit thinning is one of the most widely used methods in olive to alleviate periodicity and control fruit yield of the tree (Weiss et al., 1993; Tromp, 2000; Gadner, 2003; Krueger et al., 2005; Therios, 2009; Çiğdem, 2014).

Chemical thinning in olives is an important tool in increasing the product quality in the “on year”. NAA is a synthetic form of auxin, a plant growth regulator that increases the formation of olive grains, and has been used for fruit thinning in olives since the 1950s. Chemical thinning with NAA has been practiced for more than 50 years. However, widespread adoption of chemical thinning has been slow. Because thinning is done before the exact estimation of fruit load. However, there is a risk of excessive or insufficient thinning. Also, prices for chemicals used in thinning applications have increased significantly in recent years. NAA is the only registered chemical today and is recommended for olive thinning. The potassium salt formulation of NAA has the same effect, but its use is not common today (Krueger et al., 2005).

Chemicals such as NAA (Naphthalene Acetic Acid), NAAm (Naphthalene Acetamide), and Ethephon ((2-Chloroethyl) phosphonic acid) have been tested for table olive thinning. On the other hand, it increases the amount of oil in olive varieties for oil purposes and positively affects flower bud differentiation. Its use in olive is generally in the period when 70-80% of the flowers bloom in some countries, depending on the variety. The use of NAA is mainly in olive; It brings low thinning cost, and it also enables to reduce alternate bearing. It is also used to increase fruit size, early ripening and better quality (Weis et al., 1988).

Chemical thinning has advantages over manual or mechanical thinning, such as lower thinning cost, increased fruit size, early ripening, better quality product, and reduced periodicity. Fruit varieties that are easy to thinning fruit are overthinning by NAA. Generally, NAA is mixed with other chemicals to achieve optimum thinning. Because various studies show that chemicals used in combination are more effective than when used alone. As the dose of NAA used increases, the amount of thinning also increases. However, high doses of NAA both damage the leaves and cause small fruit formation (the fruit remains on the tree before it becomes large). Therefore, it is emphasized that the use of high doses of NAA should be avoided. At the same time, excessive chemical fruit thinning is a convenient method to reduce the severity of alternate bearing in regions where stable fruiting is not observed. Although excessive fruit thinning occurs with many chemical thinners, the main factors effective in excessive thinning are listed in Table 2 (Williams, 1979; Faust, 1989; Burak et al., 1997).

With the help of chemicals, thinning is done in 2 different periods, namely the thinning of flowers or small fruits. Sometimes these two methods are used together. DNOC, which has a caustic effect, is used as a chemical substance in flower thinning. In small fruit thinning, Carbaryl (Sevin), a broad-spectrum insecticide, is used either alone or mixed with hormone-structured chemicals (NAA, NAAm, BA). Some other chemicals such as Hydrogen Cyanamide, Ethephon and Thidiazuron are also considered for thinning (Williams, 1979; Ryugo, 1988; Childers et al., 1995; Krueger et al., 2005)

**3.2.2.2. NAA application**

The timing of NAA applications is extremely important to get the best results. Following full bloom, 10 ppm NAA solution is applied at 10-15 liters per tree per day. Full bloom is when 80% of the flowers open. In areas where the weather is unusually cold or hot, the thinning time is determined by fruit size. The applied NAA is absorbed by the leaves, and during the second week of application, a separation layer develops on the olive stems, resulting in some immature olives being shed. Trees are stressed after NAA application, with the shedding of a significant portion of the leaves. Therefore, NAA should only be applied to healthy trees. Early or late NAA applications may result in excessive or insufficient fruit set (Figure, 1). (Therios, 2009).

**Figure.1.** NAA application (Çiğdem, 2014)

Fruits begin to fall 10-14 days after NAA applications. In order for NAA to be absorbed by the leaves, it must be very well dissolved in water. For this purpose, spreader and adhesive (surfactant, adjuvant) should be added to the solution. The most effective application time is warm and windless morning hours with slow drying conditions where hormone absorption is highest. NAA is not effective at temperatures below 10°C. However, chemical thinning methods can sometimes show unstable results and excessive thinning may occur due to various factors. These factors are; age of the tree, growth strength of the tree, severity of pruning, intense flowering, poor pollination, high humidity or high temperature, and high concentrations of chemicals used in thinning. Two main methods are used to determine the NAA application time: A. Fruit Size B. Number of days after full bloom (Westwood, 1978; Therios, 2009).

**Table. 2.** Factors effective in excessive chemical thinning

| Tree Factors | Environmental Factors |
|---|---|
| Weak trees with weak fruit branches and thin-textured trees | High relative humidity conditions in the days prior to application |
| Trees that are planted too tightly or in the shade of hedge screens | High humidity on the day of application leads to low drying |
| Badly pruned trees | High temperatures |
| Insufficient pollination | Average rainfall in the days following the application |
| Young trees | Leaves affected by frost |

#### 3.2.2.3. Young fruit period

Fruit size is a widely used method. NAA is applied when the average fruit size is between 3-5 mm. Fruit size varies within the orchard and tree. Therefore, in orchards and in the north-south sections of trees, measurements should be made from different locations on the crown to obtain an average value. The stated size is usually reached 12 to 18 days after full bloom, but this time may vary according to climatic conditions (Therios, 2009)

#### 3.2.2.4. Number of days after full flowering (NDAFF)

In the use of this method, the time of full bloom should be determined for each orchard. The date of full bloom is determined when the contrast between the green leaves and the white flowers can be observed at a certain distance from the garden as the flowers begin to open. During this period, the trees appear white with 80-90% of the flowers opening and the appearance of bright yellow anthers. The remaining 10 to 20% of the flowers have not yet opened and their leaves have not fallen. In full bloom, pollen dispersal is high and by shaking the shoots by hand, this pollen can be collected. Also, full bloom is indicated by the shedding of yellow pollen when the branch is hit and the petals falling. These events indicate the time of full bloom. 3 or 4 days after full bloom, the trees acquire a yellow-bronze appearance. For the estimation of NAA application time, it is necessary to determine and record the full bloom day. NAA should be applied 12 to 18 days after full bloom. The fact that the air temperatures after flowering can vary according to the years makes it difficult to use this criterion. Spraying should be done earlier as the hot weather leads to a faster development after flowering; on the contrary, if the weather is cold, spraying should be done a little later. Therefore, for successful thinning, the orchard owner must closely monitor air temperatures and accurately determine the timing of spraying (Krueger et al., 2005).

## 4. CONCLUSION AND RECOMMENDATIONS

When the studies conducted from the past to the present are examined, the prominent topics are alternate bearing, factors affecting alternate bearing, thinning and its methods, and finally chemical thinning applications.

Alternate bearing is one of the important problems to be considered in olives. From an economic point of view, it ultimately reduces the producer's income per unit product in the 'on' year, increases the cost of harvesting, and also leads to the marketing of large quantities of poor quality products. The relative price increase in the 'off' year, on the other hand, could not cover the loss of the producer, and it also caused two important problems such as insufficient supply of goods and insufficient employment. In order to control the alternate bearing that causes such problems, thinning applications are inevitable in olives. In some regions, even if it cannot be completely prevented, chemical thinning can be said to be important in terms of controlling the alternate bearing to a certain extent and mitigating the yield loss, especially in the "off" years.

Studies dealing with thinning applications show that different thinning methods come to the fore, showing that mechanical and manual thinning are used less frequently in fruits such as olives. Chemical thinning has advantages over manual or mechanical thinning, such as lower thinning cost, increased fruit size, early ripening, better quality product, and reduced alternate bearing. In this context, chemical thinning is used more frequently in research compared to other methods, and many different chemical diluents are applied in trials. To list these chemical thinners, they are NAA, NAAm, Ethephon, Urea and $GA_3$.

The apparent alternans status in olives is not related to nutrient consumption. Fluctuation in crop (between crop and no crop years) appears to be controlled by induction and differentiation stimuli and inhibitors. Production of these regulators is initiated by growing fruit and their effectiveness is controlled by environmental conditions, mainly weather and climatic conditions. In today's climate change, the chemical applications described will be beneficial in reducing the difference between the years of product and no product. The external application of plant growth regulators promotes flower bud induction and differentiation in many fruit species. This will reduce the periodicity in olives.

When we look at the publications on chemical dilution, it is striking that the studies in our country are less in number than the studies abroad. This situation can be associated with the fact that there are still some concerns about chemical dilution in our country. The availability of "environmentally friendly" chemicals will be beneficial in reducing these concerns and protecting the environment, and producers will not suffer economically. In addition, in future studies, researchers can try different chemical thinners in different doses and olive varieties, thus deepening the research and eliminating this gap in the field. Finding environmentally friendly chemicals can also be done faster with these different researches.

## COMPLIANCE WITH ETHICAL STANDARDS

### Authors' Contributions

ZÇ: Manuscript design, Literature research

MA: Drafting, Literature research, Writing, Review and editing.

All authors read and approved the final manuscript.

### Conflict of Interest

The authors declare that there is no conflict of interest.

### Ethical Approval

For this type of study, formal consent is not required.

### Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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MUŞ ALPARSLAN ÜNİVERSİTESİ TARIM VE DOĞA DERGİSİ
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# Effect of *Bacillus* sp. application on the germination of coriander (*Coriandrum sativum* L.) under salt stress

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**A B S T R A C T**

Coriander (*Coriandrum sativum* L.), one of the annual herbaceous plants widely used as a medicinal and aromatic herb, is used as flavor and aroma, to treat digestive system diseases, as antipyretic, etc. Salinity, which is one of the soil quality index parameters, is one of the most important abiotic stress factors limiting the production of agricultural products. This study examined the effect of *Bacillus* sp. application on germination rate (%), germination speed (days), average daily germination (days), peak and germination values of coriander at different salt (NaCl) concentrations (0, 50, 100, 150, 200 mM). It was determined that the *Bacillus* sp. and salt application were significant at the level of 1% in the investigated parameters and that the bacterial application minimized the negative effects of increasing salt concentrations on the germination biology. The germination rate (67%), germination speed (8.4 days), average daily germination (4.5 days), peak (2.33%), and germination values (10.5%) were obtained. It was determined that no *Bacillus* sp. + 50 mM salt application provided the best germination values in coriander seeds.

## 1. INTRODUCTION

Plants that have been used frequently in folk medicine for centuries have been beneficial in the treatment of many diseases. Coriander, which is one of these plants, is widely used among the public as flavor and aroma, pain reliever, sedative, antipyretic, appetizer, digestive system regulator, diuretic and antimicrobial (Kadioglu et al., 2021a, 2021b, 2021c). The green sections and seeds of coriander (*Coriandrum sativum* L.) are used for medicinal and aromatic purposes. Coriander, produced from seed, grows in lime-rich, sandy-loam, lightly textured, neutral and slightly alkaline soils. Plants grow best in the conditions that are optimal for them. Soil salinity constitutes most of the mineral stress, one of the abiotic stresses. Soil quality encompasses the physical, chemical and biological properties of the soil. Soil salinity, one of the soil quality parameters, is formed as a result of the capillary rise of salts dissolved in the under groundwaters to the soil surface with high ground water, where the water is separated from the soil by evaporation. Salt stress directly affects plant diversity. Plants have different tolerances to salt stress (Parida & Das, 2005) and are affected by salt stress in their environment during growth and development. The period when plants are most sensitive to salt stress is the germination period (Shrivastava et al., 2015; Forni et al., 2017). Germination begins with the absorption of water by the seed, and the humidity of the environment increases the germination power and speed. Salinity, which is one of the soil quality parameters, negatively affects the fertility of the soils and causes large agricultural dead zones. Since the reclamation of saline soils is not economical and practical, the cultivation of salt-resistant plant species and genotypes has been considered the most rational way to make use of these areas in recent years.

As a result of excessive use of chemical fertilizers used to increase yield, problems such as salinization, nutrient deficiency, deterioration of microorganism activity occur in the soil, and bacteria that encourage plant growth are used to prevent such problems. Bacterial strains such as *Bacillus, Lactobacillus, Paenibacillus, Arthobacter, Pseudomonas* are included in the bacteria class that promotes plant growth (Çakmakçı et al., 2001), PGPRs are soil and environmentally friendly fertilizers that increase productivity. The present study examined the effect of PGPR bacteria application at different salt concentrations on the germination biology of coriander seed, which is a medicinal and aromatic plant.

## 2. MATERIAL AND METHOD

This study, which was carried out under controlled conditions (25±1°C) in 2023, aimed to determine the effect of plant growth-promoting rhizobacteria (PGPR) application at different salt concentrations during the germination period of coriander (*C. sativum* L.) seeds. The study was carried out with 10 replications following the factorial design of random plots. Five different doses of NaCl and *Bacillus* sp. bacteria (control (salt + no bacteria), 50 mM NaCl, 100 mM NaCl, 150 mM NaCl, 200 mM NaCl, control (salt + bacteria), 50 mM NaCl + *Bacillus* sp. $10^8$ CFU, 100 mM NaCl +*Bacillus* sp. $10^8$ CFU, 150 mM NaCl +*Bacillus* sp. $10^8$ CFU, 200 mM NaCl +*Bacillus* sp. $10^8$ CFU) were applied to the seeds. To ensure surface sterilization of the seeds, the seeds were sterilized in 5% sodium hypochlorite solution for 10 minutes. Sterilized seeds were planted in petri dishes with a diameter of 9 cm and a height of 1.5 cm, with 50 seeds in each petri dish, on 2 layers of filter paper (Whatman No: 2) placed at the bottom of the dishes. 10 ml of laboratory-prepared saline and saline + bacteria solutions were added to each petri dish (Prodo et al., 2000). Filter papers were changed at every 2 days to prevent salt accumulation in Petri dishes (Kiremit et al., 2017). In the experiment, coriander seeds were considered germinated when they had a root length of 2 mm (ISTA, 2003). The germination rate (%), germination speed (days), daily germination average (%), peak value (%) and germination value (%) were determined (Czabator, 1962; Ellis & Roberts, 1981; Matthews & Khajeh-Hosseini, 2007; Gairola et al., 2011).

$$Germination\ rate = \frac{n}{\sum n} \times 100 \quad (1)$$

n: Number of germinated seeds

$\sum n$: Total number of seeds

Germination speed: $n_1/t_1 + n_2/t_2 + \ldots\ldots$

$n_1$, $n_2$, … number of germinated seeds $t_1$, $t_2$, …days

$$Mean\ daily\ germination = \frac{Total\ number\ of\ germinated\ seeds}{Total\ number\ of\ days} \quad (2)$$

$$Peak\ value = \frac{Highest\ seed\ count}{Highest\ seeding\ day} \quad (3)$$

$$Germination\ value = Mean\ daily\ germination \times Peak\ value \quad (4)$$

Differences between analysis of variance and means were analyzed in the LSD multiple comparison test program JMP 5.0.1.

## 3. RESULTS AND DISCUSSION

### 3.1. Germination Rate (GP%)

The germination rate showed that bacteria and salt application were significant at 1%, while the bacteria × salt interaction was insignificant. The *Bacillus* sp. strain was effective, and its germination rate decreased as the salt concentration increased. The best results were obtained with 50 mM salt application (67.25%). As the salt concentration in the bacteria × salt interaction increased, the germination rate decreased, and the highest rate was obtained from 50 mM salt × *Bacillus* sp. application with 81% (Figure 1).

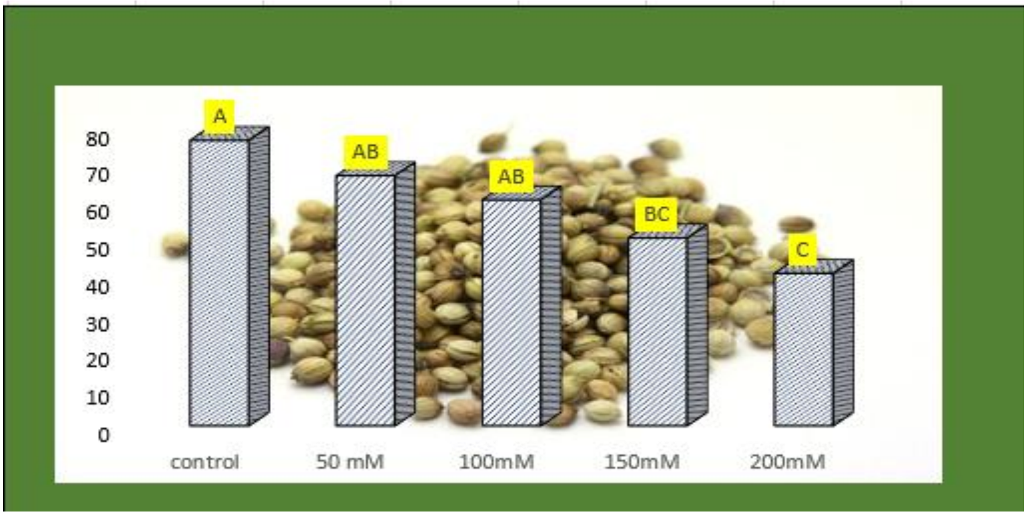


**Figure 1.** Germination rate of *Coriandrum sativum* L. in salt application (%)

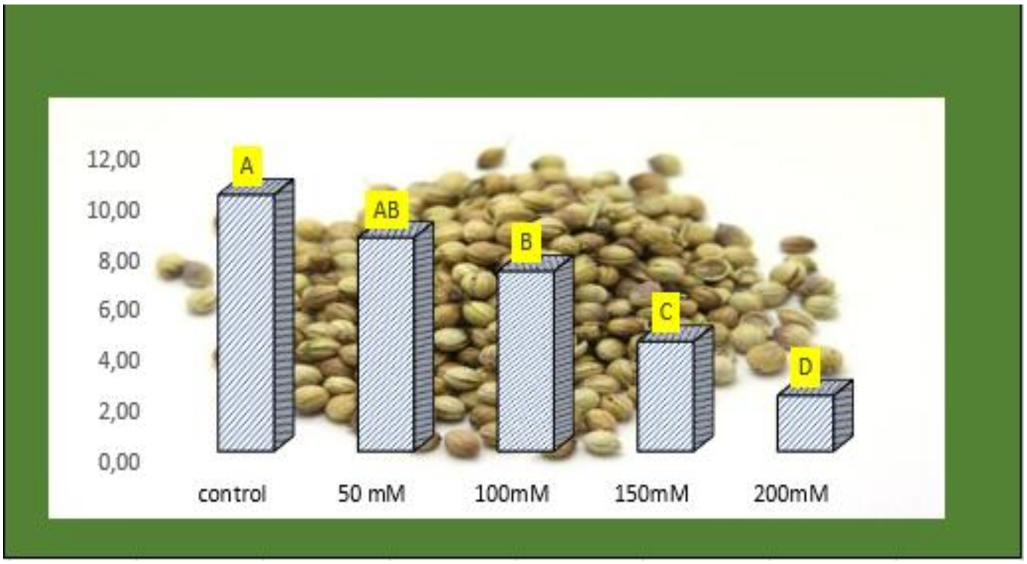


**Figure 2**. Germination time of *Coriandrum sativum* L. in salt application (days)

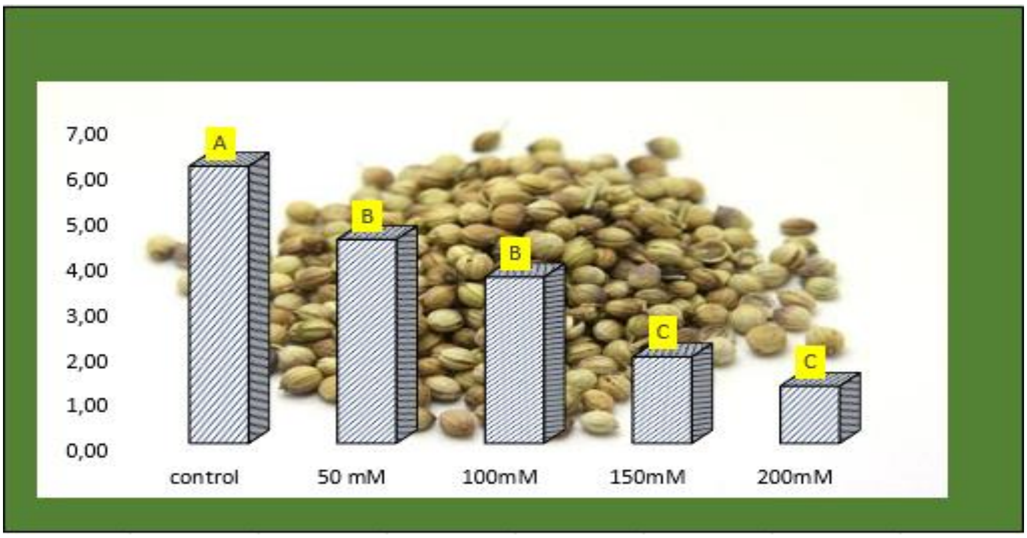


**Figure 3.** Average daily germination time of *Coriandrum sativum* L. in salt application (days)

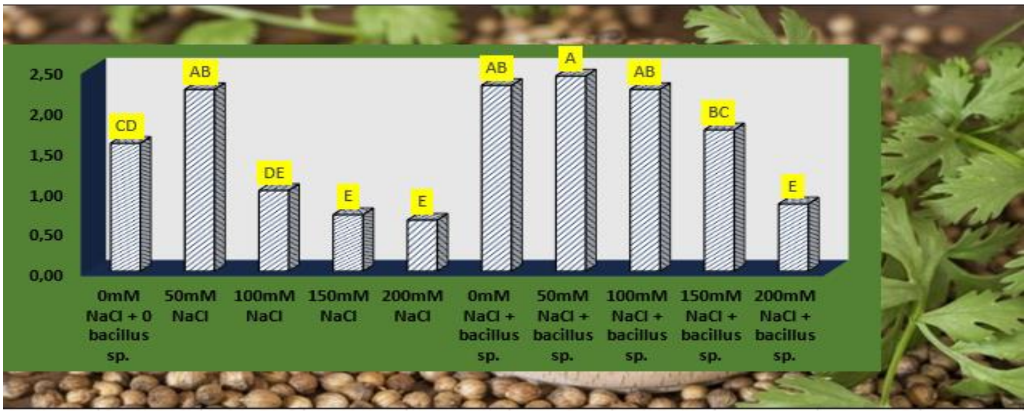


**Figure 4**. Peak (%) value of *Coriandrum sativum* L. in salt x bacteria interaction

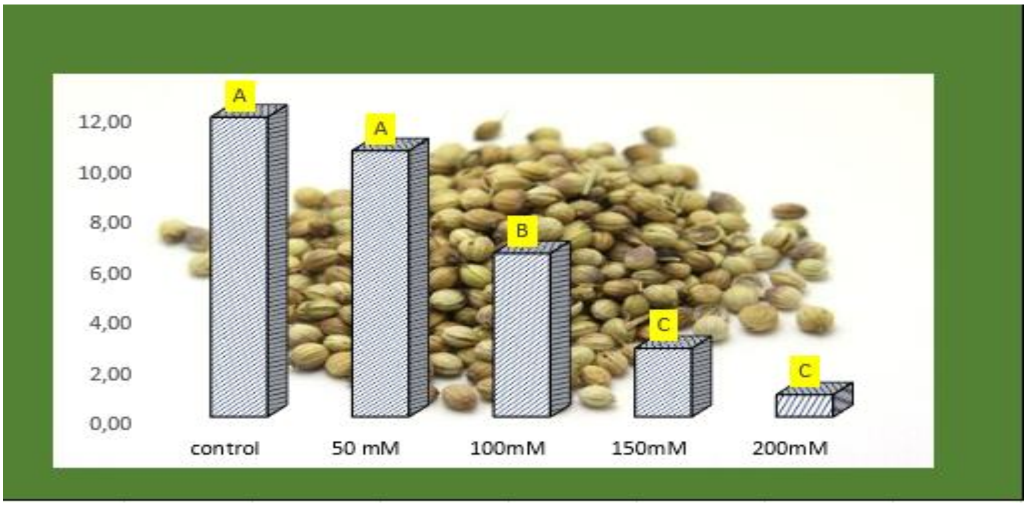


**Figure 5**. Germination value of *Coriandrum sativum* L. in salt application (%)

### 3.2. Germination Speed (GS days)

It was determined that bacteria and salt applications were significant at 1% during germination, whereas the bacteria × salt interaction was insignificant. It was determined that as the salt concentration increased, the germination speed was prolonged and the application of *Bacillus* sp. (7.19 day) minimized the negative effects of salt stress. In salt application, the highest value was obtained from 50 mM salt application with 8.4, while the lowest value was 2.20 day in 200 mM salt application. During germination, the lowest value of bacteria × salt interaction was 1.99 day under 200 mM salt + no *Bacillus* sp. conditions (Figure 2).

### 3.3. Mean Daily Germination (MDG days)

The average daily germination parameter showed that the interaction of bacteria and bacteria × salt was insignificant, while salt application was significant at 1%. In this parameter, the highest value of 4.5 day was obtained with 50 mM salt application, and the lowest value of 1.25 day was obtained with 200 mM salt application. The study showed that the mean daily germination time increased as the salt concentration increased. Although bacteria application had an effect on average daily germination, it was not statistically significant (Figure 3).

### 3.4. Peak Value (PV%)

The peak values showed that bacteria and salt applications were significant at 1%. Bacteria × salt interaction was found to be significant at 5%. It was determined that the *Bacillus* sp. strain was effective on the peak value and gave the highest value with 1.91%. In salt application, the highest value was 2.33% with 50 mM salt application, while the lowest value was 0.73% with 200 mM salt application. In the bacteria × salt interaction, the highest value of 2.4% was obtained in the 50 mM salt × *Bacillus* sp. interaction. It was determined that bacteria application was effective against salt stress and positively affected the investigated parameter (Figure 4).

### 3.5. Germination Value (GV%)

Germination value parameter analysis showed that it was significant in bacteria and salt applications at 1%. Bacteria × salt interaction was found to be insignificant. The *Bacillus* sp. strain was found to be effective against salt application, and 50 mM salt application gave the highest germination values with 10.5% (Figure 5).

This study determined that salt stress has a negative effect on the germination biology of coriander, and *Bacillus* sp. application reduces the effect of salt stress. Soil salinity is critical for seed germination. Salinity causes physiological and biochemical changes in seed germination and significantly affects seed germination and plant growth. The findings of the present study are in parallel with those reported by other studies. In a study in which different concentrations of salt were applied on three different sage cultivars to determine the effect of salt stress on seed germination in sage, it was determined that increasing salt concentrations in all three cultivars had a significant effect on seed germination biology, and germination parameters decreased in parallel with the increase in salt stress (Kadioglu, 2020). A study conducted on salt stress by Isİk (2022) indicated that as the salt concentration increased, the germination rate decreased. Çamlıca & Yaldiz (2017) determined that as salt concentrations increase, germination, shoot and root length decrease in basil. Another study reported that growth of sage was not affected much from different salt concentrations up to 100 mM salt level, but plant growth was adversely affected at levels above this salt level (Çamlıca et al., 2019). Since salinity damages plant metabolism, plant growth and germination are reduced. PGPR applications under optimal conditions minimize the negative effects of salt stress and increase plant growth, germination rate, root development and tolerance to extreme conditions such as drought/salinity by stimulating plant metabolism. A study in which PGPR was applied to linen under salt stress found that PGPR applications positively affected germination biology (Kadioglu, 2022). In a study examining the effects of the application of saline water during the germination period on the saline tolerance and morphological characteristics of linen, artichoke, safflower, and echinacea seeds, it was determined that linen and safflower seeds had more tolerance against salt stress when compared to echinacea and artichoke seeds and germination rate, offshoot and radicle lengths and plant dry weight characteristics of all plants decreased with the increasing salinity (Gholizadeh et al., 2016). Moreover, it was pointed out that increasing salinity levels caused decreases in germination parameters in sage, black cumin and linen (Yaldiz et al., 2016; Kiremit et al., 2017). Soil salinity, which is one of the soil quality index parameters, causes negative physiological and biochemical changes during the germination of seeds. The present study determined that the application of bacteria and salinity affected seed germination biology.

## 4. CONCLUSION

Soil salinity is a global problem due to its negative effects on agricultural productivity and sustainability. Salinity problems can occur in all climatic conditions due to both natural and human-induced actions. The relationship between salinity and humans has existed for centuries. The increase in salinity in agricultural areas is the biggest reason for the failure of agriculture. The best-known example of this is Mesopotamia. Soil salinity can occur due to natural causes or improper irrigation methods by reducing soil quality, compromising the integrity of the soil's buffering capacity. Soil salinity emerges as a dynamic problem in more than 100 countries and unfortunately spreads all over the world due to improper agricultural practices. Soil salinization affects plant growth and causes yield loss. Studies have been made and are being carried out to minimize yield loss, to improve salt-tolerant plant varieties and soil salinity. In our study, effects of *Bacillus* sp. application on the germination parameters of coriander in salty environment were investigated.

The results of the research showed that plant growth-promoting rhizobacteria (PGPR) used for germination biology in salty conditions was effective on germination rate, germination speed, average daily germination, peak value and germination value, and it was determined that the use of *Bacillus* sp. strain minimized the negative effect of salt stress on coriander seeds.

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The coriander seeds used in the research were collected from nature. The bacterial material used in the experiment was commercially available.

## COMPLIANCE WITH ETHICAL STANDARDS

### Conflict of Interest

The author declares that there is no conflict of interest.

### Ethical Approval

For this type of study, formal consent is not required.

### Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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MUŞ ALPARSLAN ÜNİVERSİTESİ TARIM VE DOĞA DERGİSİ
MUŞ ALPARSLAN UNIVERSITY JOURNAL OF AGRICULTURE AND NATURE

# Organik tarım koşullarında yabancı ot mücadelesinde elle yolma yönteminin buğday verimine etkisi

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**Araştırma Makalesi**

*Makale Tarihçesi*
Geliş Tarihi: 26.04.2023
Kabul Tarihi: 18.08.2023
Online Yayınlanma: 29.09.2023

*Anahtar Kelimeler:*
Buğday
Elle yolma
Organik tarım
Verim
Yabancı ot

**Ö Z E T**

Diyarbakır koşullarında yürütülen bu çalışmada konvansiyonel tarıma kıyasla organik tarım için verim açısından daha fazla önem taşıyan yabancı ot mücadelesinin buğday verimi üzerindeki etkisinin belirlenmesi amaçlanmıştır. Araştırma 2020-2021 yılı buğday yetiştirme döneminde Dicle Üniversitesi Ziraat Fakültesi'ne ait deneme alanında yağışa dayalı şartlarda yürütülmüştür. Çalışmada bitki materyali olarak bölgede yaygın olarak yetiştiriciliği yapılan 3 adet ekmeklik buğday (Ceyhan-99, Empire ve Pehlivan) ve 3 adet makarnalık buğday (Eyyubi, Sena ve Svevo) çeşidi kullanılmıştır. Araştırma organik tarım koşullarında "Tesadüf Blokları Deneme Deseni'ne göre 4 tekerrürlü olarak kurulmuştur. Çalışmada yabancı ot mücadelesi için herhangi bir kimyasal ilaç kullanılmamış ve yabancı otu elle yolma işlemi sapa kalkma dönemi sonunda el ile yapılmıştır. Araştırmaya ait varyans analiz sonuçlarına göre yabancı ot uygulama (yabancı otsuz) ve kontrol (yabancı otlu) parsellerinde ortalama verim değerinin ekmeklik ve makarnalık buğdayda birbirine yakın olduğu belirlenmiştir. Ekmeklik buğdayda verim kriteri bakımından uygulamanın genotip üzerindeki etkisi ve makarnalık buğdayda ise genotip istatistiki olarak önemli bulunmuştur. Yabancı ot yaş ağırlığının en fazla olduğu Eyyubi (91,04 g/m$^2$) ve Sena (75,71 g/m$^2$) makarnalık buğday çeşitlerinin kontrole kıyasla uygulamada (yabancı ot elle yolma) en yüksek verim artışını gösteren genotipler oldukları belirlenmiştir. Sonuç olarak; Diyarbakır iklim koşullarında gerçekleştirilen bu çalışmada iklim koşullarının uygun olduğu yıllarda organik tarımda yabancı ot mücadelesinin verim açısından bir farklılık oluşturabileceği gözlemlenmiştir. Ancak araştırma yılında olduğu gibi kuraklık ve yüksek sıcaklık etkisinin hissedildiği yıllarda kültür bitkilerinde olduğu gibi yabancı ot gelişiminde de anormallikler olduğu ve zayıf gelişim nedeniyle yabancı ot etkisinin azaldığı saptanmıştır.

# The effect of hand plucking method on wheat yield in weed control under organic farming conditions

**Research Article**

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**A B S T R A C T**

In this study carried out in Diyarbakır conditions, it was aimed to determine the effect of weed control on wheat yield, which is more important in terms of yield for organic agriculture compared to conventional agriculture. The research was carried out under rainfed conditions in the trial area of the Faculty of Agriculture of Dicle University in the wheat growing period of 2020-2021. In the study, 3 bread wheat (Ceyhan-99, Empire and Pehlivan) and 3 durum wheat (Eyyubi, Sena and Svevo) varieties, which are widely grown in the region, were used as plant material. The research was established in organic farming conditions according to the "Random Blocks Trial Design" with 4 replications. No chemical pesticides were used for weed control in the study, and weed plucking was done manually at the end of the wheat plant's stemming period. According to the variance analysis results of the research, it was determined that the average yield value in weed application (no weed) and control (weed) plots was close to each other in bread and durum wheat. The effect of the application on the genotype in terms of yield criteria in bread wheat and the genotype in durum wheat were found to be statistically significant. It was determined that Eyyubi (91.04 g/m$^2$) and Sena (75.71 g/m$^2$) durum wheat cultivars with the highest weed wet weight were the genotypes showing the highest yield increase in practice (plucking weeds by hand) compared to the control. In conclusion; in this study, which was carried out in Diyarbakır climatic conditions, it was observed that weed control in organic agriculture can make a difference in terms of yield in years when the climatic conditions are suitable. However, in the years when the effects of drought and high temperature were felt as in the research year, it was determined that there were abnormalities in weed growth as in the cultivated plants, and the weed effect decreased due to poor growth.

## 1. GİRİŞ

Günlük yaşantımıza her gün başka bir şekilde yansıması olan küresel iklim değişikliğinin olumsuz etkileri hız kesmeden artmakta ve farklılık göstermektedir. Bu olumsuz etkiler açlık krizi yaratacak oranda bir artış gösteren dünya nüfusunu da beraberinde getirmektedir. 2050 yılına gelindiğinde var olan muhtemel yaşam kaynaklarının insan nüfusunun ihtiyaçlarını karşılayamayacağı düşünülmektedir. Bu nedenle de insan beslenmesine yetecek gıda arzını karşılarken insan sağlığına ve çevreye zarar vermeyen ve üretimde kimyasal ilaçlar, sentetik gübreler, hormonlar ve genetiği değiştirilmiş organizmaların hiçbir şekilde kullanılmadığı, üretimden tüketime kadar her aşaması kontrollü ve sertifikalı bir tarımsal üretim biçimi olan organik tarım gibi ekolojik denge prensiplerini benimseyen, çevre ve insan sağlığını önemseyen tarım sistemlerine mutlak ihtiyaç söz konusudur.

Dünyada olduğu gibi ülkemizde de organik tarım faaliyetlilerinin devam ettirilmesinde ve geleneksel tarımdan organik tarıma geçişteki en önemli engellerden biri, herbisit (yabancı ot ilacı) kullanımının sınırlı olması ile mücadelesi oldukça güçleşen ve verimi ciddi oranda sekteye uğratan yabancı otlardır. Dünya çapında herbisit tüketimi, her yıl tüketilen 2 milyon ton pestisitin %47,5'ini oluşturmakta ve herbisitlerin yoğun kullanımı ciddi oranda çevre ve halk sağlığı sorunlarına yol açmaktadır (Sopeña &

Morillo, 2009). Yabancı ot bilimcileri, özellikle herbisitlere dayanıklı yabancı otların ortaya çıkışı ile gıda, toprak, yeraltı suyu ve atmosferdeki herbisit kalıntılarının çiftçileri yeni zorluklarla karşı karşıya getirdiğini bildirmişlerdir (Abouziena & Haggag, 2016). Yabancı otlar kısaca, "İstenmeyen yerde yetişen ve zararı yararından çok olan bitki" olarak ifade edilmektedir. Buğday üretiminde hastalık, zararlı ve yabancı otlar üretimi sınırlayan faktörler arasında yer almakta ve bu faktörlerin en başında da yabancı otlar gelmektedir (Belen, 2016). Yabancı otlar topraktaki besin maddeleri, ışık ve su gibi faktörler yönünden buğdayla rekabet etmekte ve bu rekabet sonucunda buğdayın canlılığı, başak uzunluğu ve tane ağırlığında azalmalara neden olmaktadır (Olesen ve ark., 2004; Grichar, 2006; Zand ve ark., 2007; Yasin ve ark., 2010). Ayrıca yabancı otlar hasadı zorlaştırarak, buğday kalitesini düşürmekte, hastalık ve zararlılara konukçuluk ederek dolaylı zararlar da vermektedir (Yasin ve ark., 2010; Kaydan ve ark., 2012). Oerke (2006) yabancı ot kontrolü olmaksızın buğdayda potansiyel ürün verimi kaybının, küresel ölçekte %43 oranında olduğu bildirmiştir. Bu nedenle de ülkemizde buğday ekim alanlarında yüksek verim elde etmek amacıyla yabancı otlarla mücadele oldukça önem arz etmektedir (Güncan & Karaca, 2018).

Araştırmacılar yabancı ot yönetiminin organik tarımın en zor kısmı olduğunu ve organik tarım ile elde edilen verimin konvansiyonel tarım ile elde edilen verimden %50 daha düşük olmasının ana sebebi olduğunu bildirmiştir (Rood, 2002; Gianessi & Reigner, 2007). Kültür bitkileri arasında yetişen bazı yaygın tek yıllık yabancı otlar, kültür bitkilerinde olduğu gibi yarım kilo kuru madde üretmek için üç kata kadar daha fazla su kullanmaktadırlar (Parker, 2003). Bu nedenle de yabancı ot kontrolünün, verim miktarını ve kalitesini artırmak ve yabancı ot rekabetinden kaynaklanan mahsul üretimindeki kayıpları en aza indirmek için mutlak gerekli olduğu bildirilmektedir (Abouziena & Haggag, 2016). Rao (2000) özellikle gıda ürünlerindeki tüm yabancı otların kontrol altına alınması halinde, mevcut dünyanın gıda üretiminin %10 ila %25 oranında daha fazla olabileceğini bildirmiştir. Dünyada tarımsal üretim alanlarında yaklaşık olarak 7000 yabancı ot türü olduğu ve bunların 200-300 kadarının tarımsal üretimi olumsuz etkilediği belirtilmiştir. Türkiye'de ise yaklaşık olarak 1800 yabancı ot türü bulunduğu bildirilmiştir (Arıkan & Elibüyük, 2015). Ayrıca dünyada buğday, mısır, çeltik, pamuk gibi belli başlı ürünlerde hastalık, zararlı ve yabancı otlardan kaynaklanan ürün kaybının %67,15 oranında olduğu ve bununda %31,62'sinin yabancı otlardan oluştuğu bildirilmiştir (Başaran, 2020).

Dünyada yapılan çalışmalarda buğday tarlalarında yabani yulaf, yabani hardal, tarla düğün çiçeği, dil kanatan, köygöçüren, kendi gelen mercimek, gelincik, papatya çobandeğneği, tarla sarmaşığı, gökbaş ve pıtrak gibi kışlık yabancı ot türlerinin baskın olduğu bildirilmiştir (Sırma & Kadıoğlu, 2010; Özaslan, 2011; Güncan, 2014; Gökalp & Üremiş, 2015; Kraehmer, 2016; Sizer & Tepe, 2016). Diyarbakır ili buğday tarlalarında yapılan çalışmalarda da Özaslan (2011), buğday yetiştiriciliğinin yapıldığı 5 ilçedeki 91 tarlada elde ettiği sürvey sonuçlarına göre toplam 33 farklı familyaya ait 134 cins ve 174 yabancı ot türü saptadığını bildirmiştir. Pala & Mennan (2017) ise buğday ekimi yapılan 17 ilçedeki 106 tarlada farklı yoğunluklarda 26 familyaya ait 107 yabancı ot türü tespit etmişlerdir. Araştırmacılar Diyarbakır tarlalarında yaygın olarak görülen yabancı otların; kısır yabani yulaf, yabani hardal, boynuzlu yoğurt otu, pelemir, tarla sarmaşığı, tarla düğün çiçeği, dil kanatan, köygöçüren, gelincik, pıtrak ve çoban çantası olduğunu bildirmişlerdir (Özaslan, 2011; Pala & Memnan, 2017). Kraehmer (2016), iklim farkları, yetiştiricilik teknikleri ve özellikle uygulanan yabancı ot kontrol yöntemlerinin tarım alanlarındaki yabancı ot kompozisyonunu değiştirebildiğini bildirmiştir. Shahzad ve ark. (2016) ise etkili bir mücadele için sorun olan yabancı ot türlerinin, dağılımlarının, yoğunluklarının ve baskınlıklarının bilinmesinin önem arz ettiğini ve tüm bunların bilinmesinin alınacak tedbirlerin ve uygulanacak yöntemlerin belirlenmesi açısından da önemli olduğunu bildirmişlerdir.

Diyarbakır koşullarında yürütülen bu çalışmanın amacı da konvansiyonel tarıma kıyasla organik tarımda verim açısından önemli rol oynayan yabancı ot mücadelesinin buğday verimi üzerindeki etkisini belirlemektir.

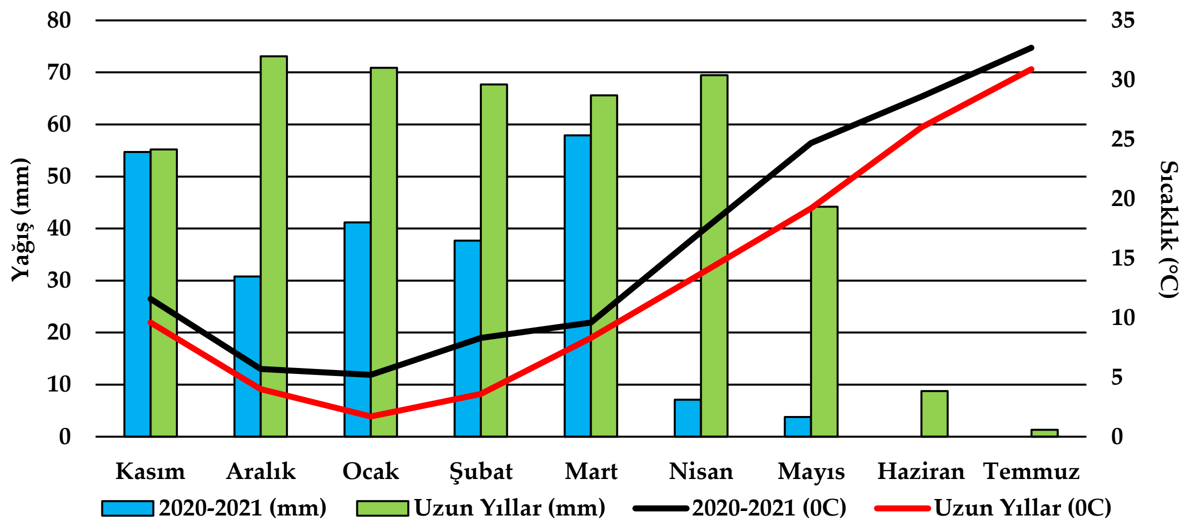
## 2. MATERYAL VE YÖNTEM

Araştırma 2020-2021 yılı buğday yetiştirme döneminde Dicle Üniversitesi Ziraat Fakültesinde organik tarım için ayrılan deneme alanında yağışa dayalı koşullarda yürütülmüştür. Çalışmada bitki materyali olarak 3 adet ekmeklik buğday (Ceyhan-99, Empire ve Pehlivan) ve 3 adet makarnalık buğday (Eyyubi, Sena ve Svevo) çeşidi kullanılmıştır (Çizelge 1). Çalışmanın yürütüldüğü Diyarbakır ilinin 2020/2021 yıllarına ve uzun yıllara (1929-2021) ait ortalama iklim verileri Şekil 1'de ve deneme alanı toprak örneklerine ait bazı analiz sonuçları Çizelge 2'de verilmiştir.

Çalışma organik tarım koşullarında "Tesadüf Blokları Deneme Deseni'ne göre 4 tekerrürlü ve her blokta bir genotipten iki parsel olacak şekilde kurulmuştur (Şekil 2). Kullanılan tohumluğun bin dane ağırlığına göre m$^2$'de 500 tohum hesabıyla her genotip 4 m uzunluğunda, sıra arası mesafe 20 cm olacak şekilde 6 sıra ekilmiş olup, parsel alanı 4,8 m$^2$ (4 m uzunluk × 1,2 m genişlik) olarak ayarlanmıştır. Ekim işlemi 6 sıralı olarak ekim yapabilen tam otomatik deneme ekim mibzeri ile 24.11.2020 tarihinde yapılmış, hasat işlemi ise orak aleti yardımıyla el ile 11.06.2021 tarihinde gerçekleştirilmiştir.

**Çizelge 1.** Deneme kullanılan buğday çeşitlerine ait bazı özellikler
**Table 1.** Some traits of the wheat cultivars used in the experiment

| Tür | Çeşit | Islahçı Kuruluş | Özellikleri |
|---|---|---|---|
| **Ekmeklik Buğday** (*Triticum aestivum* L.) | Ceyhan-99 | 1999/Çukurova Tarımsal Araştırma Enstitüsü | Bitki boyu 90-100 cm olup yatmaya dayanıklıdır. Kışa ve kurağa orta derecede dayanıklı, gübreye reaksiyonu iyi ve hastalıklara karşı dayanıklı bir buğday çeşididir. Sahil Bölgeleri ve Güneydoğu Anadolu Bölgesi için önerilmektedir. |
| | Empire | 2014/Teknobiltar Tarım ve Arge A.Ş. | Kuraklığa dayanıklı ve sap verimliliği yüksektir. Ayrıca uzun ve farklı başak yapısı ile tane sayısı da fazladır. Oldukça verimli olan bu çeşit aynı zamanda yüksek sıcaklığa da dayanıklıdır. Güneydoğu Anadolu Bölgesi için önerilmektedir. |
| | Pehlivan | 1998/Trakya Tarımsal Araştırma Enstitüsü | Bitki boyu uzun olup 95-100 cm'dir. Soğuğa karşı dayanıklılığı çok iyi ve kurak şartlara dayanıklılığı iyidir. Kardeşlenme kapasitesi oldukça yüksektir. Kurağa dayanıklı olduğundan kıraç koşullarda da ekimi tavsiye edilir. |
| **Makarnalık Buğday** (*Triticum durum* L.) | Sena | 2016/Dicle Üniversitesi Ziraat Fakültesi | Bitki boyu kısa-orta, bayrak yaprak kıvrılma oranı orta ve bayrak yaprak kını mumsuluğu çok kuvvetlidir. Yazlık ve başaklanma zamanı ortadır. Güneydoğu Anadolu Bölgesi-Kuru koşullar için uygundur. |
| | Svevo | 2001/Tasaco Tarım ve Arge A.Ş. | Alternatif gelişme tabiatlıdır ve erkenci bir çeşittir. Kardeşlenme oranı yüksektir. Yatmaya dayanıklı ve sulamaya elverişlidir. |
| | Eyyubi | 2006/GAP Uluslararası Tarımsal Araştırma ve Eğitim Merkezi | Bitki boyu uzun ve alternatif gelişme tabiatına sahip olup, orta erkenci bir başaklanma süresine sahiptir. Güneydoğu Anadolu Bölgesi yağışa dayalı koşullar için uygundur. |




**Şekil 1.** Çalışma dönemine ve uzun yıllara ait bazı iklim değerleri
**Figure 1.** Climatic values for the study period and long years

**Çizelge 2.** Deneme alanı toprak örneklerine ait bazı analiz sonuçları
**Table 2.** Analysis results of the soil samples from the experimental area

| Analiz | Değerler | | Analiz | Değerler | |
|---|---|---|---|---|---|
| Saturasyon (%) | 74,00 | **Killi Tınlı** | Potasyum (ppm) | 528,87 | **Çok Yüksek** |
| Tuzluluk (dS/m) | 1,43 | **Tuzsuz** | Kalsiyum (ppm) | 10.831,83 | **Çok Yüksek** |
| % Tuz (TS 8334) | 0,068 | **Tuzsuz** | Magnezyum (ppm) | 657,44 | **Orta** |
| pH | 8,04 | **Hafif Alkali** | Sodyum (ppm) | 52,6 | **Düşük** |
| Kireç (%) | 9,75 | **Orta** | Demir (ppm) | 10,65 | **Çok Yüksek** |
| Organik Madde (%) | 0,85 | **Düşük** | Bakır (ppm) | 2,05 | **Orta** |
| Azot (%) | 0,04 | **Düşük** | Mangan (ppm) | 37,96 | **Orta** |
| Fosfor (ppm) | 6,00 | **Düşük** | Çinko (ppm) | 0,45 | **Düşük** |

Çalışmada %50 organik madde içerikli organik sertifikalı Organoferm ticari gübresi 60 kg/da hesabıyla granül olarak ekim öncesi parsellere uygulanmıştır. Ayrıca baharda buğday bitkisinin kardeşlenme döneminde 300 cc/100 litre hesabıyla %40 organik madde içerikli organik sertifikalı Naturamix ticari gübresi sıvı olarak yapraktan uygulanmıştır. Araştırmada yabancı ot mücadelesi için herhangi bir kimyasal ilaç kullanılmamış ve yabancı otu elle yolma işlemi sapa kalkma dönemi sonunda (Zadoks ve ark., 1974) el ile yapılmıştır. Yetiştirme döneminde yaşanan yağış kuraklığı nedeniyle uygulama parsellerinde yabancı ot temizliği sadece bir defa yapılmıştır. Elle yolma yöntemi ile yabancı ot temizliğinin yapıldığı parseller uygulama olarak adlandırılırken, yabancı ot temizliğinin yapılmadığı parseller ise kontrol olarak adlandırılmıştır. Yabancı ot temizliğinin yapılmadığı kontrol parselleri yetiştirme dönemi boyunca yabancı otlu bırakılmıştır. Ayrıca parsellerde görülen yabancı otlar fotoğraflanmış ve isim tanımlaması yapılmıştır (Yücer, 2007) (Şekil 6).

Araştırmada incelenen özellikler;

- Başaklanma gün sayısı (gün): Bitki çıkış tarihi ile birlikte her parseldeki bitkilerin %70'inde başağın bayrak yaprak kınından ½ oranında çıktığı döneme kadar geçen süre başaklanma gün sayısı olarak hesaplanmıştır (Bayhan & Yıldırım, 2021).

- Fizyolojik olum süresi (gün): Bitki çıkış tarihi ile her parseldeki bitkilerin %95 oranında sarardığı tarih arasındaki gün sayısı olarak hesaplanmıştır (Bayhan & Yıldırım, 2021).
- Verim (kg/da): Hasat sonunda, her parselden elde edilen tane ürünü hassas terazide tartılarak elde edilen rakamlar kg/da cinsinden hesaplanmıştır (Bayhan & Yıldırım, 2021).
- Yabancı ot yaş ve kuru ağırlık (g/m$^2$): Yabancı ot temizliğinin yapıldığı her bir uygulama parselinde buğday bitkisinin sapa kalkma dönemi sonunda (Zadoks ve ark., 1974) el ile toplanan yabancı otlar tartılarak g cinsinden yaş ağırlıkları belirlenmiş ve daha sonra 24 saat 105°C etüvde kurutulup g cinsinden tartılarak kuru ağırlıkları belirlenmiştir. Elde edilen değerlerin m$^2$'ye bölünmesiyle 1 m$^2$ alandaki yabancı ot ağırlığı belirlenmiştir (Özen, 2021).

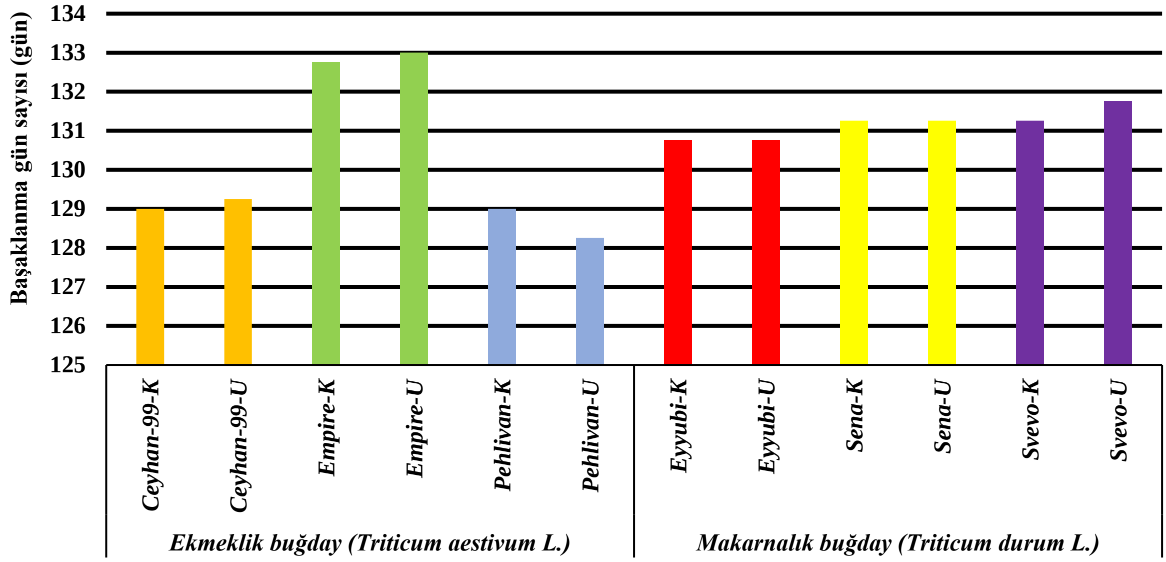
Araştırmada incelenen özelliklere ait varyans analizleri Tesadüf Blokları Deneme Deseni'ne göre JMP Pro (13.0) istatistik paket programı yardımıyla gerçekleştirilmiştir.

## 3. BULGULAR VE TARTIŞMA

Araştırmada organik tarım koşullarında ekmeklik ve makarnalık buğday genotiplerinin yabancı ot uygulama (yabancı otsuz) ve kontrol (yabancı otlu) parsellerinde incelenen özelliklere ait elde edilen ortalama değerler Çizelge 3 ve Çizelge 4 ve Şekil 2, Şekil 3, Şekil 4 ve Şekil 5'te verilmiştir.

Ekmeklik buğday genotiplerine ait ortalama değerlere bakıldığında başaklanma gün sayısı bakımından uygulama ve uygulamanın genotip üzerindeki etkisi önemsiz bulunurken, genotip istatistiki olarak önemli bulunmuştur. Ancak ekmeklik buğday genotiplerinde fizyolojik olum süresi bakımından istatistiki olarak herhangi bir farklılık oluşmamıştır. Fizyolojik olum süresi bakımından Empire, başaklanma gün sayısı bakımından ise Pehlivan çeşidinin erkenci genotip olarak ön plana çıktıkları belirlenmiştir. Makarnalık buğday genotiplerine ait elde edilen ortalama değerlere bakıldığında ise her iki özellik bakımından da genotip, uygulama ve uygulama genotip interaksiyonu istatistiki olarak önemsiz bulunmuştur. Başaklanma gün sayısı bakımından Eyyubi çeşidi, fizyolojik olum süresi bakımından ise Svevo çeşidinin erkenci genotip olarak öne çıktıkları saptanmıştır (Çizelge 3, Şekil 2, Şekil 3). Daha önce organik tarım koşullarda yapılan çalışmalarda başaklanma gün sayısı ve fizyolojik olum süresine ait değerlerin Bayhan ve Yıldırım (2021) ekmeklik buğday için sırasıyla 145,67 ve 178,80 gün olduğunu, Özkan & Akıncı (2021) ise makarnalık buğday için bu değerlerin sırasıyla 149,28 ve 180,01 gün olduğunu bildirmişlerdir.

Organik koşullarda yabancı ot uygulama ve kontrol parsellerinde ekmeklik ve makarnalık buğday genotiplerinden elde edilen ortalama verime bakıldığında değerlerin birbirine yakın olduğu saptanmıştır. Çizelge 4 ve Şekil 4'te görüldüğü üzere ekmeklik buğdayda uygulama ve genotip istatistiki olarak önemsiz bulunurken, uygulamanın genotip üzerindeki etkisi önemli bulunmuştur. Ekmeklik buğday genotiplerine ait verim değerleri bakımından kontrol parsellerinden ortalama 139,08 kg/da, uygulama parsellerinden ise ortalama 134,61 kg/da verim elde edilmiştir. Genotip bakımından yapılan değerlendirmede verim sıralamasının uygulama parsellerinde Ceyhan-99 > Empire > Pehlivan ve kontrol parsellerinde Empire > Pehlivan > Ceyhan-99 şeklinde olduğu belirlenmiştir. Makarnalık buğdayda verim bakımından genotip istatistiki olarak önemli bulunurken, uygulama ve uygulama genotip interaksiyonu önemsiz bulunmuştur. Makarnalık buğday genotiplerine ait verim değerleri bakımından kontrol parsellerinden ortalama 136,20 kg/da, uygulama parsellerinden ise ortalama 140,28 kg/da verim elde edilmiştir. Ayrıca genotipler arasında yapılan verim sıralamasının uygulama parsellerinde Sena > Svevo > Eyyubi ve kontrol parsellerinde Svevo > Sena > Eyyubi şeklinde olduğu tespit edilmiştir (Çizelge 3, Şekil 4). Organik tarım koşullarında daha önce yapılan çalışmalarda bazı araştırmacılar buğday genotipleri arasında yabancı otlarla rekabet yeteneği açısından önemli farklar bulunduğunu ve buğday çeşitlerinin organik ve konvansiyonel tarım sistemlerine tepkilerinin farksız bulunduğunu bildirmişlerdir (Kitchen ve ark., 2003; Hoad ve ark., 2008).




**Şekil 2.** Başaklanma gün sayısı bakımından kontrol (K-Yabancı otlu) ve uygulama (U-Yabancı otsuz) parsellerine ait ortalama değerler

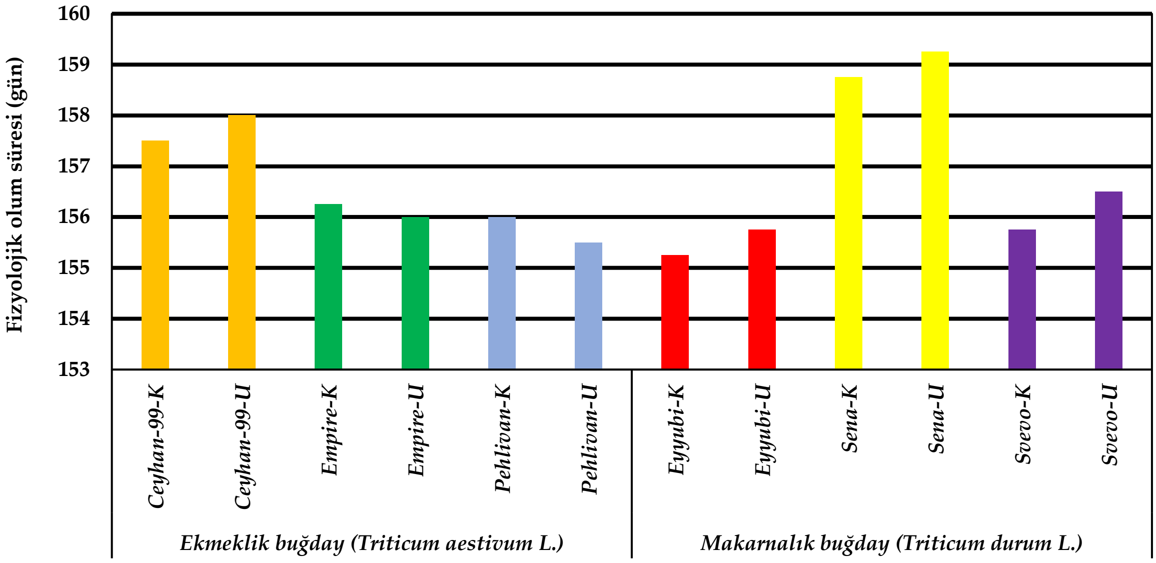
**Figure 2.** Mean values of heading time of the control (K-weed) and application (U-no weed) plots

**Çizelge 3.** Araştırmada incelenen özelliklere ait genotip ortalamaları ve oluşan gruplar

**Table 3.** Genotype means and groups of traits analyzed in this study

| | **Özellikler** | **Başaklanma gün sayısı (gün)** | | | **Fizyolojik olum süresi (gün)** | | |
|---|---|---|---|---|---|---|---|
| **Tür** | **Genotip** | **Kontrol (Yabancı otlu)** | **Uygulama (Yabancı otsuz)** | **Ortalama** | **Kontrol (Yabancı otlu)** | **Uygulama (Yabancı otsuz)** | **Ortalama** |
| **Ekmeklik buğday** *(Triticum aestivum L.)* | Empire | 132,75 | 133,00 | 132,88 [a] | 156,25 | 156,00 | 156,13 |
| | Ceyhan-99 | 129,00 | 129,25 | 129,13 [b] | 157,50 | 158,00 | 157,75 |
| | Pehlivan | 129,00 | 128,25 | 128,63 [b] | 156,00 | 155,50 | 155,75 |
| | **Ortalama** | **130,25** | **130,17** | **130,20** | **156,58** | **156,50** | **156,54** |
| | DK (%) | 0,68 | | | 1,44 | | |
| | AÖF (0,05) | (G = 0,.93**) (U = öd.) (U*G = öd.) | | | (G = öd.) (U = öd.) (U*G = öd.) | | |
| **Makarnalık buğday** *(Triticum durum L.)* | Eyyubi | 130,75 | 130,75 | 130,75 | 155,25 | 155,75 | 155,50 |
| | Sena | 131,25 | 131,25 | 131,25 | 158,75 | 159,25 | 159,00 |
| | Svevo | 131,25 | 131,75 | 131,50 | 155,75 | 156,50 | 156,13 |
| | **Ortalama** | **131,08** | **131,25** | **131,16** | **156,58** | **157,17** | **156,87** |
| | DK (%) | 0,87 | | | 2,07 | | |
| | AÖF (0,05) | (G = öd.) (U = öd.) (U*G = öd.) | | | (G = öd.) (U = öd.) (U*G = öd.) | | |

***Not:*** **: %1 düzeyinde önemli, **öd:** Önemli Değil, **DK:** Düzeltme Katsayısı, **AÖF:** Asgari Önemli Farklılık, **G:** Genotip, **U:** Uygulama, **U*G:** Uygulama*Genotip




**Şekil 3.** Fizyolojik olum süresi bakımından kontrol (K-Yabancı otlu) ve uygulama (U-Yabancı otsuz) parsellerine ait ortalama değerler

**Figure 3.** Mean values of maturity time of the control (K-weed) and application (U-no weed) plots

Verim kriteri bakımından yabancı ot mücadelesinin ekmeklik buğday da genotip verimini olumlu yönde etkilemediği, ancak makarnalık buğdayda artış sağladığı gözlemlenmiştir (Çizelge 4). Bu durum makarnalık buğday genotiplerinin ekmeklik buğday genotiplerine kıyasla yabancı ot ile rekabet gücü ve yabancı ot baskılama özellikleri yönünden daha iyi olduklarını göstermektedir. Şekil 6'da görüldüğü üzere en fazla yabancı ot yaş ağırlığının makarnalık buğday genotiplerinde olduğu belirlenmiştir. Yabancı ot yaş ağırlığının en fazla olduğu Eyyubi (91,04 g/m$^2$) ve Sena (75,71 g/m$^2$) makarnalık buğday çeşitlerinin kontrole kıyasla uygulamada en yüksek verim artışını gösteren genotipler oldukları belirlenmiştir (Şekil 5). Lacko-Bartosova & Kroslak (2001) yaptıkları çalışmada, metrekaredeki yabancı ot yoğunluğunun organik tarım sisteminde geleneksel tarım sistemine oranla daha fazla olduğunu ve organik buğday sisteminde verimi kısıtlayan en önemli faktörlerden birinin yabancı ot baskısı olduğunu bildirmişlerdir. Mason ve ark. (2007), tarım sistemlerini yabancı ot biyoması yönünden karşılaştırarak organik tarım sisteminde 134,0 g/m$^2$, geleneksel tarım sisteminde ise 1,40 g/m$^2$ yabancı ot biyoması elde edildiğini bildirmişlerdir.

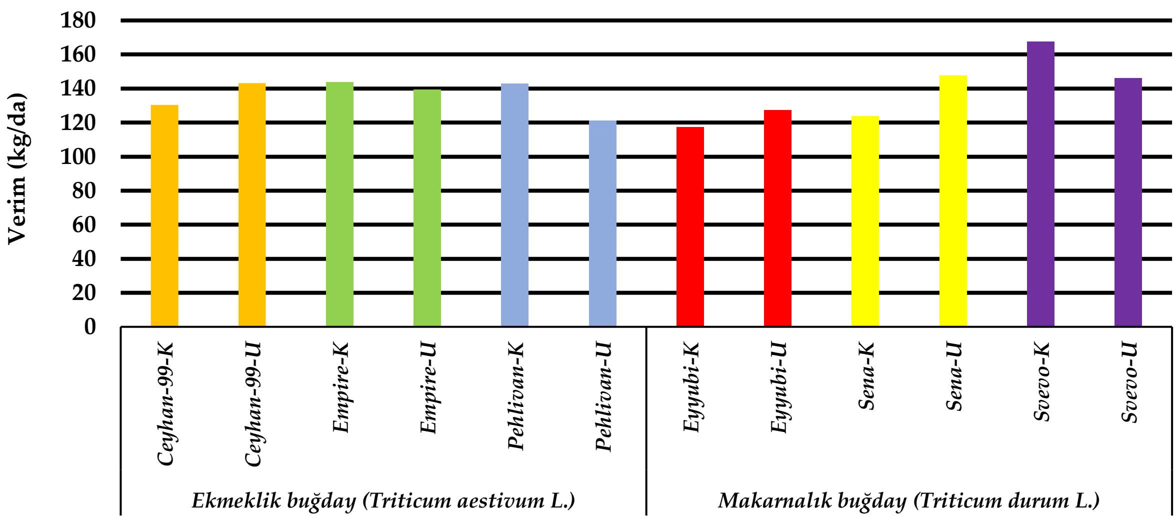
Araştırmacılar organik tarımda yabancı otlara karşı ilaçlama yapılmadığı için üretim alanında yabancı ot yoğunluğunun arttığını ve buna bağlı olarak verimde %40'a kadar azalma görüldüğünü bildirmişlerdir (Mason ve ark., 2007; Gosme ve ark., 2012). Bulut (2009), küçük alanlarda ve iş gücünün ucuz olduğu yerlerde yabancı otların elle yolunmasının yüksek verim için daha uygun olabileceğini bildirmiştir. Bazı araştırmacılar organik tarım sisteminde verim düşüklüğünün yabancı otların buğday bitkisinin besin ve suyuna ortak olması ile birlikte organik gübreleme nedeni ile buğdayın bitki besin maddesi ihtiyacının yetersiz kaldığından kaynaklandığını bildirmişlerdir (Kitchen ve ark., 2003; Mason ve ark., 2007). David ve ark. (2005), organik tarım koşullarında buğday bitkisinde başaktaki tane sayısının çiçeklenme dönemindeki azot beslenmesine ve yabancı ot yoğunluğuna bağlı olduğunu, başaktaki tane sayısının azot beslenmesi ile olumlu ve yabancı ot yoğunluğu ile olumsuz ilişki gösterdiğini bildirmişlerdir.

Araştırmanın yürütüldüğü 2020-2021 yılında bitki gelişim dönemlerine göre düşen yağış miktarı ve ortalama sıcaklık değerleri arasında farklılık oluşmuştur. Yetiştirme sezonunda toplam yağış miktarı 234,2 mm olarak gerçekleşmiş ve uzun yıllara ait yağış miktarının (456,3 mm) altında seyretmiştir. Aylık ortalama sıcaklık ise 15,9°C olarak gerçekleşmiş ve uzun yıllar ortalamasının (13°C) üzerine çıkmıştır. 2020-2021 yılında hem yaşanan yağış eksikliği hem de sıcaklık etkisi bitkilerin zayıf gelişim göstermesine, daha erken başaklanmasına, daha erken olgunlaşmasına ve zayıf ve cılız tane oluşturmasına neden olmuştur. Kültür bitkilerinde olduğu gibi yaşanan yağış kuraklığı ve yüksek sıcaklığın etkisiyle araştırmada hem daha az yabancı ot oluşumu gözlemlenmiş hem de zayıf ve cılız ot gelişimi saptanmıştır. Bu durum hem parseldeki yabancı ot yoğunluğunun az olmasını hem de yabancı otların buğday genotiplerini baskılaması durumunu azaltmıştır. Bu nedenle de araştırmadan elde edilen yüksek ve düşük verim değerlerinin sadece yabancı ot durumu ile ilişkilendirilmemesi, yaşanan iklim etkilerinin de dikkate alınması gerektiği tespit edilmiştir.

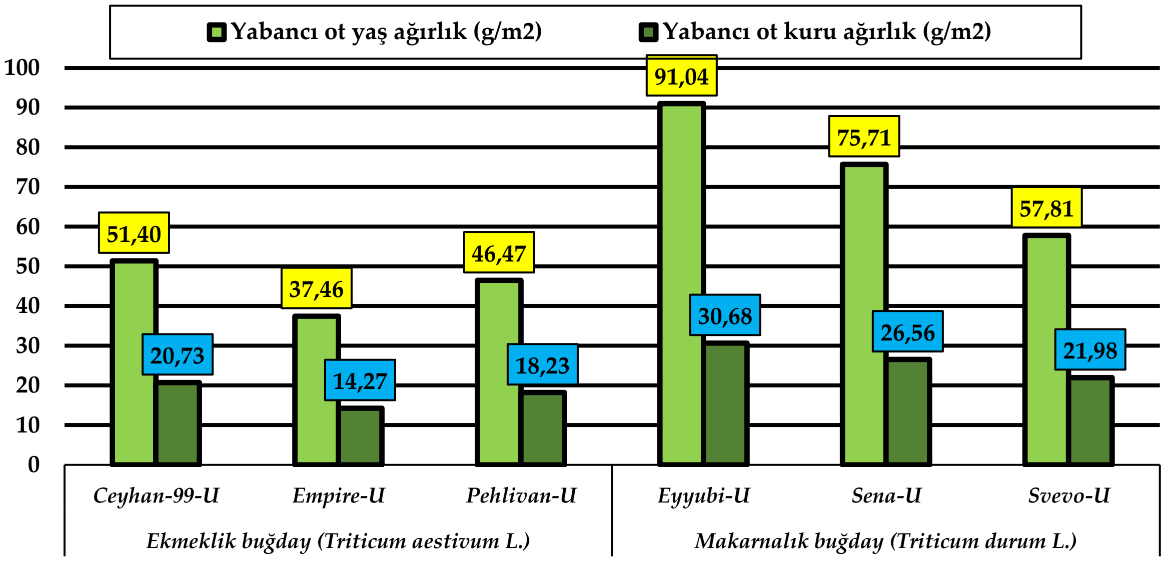
**Çizelge 4.** Araştırmada incelenen verim özelliğine ait genotip ortalamaları ve oluşan gruplar
**Table 4**. Genotype means and groups of yield traits analyzed in this study

| **Verim (kg/da)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Ekmeklik buğday (*Triticum aestivum* L.)** | | | | **Makarnalık buğday (*Triticum durum* L.)** | | | |
| **Genotip** | **Kontrol (Yabancı otlu)** | **Uygulama (Yabancı otsuz)** | **Ortalama** | **Genotip** | **Kontrol (Yabancı otlu)** | **Uygulama (Yabancı otsuz)** | **Ortalama** |
| Empire | 143,78 [a] | 139,52 [a] | 141,65 | Sena | 123,71 | 147,48 | 135,60 [b] |
| Ceyhan-99 | 130,46 [ab] | 143,13 [a] | 136,80 | Svevo | 167,54 | 146,00 | 156,77 [a] |
| Pehlivan | 143,00 [a] | 121,19 [b] | 132,10 | Eyyubi | 117,35 | 127,38 | 122,36 [b] |
| **Ortalama** | **139,08** | **134,61** | **136,84** | **Ortalama** | **136,20** | **140,28** | **138,24** |
| DK (%) | 8,63 | | | 13,73 | | | |
| AÖF (0,05) | (G = öd.) (U = öd.) (U*G = 17,78*) | | | (G = 20,21**) (U = öd.) (U*G = öd.) | | | |

***Not:*** *****: %1 ve ******: %5 düzeyinde önemli, **öd:** Önemli Değil, **DK**: Düzeltme Katsayısı, **AÖF**: Asgari Önemli Farklılık, **G:** Genotip, **U:** Uygulama, **U*G:** Uygulama*Genotip




**Şekil 4.** Verim bakımından kontrol (K-Yabancı otlu) ve uygulama (U-Yabancı otsuz) parsellerine ait ortalama değerler
**Figure 4.** Mean values of yield of the control (K-weed) and application (U-no weed) plots




**Şekil 5.** Yabancı ot temizliğinin yapıldığı uygulama parsellerinde yabancı ot yaş ağırlık ve kuru ağırlık özelliklerine ait ortalama değerler
**Figure 5.** Mean values of weed wet weight and dry weight traits in the weed-cleaning plots


**Şekil 6.** Yabancı ot temizliğinin yapıldığı uygulama parsellerindeki yabancı otlar ve isim tanımlamaları (Yücer, 2007)
**Figure 6.** Weeds and their names in the treatment plots where weed cleaning was performed (Yücer 2007)

Araştırmada uygulama parsellerinden elde edilen yabancı ot türleri Şekil 6'da görsel olarak verilmiştir. Çalışmanın yürütüldüğü Diyarbakır ili Sur ilçesinde daha önce yapılan yabancı ot sürvey çalışmaları ile araştırmadan elde edilen yabancı ot türleri birbirleri ile benzerlik göstermektedir. Pala & Mennan (2017), Diyarbakır iline ait farklı ilçelerdeki buğday tarlalarında yapılan sürveyler dikkate alındığında, baskın türleri büyük oranda aynı yabancı ot türlerinin oluşturduğunu ve sürveyler sonucu rastlama sıklığı %50'den fazla olan türlerin sırasıyla *Avena fatua* (%87), *Sinapis arvensis* (%78), *Ranunculus arvensis* (%72), *Galium aparine* (%62), *Cirsium arvense* (%58), *Lens culinaris* (%57), *Papaver rhoeas* (%56), *Turgenia latifolia* (%54), *Hordeum* sp. (%53) ve *Capsella bursa-pastoris* (%51) olduğunu bildirmişlerdir.

Özaslan (2011), Diyarbakır'da yürütmüş olduğu çalışmada Diyarbakır il genelinde rastlanma sıklığı %50'nin üzerinde ve yoğunluğu 0,25 bitki/m² üzerinde olan yabancı ot türlerinin; *Avena sterilis* L. (Kısır yabani yulaf) *Sinapis arvensis* L. (Yabani hardal), *Galium tricornutum* Dandy. (Boynuzlu yoğurt otu), *Cephalaria syriaca* L. (Pelemir), *Convolvus arvensis* L. (Tarla sarmaşığı) ve *Lallemantia iberica* (Bieb.) olduğunu bildirmiştir.

Akıncı (2021), Diyarbakır ili Bismil ilçesinde yapılan sürvey çalışması sonucunda toplam 17 familyaya ait 33 farklı yabancı ot türü ve Sur ilçesinde yapılan sürvey çalışmasında ise toplam 10 familyaya ait 17 farklı yabancı ot türü tespit edildiğini bildirmiştir. Ayrıca Sur ilçesine bağlı Dicle üniversitesi kampüsünde sürvey yapılan arazide; *Triticum aestivum* Spring. (87 adet/m²) (Kendi gelen buğday), *Avena sterilis* L. (8,25 adet/m²) (Kısır yabani yulaf), *Anthemis arvensis* L. (5,6 adet/m²) (Tarla köpek papatyası), *Lolium temulentum* L. (5,3 adet/m²) (Delice), *Hordeum spontaneum* C. Koch. (4,5 adet/m²) (Yabani arpa), *Sisymbrium officinale* (L.) Scop. (3,5 adet/m²) (Bülbül otu), *Scabiosa calocephala* Boiss. (3 adet/m²) (Uyuz otu), *Bromus tectorum* L. (3 adet/m²) (Püsküllü çayır), *Galium tricornutum* Dandy. (2,25 adet/m²) (Boynuzlu yoğurt otu), *Hordeum murinum* L. (2,25 adet/m²) (Duvar arpası), *Medicago* sp. (1,75 adet/m²) (Yonca), *Astragalus* sp. (1,5 adet/m²) (Geven), *Papaver* spp. (1,5 adet/m²) (Gelincik), *Crepis* sp. (1,25 adet/m²) (Kıskı), *Sinapis arvensis* L. (1,25 adet/m²) (Yabani hardal), *Trifolium arvense* L. (1,25 adet/m²) (Tarla üçgülü) ve *Vicia narbonensis* L. (1,25 adet/m²) (Koca fiğ) yabancı ot türlerinin yoğunluğu 1'den fazla bulunduğunu bildirmiştir.

## 4. GENEL SONUÇLAR

Araştırma sonucunda Diyarbakır iklim koşullarında gerçekleştirilen bu çalışmada iklim koşullarının uygun olduğu yıllarda yabancı ot mücadelesinin verim açısından bir farklılık oluşturabileceği, ancak araştırma yılında olduğu gibi kuraklık ve yüksek sıcaklık etkisinin hissedildiği yıllarda kültür bitkilerinde olduğu gibi yabancı ot gelişiminde de anormallikler olduğu ve zayıf gelişim nedeniyle yabancı ot etkisinin azaldığı saptanmıştır. Bu nedenle de araştırmadan elde edilen yüksek ve düşük verim değerlerinin sadece yabancı ot durumu ile ilişkilendirilmemesi, yaşanan iklim etkilerinin de dikkate alınması gerektiği sonucuna varılmıştır.

## ETİK STANDARTLAR İLE UYUM

### Yazarların Katkısı

MY çalışmayı tasarladı, RÖ makalenin ilk taslağını yazdı, MB istatistiksel analizleri yaptı ve yönetti. Tüm yazarlar son makaleyi okudu ve onayladı.

### Çıkar Çatışması

Yazarlar herhangi bir çıkar çatışması olmadığını beyan etmektedir.

### Etik Onay

Yazarlar bu tür bir çalışma için resmi etik kurul onayının gerekli olmadığını bildirmektedir.

### Veri Kullanılabilirliği

Veri setleri ile ilgili sorular için, sorumlu yazar ile iletişime geçilmelidir.

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