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THE USE OF Q-METHODOLOGY IN EXPLORING FARMERS' PERSPECTIVES IN THE CONTEXT OF CLIMATE CHANGE

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Abstract: This paper aimed to examine the literature to determine the extent to which Q-methodology has been employed in empirical studies in order to measure farmers' perspectives in various contexts of climate change. The analysis revealed a surprisingly limited application of Q-methodology in this area. A search of the SCOPUS database, using the advanced search string TITLE-ABS-KEY ("Q-method*" OR "Q-sort*" OR "Q-stud*" OR "Q-technique" AND "farmer*" OR "agricultur*" AND "clima*"), identified 21 published articles that met the specified criteria. All these papers were published over the last decade, indicating an upward trend in the number of publications over the years. The analysis of these studies demonstrates that Q-methodology can be effectively applied in research aimed at uncovering and comprehending farmers' perceptions regarding climate change mitigation and adaptation to its risks. Despite its evident potential, this method remains underutilized and merits greater attention from scholars and practitioners. To the best of the authors' knowledge, no such review has been conducted previously. Hence, this paper makes a substantial contribution and serves as both an incentive and a valuable starting point for researchers considering the use of Q-methodology in empirical studies concerning farmers' subjectivity in the context of climate change.

Key words: Q-methodology, farmers, climate change, scoping review.

Introduction

The interplay between climate change and agriculture has spurred scientific interest in examining the subjectivity of farmers, as their decisions and implemented practices can impact climate change outcomes. To investigate this subjectivity, researchers employ various approaches and employ a wide array of methods, instruments, and scales. One of these methods is the Q-methodology, which is both a qualitative and statistical protocol (Seghezzo et al., 2023). This methodology facilitates the exploration of many different views and attitudes of

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individuals. Through factor analysis, the Q-methodology enables the identification of existing perspectives on specific topics, exploring individual subjectivity and offering insights into the behavior of these individuals and how they perceive their social and environmental environments (Barry and Proops, 1999). Particularly, Q-methodology seeks to reveal common understandings and shared worldviews, particularly regarding topics that are the subject to debate and contestation (Eden et al., 2005).

The Q-methodology categorizes participants into groups based on similar value orientations, using written statements or photographs. The process of Q-sorting and subsequent interviews allows for the analysis of individual beliefs, interests, and attitudes, ultimately revealing distinct value systems and perspectives on a given topic (Cheng et al., 2019). Unlike surveys, where researchers create statements for respondents to evaluate, the Q-methodology relies on statements originating from the participants themselves. These statements may stem from a variety of sources, including prior interviews, media, information campaigns, governmental and non-governmental organizations, and public documents. Consequently, Q-methodology captures the existing perspectives and worldviews of diverse individuals within specific contexts (Western et al., 2017). This approach allows respondents to define their own attitudes rather than categorizing the statements produced by the researcher (Bumbudsanpharoke et al., 2009). All of the above components constitute what Western et al. (2017) defined as "a pattern of subjective views held by a certain group of people". These views include central ideas, meanings, attributes, and compromises related to a particular topic. Even though it employs complex mathematical (factor) analysis, the Q-methodology is essentially a research tool that does not demand mathematical expertise to interpret the results, which makes it an exceptionally accessible method (Shemmings, 2006). Moreover, the process of sorting statements in Q-methodology is intriguing and resembles a card game, which fosters an interactive and engaging approach to involving research subjects (Eden et al., 2005). This interactive element contributes to a higher response rate (Davies and Hodge, 2007). Additionally, Q-methodology is very cost-effective as it requires modest sample sizes (Barry and Proops, 1999).

The primary criticisms of the Q-methodology center on its reliability (some authors suggest that respondents may not provide consistent answers in repeated surveys) and potential researcher bias when interpreting the results (Cross, 2005). Advocates of the Q-methodology counter these criticisms by claiming that, like other measurement scales, it relies on the honesty and cooperation of respondents, which are not and cannot be guaranteed. Moreover, the bias of the researcher in interpreting the results is not unique to this method but can be encountered in other research approaches as well.

While certain limitations of the Q-methodology cannot be ignored, it is a method applied across diverse research contexts, fields, and with various

participant groups (Western et al., 2017; Peters and Fontaine, 2020). Being qualitative in nature and centred on subjectivity, the Q-methodology finds its most extensive application in the social sciences (Mathur and Skelcher, 2007). However, it has been employed in numerous studies comprising various domains, including medical and health sciences (Baker et al., 2006), engineering (Niemeyer et al., 2005), the IT sector (Hazari, 2005), business and management (Angelopulo, 2009), psychology (Shemmings, 2006), arts (Thumvichit, 2022), mathematics (Nahm et al., 2002), as well as agriculture and related biological sciences (Brodt et al., 2006).

The success of using the Q-methodology is directly related to the interest of the participants. Therefore, the selection of participants is of particular importance in this method. Previous research included various participants, such as different professionals, experts in specific fields, political decision-makers, scientists, students, children, parents, and others (Dziopa and Ahern, 2011).

Recently, the Q-methodology has seen growing utilization in the field of agriculture. It is no longer limited solely to exploring the perspectives of farmers (Zobeidi et al., 2016; Norris et al., 2021; Mataruse et al., 2022; Reichenspurner et al., 2023). Instead, it has been employed to study the attitudes of advisors (Schulze and Matzdorf, 2023), policymakers in agribusiness (Turhan, 2016; Cruz et al., 2021), landowners (Carmenta et al., 2017), members of governmental and non-governmental organizations (Hall and Wreford, 2012; Rittelmeyer, 2020; Adams and Carodenuto, 2023), members of agricultural and local associations (Armatas et al., 2017), local managers (Carmenta et al., 2017), researchers, experts in various fields (Kopytko and Pruneddu, 2018; Steeves and Filqueira, 2019; Hinzmann et al., 2021), and other relevant actors.

Q-methodology proves highly effective in measuring subjectivity within diverse contexts, including the realm of climate change. This topic is becoming increasingly important for research, and the results derived from such measurements may be of significant societal importance.

According to Xiao and Watson (2019), advancing knowledge relies on a comprehensive understanding of existing achievements. Therefore, before embarking on new research, a literature review of prior scientific publications is necessary. To the best of the authors' knowledge, there is no stand-alone overview of the scientific literature focused on the application of Q-methodology to farmers, particularly within the context of climate change. Therefore, this paper sets out to provide such an overview, which will serve as a cornerstone for academic research.

An overview of the relevant literature serves as a means to understand the existing knowledge, assess the quality and validity of prior research, and reveal certain weaknesses, inconsistencies, and contradictions (Paré et al., 2015). Furthermore, it allows for identifying research gaps, exploring new research directions, testing specific research hypotheses, and/or developing new theories. A literature review should be valid, reliable, and reproducible (Xiao and Watson,

2019). To meet these criteria, it must be conducted systematically. In this paper, a systematic review is defined as "a review of a clearly formulated question that uses systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review" (Moher et al., 2009).

Literature reviews can be categorized into four distinct types, depending on whether their objective is describing, testing, extending, or critisizing a body of existing literature (Xiao and Watson, 2019). Given that the primary aim of this study is to describe the application of the Q-methodology in empirical studies for measuring farmers' subjectivity in various climate change contexts, a scoping review is employed. This type of review should provide a comprehensive overview of what has been accomplished in a specific area by extracting relevant data from each piece of the literature. A scoping review does not seek to extend the existing literature, but rather offers an overview of the state of the literature at the time when the review was published (Xiao and Watson, 2019). Such an approach does not diminish its value, especially considering the growing multidisciplinarity of research and the (hyper) production of scientific work, which can lengthen and complicate the reviewing process. The primary advantage of a scoping literature review lies in its comprehensiveness and its independence from the type of literature sources (quantitative, qualitative, etc.). Its key contributions include providing an overview of the scope of the research field, highlighting conceptual limitations, summarizing existing achievements, presenting various types of scientific evidence, and identifying research gaps (Munn et al., 2018; Xiao and Watson, 2019). However, a notable disadvantage of this type of review is neglecting the quality of the papers included in the review (Peters et al., 2015).

Previous literature reviews have explored various applications of Q-methodology in different domains. For instance, Dziopa and Ahern (2011) and Churruca et al. (2021) have analyzed its use in health sciences, while Zabala et al. (2018) delved into its application in conservation biology. In the field of education, Lundberg et al. (2020) have provided an overview, and Sneegas et al. (2021) have focused on its application in environmental sustainability, among others. However, as previously noted, there is no comprehensive review of studies employing Q-methodology among farmers in the context of climate change in the available literature. This article aims to address this gap by providing a review of existing publications. Our goal is to find out whether there are enough studies to justify a future systematic review and to identify future research avenues.

The structure of this article is as follows: The subsequent section outlines the methodology employed in this study. The obtained results are then presented and discussed, featuring a brief analysis of each of the papers included in this review. The final section draws conclusions, highlights the main limitations of the study and makes recommendations for future research.

Material and Methods

We conducted a scoping review of the literature following the instructions outlined in PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) (Tricco et al., 2018). This approach is recommended for writing review papers of this type (McGowan et al., 2020; Pollock et al., 2021). PRISMA-ScR, like other PRISMA extensions, was developed in response to the need to adapt the PRISMA guidelines (Moher et al., 2009) to accommodate the growing output of review papers across diverse topic areas that employ different methods (McGowan et al., 2020). This guideline offers three unique advantages: 1) it insists on the formulation of clear research questions, 2) it identifies criteria for the inclusion/exclusion of specific publications from the review, and 3) it aims to explore large bodies of scientific literature within a limited timeframe (Sierra-Correa and Cantera Kintz, 2015).

We conducted the literature search using the Scopus database, the largest and most widely used repository of peer-reviewed scientific publications (de Moya-Anegón et al., 2007; Aghaei Chadegani et al., 2013). While databases such as Web of Science, PubMed, Google Scholar, Science Direct, MEDLINE, CINAHL, JSTOR, and various others are used to access scientific publications in specific scientific fields, comparative analyses have shown the advantages of the Scopus database. Scopus offers a more extensive collection of scientific papers across a wider range of disciplines. Additionally, the Scopus search engine is faster than the search engines of the other databases (Falagas et al., 2007; Aghaei Chadegani et al., 2013). The popularity of the Scopus database can be attributed, in part, to its user-friendly platform and the array of search tools it offers (Burnham, 2006; Tober, 2011).

This review was based on a search conducted on July 3, 2023. The central research question was: Whether and how has Q-methodology been employed to explore farmers' perspectives in the context of climate change? Recognizing that Q-methodology can be referred to in various ways in the literature, such as Q-method, Q-sort, Q-study, and Q-technique (Dziopa and Ahern, 2011; Dieteren et al., 2023), an advanced search using relevant keywords included all its synonyms (in English: Q-method*[†], Q-sort, Q-stud*, and Q-technique). Given the objective of scoping studies where Q-methodology was applied to farmers, we included the term 'farmer*' in the search string. To avoid overlooking participants engaged in agriculture but described using terms other than "farmer" (e.g., agricultural workers, agriculturalist, agriculturist), we included the additional search criterion "agricultur*". The last key term we selected was based on the criterion of climate

[†]The Boolean operator *refers to the shortest possible keyword, i.e., it replaces all possible suffixes that can be found in a certain expression, such as Q-method* = Q-method; Q-methods; Q-methodology, etc.

change. To allow for its variations, we reduced the term to its very basic form "clima*". Therefore, the search string used in the Scopus database was as follows:

TITLE-ABS-KEY ("Q-method*" OR "Q-sort*" OR "Q-stud*" OR "Q-technique" AND "farmer*" OR "agricultur*" AND "clima*").

Surprisingly, despite the relatively wide application of Q-methodology, the search yielded only a few (n=24) scientific publications that met the specified criteria, requiring the publications to contain the search keys in the title, abstract, or keywords (Figure 1). Subsequently, the search focused on papers published or approved for publication after peer review, which was one of the reasons for choosing the Scopus database. We included papers from all scientific fields and disciplines that were written in English. A specific time frame was not set since it could not limit this research because Q-methodology has been in use since 1935 (Dieteren et al., 2023), and the Scopus database refers to publications from before that period. Spatial limitations were not set either. The criteria used to include articles for further analysis were twofold: 1) Q-methodology was applied to the population of farmers (though not exclusively), and 2) the research objectives and results could be contextualized in the context of climate change, contributing to our understanding of farmers' subjectivity concerning various topics related to climate change.

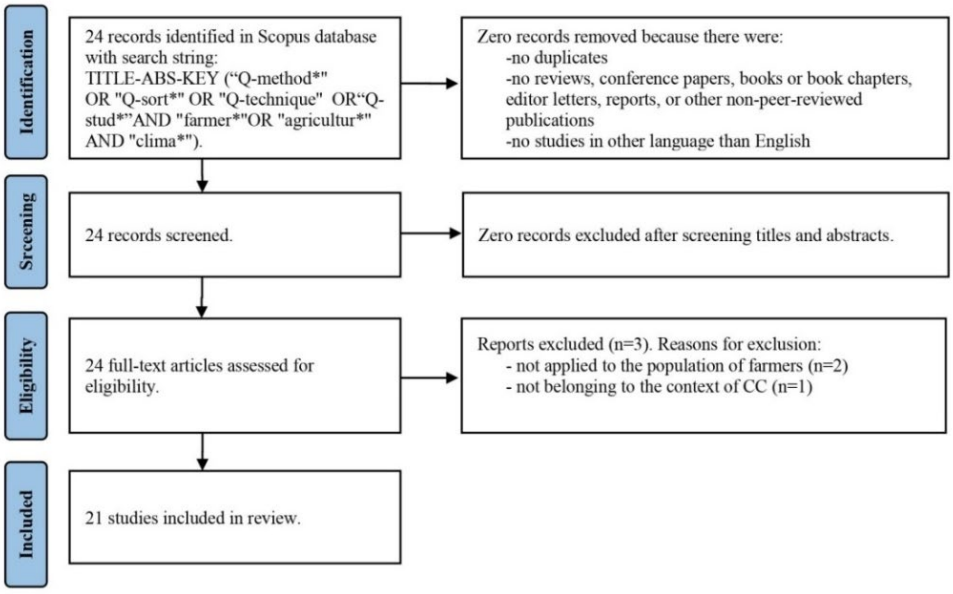

Figure 1. A flowchart of the selection process of publications for the scoping review following the PRISMA-ScR instructions.

After a review of the full papers, three were excluded from further analysis. Two of these did not apply Q-methodology to a population of farmers, while one study was not conducted in the context of climate change. A total of 21 scientific papers were included in the in-depth analysis.

Results and Discussion

The search conducted in the SCOPUS database revealed an upward trend in the application of Q-methodology in general, thus confirming the conclusions of Dieteren et al. (2023). Figure 2 illustrates the number of publications referenced in the Scopus database using the search string TITLE-ABS-KEY ("Q-method*" OR "Q-sort*" OR "Q-stud*" OR "Q-technique"). The cumulative number of publications meeting the search criteria was 5.093.

There is a similar trend in the application of Q-methodology for measuring the subjectivity of farmers. When the search string is extended to TITLE-ABS-KEY ("Q-method*" OR "Q-sort*" OR "Q-stud*" OR "Q-technique" AND "farmer*" OR "agricultur*"), the cumulative number of publications found totaled 166.

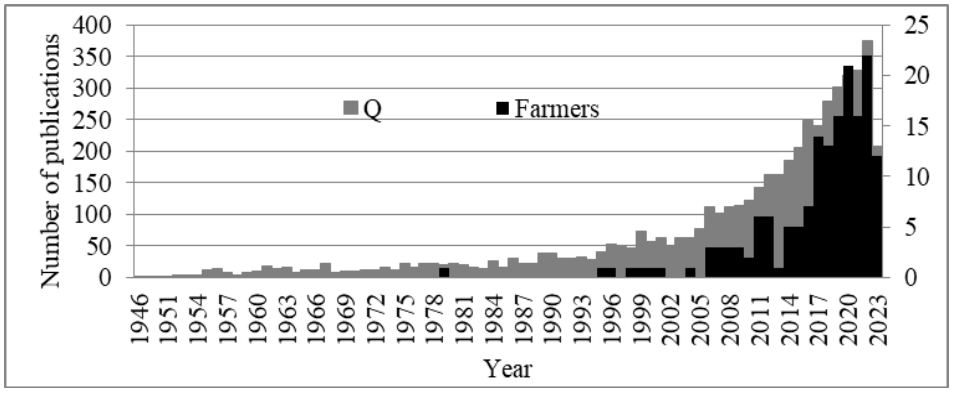

Figure 2. Number of referenced publications per year.

More than half (53%) of the total number of publications that applied Q-methodology were referenced within the last decade. Furthermore, 79% of the total number of publications that applied this method to the population of farmers were referenced in the last 10 years. This increase implies that the Q-methodology is gaining considerable importance in research.

Following the procedure outlined in the Methodology section, we identified 21 scientific articles that met the given criteria – namely, the use of the Q-methodology to explore farmers' perspectives in the context of climate change TITLE-ABS-KEY ("Q-method*" OR "Q-sort*" OR "Q-stud*" OR "Q-technique" AND "farmer*" OR "agricultur*" AND "climate*"). The earliest referenced paper

was published in 2012. Figure 3 shows the number of these articles per year, revealing a clear growing trend.

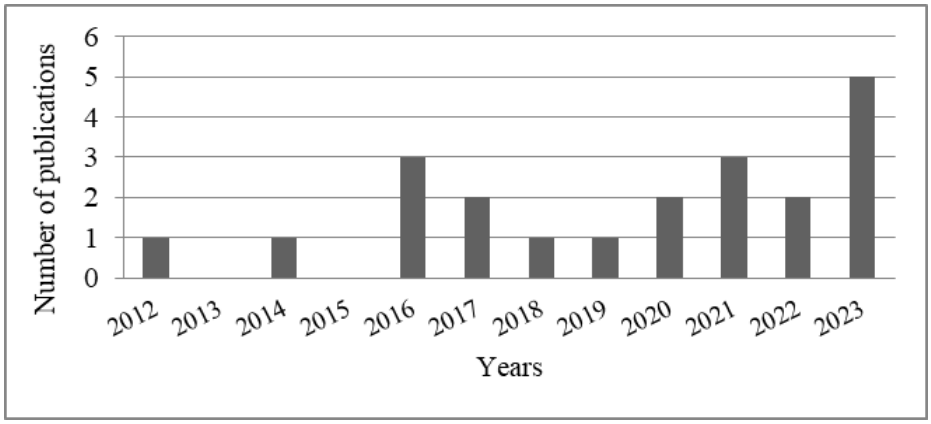

Figure 3. Number of publications selected for this review referenced per year.

Figure 4 presents the spatial distribution of the study areas. The papers included in this review encompassed all continents. The majority of these papers were based on research conducted in Europe, including two papers each from Germany and the Netherlands, and one paper each from Great Britain, Ukraine, and Sweden. Given that the nature of the selected methodology does not imply a representative or simple random sample, the participants in these studies were mainly from smaller regions, districts, or provinces.

Figure 4. Study areas of selected publications.

Table 1 offers a brief overview of each study included in this review. The topics investigated in these studies are diverse, yet all of them directly or indirectly can be connected to climate change. In addition, each study has made a certain contribution to climate change mitigation and/or adaptation.

The Q-methodology was applied to samples of farmers in just six observed studies (references in Table 1: #2, 10, 12, 13, 14, and 21). In the remaining studies, other stakeholders were also involved, including members of non-governmental organizations (#1, 3, and 17), researchers (#1, 6, 7, and 19), members of government communities, managers, and policy makers (#1, 3, 5, 7, 15, 17, and 20), experts in different fields (#8 and 9), local residents (#11 and 18), and other participants (#4 and 16).

Table 1. Brief description of the studies included in the scoping review.

No.	Reference	Themes/conclusions/contribution
1	Adams and Carodenuto, 2023	Stakeholders' perceptions of government measures aimed at reducing the poverty of cocoa farmers in Ghana were examined. Key attitudes are identified. Stakeholders believe that the introduced measures are indiscriminate, that they accelerate deforestation, and do not contribute to the desired poverty reduction.
2	Al-Maruf et al., 2022	The factors affecting the migration of farmers in Bangladesh from the countryside to the city were examined. Among the six identified dimensions, there are also climate-induced extremes (seasonal floods, above-average rainfall, heat waves, droughts, and river erosion).
3	Armatas et al., 2017	The analysis of the vulnerability of different users of the ecosystem services provided by the Wyoming National Forest (USA) watershed identified 4 distinct discourses. The paper explains the differences in those discourses, related to the concern for climate change and its negative impacts.
4	Buckwell et al., 2023	Discourses on the conservation of tropical forests in the equatorial region of Congo and initiatives for their conservation were identified. The collective perspectives of the community were established. The study concludes that social forms of compensation (such as educational and health institutions and services, strengthening moral responsibility for forest conservation, and reducing the gap within the population) are more acceptable than monetary ones.
5	Carmenta et al., 2017	Indonesian stakeholders' perceptions of peatland fire management initiatives. Given the significant role that peatlands play in storing CO_2, their exploitation by burning and drying for the sake of raising plantations requires urgent interventions. The authors emphasize the complexity and necessity of a multi-stakeholder approach to the solution of this problem.
6	Cruz et al., 2021	The authors examined the extent to which information about climate change is available to grassland-based livestock stakeholders in Uruguay. They found 4 different types of the use of climate information and proposed specific activities aimed at better adaptation.

Continuation Table 1. Brief description of the studies included in the scoping review.

7	Hall and Wreford, 2012	An analysis on the attitudes of stakeholders in the United Kingdom towards adaptation to climate change in the livestock sector was conducted. Depending on the attitudes, 4 groups of livestock farmers were defined, and it was determined that in three of the four groups, the adaptive capacity of farmers is not adequate and that it is necessary to provide appropriate market conditions, additional information, and financial support.
8	Hinzmann et al., 2021	Differences in views on subsoil amelioration, as a measure of adaptation to climate change in two regions in Germany, were examined. A typology of farmers was performed based on their willingness to accept ameliorative measures. The fundamental limitations of the application of such measures were identified and suggestions were made for overcoming them.
9	Kopytko and Pruneddu, 2018	The authors examined the attitudes of farmers in Ukraine towards crop rotation as a measure of adaptation to climate change. They identified the views on which there is a consensus and the disagreements that exist, and subsequently proposed measures for policy making.
10	Lairez et al. 2020	In this study, Q-methodology was applied as an additional method to gain an in-depth understanding of the differences in attitudes of farmers in Laos regarding soil fertility.
11	Lynch et al., 2014	Different perspectives were examined to define optimal strategies for policy innovation aimed at conserving Australia's Murray–Darling Basin, which faces severe droughts and extreme floods. The potential for a dialogue, which should result in solutions acceptable to all participants, was identified, even if it is rather modest.
12	Mataruse et al., 2022	The subject of this research is small farmers' perception of the natural and anthropogenic causes of deforestation and forest degradation in Zimbabwe. The study concludes that along with climate change, the destruction of forests is also caused by insect infestation, diseases, unavoidable external events, the lack of alternative sources of fuel, and the failure of existing institutional agreements. As a result, they recommend certain measures to create effective strategies for forest conservation.
13	Norris et al., 2021	The authors examine the views of Dutch farmers on climate mitigation plans and policies on agricultural peatlands. They conclude that support policy must change and focus on measures that go beyond compensation payments, by providing more information on funding sources, as well as potential business models for the use of peatlands with elevated water levels.
14	Reichenspurner et al., 2023	The study examines the perception of farmers in the Netherlands regarding agri-environmental climate measures. The survey shows that farmers agree that collective agroecological schemes are better than individual ones in the fight against climate change. However, farmers would like to see more flexibility and better integration of their knowledge and experience into scheme design.
No.	Reference	Themes/conclusions/contribution
15	Rittelmeyer, 2020	The paper reveals discourses among stakeholders regarding flood risk and flood management in the Sacramento-San Joaquin Delta (California, USA). The results indicate that decades of mistrust among stakeholders will continue to be a major challenge and that only a changed approach to understanding the different perspectives will enable the necessary communication on adaptation strategies.

Continuation Table 1. Brief description of the studies included in the scoping review.

16	Röös et al., 2023	The authors shed light on different perspectives regarding the sustainability of the food system in Sweden. The identified differences in priorities can be the main obstacle to the transformation of the food system, while the focus on healthy diets and increased production of fruits and vegetables represents the common priority of all participants and can be a good starting point for change.
17	Schulze and Matzdorf, 2023	The research aims to determine differences in the perception of contractual agri-environmental climate measures in Germany. The authors conclude that the differences between the perspectives of policy designers and farmers, who implement those policies, do not account for the institutional mismatch. It is recommended that policymakers gain a deeper understanding of the target group and consider its views when creating specific programs.
18	Sherren et al., 2016	In this study, the authors examined the preferences of interested actors in the coastal area of Nova Scotia (Acadian dykelands of Nova Scotia, Canada) regarding dyke maintenance measures and wetland restoration. They concluded that their views are polarized and that proposals to change the landscape must be focused on flood mitigation rather than cost savings.
19	Steeves and Filqueira, 2019	The focus of the work is to discover the perspectives of different Canadian stakeholders in shellfish production and aquaculture regarding measures of adaptation to climate change. The study concludes that, in order to improve the sustainability of the aquaculture industry by creating plans and decision-making, a higher level of integration and understanding among farmers and managers is necessary. Researchers should play a mediating role in knowledge transfer.
20	Turhan, 2016	The author examined the value orientations of political decision-makers in Turkey regarding climate change adaptation strategies. He identified four different discourses regarding the desirable direction of the development of the Turkish adaptation policy: productivist, eco-localist, techno-modernist, and authoritarian. He made suggestions for overcoming the differences and clearly defining priorities.
21	Zobeidi et al., 2016	Analyzing the discourse of Iranian farmers on climate change, the authors identified three groups of farmers depending on their attitudes towards climate change. Understanding the differences in the attitudes of these different groups can contribute to the development of more appropriate strategies for their adaptation to climate change.

The main steps in the implementation of the Q-methodology are the creation of the list of selected statements (so-called Q-set), the identification of the participants (P-set), the data collection, and their analysis and interpretation (Alderson et al., 2018).

Q-methodology starts from numerous statements that should reflect the diversity of possible attitudes towards a certain topic, often referred to as the concourse. There are various sources from which such statements can be collected (Alderson et al., 2018). In most studies examined in this review, the concourse was created from theoretical sources. This involved extracting dozens of statements pertinent to the specific topic from relevant literature, political documents, reports, news, and political announcements. Experts were consulted during this process. In

some studies, the concourse was created through interviews, workshops, and focus groups. There are also studies where the concourse was fashioned using a combination of theoretical and empirical approaches. In their systematic review of 613 scientific publications employing Q-methodology, Dieteren et al. (2023) observe a similar set of sources used for concourse creation.

In the following phase, statements or assertions to form the Q-set are chosen from the overall collection. This set comprises statements that participants will arrange based on their level of agreement with each statement. From the papers reviewed in this article, the authors have included 24 to 55 statements in the Q-set (Table 2). This is in line with numerous other studies utilizing Q-methodology (Dziopa and Ahern, 2011; Dieteren et al., 2023), where Q-sets normally contain from 20 to 100 statements. However, it is worth noting that a smaller number of statements makes the sorting process easier and more time-efficient (Barbosa et al., 1998).

Regarding sample size (P-set), Q-methodology has modest requirements. Barry and Proops (1999) demonstrated that even a sample of 12 participants can yield statistically significant results, particularly in terms of revealing implicit discourses (Barry and Proops, 1999). Some scholars recommend that the ratio of the number of participants and statements should be approximate, while others suggest that the P-set should include at least half the size of the Q-set (Dziopa and Ahern, 2011). In the systematic analysis conducted by Dieteren et al. (2023), it was observed that the number of participants in the analysed studies ranged from 3 to 302 participants. However, most of these studies typically included from 20 to 50 participants (Dieteren et al., 2023). As indicated in Table 2, the number of participants in the studies included in this review ranged from 15 to 254 individuals, with an average sample size of 65 participants. In nine of these papers, the size of the P-set exceeded that of the Q-set. While it is a more common practice that the number of participants is smaller or approximately equal to the number of items comprising the Q-set, there are review papers that also document research where the P-set surpasses the Q-set (Dieteren et al., 2023).

Only nine reviewed studies explicitly stated the type of sample used, and in each of these studies, a purposive sample was applied. The strength of purposive sampling lies in its capacity to select cases and individuals with a wealth of information about the topic under investigation (Baker et al., 2006). Hence, such a sample is desirable in any research employing Q-methodology.

The data collection process involves participants ranking (sorting) the provided statements based on their level of agreement in predefined Q-grids. These Q-grids most often have the form of a normal distribution or similar. This quasi-normal geometric form of the Q-sort was chosen due to the understanding that in any set of subjective self-reported statements, there are likely to be only a few with which participants strongly agree or strongly disagree. Those extremes (polar

opposites in the continuum of an individual's personal feelings) and middle positions of the distribution (representing less strong feelings, neutrality, or ambivalence) serve to interpret the results (Barbosa et al., 1998). The range of the scale used to gauge the degree of agreement primarily depends on the Q-grid and the number of statements involved. In the reviewed publications, the answer options typically span from -4 to +4 (found in 11 papers). However, there are instances where a five-point scale was used (ranging from -2 to +2, in one paper), a seven-point scale (ranging from -3 to +3, in three papers), and an eleven-point scale (ranging from -5 to +5, in three papers).

In all the studies observed, where this information was provided, the researchers applied principal component analysis (PCA) and utilized varimax rotation for the extracted factors. Applying these statistical procedures, three to four factors that met the necessary statistical criteria were extracted (Table 2). The extracted factors accounted for 56.80% of the variance. The highest percentage of variance explained was 72.97%, while the lowest was 41.00% (Table 2).

Table 2. Basic (technical) data about studies included in the scoping review.

No.	Reference	P-set	Q-set	Number of factors	% of variance
1	Adams and Carodenuto, 2023	32	36	3	53.00
2	Al-Maruf et al., 2022	254	30	6	72.97
3	Armatas et al., 2017	96	34	3	48.00
4	Buckwell et al., 2023	130	37	3	48.00
5	Carmenta et al., 2017	221	30 (40)*	4 (5)*	47.00 (39.00)*
6	Cruz et al., 2021	19	25	4	70.00
7	Hall and Wreford, 2012	22	24	4	58.00
8	Hinzmann et al., 2021	86	27	3	62.00
9	Kopytko and Pruneddu, 2018	10	27	3	53.00
10	Lairez et al., 2020	19	47	3	n. a.**
11	Lynch et al., 2014	37	27	4	64.00
12	Mataruse et al., 2022	42	25	5	48.00
13	Norris et al., 2021	15	37	3	61.30
14	Reichenspurner et al., 2023	15	37	3	66.31
15	Rittelmeyer, 2020	33	35	4	59.00
16	Röös et al., 2023	36	55	5	58.70
No.	Reference	P-set	Q-set	Number of factors	% of variance
17	Schulze and Matzdorf, 2023	25	38	3	57.00
18	Sherren et al., 2016	183	34	4	41.00
19	Steeves and Filqueira, 2019	20	40	3	68.00
20	Turhan, 2016	29	30	4	63.00
21	Zobeidi et al., 2016	46	42	3	56.00

*Q-methodology was applied twice on the same sample; the values in parentheses refer to the second application; **Not available.

Conclusion

Considering the importance of researching the contribution of agriculture to climate change, the possibility of mitigating the negative impacts of climate change on agriculture, and adapting the sector to them on one hand, and regarding the applicability of Q-methodology for such research on the other hand, the available literature lacks a scoping review of papers applying Q-methodology to the population of agricultural producers in the context of climate change. The performed search resulted in a surprisingly small number of papers (n=21) that met the given search criteria. However, since this review aims to highlight the possibility of using this promising methodology in research, the authors believe that its outcome does not limit the value of this work. Its contribution is evident in being the first review of its kind, to the best of the authors' knowledge, and in its potential to be a good initial reference for future researchers who decide to use Q-methodology in their research.

The results of the review demonstrate that the Q-methodology can indeed be successfully applied in this type of research. Although the number of researchers opting for this methodology has been small so far, its application has been gaining momentum over the last decade. This review may act as a stimulus for researchers to apply it. Our paper gives a brief description of each study reviewed in this research. These papers not only recommend and justify the use of Q-methodology but also provide guidance for crafting research plans. They provide theoretical context and insight into the gaps that future research needs to close.

As all research papers, this one also comes with certain limitations. While we carefully selected our literature review method and strictly followed relevant guidelines, it is necessary to acknowledge that the described search may not have covered all scientific publications where Q-methodology was applied to agricultural producers in the context of climate change, but its application was not evident from the title, abstract, or keywords. Researchers should consider this when defining paper titles, writing abstracts, and selecting keywords.

In future review papers, there are several possible directions for an improved approach. One such approach involves searching the database using terms such as "Q-methodology" (and related terms) and "farmers" (and related terms). This should be followed by a comprehensive reading of all selected papers to identify studies conducted in the context of climate change. Another method builds upon the first, incorporating additional filtering criteria by adding terms related to specific activities, practices, problems, policies, measures, and more. Although both approaches are complex and very time-consuming, they minimize the risk of overlooking significant publications, particularly if the first approach is applied. Additionally, future reviews may include "grey literature" in this area for a more comprehensive analysis.

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PRIMENA Q-METODOLOGIJE MEĐU POLJOPRIVREDNIM PROIZVOĐAČIMA U KONTEKSTU KLIMATSKH PROMENA: SISTEMATSKI PREGLED

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R e z i m e

Cilj ovog rada je da pruži sistematski pregled literature u kojoj je primenjena Q-metodologija među poljoprivrednim proizvođačima u kontekstu klimatskih promena. Analiza je pokazala neočekivano skromnu primenu Q-metodologije među poljoprivrednim proizvođačima u kontekstu klimatskih promena. Pretragom baze podataka SCOPUS, kao jedne od najvećih baza apstrakata i citata akademskih časopisa, za ključne termine: poljoprivrednici, klimatske promene i Q-metodologija u naslovu, apstraktu i ključnim rečima naučnih radova, identifikovan je samo 21 rad. Svi radovi su publikovani u poslednjoj deceniji, ukazujući na rastući trend publikovanja tokom godina. Detaljan opis i analiza ovih radova ukazuju da Q-metodologija ima i može i u budućnosti imati uspešnu primenu među poljoprivrednim proizvođačima u različitim istraživanjima koja doprinose otkrivanju i razumevanju stavova i pogleda poljoprivrednih proizvođača u različitim istraživačkim problemima koja doprinose borbi protiv klimatskih promena i ublažavanju njihovih negativnih posledica. Koliko je autorima poznato, ovakav pregled nije do sada sproveden i zbog toga predstavlja značajan doprinos i polaznu tačku istraživačima koji planiraju primenu Q-metodologije u svojim studijama koje se tiču subjektivnosti poljoprivrednika u oblasti klimatskih promena.

Ključne reči: Q-metodologija, poljoprivrednici, klimatske promene, sistematski pregled literature.

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INFLUENCES OF SOWING DATE AND CLIMATE CONDITIONS ON THE PHENOLOGICAL PHASES OF DIFFERENT MAIZE HYBRIDS

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Abstract: The experiment was set up during 2016 and 2017 in the Leskovac area on an alluvial soil. For research purposes, the duration of certain phenological phases, the entire vegetation period of 6 maize hybrids, and three FAO maturity groups (400–600) were monitored. The research aims to determine the duration of each phenological phase and the entire growing season based on the number of days, the sum of the total, and the sum of the effective temperatures, and to recommend suitable hybrids for the investigated area. In terms of years and sowing dates, the difference in vegetation period between the hybrid with the longest and the hybrid with the shortest vegetation period was 38 days, the difference in SUT was 414.7°C, and the difference in SET was 240.0°C. On average over two years, the lowest sum of effective temperatures was measured at 1158.8°C for the FAO hybrid group 400, ZP 434, and the highest at 1398.9°C for the FAO hybrid group 600, NS 6030. Depending on the temperature conditions, the year in the first sowing period of the individual phases was shortened with increasing temperature. The onset of periods with lower air temperatures and the length of the phenological phases lasted longer. The method of the sum of effective temperatures proved to be the most reliable method for determining the vegetation length of the maize hybrids examined.

Key words: maize, length of vegetation, number of days, total air temperature, effective temperature.

Introduction

Maize is a field crop that, along with wheat and rice, occupies the largest production areas in the world's total crop production. In the Republic of Serbia,

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maize has been the most widely cultivated crop for years, and in 2023, 922.980 ha were sown under this crop (SORS, 2023). The constant work on breeding maize has resulted in various phenotypic changes, leading to a large number of hybrids with good agronomic properties (Popović et al., 2022; Akintunde, 2024). To achieve high and stable yields, a large number of researchers studied the vegetation length of different maize hybrids under different production conditions from germination to maturation. The duration of a certain phenological phase of various hybrids differs in length (Junyan et al., 2023). Crop phenology characterises the physiological stages of crop development, spanning from sowing to harvest (Gao et al., 2021). In production areas with less rainfall, hybrids of FAO group 300–500 should be produced, as hybrids with a longer vegetation period (Glamočlija and Prijić, 2004; Biberdžić et al., 2018a). The possibility of using heat units has been extensively studied in the production of maize, and different methods are used to calculate them. Calculating the sum of heat units to determine the vegetation period of various cultivated crops was first used in the production of peas (*Pisum sativum* L.). The classification of the length of the maize vegetation according to the required number of days from sprouting to ripening has proven to be unreliable in practice, because it mainly depends on the agrometeorological conditions of the year, but also on the edaphic and orographic conditions of the relief (Jovanović et al., 2013). The goal of these studies was to determine the duration of certain phenological phases of different maize hybrids, depending on the time of sowing and the climatic conditions of the year.

Material and Methods

The two-year experiment was based on the property of the Secondary Agricultural School in Leskovac, on alluvial soil at an altitude of 225 m above sea level. The experiment included 6 maize hybrids from three FAO maturity groups, namely: H1 – ZP 434, H2 – NS 4023, (FAO 400); H3 – ZP 555, H4 – NS 5051 (FAO 500); H5 – ZP 666, H6 – NS 6030 (FAO 600). During the production process, the standard agricultural practices were applied in the production of maize, characteristic of the examined area. Sowing was done during April in two sowing periods: I – early April; II – mid-April. The trial was set up in 3 repetitions in a randomised block system. Four rows of each hybrid were sown. To provide the plants with an optimal density, sowing was done at an inter-row distance: 70 cm x 20 cm (FAO group 400), 70 cm x 25 cm (FAO group 500) and 70 cm x 30 cm (FAO group 600) (Figure 1). The meteorological station in Leskovac, which is located in the immediate vicinity of the trial field, was used to obtain data on the mean, minimum and maximum daily air temperatures and on the amount and distribution of precipitation. The following phenological phases were monitored on all hybrids from both sowing periods: from sowing to sprouting; from sprouting to the phase of the 10^{th} leaf; from the phase of the 10^{th} leaf to silking; from silking to

the appearance of a black layer at the base of the grain; from the appearance of a black layer at the base of the grain to full maturity; from sowing to full maturity (harvest). To determine the phenological phases, a visual assessment was made when 70% of the plants entered into the observed phenological phase. For each phenological phase, the duration was determined based on the number of days, the sum of effective air temperatures (SET) and the sum of total air temperatures (SUT). The accuracy of each method was determined based on the standard deviation (Sd) and the coefficient of variation (Cv). During the two-year research period, the lowest average air temperature was recorded in 2016, and the highest average air temperature in 2017. Figure 1 shows the average monthly air temperatures (°C) and the distribution and amount of precipitation (mm) by month of the maize vegetation period in both years of the study. During the two-year research based on the data on the mean monthly air temperatures, it was observed that the temperature increased from April to July, while a decrease in temperature was recorded from August onwards. The highest amount of precipitation was recorded in 2016, with 569.8 mm in the period from April to November, and the lowest in 2017 (434.0 mm). Analysing the mean monthly air temperatures, as well as the amount and distribution of precipitation by month, during the research period, it can be seen that the temperature conditions were more advantageous during the production year of 2016, especially in the period from June to August, which is very important during the maize vegetation period, and especially for yield formation. The second year of the research was characterised by a much lower amount of precipitation and was characterised as less favourable for maize production.

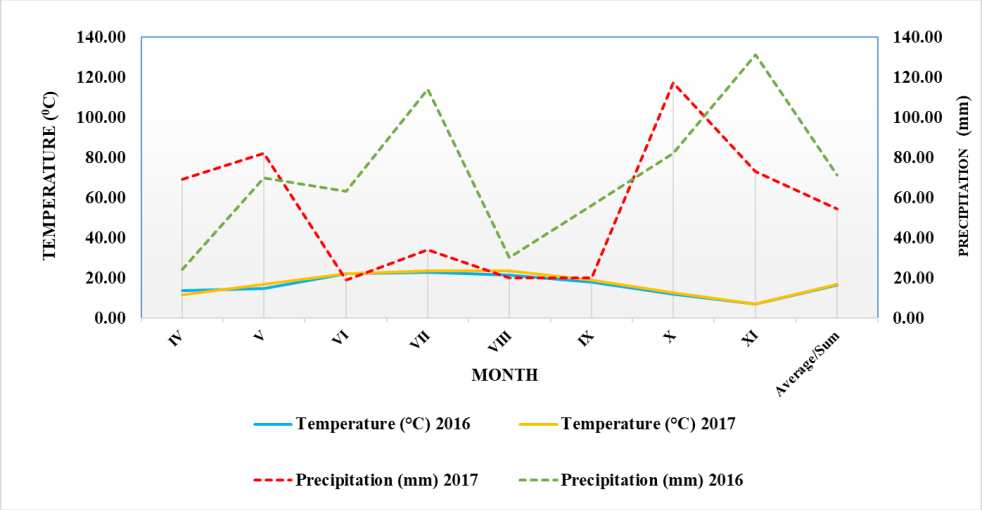

Figure 1. Average monthly air temperatures (°C) and sums of monthly precipitation (mm) and their distribution in the examined years.

Results and Discussion

Table 1 shows the duration of individual maize phenological phases and the sowing date in 2016. In the first sowing period, the phase from sowing to sprouting in all hybrids lasted 13 days. During this period, the sum of total air temperatures (SUT) was measured at 140.5°C, and the sum of effective temperatures (SET) at 55.8°C. The phenological phase from sprouting to the appearance of the 10th leaf in all hybrids lasted 41 days with a total air temperature of 615.6°C and an effective temperature of 312.2°C.

Table 1. Duration of certain phenological phases in the first sowing date of different maize hybrids in 2016.

Phenological phase	Sowing–Sprouting			Sprouting – 10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	13.0	140.5	55.8	41.0	615.6	312.2	22.0	400.2	210.1
H 2	13.0	140.5	55.8	41.0	615.6	312.2	22.0	400.2	210.1
H 3	13.0	140.5	55.8	41.0	615.6	312.2	23.0	410.6	221.1
H 4	13.0	140.5	55.8	41.0	615.6	312.2	24.0	422.1	231.1
H 5	13.0	140.5	55.8	41.0	615.6	312.2	23.0	410.6	221.1
H 6	13.0	140.5	55.8	41.0	615.6	312.2	23.0	410.6	221.1
Average	13.0	140.5	55.8	41.0	615.6	312.2	22.8	409.5	219.1
Sd	0.00	0.00	0.00	0.00	0.00	0.00	0.75	8.18	7.97
Cv	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.04
Sowing date I – 2016									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	39.0	827.4	368.5	24.0	439.0	231.2	139.0	2422.7	1177.8
H 2	40.0	831.9	375.6	26.0	458.6	240.3	142.0	2446.8	1194.0
H 3	42.0	864.5	397.4	28.0	487.4	260.0	147.0	2518.8	1246.5
H 4	44.0	893.1	435.2	32.0	531.2	286.4	154.0	2602.5	1320.7
H 5	44.0	879.8	437.3	35.0	549.6	294.2	156.0	2596.1	1320.6
H 6	46.0	919.7	445.4	36.0	562.1	302.6	157.0	2648.5	1332.9
Average	42.5	869.4	409.9	29.8	504.6	269.1	149.1	2539.2	1265.4
Sd	2.66	35.76	33.76	4.49	50.51	29.67	7.63	91.34	68.98
Cv	0.06	0.04	0.08	0.15	0.10	0.11	0.05	0.04	0.05

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

The phenological phase from the 10th leaf to silking in the first sowing period lasted 22–24 days, depending on the hybrid. The measured sum of the total air temperatures was 400.2–422.1°C, and the sum of the effective temperatures was

210.1–231.1°C. The phase from silking to the appearance of a black layer at the base of the grain in the first sowing period lasted 39–46 days, with the measured sum of total temperatures being 827.4–919.7°C, or 368.5–445.4°C, depending on the hybrid. The phase from the appearance of the black layer at the base of the grain to full maturity lasted 24–36 days, while the total temperatures measured were 439.0–562.1°C, and the effective temperatures were 231.2–302.6°C. The total vegetation period (from sowing to full maturity) in the first sowing period of 2016 (Table 1), depending on the hybrid, lasted 139–157 days, with the sum of total temperatures being 2422.7–2648.5°C, and the sum of effective air temperatures 1177.8–1332.9°C. Biberdžić et al. (2018b) state that despite the recorded difference in the length of the vegetation period in the number of days, no major differences were found in the sum of the effective temperatures for the same hybrid, regardless of the influence of the year and sowing dates.

During the first sowing period, the ZP 434 hybrid had the shortest vegetation period. The vegetation period lasted 139 days, the measured sum of total air temperatures was 2422.7°C, while the sum of effective temperatures was 1177.8°C. The hybrid with the longest vegetation period in the first sowing period (Figure 2) was NS 6030 (157 days). The sum of total air temperatures was 2648.5°C, and the sum of effective temperatures was 1332.9°C. In the second sowing period in 2016, the phase from sowing to sprouting lasted the same as in the first sowing period, namely 13 days for all hybrids (Table 2). The measured sum of total air temperatures was 129.3°C, and the sum of effective temperatures was 60.9°C.

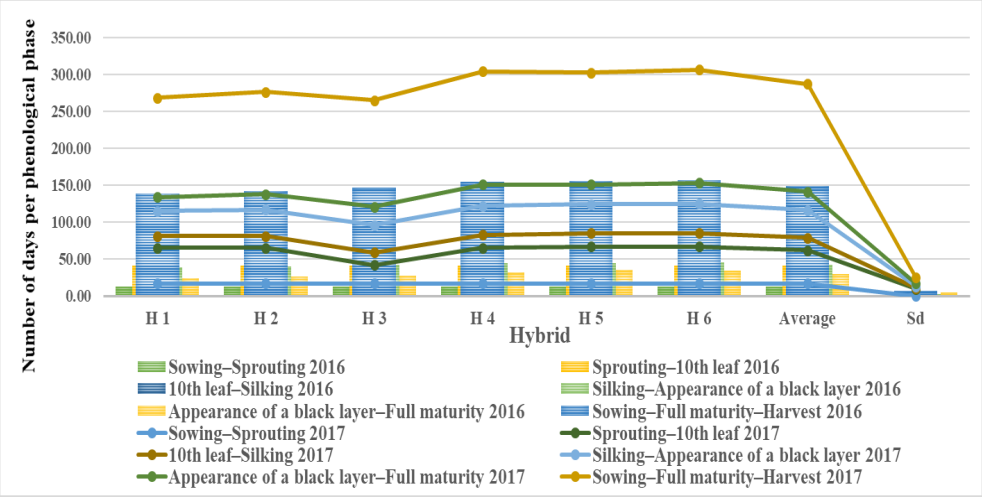

Figure 2. Number of days per phenological phase of maize hybrids in the first sowing date in both examined years.

Table 2. Duration of certain phenological phases in the second sowing date of different maize hybrids in 2016.

Phenological phase	Sowing–Sprouting			Sprouting – 10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	13.0	129.3	60.9	42.0	660.6	311.9	22.0	390.5	204.3
H 2	13.0	129.3	60.9	42.0	660.6	311.9	22.0	390.5	204.3
H 3	13.0	129.3	60.9	42.0	660.6	311.9	23.0	405.2	217.3
H 4	13.0	129.3	60.9	42.0	660.6	311.9	24.0	421.5	238.3
H 5	13.0	129.3	60.9	42.0	660.6	311.9	24.0	421.5	238.3
H 6	13.0	129.3	60.9	42.0	660.6	311.9	25.0	435.3	246.2
Average	13.0	129.3	60.9	42.0	660.6	311.9	23.3	410.8	224.8
Sd	0.00	0.00	0.00	0.00	0.00	0.00	1.21	18.36	18.54
Cv	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.04	0.08
Sowing date II – 2016									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	38.0	805.0	381.4	25.0	470.6	239.1	140.0	2456.0	1197.1
H 2	39.0	814.3	391.5	26.0	486.2	246.4	142.0	2480.0	1215.0
H 3	42.0	852.0	419.7	31.0	518.0	269.7	151.0	2565.1	1279.0
H 4	43.0	869.7	430.7	36.0	570.6	292.8	158.0	2651.7	1335.2
H 5	43.0	890.0	448.5	37.0	586.7	300.3	159.0	2688.1	1359.9
H 6	45.0	909.7	463.1	39.0	609.0	316.8	164.0	2743.9	1398.9
Average	41.7	846.2	414.4	32.3	540.1	277.5	152.3	2597.4	1297.5
Sd	2.66	41.42	31.78	5.92	56.70	30.99	9.73	116.15	81.03
Cv	0.06	0.05	0.08	0.18	0.10	0.11	0.06	0.04	0.06

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

The phase from sprouting to the appearance of the 10th leaf in the second sowing period lasted 42 days for all hybrids. The sum of total air temperatures was 660.6°C, while the sum of effective temperatures was 311.9°C. In the second sowing period, the phase from the appearance of the 10th leaf to silking lasted 22–24 days, depending on the hybrid, with the sum of total temperatures being 390.5–435.5°C, while the sum of effective temperatures was 204.3–246.2°C. The phase from silking to the appearance of a black layer at the base of the grain in the second sowing period lasted 38–45 days depending on the hybrid, with the measured sum of total air temperatures being 805.0–909.7°C, and the sum of effective temperatures 381.4–663.1°C. The phase from the appearance of the black layer at the base of the grain to full maturity lasted 25–39 days. During this period, the sum of total temperatures was measured at 470.6–609.0 °C, while the sum of effective temperatures was 239.1–316.8°C. The vegetation period from sowing to full

maturity in the second sowing period in 2016, depending on the hybrid, lasted 140–164 days (Figure 3) with a sum of total temperatures of 2456.0–2743.9°C, and the measured sum of effective temperatures was 1197.1–1398.9°C. The ZP 434 hybrid also showed the shortest vegetation period in the second sowing period. Expressed in days, the vegetation period lasted 140 days, with a total temperature of 2456.0°C, and the sum of effective temperatures in this period amounted to 1197.1°C. The hybrid NS 6030 (H6) had the longest vegetation period in the second sowing period (164 days with the measured sum of total air temperatures 2743.9°C), while the measured sum of effective temperatures was 1398.9°C. During the second year of research, in the first sowing period, the phenological phase from sowing to sprouting lasted 17 days for all hybrids. The sum of the total temperatures measured during this period was 183.6°C, and the sum of the effective temperatures was 60.2°C.

The phase from emergence to the appearance of the 10th leaf lasted 48–50 days, depending on the hybrid. During this phenological phase, the sum of total temperatures was measured at 750.8–767.2°C and the sum of effective temperatures at 310.6–327.0°C. During this period, the sum of total temperatures was measured at 384.0–436.0°C, that is, the sum of effective temperatures at 204.0–236.0°C. The phase from silking to the appearance of a black layer in the grain in the first sowing period lasted 34–40 days, depending on the hybrid, with the sum of total air temperatures being 592.7–731.6°C and the sum of effective temperatures 356.0–429.8°C. The period from the 10th leaf to silking in the first sowing period lasted 16–18 days. The phase from the appearance of the black layer in the grain to full maturity lasted 19–28 days, depending on the hybrid. The measured sum of total temperatures was 420.0–588.7°C. In the first sowing period, in 2017, the vegetation period lasted 134–153 days, with the sum of total temperatures being 2331.0–2707.1°C, while the sum of effective temperatures was 1169.0–1368.0°C, depending on the hybrid. The ZP 434 hybrid (134 days, SUT 2331.0°C, SET 1169.0°C) had the shortest vegetation period in the first sowing period in 2017 (Table 3). In the same period, the NS 6030 hybrid had the longest growing season (153 days, SUT 2707.1°C, SET 1368.4°C).

In the second sowing period (Table 4), the phase from sowing to sprouting lasted 15 days for all hybrids. During this period, the sum of total air temperatures was measured at 199.7°C, while the sum of effective temperatures was 61.6°C. The phase from sprouting to the appearance of the 10th leaf in the second sowing period lasted 40–43 days, depending on the hybrid. The sum of total air temperatures was 682.8–741.2°C, and the sum of effective temperatures was 310.1–336.5°C. The phenological phase from the 10th leaf to silking lasted 16–18 days, depending on the hybrid, with a sum of total temperatures of 378.8–433.6°C.

Table 3. Duration of certain phenological phases in the first sowing date of different maize hybrids in 2017.

Phenological phase	Sowing–Sprouting			Sprouting –10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H1	17.0	183.6	60.2	48.0	750.8	310.6	16.0	384.0	204.0
H 2	17.0	183.6	60.2	48.0	750.8	310.6	16.0	384.0	204.0
H 3	17.0	183.6	60.2	48.0	750.8	310.6	17.0	409.2	219.2
H 4	17.0	183.6	60.2	48.0	767.2	327.0	18.0	436.0	236.0
H 5	17.0	183.6	60.2	48.0	767.2	327.0	18.0	436.0	236.0
H 6	17.0	183.6	60.2	48.0	767.2	327.0	18.0	436.0	236.0
Average	17.0	183.6	60.2	44.8	759.0	318.8	17.2	414.2	222.5
Sd	0.00	0.00	0.00	9.77	8.98	8.98	0.98	25.59	15.76
Cv	0.00	0.00	0.00	0.22	0.01	0.03	0.06	0.06	0.07
Sowing date I – 2017									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (0C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	34.0	592.7	356.0	19.0	420.0	238.4	134.0	2331.0	1169.0
H 2	36.0	623.3	380.4	21.0	441.3	257.3	138.0	2383.0	1212.8
H 3	37.0	648.3	349.9	25.0	510.3	281.2	144.0	2502.2	1265.6
H 4	39.0	702.4	394.4	29.0	600.0	325.6	153.0	2689.2	1361.0
H 5	39.0	702.4	394.4	27.0	571.3	290.7	151.0	2660.6	1326.1
H 6	40.0	731.6	429.8	28.0	588.7	315.4	153.0	2707.1	1368.4
Average	37.5	653.8	334.2	24.8	521.9	284.8	145.5	2545.5	1283.8
Sd	2.26	53.78	141.30	4.02	77.48	33.34	8.17	163.89	81.80
Cv	0.06	0.08	0.42	0.16	0.15	0.12	0.06	0.06	0.06

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

The sum of effective temperatures in the same period was 204.6–225.8°C. In the second sowing period of 2017, the phase from silking to the appearance of a black layer at the base of the grain lasted 34–40 days, depending on the hybrid. The measured sum of total temperatures during this period was 618.1–757.9°C, while the sum of effective temperatures was 354.8–421.0°C. The phenological phase from the appearance of the black layer at the base of the grain to full maturity lasted 21–32 days, depending on the hybrid, with the measured sum of total temperatures being 448.9–622.3°C and the sum of effective temperatures 250.1–389.5°C. The period from sowing to full maturity in the second sowing period of 2017, depending on the hybrid, lasted 126–148 days (Figure 4), with the sum of total air temperatures being 2328.3–2754.0°C, and the measured sum of effective temperatures being 1158.9–1434.4°C. The ZP 434 hybrid (H1) had the shortest vegetation period, 126 days with a total temperature of 2328.3°C, while the sum of

effective temperatures in this period was 1158.9°C. The longest vegetation period was recorded for the NS 6030 (H6) hybrid. The vegetation period lasted 164 days with a measured sum of total temperatures of 2754.0°C, while the measured sum of effective temperatures amounted to 1245.7°C. As the most accurate method for determining the length of the maize vegetation period, the method of the sum of the effective temperatures of the GDU (Biberdžić et al., 2000) was used. The average duration of certain phenological phases of maize in the first sowing period in days during the two years is shown in Figure 2, as well as SUT and SET (Figure 3). The phase from sowing to emergence in the first sowing period in all hybrids lasted 16 days on average (SUT – 162.1°C, and SET – 58.0°C). The phase from sprouting to the appearance of the 10th leaf in the first sowing period for all hybrids lasted an average of 42.9 days with a measured SUT of 687.3°C, while the measured SET was 331.4°C.

Table 4. Duration of certain phenological phases in the second sowing date of different maize hybrids in 2017.

Phenological phase	Sowing–Sprouting			Sprouting – 10th leaf			10th leaf – Silking		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	15.0	199.7	61.6	40.0	682.8	310.1	16.0	378.8	204.6
H 2	15.0	199.7	61.6	40.	682.8	310.1	16.0	378.8	204.6
H 3	15.0	199.7	61.6	42.00	720.6	325.9	17.0	405.6	225.8
H 4	15.0	199.7	61.6	42.0	720.6	325.9	17.0	405.6	225.8
H 5	15.0	199.7	61.6	43.0	741.2	336.5	18.0	433.6	225.8
H 6	15.0	199.7	61.6	43.0	741.2	336.5	18.0	433.6	225.8
Average	15.0	199.7	61.6	41.7	714.9	321.7	17.0	406.0	218.7
Sd	0.00	0.00	0.00	1.37	26.49	11.88	0.89	24.51	10.95
Cv	0.00	0.00	0.00	0.03	0.04	0.04	0.05	0.06	0.05
Sowing date II – 2017									
Phenological phase	Silking – Apperance of a black layer			Apperance of a black layer – Full maturity			Sowing – Full maturity		
Maize hybrid	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)	No. of days	SUT (^{0}C)	SET (^{0}C)
H 1	34.0	618.1	354.8	21.0	448.9	250.1	126.0	2328.3	1158.9
H 2	36.0	657.0	385.5	22.0	461.3	265.8	129.0	2379.6	1227.6
H 3	37.0	669.3	394.3	27.0	530.7	342.6	138.0	2525.9	1350.8
H 4	39.0	739.1	407.9	30.0	589.4	360.0	143.0	2653.7	1381.2
H 5	39.0	737.6	406.4	32.0	615.0	385.3	147.0	2727.1	1385.4
H 6	40.0	757.9	421.0	32.0	622.3	389.5	148.0	2754.0	1434.4
Average	37.5	696.5	394.9	27.3	544.6	332.2	138.5	2411.3	1245.8
Sd	2.26	52.91	23.15	4.89	76.54	60.22	9.27	102.54	97.23
Cv	0.06	0.08	0.06	0.18	0.14	0.18	0.07	0.04	0.08

Legend: H1 – ZP 434, H2 – NS 4023, H3 – ZP 555, H4 – NS 5051, H5 – ZP 666, H6 – NS 6030, Sd – standard deviation, Cv – coefficient of variation.

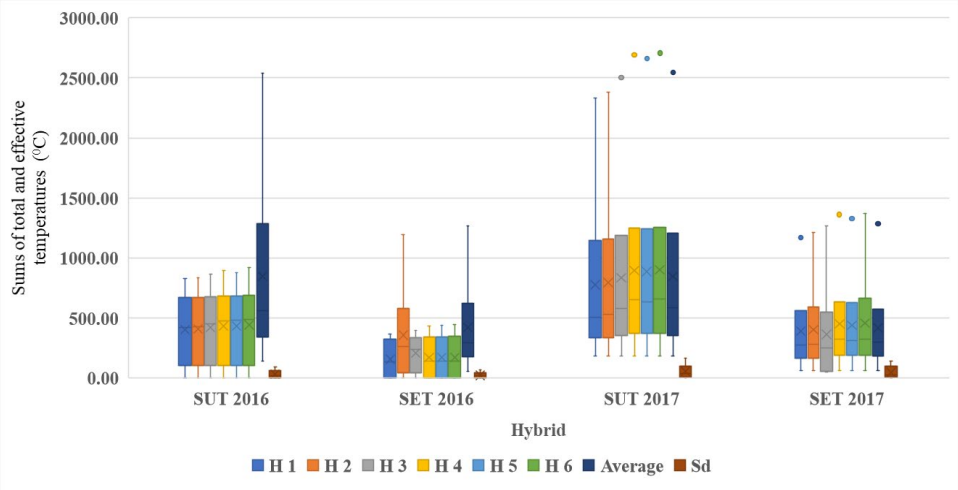

Figure 3. SUM (^{0}C) and SET (^{0}C) in the first sowing period of the maize hybrid in both examined years.

In the first sowing period, during the two years, the phase from the 10th leaf to silking lasted an average of 19.9 days, with the sum of total temperatures being 407.8°C and the sum of effective temperatures being 220.8°C. The phenological phase from silking to the appearance of the black layer at the base of the grain lasted an average of 40 days (SUT 761.6°C and SET 372.0°C). During the two years, the phase from the appearance of the black layer at the base of the grain to full maturity lasted an average of 27.3 days, with a sum of total temperatures of 513.2°C, and SET of 276.9. The total vegetation period during the first sowing period lasted 147.3 days. During this period, SUT was measured at 2542.3°C. In the first sowing period, the shortest period of vegetation was observed in the ZP 434 hybrid (136.5 days, SUT – 2376.9°C and SET – 1173.4°C).

The duration of each phenological phase of maize in days, in the second sowing period during the two years, is shown in Figure 4, and the SUT and the SET are calculated in Figure 5. The phase from sowing to sprouting in the first sowing period in all hybrids lasted an average of 14 days (SUT – 164.5°C, and SET – 61.3°C). The phase from sprouting to the appearance of the 10th leaf in the second sowing period lasted 41.8 days on average for all hybrids, while the SUT was measured at 687.7°C and the SET at 316.8°C. During the two-year experiment, in the second sowing period, the phase from the 10th leaf to silking lasted an average of 20.1 days, with the sum of total temperatures being 408.4°C and the sum of effective temperatures 221.8°C. The phase from silking to the appearance of a black layer at the base of the grain lasted an average of 39.6 days (SUT – 771.4°C and SET – 404.7°C). On average, the phase from the appearance

of the black layer at the base of the grain to full maturity lasted 29.8 days, with the sum of total air temperatures 542.3°C, and SET 304.9. The vegetation period during the two years in the second sowing period lasted an average of 39.2 days, with SUT – 2504.3°C and SET – 1271.7°C. The ZP 434 hybrid (133 days, SUT 2392.0°C and SET 1177.5°C) had the shortest vegetation period in the second sowing period, during both years. The NS 6030 hybrid (156 days, SUT 2748.9°C, and SET 1416.5°C) had the longest vegetation period in the second sowing period during both years. During the two-year research period, in terms of sowing dates, the vegetation period varied, depending on the hybrid. Observed by years and sowing dates, the difference in vegetation length between the hybrid with the longest and the hybrid with the shortest vegetation period was 38 days, the difference in SUT was 414.7°C, and the difference in SET was 240.0°C. The period from sowing to sprouting was the same for all hybrids in terms of years and sowing dates. Depending on the duration and year of the research, the number of days and SUT differed. In the observed period, the sum of effective temperatures had the most approximate values. In the second year of testing, the phenological phases of all maize hybrids lasted shorter than in 2016, except for the period from sowing to sprouting and from sprouting to the 10th leaf. This difference is particularly evident in the total vegetation period of the second sowing period. In 2016, in the second sowing period, the total vegetation period lasted 152.3 days, and in 2017, 138.5 days.

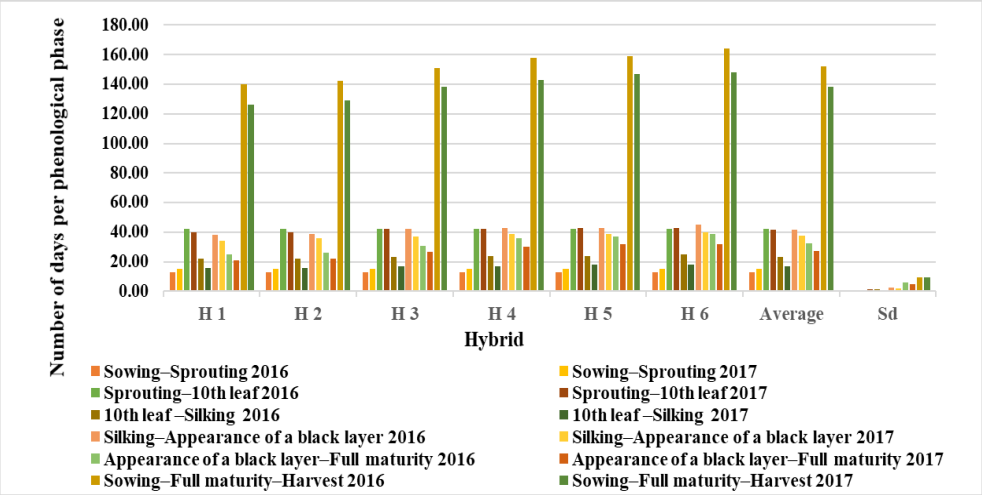

Figure 4. Number of days per phenological phase of maize hybrids in the second sowing date in both investigated years.

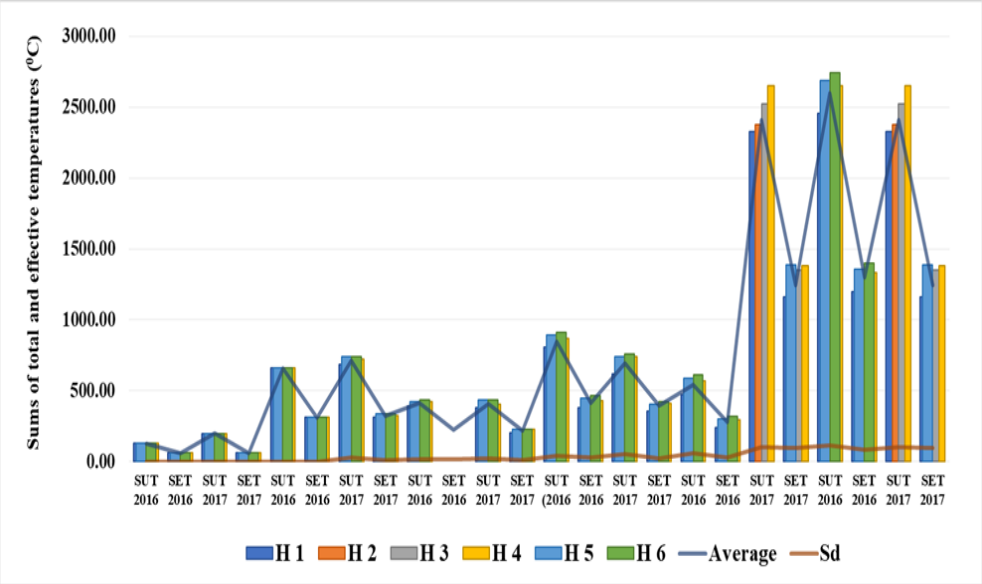

Figure 5. SUM (0C) and SET (0C) in the second sowing date of maize hybrids in both investigated years.

In a five-year study of the length of vegetation of individual ZP hybrids, Jovanović et al. (2013) determined that the average length of vegetation of a mid-early hybrid (FAO 400) lasted 121 days, with a sum of effective temperatures of 1315.0°C. In medium-sized hybrids (FAO 500), the vegetation period lasted 125–128 days, with a sum of effective temperatures of 1315.0–1365.0°C. Medium-late hybrids (FAO 600) had a vegetation length of 130–134 days with a SET of 1425.0–1452.0°C. In this research, the method of the sum of heat units proved to be effective. In the Republic of Serbia, the old, already outdated classification of the length of the maize vegetation according to the required number of days from sprouting to maturity has been accepted. Over time, this method has proven to be unreliable in practice, because it depends on the agrometeorological conditions during the year, but also on the area where the tests were conducted (Jovanović et al., 2002). Based on five years of research with different hybrids and sowing dates, Penčić (1996) states that the number of days is the least accurate method for determining the length of the vegetation period or certain phenological phases of maize. The biggest variations in the number of days between the years were found in the periods with the biggest temperature oscillations. Similar results were obtained by other authors (Drezgić et al., 1981; Biberdžić et al., 2000). Svečnjak et al. (2012) also state in their research that they have observed that the sum of heat units from sowing to physiological maturity is 1270.0°C for hybrids of FAO group

200 and 1490.0°C for hybrids of the latest FAO maturity groups. They determined that the studied hybrids differed significantly both in the number of days of vegetation and in the sum of heat units from sowing to silking and from silking to physiological maturity. From the phenological stage of the appearance of the 10th leaf to full maturity, depending on the hybrid, the date of sowing and the year of production, the differences were noticeable. Depending on the year (temperature conditions and the amount and distribution of precipitation) and the time of sowing, the period of certain phases was shortened when the increase in temperature was recorded. When the period with lower temperatures was recorded, the length of the phenological phases lasted longer. The research is in agreement with the research of Biberdžić et al. (2000), who state that the length of certain phenological phases is related to the height of the temperature and very often shortens linearly with the increase in temperature. The duration of certain phenological phases and the entire length of the maize vegetation has been the subject of numerous studies. It has been found that the lower the daily air and soil temperature, the longer a particular phenological phase lasts (Čirkov, 1972). Following the results of research on the influence of sowing date on the yield of different maize hybrids, Starčević et al. (1981) observed a mutual dependence between the height of soil or air temperatures and the length of the period from sowing to sprouting. The duration of certain phenological phases depends on the climatic conditions of the area and the year (air and water temperature), the choice of hybrids, the time of sowing, the type of soil and agrotechnical measures. Starčević et al. (1986) experimented with different sowing dates and different hybrids for research purposes and monitored the phenological stages of maize. They have also stated that the duration of the studied phenological phases depends on the height of the air temperature and shortens linearly with the increase in air temperature. Similarly, they have noticed that the dependence between the duration of a certain phenological phase and the height of the air temperature is more significant in those phases in which the temperature fluctuations are greater.

Conclusion

Observed by years and sowing dates, the difference in vegetation length between the hybrids with the shortest and the hybrids with the longest vegetation period was 38 days, the difference in SUT was 414.7°C, and the difference in SET was 240.0°C. During both years, the lowest sum of effective temperatures was 1158.8°C recorded in the FAO hybrid group 400, ZP 434 (H1), and the highest 1398.9°C in the FAO hybrid group 600, NS 6030 (H6). In 2017, for all maize hybrids, the phenological phases lasted shorter compared to 2016, except for the period from sowing to sprouting and from sprouting to the tenth leaf. This difference is particularly evident in the total vegetation period of the second sowing

period. In 2016, the total vegetation period in the second sowing period lasted 152.3 days, and in 2017, 138.5 days. Depending on the date of sowing and the year of the research, the number of days and the sum of total air temperatures differed. In the observed period, the sum of effective temperatures had the most approximate values. The period after silking was more susceptible to temperature oscillations compared to the phenological stages up to silking. Depending on the temperature conditions, according to the years and the sowing dates, the period of certain phases was shortened with the increase in the air temperature. When there was a period with lower temperatures, the length of the phenological phases lasted longer. When selecting hybrids, it should be noted that there are large oscillations in the length of vegetation in hybrids of different FAO maturity groups. Depending on the sowing plan and the next crop, hybrids of the appropriate vegetation period should be selected.

Acknowledgments

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UTICAJI ROKA SETVE I KLIMATSKIH USLOVA NA FENOLOŠKE FAZE RAZLIČITIH HIBRIDA KURUZA

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R e z i m e

Ogled je postavljen tokom 2016. i 2017. godine na području Leskovca, na zemljištu tipa aluvijum. Za potrebe istraživanja praćena je dužina trajanja pojedinih fenoloških faza, kao i celog perioda vegetacije 6 hibrida kukuruza, tri FAO grupe zrenja (400–600). Istraživanje ima za cilj da se na osnovu broja dana, sume ukupnih, kao i sume efektivnih temperatura odredi dužina trajanja pojedinih fenoloških faza i cele vegetacije i preporuče odgovarajući hibridi za ispitivano područje. Posmatrano po godinama i rokovima setve razlika u dužini vegetacije između hibrida sa najdužim i hibrida sa najkraćim periodom vegetacije bila je 38 dana, razlika u SUT iznosi 414.70°C, a razlika u SET iznosi 240.00°C. Prosečno, za dvogodišnji period, najmanja suma efektivnih temperatura od 1158.80°C je zabeležena kod hibrida FAO grupe 400 ZP 434, a najveća 1398.90°C kod hibrida FAO grupe 600, NS 6030. Zavisno od temperaturnih uslova, po godinama i roku setve, period pojedinih faza se skraćivao sa porastom temperature. Sa nastupanjem perioda sa nižim temperaturama vazduha, dužina fenoloških faza je trajala duže. Kao najpouzdaniji metod za određivanje dužine vegetacije ispitivanih hibrida kukuruza pokazao se metod sume efektivnih temperatura.

Ključne reči: kukuruz, dužina vegetacije, broj dana, ukupne temperature vazduha, efektivne temperature.

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OPTIMIZING YIELD, NITROGEN UPTAKE AND NITROGEN USE EFFICIENCY IN FLUTED PUMPKIN THROUGH FERTILIZER MICRODOSING

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Abstract: Due to severely weathered soils and copious amounts of rainfall, the timing and rate of fertilizer application to enhance yields, nitrogen use efficiency, and recovery of fluted pumpkin (*Telfairia occidentalis*) have been key concerns in southwestern Nigeria. The experiment was conducted using a 2 x 2 x 5 randomized complete block split plot design (RCBSPD) with four varieties. Ilesa and Ogbomoso made up the main plot, whereas the timing of urea fertilizer application and the five nitrogen levels 0, 20, 40, 60, and 80 kg ha^{-1} made up sub-plots. The base application of 5 tons ha^{-1} of organic fertilizer was added (0, 20, 40, 60 kg ha^{-1}) a week prior to planting. We calculated the biomass yield, recoveries, and nitrogen utilization efficiency. Regarding control, 20, 80 (kg N ha^{-1}) urea, the fresh yields in tons ha^{-1} were 7.7, 9.4, 10.7, and 3.3, 8.3, 9.5 (kg N ha^{-1}) for Ilesa and Ogbomoso, respectively. The highest nitrogen use efficiency (60.26 kg N ha^{-1}) was obtained at the rate of 40 kg N ha^{-1} in Ilesa, and at the rate of 20 kg N ha^{-1} (61.91 kg N ha^{-1}) in Ogbomoso. A higher fresh yield was obtained in Ilesa compared to the yield in Ogbomoso. It was determined that the best method for producing fluted pumpkin in southwestern Nigeria was to combine 5 tons of organic fertilizer with a microdosing of 20 to 40 kg N ha^{-1} as urea.

Key words: *Telfairia occidentalis,* biomass, fertilizer, microdosing.

Introduction

A suggested minimum daily consumption of 400 grams of fruits and vegetables has been indicated by Nishida et al. (2004) as a means to promote good health and general well-being. The fluted pumpkin, a native vegetable, is consumed

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by economically weaker women in southwestern Nigeria as a means to fulfil their usual vegetable intake. This vegetable serves as a source of essential minerals, vitamins and proteins, compensating for their limited access to foods rich in essential nutrients such as eggs, meat, milk, etc. Marketing of the indigenous vegetables also helps farmers in income generation (Gupta et al., 2011). However, most of the indigenous vegetables are collected from the natural environment. The genetic resources are gradually being eroded. Ten underutilized indigenous vegetables were selected by the Nigeria-Canada Underutilize Indigenous Vegetables Project (NICANVEG) in 2011 to provide means for better production, processing and marketing to enhance food security, economic growth and conservation of the vegetables. Six premium vegetables were finally selected from the ten underutilized indigenous vegetables based on their fertilizer requirements, agronomic practices, income generation and human consumption. Sustaining the nutrient status of soils in vegetable production was one of the challenges identified within the project. However, this study focused on the fluted pumpkin.

The fluted pumpkin requires a high amount of nitrogen for the production of leaves, stems and fruits (Walters, 2020). Excessive application of nitrogen at the expense of other nutrients, results in production of leaves that are light and have low water retention. Nitrate accumulation in vegetables has been previously described by Schaller (2020). Nitrogen is found mostly as nitrate in the soil solution and it is highly mobile. The leaching of nitrogen from vegetable lands to water bodies could lead to eutrophication and the blue bay syndrome (Karthik et al., 2021). There are inconsistent reports on the amount of nitrogen required by vegetables. According to Olaniyi et al. (2014), the nitrogen requirement for vegetables is 60 kg N ha^{-1}. In addition, 100 kg N ha^{-1} was reported to be suitable for vegetables that produce both leaves and fruits. Idowu et al. (2014) also observed the highest shoot yield with an application of 160 kg N ha^{-1} applied equally at planting and after the first harvest. Olatoberu et al., (2019) observed maximum yield at the rate of 60 kg N ha^{-1}, while the usual practice of farmers is 80 kg N ha^{-1}. However, most soils in the forest and savannah zones of southwestern Nigeria are highly weathered and therefore, have a low ability to hold nutrients for plant use, so there is a need for the addition of organic fertilizer to improve the soil organic matter.

Due to the high temperature and rainfall in tropical Africa, including Nigeria, the rapid decomposition of organic matter and leaching away of inorganic fertilizers have made the nutrients in fertilizers added to soils not optimal for improving plant growth, yield and nitrogen use efficiency. Fertilizer microdosing has been recommended as an alternative way of applying fertilizers. Microdosing refers to the application of small quantities of fertilizer with the seed at sowing time or as a top dressing three to four weeks after emergence (Twomlow et al., 2010; Aune and Ousman, 2011). It refers to the utilization of relatively low

quantities of fertilizer through point placement in cropping systems. It is a technology where a small dose of fertilizer is applied at two to three different times instead of applying the entire quantity once. Fertilizer microdosing has been applied as a source of nitrogen for maize in some parts of Africa, but there is no study yet on its application to crops in Nigeria, including the African indigenous vegetables. Furthermore, nothing has been documented on the effects of fertilizer microdosing on the NUE of selected underutilized indigenous vegetables, especially in Nigeria, and there is limited information on the effects of timing of organic fertilizer application with or without urea on fluted pumpkin production. Hence, the primary aim of this research was to investigate the impact of nitrogen fertilizer application timing, both with and without organic fertilizer, on the development, yield, and nitrogen usage efficiency of fluted pumpkins in the rainforest and savanna regions of southwestern Nigeria.

Material and Methods

The study was carried out at two locations in the southwestern part of Nigeria: Ilesa (rainforest) which lies between latitude 7° 30' N to 7° 38' N and longitude 4° 30' E to 4° 45' E in Osun State and Ogbomosho (derived savanna), which lies between latitude 8° 2' N to 8° 14' N and longitude 4° 10' E to 4° 19' E in Oyo State, Nigeria. The MICROVEG experiments took place at these two locations. The climatic conditions prevailing in both locations are characterized by a hot and humid tropical environment, which shows clear demarcations between the dry and rainy seasons.

Bulk top soil at a depth of 0–15 cm was collected before the application of organic fertilizer. The samples were subjected to air-drying, crushing and subsequent sieving using a 2-mm screen. The portions that successfully passed through the 2-mm sieve were selected for further physical and chemical evaluations. The particle size distribution was determined using the modified method of Bouyoucos (1962) as described by Gee and Or (2002), using a 0.2 M NaOH solution as the dispersion agent.

Soil pH was determined in 0.01 M $CaCl_2$ and water as described by Peech (1965) and modified by Thomas (1996). Ten (10) g of air-dried soil was weighed into 100-mL beakers. The soils in the beakers were replicated twice, 10 mL of deionized water was added to the first replicate of the soils to obtain a 1:1 ratio of soil to water and 20 mL of 0.01 M $CaCl_2$ was added to the second replicate of the soils in the beakers to obtain a 1:2 ratio of soil to $CaCl_2$ solution. The mixtures were stirred thoroughly and allowed to stand for 30 minutes. The suspensions were swirled in the beakers and the pH meter (Eco Tester pH 1 model) was calibrated using a buffer solution with pH values of 4.0 and 7.0, the electrodes were inserted

into the suspension. The pH of the first replicate was recorded as pHw, while the pH of the second replicates was recorded as $pHCaCl_2$.

This method was subsequently updated by Thomas (1996). The extraction of total nitrogen (N) was conducted following the digestion method outlined by Bremner and Keeney (1965), with modifications made by Bremner (1996). This analysis was carried out using an autoanalyzer, the Seal AA3 HR autoanalyzer.

Soil organic matter was determined according to the method described by Walkley and Black (1934) and modified by Nelson and Sommers (1996). One-half (0.5) g of air-dried soil was weighed and transferred to 500-ml Erlenmeyer flasks. Ten (10) ml of 1 N $K_2Cr_2O_7$ was added and swirled to mix, 20 ml of concentrated H_2SO_4 was added and swirled gently for 1 minute. The mixture was allowed to stand for 30 minutes. Then 200 ml of distilled water was added to dilute the suspension, 10 ml of 85% H_3PO_4, 0.2 g of NaF and 1 ml of diphenylamine indicator were added. The excess $Cr_2O_7^{2-}$ was back titrated with 0.5 N ferrous solution to a green end point. A reagent blank was run with the same procedure with no soil. The amount of organic carbon in the soil samples was calculated as follows:

$$\text{Milliequivalents of readily oxidizable material per gram of soil (meq/ox/g)} = \frac{(\text{ml of } Fe^{2+} \text{ blank} - \text{ml of } Fe^{3+} \text{ sample}) \times \text{normality of } Fe^{2+}}{\text{Weight of the soil in gram}}$$

$$\% \text{ carbon} = \frac{\text{meq.ox/g} \times 12 \times 100}{4000 \times 0.77}$$

% organic matter = % organic carbon x 1.72;
where: 12/4000 = milliequivalent weight of carbon;
1/0.77 = factors for converting oxidized carbon to total carbon;
100 = factors for converting decimals to percentages;
1.72 = factors for converting carbon to organic matter (van Bemmelen factor).

The extraction of available phosphorus (P) was conducted using the method described by Bray and Kurtz (1965) and modified by Kuo (1996), namely, 2 g of the air-dried soil was weighed and transferred into a 50-ml conical flask. Twenty (20) ml of P-A solution (0.03 N NH_4F + 0.025 N HCl) was added and shaken for 5 minutes. The solution was filtered through a 9-cm Whatman No. 2 filter paper into funnel tubes. A 3-ml aliquot of the filtrate was transferred into a colorimeter tube, and the available P in the filtrate was determined using a spectrometer (Model 721 Visible Spectrophotometer, Axiom Mediral LMD, UK). The extraction of exchangeable cations was conducted using a 1 N-NH4OAc solution, as first described by Thomas (1982) and subsequently modified by Jones (1998). The concentrations of potassium (K) and sodium (Na) in the solution were measured

using a flame photometer (specifically, the PG-FP902 microprocessor model). On the other hand, the concentrations of calcium (Ca) and magnesium (Mg) were assessed using an atomic absorption spectrophotometer (namely, the Pg-AA 500 model). The cation exchange capacity (CEC) of the soil was assessed using the effective approach, as described by Thomas (1982) and Black (1986) and modified by Sumner and Miller (1996).

The materials used for the research were: *Telfairia occidentalis* seeds, sunshine organic fertilizer, urea fertilizer and neem extract. The sunshine organic fertilizer was composed of 3.5% nitrogen (N), 1.00% phosphorus (P), and 1.2% potassium (K).

The experimental design employed in this study was a 2 x 5 split plot arrangement, following a randomized complete block design framework. The entire experiment was reproduced four times. The main plot revolved around two distinct environments, namely Ilesa, characterized by a rainforest environment, and Ogbomoso, characterized by a derived savanna environment. Additionally, the sub-plot focused on the timing of inorganic fertilizer application, namely at the time of planting and two weeks subsequent to planting. The experimental treatments consisted of five different levels of inorganic fertilizers (specifically urea) applied at varying rates: 0, 20, 40, and 60 kg N ha^{-1}, as well as 80 kg N ha^{-1}. The initial four levels of nitrogen applications (ranging from 0 to 60 kg N ha^{-1}) involved the pre-planting application of organic fertilizer (OF) at a rate of 5 tons per hectare, one week prior to planting. In contrast, the application of 80 kg N ha^{-1} corresponded to the conventional farming practices employed by farmers. The crop selected for the experiment was *Telfairia occidentalis*, commonly known as fluted pumpkin or ugu. Each crop was cultivated on a plot of size 3 m by 2 m, with a spacing of 1 meter between each plot. The treatments were replicated four times to give total experimental units of 40 per location. The deep placement method was incurred for the application of the fertilizer. The seeds of fluted pumpkin were sown at a spacing of 0.5 x 0.75 m and there were twenty (20) seeds per plot.

The management of weeds involved hand picking and the use of a hoe. According to a study conducted by Idowu et al. (2014), the utilization of neem (*Azadirachta indica*) leaf extract was employed as a means to manage insect pests.

The fluted pumpkin was harvested five weeks after planting for the first harvest, the second harvest took place two weeks after the first harvest, and the third harvest two weeks after the second harvest. The harvesting was done by cutting the vegetables off at the shoot. The fresh weight of the harvested vegetables was measured on-site and a subsample was dried in the oven at a temperature of 60^{oC} until a stable weight was achieved. The dry matter yield percentage was determined following the methodology outlined in the study by Sally et al. (2008).

The nitrogen content of the plant samples was determined using the previously mentioned digestion method outlined by Bremner and Keeney (1965), which was

later modified by Bremner (1996). The plant extract was analyzed for nitrogen content using an autoanalyzer, specifically the Seal AA3 HR autoanalyzer. The nitrogen content was multiplied by the dry matter yield to determine the nitrogen uptake, according to Sally et al. (2008).–Nitrogen use efficiency was determined according to Eivazi and Abibi (2013) and % N recovery according to Vanlauwe et al. (2011). The acquired data were statistically analyzed employing analysis of variance (ANOVA).

Results and Discussion

The physical and chemical properties of the soil shown in Table 1 were sandy loam, slightly acidic. The pH values of the two locations were within the optimum range for major vegetable production. Total N, organic carbon, available P and exchangeable Ca, Mg, K and Na were above the critical values (Adepetu et al., 2014). The values were higher in Ilesha compared with Ogbomoso. This might be due to the fact that Ilesa (rainforest) received more rainfall, resulting in a dense forest compared to Ogbomoso (derived savanna). These results are in line with the observation of Bala (2015) that more rainfall in the rainforest zone leads to a dense plant population and hence to a high organic matter content.

Table 1. Physical and chemical properties of the soils at the locations before planting.

Properties	Location	
	Ilesa (Rainforest)	Ogbomoso (Derived savanna)
Sand (g kg^{-1})	760	820
Silt (g kg^{-1})	90	50
Clay (g kg^{-1})	150	130
Textural class	Loamy sand	Loamy sand
pH (0.01 M $CaCl_2$)	5.4	5.7
Total N (g kg^{-1})	23.0	18.0
Organic carbon (g kg^{-1})	16.6	8.4
Available P (mg kg^{-1})	23.48	19.03
Exchangeable acidity	0.07	0.08
Exchangeable cations (cmol kg^{-1})		
Ca	1.78	1.30
Mg	0.49	0.43
K	0.48	0.40
Na	0.11	0.1
CEC (cmol kg^{-1})	2.86	2.23

The study by Idowu et al. (2017) also corroborated the finding. However, the need for rapid growth of vegetable crops for many harvests necessitates N

application because vegetable crops require high amounts of nitrogen in the soil, which can be met through the addition and mineralization of inorganic and organic fertilizers (Subramanian et al., 2010), and N undergoes quick chemical and biochemical transformations in the soil, which affects its availability to the plants, and it is subject to soil-plant system losses, causing damage to the environment. Therefore, this study found that fertilizer microdosing technology could help to reduce the impact of excess N effect on soil fertility and the environment.

The timing of nitrogen fertilizer application had no effect on any of the parameters determined, yield, nutrient uptake, N use efficiency and N recovery. The rainforest had a greater fresh yield in comparison to the derived savanna. This could be due to the fact that more nitrogen was available in the rainforest compared to the savanna. In the rainforest, the application of 40 kg N ha^{-1} urea combined with 5 tons ha^{-1} organic fertilizer resulted in the highest fresh yields. Conversely, in the derived savanna, the combination of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer produced the highest fresh yields when compared to the other application rates (Figure 1).

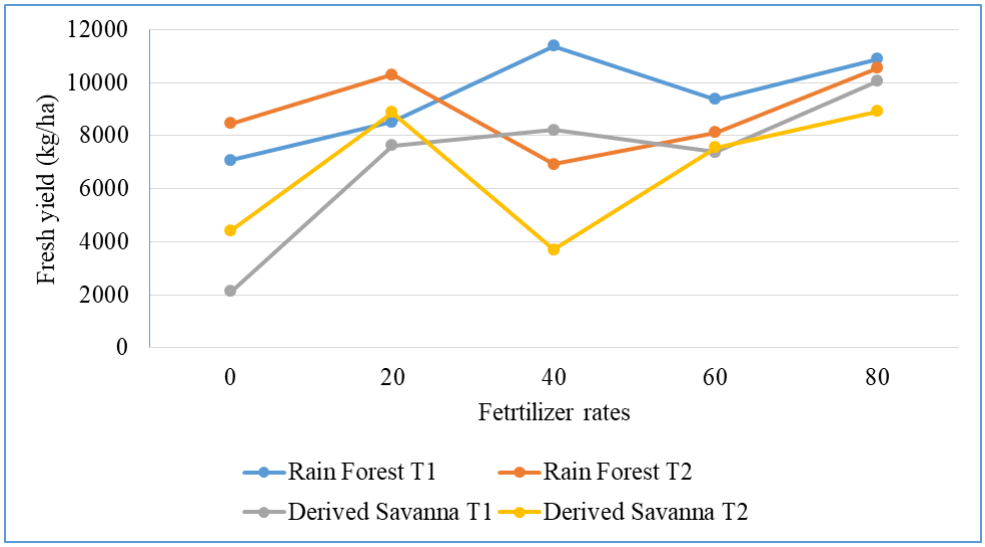

Figure 1. Effects of timing and rate of nitrogen fertilizer application on fresh yield (kg ha^{-1}) of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

This could be due to the fact that the application of fertilizer at low rate (fertilizer microdosing) reduces the risk of nutrient loss by leaching. This is in line with the work of Oluoch et al. (2009), who reported that the microdosing technique would help farmers to use little fertilizer and support sustainability. This practice

was found to result in reduced input costs and minimized investment risks, while increasing crop yields. However, the findings of Tovihoudji et al. (2017) suggest that the use of fertilizer microdosing in the absence of organic fertilizer may not be a viable long-term fertilization approach. Therefore, the organic fertilizer could be applied as a basal application before applying fertilizer microdosing, as it was done in this research. The organic fertilizer was used in this experiment, at a rate of 5 tons per hectare.

The rate of nitrogen absorption was found to be greater in the rainforest ecosystem of Ilesa compared to the derived savanna ecosystem of Ogbomoso (Figure 2). This was corroborated by the results of the native soils in Table 2. The dense vegetation found in the rainforest (Ilesa) as a result of more moisture (Adepetu et al., 2014) when decomposed could lead to the higher content of nitrogen in Ilesa soil which eventually might result in higher nitrogen uptake in Ilesa compared with Ogbomoso (derived savanna).

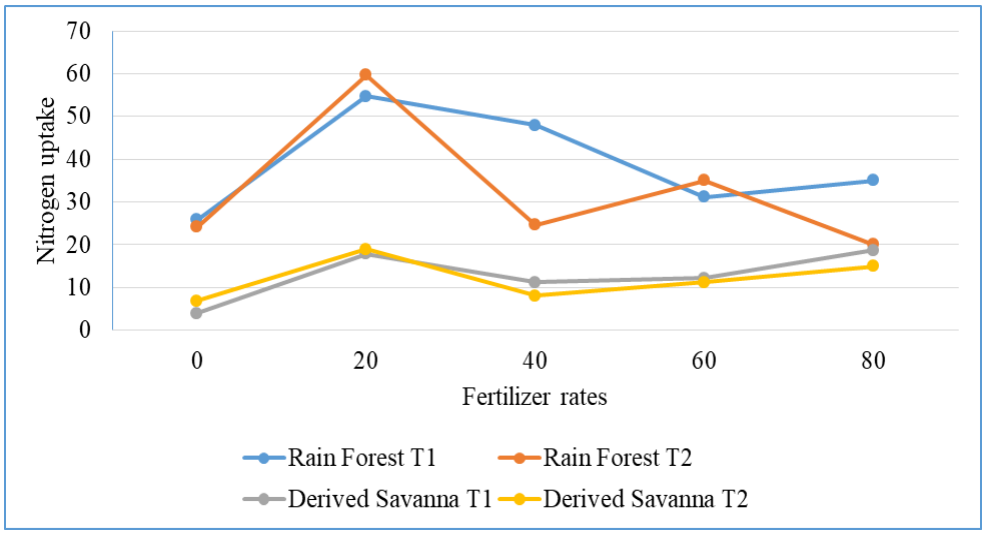

Figure 2. Effects of the timing and rate of nitrogen fertilizer application on the nitrogen uptake of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

The nitrogen uptake increased significantly when applied at a rate of 20 kg N ha^{-1} urea in combination with 5 tons ha^{-1} organic fertilizer, surpassing the uptake observed at other rates (0, 40, and 60 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer, as well as 80 kg N ha^{-1}) in a rainforest environment. This supports further the earlier result from Figure 1 that applying inorganic fertilizer at reduced rates (fertilizer microdosing) with organic fertilizer reduced the risk of nutrient mining and made more nutrients available for plant uptake. This could

mean that the fluted pumpkin absorbed nitrogen from the existing sources of nitrogen as organic matter apart from urea applied. This is in line with the work of Courtney et al. (2005) who reported that crop N needs could be met through existing N sources such as soil organic matter. Parrish and Fike (2005) have reported in their study that not all the N appearing in the shoot biomass is accumulated from recently applied N and that significant amounts of N in the biomass may not be taken up directly from the soil, but may reach the shoots from root N reserves, making the plants relatively unresponsive to recently applied N. This is also in line with the work of Sheu (2014), who reported a higher N uptake of *Sesamum indicum* L. with a reduced nitrogen fertilizer application of 75 kg N ha^{-1} compared to 112.5 kg N ha^{-1}.

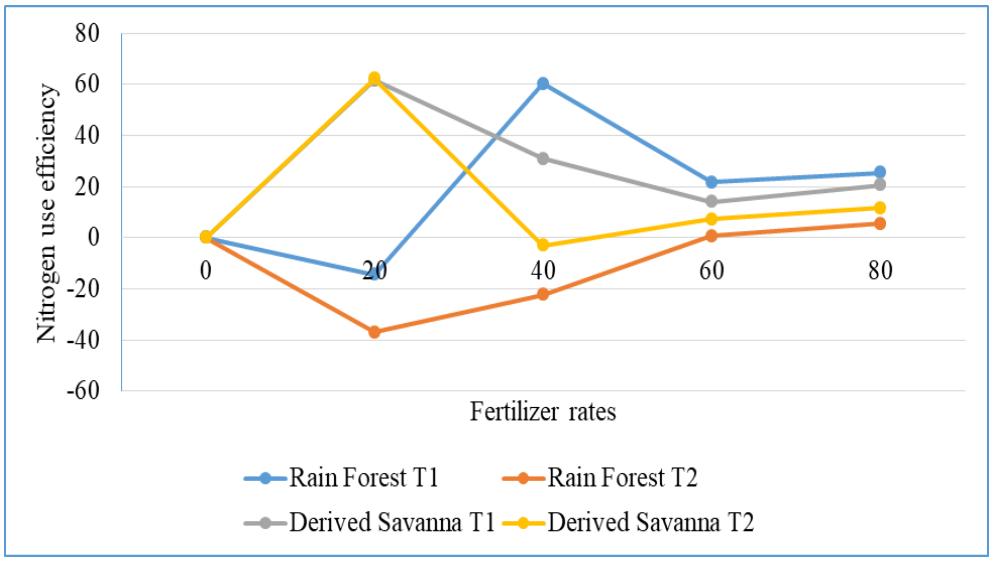

Figure 3. Effects of timing and rate of nitrogen fertilizer application on nitrogen use efficiency of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

Nitrogen use efficiency was higher in the derived savanna (Ogbomoso) compared with the rainforest (Ilesa) (Figure 3). This was an indication that the small percent of N uptake was used for the production of biomass by the fluted pumpkin in the rainforest compared to derived savanna, though N uptake was higher in the rainforest compared to the savanna. This could be due to the dilution effect in the fluted pumpkin, that is, the inability of the plants to make use of all the nitrogen taken up by the plant for yield production. Ciampitti et al. (2013) reported that close planting of maize resulted in high grain yield due to the efficient use of nitrogen (N) and the comparatively low application of N.

The highest nitrogen use efficiency was obtained at the rate of 40 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer in the rainforest, which corresponded to the microdosing at recommended rate of 40 kg N ha^{-1}, whereas in the derived savanna, the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer gave significantly the highest NUE compared to the other rates (0, 60 kg N ha^{-1} urea with 5 tons ha^{-1} fertilizer and 80 kg N ha^{-1}). This could be due to the fact that the application of much nitrogen fertilizer had no effect on the NUE and the application of excess N could lead to lodging of the vegetable as well as environmental pollution. This could be due to the dilution effect in the fluted pumpkin, that is, inability of the plants to make use of all the nitrogen taken up by the plant for yield production. Cui et al. (2009) and Ciampitti et al. (2013) observed high maize grain yields through high NUE and relatively low N application under close planting because of high biomass or N accumulation and allocation to grain. This is also in line with the work of Whitbread et al., (2013), who recorded the highest agronomic efficiency use of nitrogen at the application rates of 15 and 30 kg N ha^{-1} compared with application at 0, 60 and 120 kg N ha^{-1}.

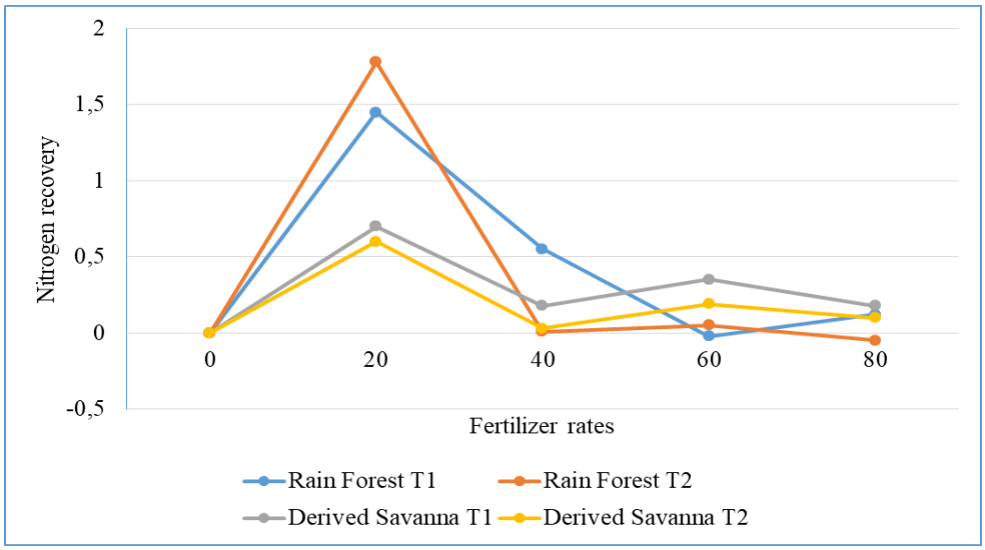

Figure 4. Effects of the timing and rate of nitrogen fertilizer application on the nitrogen recovery of fluted pumpkin in rainforest and derived savanna regions of southwestern Nigeria.

The effects of N supply on the physiological and morphological development of the fluted pumpkin under different ecosystems need to be further investigated to avoid excessive nitrogen application.

Higher nitrogen recovery was obtained in the rainforest (Ilesa) compared to the derived savanna (Ogbomoso) (Figure 4). This corroborated the higher nitrogen

uptake in the rainforest in Figure 2, that is, all the factors favored higher nitrogen uptake in Ilesa. This also enhanced higher nitrogen recovery in Ilesa compared with Ogbomoso. A significantly higher N recovery was obtained at the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer application both in the rainforest and the derived savanna. In addition, all the factors favoring the highest nitrogen uptake at the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} also promoted the highest nitrogen recovery at the rate of 20 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer compared with other rates (0, 40, 60 kg N ha^{-1} urea with 5 tons ha^{-1} organic fertilizer and 80 kg N ha^{-1}).

Conclusion

The optimal production of fluted pumpkin in southwestern Nigeria was observed when the microdosing approach was applied, using 20 to 40 kg N ha^{-1} urea in combination with 5 tons ha^{-1} organic fertilizer. This study demonstrated that the utilization of a combined approach involving fertilizer microdosing and the application of organic fertilizer was a more favorable alternative for achieving optimal fluted pumpkin production, while concurrently mitigating the excessive use of fertilizers by farmers. Further research is required to include other underutilized indigenous vegetables in Africa to establish the efficacy of microdosing for all underutilized indigenous vegetables in Africa.

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OPTIMIZACIJA PRINOSA, USVAJANJA I EFIKASNOSTI USVAJANJA AZOTA KOD REBRASTE TIKVE PRIMENOM MIKRODOZIRANJA ĐUBRIVA

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R e z i m e

Zbog izrazitog ispranja zemljišta i obilnih padavina, vreme i doza primene đubriva radi povećanja prinosa, efikasnosti usvajanja azota i njegovog iskorišćenja kod rebraste tikve (*Telfairia occidentalis*) predstavljaju ključna pitanja u jugozapadnoj Nigeriji. Eksperiment je sproveden koristeći potpuno slučajni blok dizajn sa potparcelama (2 x 2 x 5), sa četiri sorte. Ilesa i Ogbomoso su činili glavne varijante, dok su vreme primene đubriva uree i pet nivoa azota (0, 20, 40, 60 i 80 kg ha^{-1}) činili podvarijante. Osnovna primena organskog đubriva u količini od 5 tona po hektaru (0, 20, 40, 60 kg ha^{-1}) izvršena je nedelju dana pre setve. Izračunati su prinos biomase, iskorišćenje i efikasnost upotrebe azota. Kada je reč o kontrolnom tretmanu, 20 i 80 kg N ha^{-1} uree, sveži prinosi u tonama po hektaru iznosili su 7,7, 9,4 i 10,7 za Ilesu, odnosno 3,3, 8,3 i 9,5 za Ogbomoso. Najveća efikasnost upotrebe azota (60,26 kg N ha^{-1}) postignuta je pri primeni 40 kg N ha^{-1} u Ilesi, dok je u Ogbomosu najveća efikasnost (61,91 kg N ha^{-1}) ostvarena pri dozi od 20 kg N ha^{-1}. Viši sveži prinos ostvaren je u Ilesi u poređenju sa prinosom u Ogbomosu. Utvrđeno je da je najbolji način za proizvodnju rebraste tikve u jugozapadnoj Nigeriji kombinacija 5 tona organskog đubriva i mikrodoziranja uree u količini od 20 do 40 kg N ha^{-1}.

Ključne reči: *Telfairia occidentalis,* biomasa, đubrivo, mikrodoziranje.

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AGROBIOLOGICAL AND ECONOMIC POTENTIAL OF WINE GRAPEVINE CULTIVARS GROWN IN THE KYUSTENDIL REGION, BULGARIA

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Abstract: A comparative analysis of the agrobiological and economic potential of 2 white ('Slava' and 'Droujba') and 3 red ('Kaylashki rubin', 'Trapezitsa' and 'Rubin') wine grapevine cultivars under the soil and climatic conditions of the Kyustendil region in Bulgaria was carried out. Comparative variants (standards) for red cultivars were 'Pamid', and for white cultivars – 'Tamyanka'. The study was conducted during the period 2021–2024 in a collection vineyard of the Institute of Agriculture – Kyustendil, Bulgaria. In terms of quality, fertility and size of the bunches and berries, the studied cultivars reached and even exceeded the values characteristic for each of them. The percentage of berries in the bunch was "high" in all variants – from 95.0% for 'Trapezitsa' to 97.2% for 'Kaylashki rubin' and 'Droujba'. The grapes of the 'Pamid' and 'Tamyanka' standards, as well as the interspecific cultivars 'Droujba' and 'Kaylashki rubin', were characterized by a "very high" theoretical yield. In economic terms, the best results, under the experimental conditions, were achieved with the red cultivars 'Trapezitsa' and 'Kaylashki rubin'. The high level of net income and profitability show that the white cultivar 'Droujba' also has considerable economic potential.

Key words: wine grape cultivars, yield, economic evaluation.

Introduction

The grapevine (*Vitis)* exhibits great ecological plasticity and adaptability. However, despite this characteristic, the introduction of grapevine cultivars must be carried out precisely and on a scientific basis. The agrobiological properties and technological qualities of a cultivar are only fully developed when the natural conditions are most favorable for its development. Therefore, the adaptive capabilities of each cultivar to the environment must be studied to determine its economic potential and specific requirements (Katerov et al., 1990; Pappalardo et

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al., 2013; Borisenko et al., 2015; Milić et al., 2016; Filipovic et al., 2017; Krumov et al., 2020; Jelocnik et al., 2024).

Against the backdrop of changing climatic conditions, the development and introduction of grape cultivars with complex resistance to stressful biotic and abiotic factors represent an extremely important and contemporary scientific direction with significant economic implications. Both Bulgarian and global grape breeding efforts address these new challenges by developing and introducing cultivars with increased resistance to low winter temperatures and diseases while maintaining valuable biological and economic qualities (Fengmei et al., 1990; Pernesz, 2004; Hajdu, 2004; He et al., 2007; Xiang et al., 2008; Slavtcheva, 2008; Zhao et al., 2009; Jiang et al., 2009; Ivanov et al., 2011a; Ivanov et al., 2011b; Ivanov et al., 2012; Ivanov, 2013; Eibach and Töpfer, 2015; Ivanov et al., 2015; Dyakova et al., 2015; Mincheva et al., 2015; Ivanov, 2016; Simeonov et al., 2017; Delrot et al., 2020; Vannozzi et al., 2021).

In recent years, the Kyustendil region of Bulgaria has experienced record-low winter temperatures, reaching -29.5ºC, as well as late spring frosts that have destroyed grape yields. Prolonged periods of drought accompanied by extremely high temperatures have also become increasingly common. Each of these stress factors negatively affects the vitality of the vines, the quantity and quality of the harvest, and, consequently, the economic profitability of grape cultivation. Therefore, the objective of this study was to conduct an economic assessment of the potential for cultivating seven wine grape cultivars in the Kyustendil region (the second sub-region of the southwestern wine-growing region of Bulgaria).

Material and Methods

The study was conducted in a collection vineyard at the Institute of Agriculture – Kyustendil, Bulgaria, during the period 2021–2024. The experimental site is located in the eastern part of the Kyustendil Valley. The soil is a highly leached, medium sandy-clayey, slightly to moderately stony cinnamon forest soil (*Chromic Luvisols*) with a neutral reaction.

The subject of the study was wine grape cultivars developed at the Institute of Viticulture and Enology – Pleven, Bulgaria (IVE-Pleven): White cultivars: 'Slava' ('Dunavska Gamza' × 'Tsvetochnyi'), 'Droujba' ('Misket Kaylashki' × Hybrid II-51/23 × 'Zarya Severa' × 'Muscat Hamburg'), red cultivars: 'Trapezitsa' ('Dunavska Gamza' × 'Noir Hatif de Marseille'), 'Kaylashki rubin' ('Pamid' × Hybrid VI 2/15 × 'Gamay Noir' × *Vitis amurensis*), and 'Rubin' ('Nebbiolo' × 'Syrah'). For comparative purposes, the study included widely distributed standard cultivars – red cultivars: 'Pamid' (an old cultivar from the Black Sea ecological-geographical group) and white cultivars: 'Tamyanka' (an old cultivar from the Oriental ecological-geographical group).

The vines were planted in the spring of 2015. They were grafted onto the Berlandieri × Riparia SO4 rootstock and trained using the Guyot system (stemmed). The planting distances were 2.50 m between rows and 1.30 m within the row. During the study period, the vine load was set at 18 buds per vine (3 × 2 + 1 × 12). Each variant was arranged in three replicates, with 10 vines per replicate, aligned in terms of vegetative development.

During the grape growing period, the main economic indicators were calculated annually: gross output, euro/ha; production costs, euro/ha; net income, euro/ha; rate of profitability, %, prime cost, euro/ha and euro/kg. The necessary funds for obtaining grape production were established on the basis of the actual costs incurred in accordance with the standardized norms and tariffs for labor and mechanized works used in the Institute of Agriculture – Kyustendil as well as taking into account the market prices of the raw materials and other materials utilized. The valuation of production was determined using the actual realization prices in the individual years.

The yield elements were determined according to the methodology approved in Bulgarian Ampelography, Volume 1 (Katerov et al., 1990). The experimental data were analyzed using the analysis of variance (ANOVA) method, applying the least significant difference (LSD) criterion to assess the statistical significance of the differences between the control and the variants (Maneva, 2007).

Results and Discussion

The timing of the individual phenological phases of the studied cultivars under the soil and climatic conditions of the Kyustendil region was established. Cultivars of interspecific origin begin their development relatively earlier than those belonging to the *V. vinifera* group. The earliest budburst was observed in ‘Kaylashki rubin’ (April 9), which occurred six days earlier than in the standard red cultivar ‘Pamid’ (April 23). The budburst of ‘Trapezitsa’ (April 22) occurred one day earlier, while that of ‘Rubin’ (April 24) occurred one day later than that of ‘Pamid’.

Among the white cultivars, ‘Droujba’ (April 22) and ‘Slava’ (April 21) began to develop, on average, two days earlier than the standard ‘Tamyanka’ (April 24). Flowering began in the first half of June, with the differences mainly attributed to the specific characteristics of each cultivar. The *V. vinifera* cultivars ‘Pamid’, ‘Tamyanka’, and ‘Rubin’ initiated flowering later (June 10–11) compared to the interspecific cultivars ‘Kaylashki rubin’, ‘Trapezitsa’, ‘Slava’, and ‘Droujba’ (June 4–10).

Based on the timing of technological maturity in the Kyustendil region, the studied cultivars were classified into two groups: mid-ripening cultivars – ‘Rubin’ (September 15), and late-ripening cultivars – ‘Tamyanka’ (September 16),

'Droujba' (September 20), 'Trapezitsa' (September 23), 'Slava' (September 23), 'Pamid' (September 25), and 'Kaylashki rubin' (September 29).

Table 1. Phenological observations for the period 2021–2024.

Cultivar	Year	Development of buds (start), date	(+) or (-) days in comparison to standard	Flowering, date			Technological ripeness, date	(+) or (-) days in comparison to standard	Vegetation period, number of days
				Beginning	Massive	Finish			
Cultivars for red wines									
'Kaylashki rubin'	2021	26/IV	-4	02/VI	06/VI	10/VI	08/X	+2	166
	2022	26/IV	-4	05/VI	09/VI	14/VI	26/IX	+12	154
	2023	12/IV	-9	08/VI	11/VI	15/VI	12/X	-	173
	2024	09/IV	-8	30/V	02/VI	05/VI	20/IX	+4	164
	x*	17/IV	-6	04/VI	07/VI	09/VI	29/IX	+6	164
'Trapezitsa'	2021	30/IV	0	14/VI	18/VI	21/VI	03/X	-3	157
	2022	29/IV	-1	15/VI	19/VI	22/VI	14/IX	0	139
	2023	20/IV	-1	13/VI	16/VI	19/VI	18/IX	-	151
	2024	15/IV	-2	05/VI	09/VI	11/VI	13/IX	-3	151
	x	22/IV	-1	10/VI	14/VI	16/VI	23/IX	-2	150
**'Rubin'	2021	01/V	+1	15/VI	19/VI	23/VI	26/IX	-10	149
	2022	01/V	+1	14/VI	18/VI	21/VI	07/IX	-7	130
	2023	22/IV	+1	14/VI	18/VI	21/VI	-	-	-
	2024	18/IV	+1	06/VI	10/VI	13/VI	05/IX	-11	140
	x	24/IV	+1	11/VI	14/VI	18/VI	15/IX	-9	140
**Pamid' (standard)	2021	30/IV	-	15/VI	19/VI	23/VI	06/X	-	160
	2022	30/IV	-	16/VI	18/VI	22/VI	14/IX	-	138
	2023	21/IV	-	14/VI	17/VI	20/VI	-	-	-
	2024	17/IV	-	07/VI	10/VI	14/VI	16/IX	-	152
	x	23/IV	-	11/VI	14/VI	18/VI	25/IX	-	150
Cultivars for white wines									
'Slava'	2021	28/IV	-3	09/VI	14/VI	17/VI	29/IX	+4	154
	2022	29/IV	-1	12/VI	15/VI	18/VI	19/IX	+12	144
	2023	18/IV	-3	12/VI	16/VI	18/VI	18/IX	-	153
	2024	15/IV	-3	03/VI	06/VI	09/VI	16/IX	+8	154
	x	21/IV	-2	07/VI	10/VI	13/VI	23/IX	+8	151
'Droujba'	2021	29/IV	-2	08/VI	13/VI	17/VI	06/X	+11	160
	2022	29/IV	-1	11/VI	15/VI	18/VI	09/IX	-7	133
	2023	18/IV	-3	12/VI	16/VI	19/VI	10/IX	-	140
	2024	15/IV	-3	03/VI	06/VI	09/VI	05/IX	-3	143
	x	22/IV	-2	07/VI	11/VI	14/VI	20/IX	-1	144
**Tamyanka' (standard)	2021	01/V	-	14/VI	18/VI	21/VI	25/IX	-	148
	2022	30/IV	-	15/VI	20/VI	22/VI	16/IX	-	140
	2023	21/IV	-	14/VI	18/VI	21/VI	-	-	-
	2024	18/IV	-	06/VI	10/VI	14/VI	08/IX	-	143
	x	24/IV	-	10/VI	14/VI	18/VI	16/IX	-	144

*Average for the period 2021–2024; **Due to the impact of downy mildew (*P. viticola*) on the harvest in 2023, no phenological observations were carried out in the cultivars of the *V. vinifera* group.

The duration of the period from budburst to technological maturity (average for the study period) was as follows: 'Rubin' – 140 days, 'Droujba' and 'Tamyanka' – 144 days, 'Trapezitsa' and 'Pamid' – 150 days, 'Slava' – 151 days and 'Kaylashki rubin' – 164 days (Table 1).

Phenological observations conducted under the specific agro-climatic conditions of the Kyustendil region revealed distinct differences between *Vitis vinifera* and interspecific cultivars in terms of both the onset and duration of their vegetative cycles. Interspecific varieties such as 'Kaylashki rubin', 'Trapezitsa', 'Slava', and 'Droujba' demonstrated earlier budburst and more rapid initial development compared to traditional wine cultivars like 'Pamid', 'Tamyanka', and 'Rubin'. This trend likely reflects their enhanced adaptability to shortened and fluctuating growing seasons – an increasingly valuable trait under current climate dynamics. Of particular interest is the fact that 'Kaylashki rubin', despite its early budburst, reached technological maturity only by late September, indicating an extended vegetative period and slower progression during later phenological stages. These findings highlight the importance of selecting cultivars suited to regional agroecological conditions. Interspecific varieties are promising for climate-resilient viticulture, but breeding programs must carefully consider the entire vegetative season and the associated risks, such as early autumn frosts. An integrated selection approach—balancing precocity and environmental adaptability is essential for promoting sustainable viticulture under both present and anticipated climate scenarios.

At technological maturity, a mechanical analysis was performed to determine the structure of the bunches and berries, as well as the sugar and acid content in the grape juice (Table 2).

Among the red cultivars, 'Trapezitsa' had the largest average bunch weight (304.0 g), followed by 'Rubin' (280.3 g), the standard 'Pamid' (269.4 g) and 'Kaylashki rubin' (242.7 g).

Among the white cultivars, 'Droujba' had the largest average bunch weight (256.3 g), followed by the standard 'Tamyanka' (186.3 g). 'Slava' had the smallest bunches (159.4 g).

Regarding bunch dimensions, the red cultivar 'Trapezitsa' had the largest linear length and width (16.7 × 12.2 cm), while among the white cultivars, 'Droujba' stood out (16.5 × 11.4 cm). The other cultivars exhibited bunch dimensions ranging from 14.4 × 8.7 cm ('Tamyanka') to 16.2 × 11.1 cm ('Pamid') (Table 3, Figure 1).

According to the accepted classification, the studied wine grape cultivars had bunches ranging from small to medium-large, reaching or even exceeding the characteristic values for each cultivar. The mechanical analysis of the red cultivars showed that the average mass of 100 berries was the highest in the standard 'Pamid' (214.7 g), which, according to ampelographic descriptions, has a dual-

purpose use. The smallest berries were recorded in ‘Rubin’ (141.6 g). ‘Kaylashki rubin’ and ‘Trapezitsa’ had almost identical berry sizes, at 165.0 g and 168.0 g, respectively.

Table 2. Mechanical analysis of grapes of red wine grapevine cultivars, 2021–2024.

Cultivar	Year	Weight per bunch	Bunch sizes		Weight per 100 berries	Berry sizes		Structure of bunch		Theoretical yield
			Length	Width		Length	Width	Rachis	Berries	
		g	cm	cm	g	mm	mm	%	%	%
‘Kaylashki rubin’	2021	208.5	14.9	9.8	158.0	13.2	13.0	3.1	96.9	82.4
	2022	262.3	15.8	11.4	166.0	13.5	13.1	2.6	97.4	85.1
	2023	264.0	15.9	11.2	169.0	13.6	13.2	2.7	97.3	85.9
	2024	236.0	16.0	10.6	167.0	13.5	13.2	2.7	97.3	84.9
	x*	242.7	15.7 n.s.	10.8 n.s.	165.0	13.5	13.1	2.8	97.2	84.6
		n.s.			-	--	-	-	+	n.s.
‘Trapezitsa’	2021	244.7	15.6	11.3	120.0	12.2	11.9	5.7	94.3	72.1
	2022	400.4	16.9	12.6	224.0	15.3	14.8	3.7	96.3	82.5
	2023	265.0	16.0	11.7	198.0	14.4	14.0	5.5	94.5	78.9
	2024	305.8	18.2	13.0	130.0	12.7	12.1	5.1	94.9	74.4
	x*	304.0	16.7	12.2	168.0	13.7	13.2	5.0	95.0	77.0
		n.s.	n.s.	+	-	--	-	+++	---	---
‘Rubin’	2021	222.8	14.7	10.9	122.8	12.5	12.0	4.2	95.8	78.7
	2022	331.8	16.5	12.0	165.0	13.5	13.0	3.6	96.4	84.7
	2023**	-	-	-	-	-		-	-	-
	2024	286.3	16.1	12.8	137.0	13.2	12.1	3.3	96.7	82.1
	x*	280.3	15.8	11.9	141.6	13.0	12.4	3.7	96.3	81.8
		n.s.	n.s.	n.s.	--	---	--	n.s.	n.s.	--
‘Pamid’ (standard)	2021	245.1	16.0	11.3	180.0	14.0	12.8	4.1	95.9	85.2
	2022	300.8	16.3	11.2	254.0	16.3	15.7	2.8	97.2	89.1
	2023**	-	-	-	-	-	-	-	-	-
	2024	262.3	16.3	10.9	210.0	15.5	14.9	3.9	96.1	86.4
	x*	269.4	16.2	11.1	214.7	15.3	14.5	3.6	96.4	86.9
F		3.7	3.1	5.7	7.4	10.2	5.7	20.0	20.1	23.6
SD		18.8	0.4	0.4	15.9	0.4	0.5	0.3	0.3	1.2
LSD 0.05		42.4	0.8	0.9	35.9	1.0	1.2	0.7	0.7	2.8

*Average for the period 2021–2024 **Due to the impairment of the harvest by downy mildew (*P. viticola*) in the cultivars of the *V. vinifera* group, in 2023 no mechanical analysis of the yield was carried out – ns (non-significant differences); +/- (P<0.05); ++/-- (P<0.01); +++/--- (P<0.001).

Among the white cultivars, ‘Droujba’ had the largest berries (354.0 g) in all years of the study. According to the ampelographic descriptions, ‘Droujba’ is a dual-purpose cultivar. The standard ‘Tamyanka’ ranked second (188.0 g), while ‘Slava’ had the smallest berries (165.5 g).

A similar trend was observed regarding berry dimensions. ‘Droujba’ had the highest average length-to-width ratio (18.3 × 17.5 mm), while ‘Slava’ had the lowest (13.1 × 12.7 mm). Among the red cultivars, the standard cultivar ‘Pamid’

had the largest berries (15.3 × 14.5 mm), while the other cultivars had nearly identical sizes.

The comparative analysis showed that the differences between the red cultivars and the standard were insignificant, whereas in 'Droujba', the differences in berry size were statistically significant.

The data on bunch and berry structure indicate that the percentage of berries within the bunch was consistently high across all variants, ranging from 95.0% in 'Trapezitsa' to 97.2% in 'Kaylashki rubin' and 'Droujba'. Under the specific regional conditions, the theoretical yield was high for all cultivars and ranged from 77.0% to 86.9% (Tables 2 and 3).

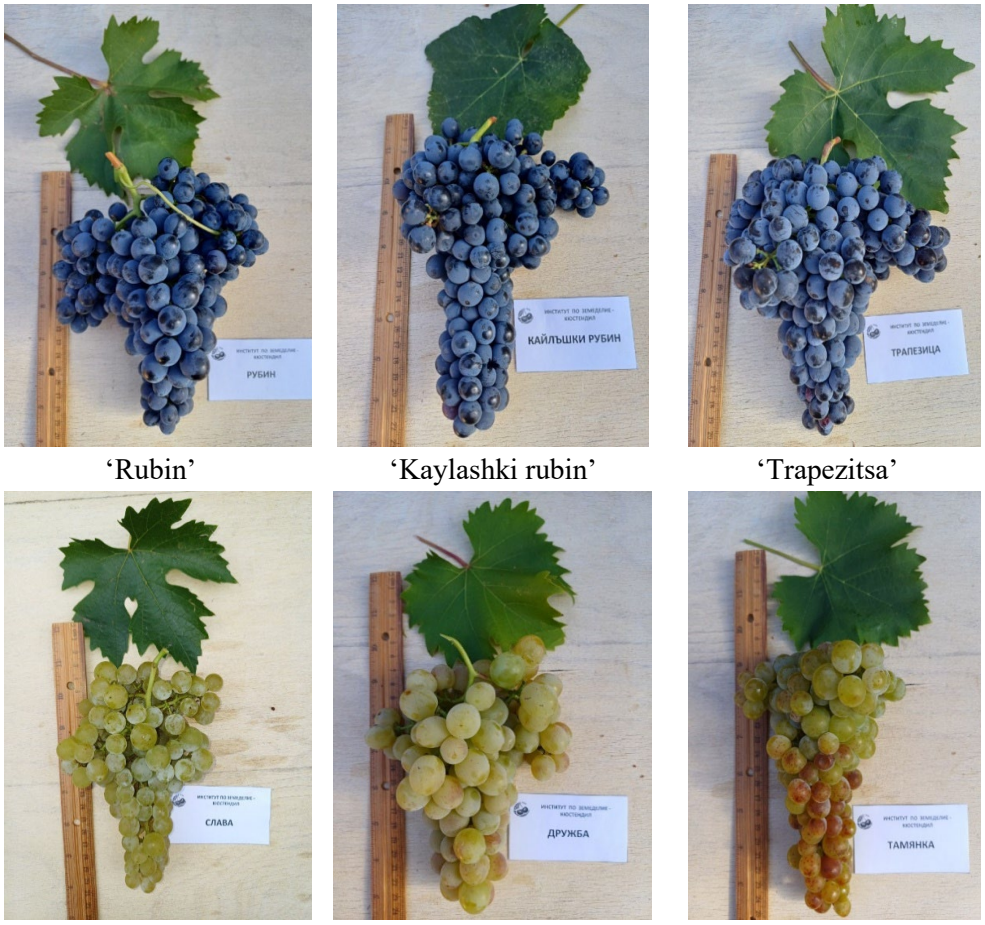
Table 3. Mechanical analysis of grapes of white wine grapevine cultivars, 2021–2024.

Cultivar	Year	Weight per bunch	Bunch sizes		Weight per 100 berries	Berry sizes		Structure of bunch		Theoretical yield
			Length	Width		Length	Width	Rachis	Berries	
		g	*cm*	*cm*	*g*	*mm*	*mm*	*%*	*%*	*%*
'Slava'	2021	125.5	12.8	8.6	154.0	12.6	12.4	4.0	96.0	79.9
	2022	209.2	14.8	10.8	175.0	13.5	13.2	3.0	97.0	82.0
	2023	154.1	13.3	8.8	174.0	13.2	12.7	3.9	96.1	80.4
	2024	148.6	14.3	9.2	159.0	13.0	12.7	4.3	95.7	80.2
	x*	159.4	13.8	9.4	165.5	13.1	12.7	3.8	96.2	80.6
		n.s.	n.s.	n.s.	n.s.	-	--	n.s.	n.s.	---
'Droujba'	2021	234.8	15.2	11.4	305.0	16.8	16.7	3.4	96.6	84.5
	2022	311.2	18.4	11.5	404.0	19.7	18.6	2.2	97.8	87.1
	2023	239.0	16.3	11.2	377.0	18.7	17.5	3.0	97.0	86.1
	2024	240.3	16.0	11.5	330.0	18.0	17.0	2.5	97.5	86.3
	x*	256.3	16.5	11.4	354.0	18.3	17.5	2.8	97.2	86.0
		+	n.s.	+	+++	+++	+++	-	+	n.s.
'Tamyanka' (standard)	2021	177.3	14.5	8.1	161.0	12.9	12.8	3.8	96.2	86.2
	2022	165.5	12.6	7.7	213.0	15.2	14.9	5.6	94.4	85.6
	2023**	-	-	-	-	-	-	-	-	-
	2024	216.0	16.0	10.4	190.0	13.9	13.8	4.2	95.8	86.3
	x*	186.3	14.4	8.7	188.0	14.0	13.8	4.5	95.5	86.0
F		11.5	4.1	7.4	122.0	150.7	225.8	5.3	5.2	63.0
SD		20.8	1.0	0.7	13.2	0.3	0.2	0.5	0.54	0.6
LSD 0.05		51.1	2.4	1.8	32.3	0.8	0.6	1.3	1.3	1.4

*Average for the period 2021–2024 **Due to the impairment of the harvest by downy mildew (*P. viticola*) in the cultivars of the *V. vinifera* group, in 2023 no mechanical analysis of the yield was carried out – ns (non-significant differences); +/- (P<0.05); ++/-- (P<0.01); +++/--- (P<0.001).

The results of this study demonstrate clear trends in the selection and adaptation of the evaluated wine grape varieties to the current climatic conditions. Among the red varieties, 'Trapezitsa' and 'Kaylashki rubin' stood out due to their excellent technological qualities. 'Trapezitsa' is characterized by the highest average bunch weight and size, combined with a high percentage of berries and an optimal bunch and berry structure, resulting in the greatest theoretical yield.

Despite the smaller berry size, ‘Kaylashki rubin’ achieved a comparable yield efficiency. Both varieties significantly outperformed the standard cultivar ‘Pamid’, thereby confirming the effectiveness of the breeding efforts aimed at enhancing resilience and productivity (Ivanov et al., 2011b; Ivanov et al., 2012; Roychev, 2012; Ivanov, 2016).



‘Rubin’ ‘Kaylashki rubin’ ‘Trapezitsa’

‘Slava’ ‘Droujba’ ‘Tamyanka’

Figure 1. Grapevine cultivars.

Among the white cultivars, ‘Droujba’ is characterized by its large bunches and berries, high yield potential, and favorable technological characteristics, supporting its classification as a dual-purpose variety (Simeonov et al., 2009; Roychev, 2012). The mechanical analysis further substantiated the superiority of ‘Droujba’ over ‘Tamyanka’ and ‘Slava’.

In conclusion, the cultivars ‘Trapezitsa’, ‘Kaylashki rubin’, and ‘Droujba’ demonstrated strong potential for integration into contemporary viticultural systems. Their high productivity and desirable technological traits position them as valuable assets for sustainable viticulture under evolving climatic conditions.

The grape yield is a function of the number of bunches per vine and their average weight. Among the red cultivars, ‘Trapezitsa’ (21252 kg/ha) and ‘Kaylashki rubin’ (20328 kg/ha) stood out with the highest and almost equal average grape yield per hectare (2021–2024). The differences compared to the ‘Pamid’ standard (17248 kg/ha) were statistically significant. ‘Rubin’ had the lowest yield, at 14168 kg/ha. Among the white cultivars, ‘Droujba’ had the highest recorded yield per hectare (15092 kg/ha), due to its larger bunches, followed by ‘Slava’ (10780 kg/ha). The lowest average yield per vine was recorded for the ‘Tamyanka’ standard (8932 kg/ha) (Figure 2). The price of the grapes is determined by the actual prices realized over the years and is given as an average value for the period. Its value was 0.61 euro/kg. The profitability rate ranged from 82% to 175%.

The highest gross output was achieved by the red cultivars ‘Trapezitsa’ (13039 euros/ha) and ‘Kaylashki rubin’ (12472 euros/ha), while the lowest was recorded for the white standard ‘Tamyanka’ (5480 euros/ha). The red cultivars demonstrated higher economic value compared to the white ones.

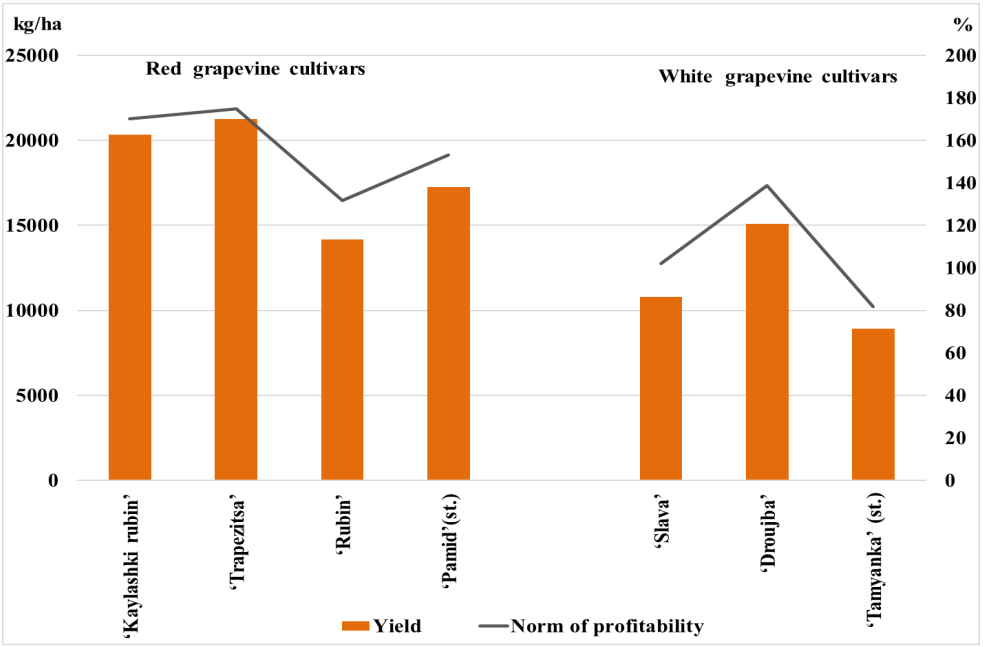


Figure 2. Yield (kg/ha) and profitability rate (%).

Production costs for red cultivars ranged from 3749 euros/ha (‘Rubin’) to 4745 euros/ha (‘Trapezitsa’). White cultivars had lower production costs, making them more attractive from this point of view. ‘Tamyanka’ had the lowest costs (3013 euro/ha), which is due to its lower yield.

The net income followed the trend observed for the gross output, with the highest values recorded for ‘Trapezitsa’ (8294 euro/ha), followed by ‘Kaylashki rubin’ (7857 euro/ha). Compared to the standard, these cultivars generated higher net incomes of 1893 euros/ha and 1456 euros/ha, respectively (Figure 3). The gained research results are generally in line with some previous researches providing the evidence that grape cultivation could be profitable (Pappalardo et al., 2013; Milić et al., 2016; Filipovic et al., 2017; Jelocnik et al., 2024).

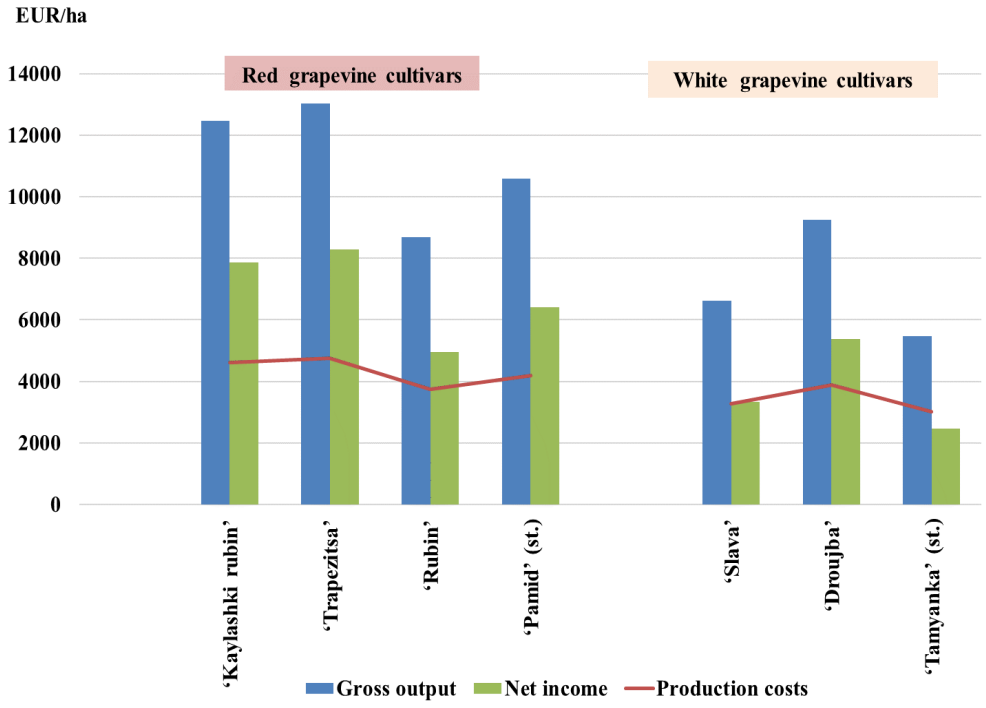


Figure 3. Gross output, net income and production costs, euro/ha.

The red cultivars were more cost-effective to produce, with lower production costs. The lowest prime cost was recorded for ‘Trapezitsa’ (0.22 euro/kg), while ‘Rubin’ had the highest value (0.26 euro/kg). Among the white cultivars, the lowest prime cost was observed for ‘Droujba’ (0.26 euro/kg), whereas ‘Tamyanka’

had the highest cost (0.34 euro/kg). The prime costs per hectare were highest for ‘Trapezitsa’ and lowest for ‘Tamyanka’ (Figure 4).

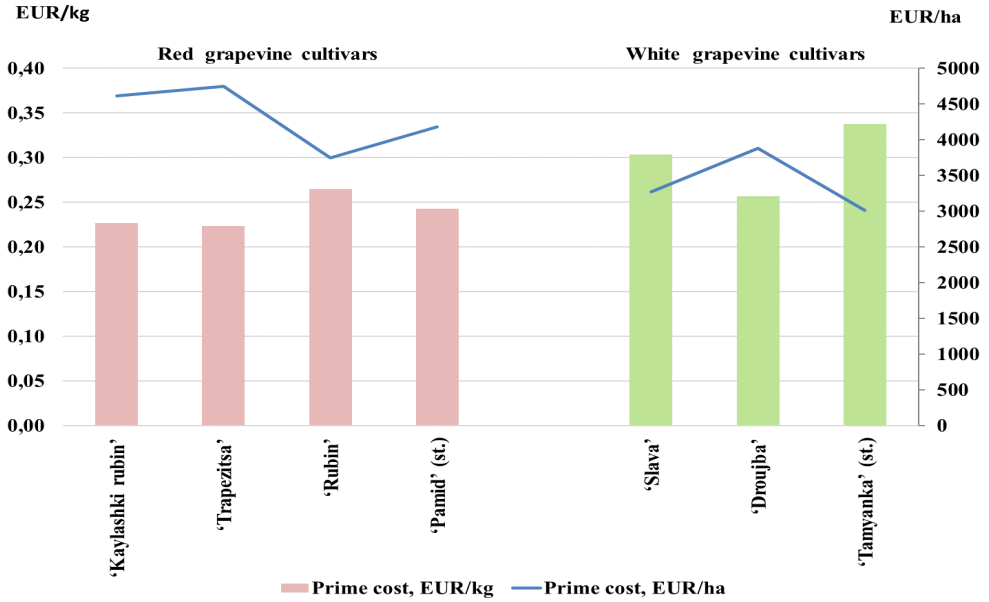


Figure 4. Prime costs, euro/ha and euro/kg.

Conclusion

The timing of the individual phenophases of the studied cultivars under the soil and climatic conditions of the Kyustendil region, Bulgaria, has been determined. Cultivars of interspecific origin began their development relatively earlier than those belonging to the *V. vinifera* group. Based on the onset of technological maturity, the studied cultivars can be classified into two groups: mid-ripening – ‘Rubin’ (15/IX) and late-ripening – ‘Tamyanka’ (16/IX), ‘Droujba’ (20/IX), ‘Trapezitsa’ (23/IX), ‘Slava’ (23/IX), ‘Pamid’ (25/IX), and ‘Kaylashki rubin’ (29/IX).

The bunches of the studied wine cultivars ranged from small to medium-large and reached the characteristic values. The percentage of berries within the bunch was high across all variants, ranging from 95.0% in ‘Trapezitsa’ to 97.2% in ‘Kaylashki rubin’ and ‘Droujba’. The grapes of the ‘Pamid’ and ‘Tamyanka’ standards, as well as ‘Droujba’ and ‘Kaylashki rubin’, had a very high theoretical yield.

Among the red cultivars, ‘Trapezitsa’ and ‘Kaylashki rubin’ outperformed the others in almost all indicators, including yield, net income, and profitability. Their cultivation under the soil and climatic conditions of the Kyustendil region provides opportunities for achieving high economic returns. Although white cultivars such as ‘Droujba’ have lower production costs, they cannot compete with the high economic efficiency of the red ones.

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AGROBIOLOŠKI I EKONOMSKI POTENCIJAL VINSKIH SORTI VINOVE LOZE GAJENIH U REGIONU ĆUSTENDILA, BUGARSKA

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R e z i m e

Sprovedena je uporedna analiza agrobiološkog i ekonomskog potencijala dve bele sorte vinove loze (‘slava’ i ‘družba’) i tri crvene sorte (‘kajlaški rubin’, ‘trapezica’ i ‘rubin’) u zemljišnim i klimatskim uslovima regiona Ćustendila u Bugarskoj. Kao uporedne varijante (standardi) korišćene su sorte ‘pamid’ za crvene i ‘tamjanika’ za bele sorte. Istraživanje je sprovedeno u periodu od 2021. do 2024. godine u kolekcionom vinogradu Instituta za poljoprivredu – Ćustendil, Bugarska. Kada je reč o kvalitetu, plodnosti i veličini grozdova i bobica, ispitivane sorte su dostigle, pa čak i premašile vrednosti karakteristične za svaku od njih. Udeo bobica u grozdu bio je „visok” kod svih varijanti – od 95,0% kod sorte ‘trapezica’ do 97,2% kod sorti ‘kajlaški rubin’ i ‘družba’. Grožđe standardnih sorti ‘pamid’ i ‘tamjanika’, kao i međuvrsnih sorti ‘družba’ i ‘kajlaški rubin’, odlikovalo se „veoma visokim” teorijskim prinosom. Sa ekonomske tačke gledišta, najbolji rezultati u eksperimentalnim uslovima postignuti su kod crvenih sorti ‘trapezica’ i ‘kajlaški rubin’. Visok nivo neto prihoda i profitabilnosti pokazuje da i bela sorta ‘družba’ ima značajan ekonomski potencijal.

Ključne reči: vinske sorte vinove loze, prinos, ekonomska evaluacija.

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INTEGRATION OF MINERAL OIL AND WATER-WASHING AS AN EFFECTIVE TOOL TO CONTROL *PSEUDAULACASPIS PENTAGONA* (TARGIONI-TOZZETTI) (HEMIPTERA: DIASPIDIDAE)

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Abstract: This study was aimed to evaluate the efficiency of winter control by water-washing + mineral oil compared to repeated use of insecticides in controlling *Pseudaulacaspis pentagona* (Targioni-Tozzetti) in peach orchards of the Mazandaran province. This experiment was conducted as a completely randomised design with three treatments and five replications in a peach orchard located in the Makran village, Miandorud city: (1) chlorpyrifos (Chlorpyrifos-methyl Kavosh®, 40% EC) and ethion (Ethion Kavosh®, 47% EC) at a concentration of 2 L/1000L of water, (2) water-washing + mineral oil (Volk Kavosh®, 90% EC) at a ratio of 5% (V/V), and (3) control (no spraying). The results showed that there was a significant difference between the efficiency of water-washing+mineral oil compared to the chemical insecticides in controlling *P. pentagona*. Water-washing+mineral oil spraying showed an efficacy of 80.25% and 75.71% in controlling nymphs and adults of *P. pentagona*, respectively, during the spring season. The efficiency of the mentioned treatment in reducing the population of nymphs and female adults during the summer season was 77.00% and 69.12%, respectively. Water-washing + mineral oil recorded 70.32% and 71.09% in controlling the populations of nymphs and adults of this pest during the autumn season. On the other hand, the efficiency of the insecticides on the nymphs and adults was 63.70% and 55.78%, 61.68% and 49.78%, 37.03% and 40.83% during spring, summer and autumn, respectively. As a result, the findings showed that winter control with a single application of water-washing + mineral oil had higher and significant efficiency than three applications of chemical insecticides.

Key words: white peach scale, mineral oil, chemical insecticide, efficiency.

Introduction

More than 25 million tons of peaches and nectarines are produced worldwide every year. Iran is the fifth largest peach and nectarine producer in the world with a production volume of approximately 864 thousand tons per year

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(FAO, 2022). Among the provinces that produce peaches and nectarines in Iran, the Mazandaran province has the highest production of the above products with more than 273.7 thousand tons (Anonymous, 2023). Several pests are active in stone fruit orchards, especially peaches in the region, each of which causes significant damage to this product. One of the most important pests of peach trees is white peach scale (WPS), *Pseudaulacaspis pentagona* (Targioni-Tozzetti) (Hemiptera: Diaspididae), whose habitat is mostly in tropical, temperate and humid regions (Sharifi et al., 2020).

This pest was first introduced to northern Iran (Guilan province) in 1964 along with improved mulberry cuttings from Japan. Since then, pest outbreaks have been observed on Japanese and native mulberry trees of this province (Taksokhan, 1999). The WPS has a wide host range, including fruit, forest and ornamental trees, and damages 121 genera from 54 plant families (CABI, 2022; Miller and Davidson, 2005; Toorani, 2017). This pest generally settles on the branches and trunks of stone fruits and it is also observed on fruits and leaves in high population density or severe infestation (Sharifi et al., 2020). Trees infested by this scale gradually weaken and eventually decline (Gholamian and Aghajanzadeh, 2016).The study of the biology of WPS in the west of the Mazandaran province shows that this pest has three generations per year and overwinters as fertile female adults (Gholamian et al., 2013).Currently, the WPS is a serious threat to peach and kiwi orchards. Due to the increase in the cultivated area of these crops as well as mulberry orchards to produce silkworms, the damage caused by this pest has become economically important (Ali Akbar Aghadokht et al., 2018).

The application of chemical insecticides is a common and main strategy for controlling WPS in fruit orchards (Morales-Rodriguez and McKenna, 2019). The most susceptible developmental stage of WPS and other armoured scales is the first-instar nymphs, which do not have a wax cover (Erkiliçand Uygun, 1997; Tatara, 1998; Graora, 2005), so that chemical control measures are carried out simultaneously with this developmental stage and most sprays are timed to correspond to about 50% of crawler (first-instar nymphs) emergence (Zhuang et al., 2016; Morales-Rodriguez and McKenna, 2019). Suppressing the population of WPS is difficult in the later developmental stages (second- and third-instar nymphs and female adults) due to the development of a hard and waxy cover (armour) on their body that effectively protects them from adverse conditions, especially exposure to insecticides (Graora, 2005; Bazrafshan et al., 2010; Tozlu et al., 2020). This issue has led to an increase in the times of insecticide use to control this pest in the above developmental stages. However, the application of chemical insecticides causes serious problems such as the development of pesticide resistance in pests, disruption of the natural balance, negative effects on natural enemies of the pests and beneficial insects (pollinators) and environment (Kwaiz et al., 2009). The search for alternative control methods that have less negative and

destructive effects is necessary for implementing an effective pest management programme and control WPS at all developmental stages. One alternative in the management of scale insects is the application of mineral oil spray (Moretti et al., 2002; Bazrafshan et al., 2010). Spraying with mineral oils plays a significant and important role in controlling armoured scales in many crops, especially fruit trees (Morales-Rodriguez and McKenna, 2019). Zhuang et al. (2015)found that mineral oil effectively controlled the first nymphal instars of WPS on kiwifruit in China. The results on peach and nectarine trees in Iran revealed that mineral oil at a rate of 2.5% caused a high mortality in the overwintering adults of *P. pentagona* (Bazrafshan et al., 2010; Mafi Pashakolaei et al., 2015; Alizadeh et al., 2021). Gholamian et al. (2013) also indicated that winter spraying of kiwifruit trees in the Ramsar city (in northern Iran) using mineral oil at a rate of 2% caused the highest mortality rate in the overwintering generation of WPS. The results of another study showed that the use of mineral oils such as misrona oil and alboleum oil at a rate of 2.5% caused a decrease in the WPS population by more than 88% (Kwaiz et al., 2009). The high density of *P. pentagona* on peach and nectarine trees in fruit orchards of northern Iran is considered a serious threat, and in some cases, gardeners spray 3 to 5 times using chemical pesticides to control this pest. The aforementioned problems related to the harmful effects of pesticides further highlight the importance of this research to reduce pesticide use. It should be noted that due to the lack of sufficient knowledge about the management and control of WPS, many sprayings are unnecessary, ineffective and poorly timed. Accordingly, this study was aimed to investigate the effect of mineral oil application at the appropriate time on the control of *P. pentagona*in peach orchards.

Material and Methods

This research was carried out in a peach orchard within an area of 2250 m^2 (75×30 m) located in the Makran village (36º 41E, 53º 16N) of the Miandorud city in the Mazandaran province, Iran, at an altitude of 15 m above mean sea level, from January 6 to November 15, 2021. The peach trees were a 7-year old Crest variety (*Prunus persica* var. *persica* 'Crest') in 15 rows and each row contained six trees (90 trees in total). The inter-row distance and the distance between trees within a row was 5 m. This experiment was conducted as a randomised complete block design with three treatments and five replications. The experimental treatments included: (1) chlorpyrifos (Chlorpyrifos-methyl Kavosh®, 40% EC, Kavosh Kimia Kerman Co., Kerman, Iran) and ethion (EthionKavosh®, 47% EC, Kavosh Kimia Kerman Co., Kerman, Iran) at a concentration of 2 L/1000 L of water, (2) water-washing + mineral oil (Volk Kavosh®, 90% EC, Kavosh Kimia Kerman Co., Kerman, Iran) at a ratio of 5% (V/V), and (3) control (no spraying). The orchard was divided into five blocks and each block included three rows and

each row had six trees. Each row of trees in each block was randomly assigned to a treatment.

The treatments were applied to the studied trees when 70% of the WPS eggs had hatched on the tree trunk (Table 1). Foliar spraying with the appropriate insecticides was carried out on three dates based on the executive instructions provided by the Plant Protection Organization and the recommendations of the experts of the Ministry of Agricultural Jihad (Table 1). Foliar spraying was done uniformly by a rechargeable manual sprayer and ten litres of solution were used for each treatment. After the treatment, the name of each treatment was written on an aluminium sheet and installed on the trees of each row. It should be noted that a random sample was taken in the blocks (one tree of each row in each block) on January 6, 2021, to determine the WPS population before applying treatments. For sampling, a 10-cm^2 piece (5 × 2 cm) was separated from the bark of the trunk or tree branch, where the pest infestation was observed. Sampling was done at 14-day intervals from February 4, 2021 to mid-November, 2021. The sampling method was as follows: on the first sampling date, a tree in each row of each block was randomly selected and a sample was taken from it. Then, on the subsequent date, the next tree in the same row was sampled, so that, at the end of this study, all the trees in each row of each block (all the trees in the orchard) were sampled. The samples were placed in plastic bags and transported to the laboratory. Then, the nymphs (not separated into nymphal stages) and adults were counted under a stereomicroscope. The mobility of nymphs and adults after stimulation with a needle was a measure of their viability. After counting the number of live and dead nymphs and adults, the efficacy of the control methods was calculated using the formula of Henderson and Tilton (1955):

$$Efficacy(\%) = (1 - \frac{T_a \times C_b}{T_b \times C_a}) \times 100 (1) \quad (1)$$

where T_a was the number of live individuals in the treatment after spraying, T_b was the number of live individuals in the treatment before spraying, C_a was the number of live individuals in the control after spraying, and C_b was the number of live individuals in the control before spraying.

Table 1. Dates of the application of the treatments during the seasons in 2021.

Treatments	Dates of application				
	January 7	January 21	May 5	July 6	August 21
WMO	Water-washing	Mineral oil spraying			
INCS			Chlorpyrifos	Ethion	Chlorpyrifos

WMO: water-washing and mineral oil treatment; INCS: insecticide treatment.

Statistical analysis

The data of WPS population were statistically analysed based on a randomised complete block design using the SAS software, version 9.3 (SAS Institute, 2017) by the GLM method. The mean comparison of the treatments was also done using the Duncan's multi-range test at the probability level of 5%. In addition, the efficacy of mineral oil and insecticides was compared using an independent two-sample t-test.

Results and Discussion

The effect of the control methods on the WPS population on different sampling dates

Spring

According to the results of variance analysis on the sampling dates in spring, applying the treatments had a significant effect on the control of the different developmental stages of *P. pentagona* ($p<0.01$). Since water-washing + mineral oil was the only treatment applied until April 27, therefore, a significant difference was observed between this treatment and the other treatments in the number of nymphs and adults of WPS, and the lowest population density of both developmental stages was obtained for the water-washing + mineral oil treatment. Considering that the insecticide treatment had not yet been applied, there was no significant difference between the insecticide and the control treatments (Table 2).

Table 2. Mean comparison of the nymphs and the adult population of *P. pentagona* affected by the treatments on the different sampling dates in the spring of 2021.

Developmental stage	Sampling date	Mean±SE‡			F-value
		CONT	INCS	WMO	
Nymphs	April 1	3.00±0.25a	3.20±0.18a	0.60±0.12b	31.40**
	April 13	4.20±0.23a	4.40±0.28a	0.80±0.10b	87.71**
	April 27	6.20±0.31a	5.80±0.26a	1.00±0.10b	66.11**
	May 11	10.60±0.47a	3.40±0.22b	2.40±0.15b	103.52**
	May 25	10.00±0.51a	3.60±0.26b	2.00±0.16c	70.74**
	June 10	5.00±0.38a	2.00±0.14b	1.20±0.09c	86.00**
	Spring	6.50±0.36a	3.73±0.23b	1.33±0.11c	68.78**
Adults	April 1	9.00±0.45a	9.00±0.30a	2.20±0.18b	105.09**
	April 13	13.60±0.64a	13.00±0.55a	2.20±0.15b	176.40**
	April 27	8.80±0.74a	8.20±0.65a	1.80±0.13b	123.71**
	May 11	4.20±0.34a	1.40±0.10b	1.00±0.11b	45.60**
	May 25	4.40±0.36a	2.20±0.14b	1.20±0.09c	33.50**
	June 10	6.00±0.32a	3.00±0.15b	1.80±0.10c	31.91**
	Spring	7.67±0.30a	6.13±0.28b	1.70±0.11c	35.41**

‡Different letters in each row indicate a significant difference between the treatments;**indicates that the effect of the treatments was statistically significant at a 1% probability level ($p<0.01$); CON: control treatment; INCS: insecticide treatment; WMO: water-washing and mineral oil treatment.

The results of the mean comparison on May 11 showed that the highest number of live nymphs and adults counted on this date was related to the control treatment, with the averages of 10.60 and 4.20 individuals per 10 cm^2 of tree trunk bark, respectively, which was a significant difference from the averages obtained for the other treatments. On the other hand, the lowest number of live nymphs and adults counted among the treatments on May 11 was obtained for the water-washing + mineral oil treatment with the averages of 2.40 and 1.00 individuals per 10 cm^2 of tree trunk bark, respectively, which was not significantly different from the insecticide treatment (Table 2). The results of the mean comparison of the effect of the studied treatments on the number of nymphs and adults of WPS on May 25 and June 10, 2021 in Table 1 show that the highest number of live nymphs and adults was counted on these dates in the control treatment, which was significantly different from the other treatments. On the other hand, the lowest number of live nymphs and adults was counted for the water-washing + mineral oil treatment, which was significantly different from the other treatments (Table 2).

Table 3. Mean comparison of the nymphs and the adult population of *P. pentagona* affected by the treatments on the different sampling dates in the summer of 2021.

Developmental stage	Sampling date	Mean±SE‡			F-value
		CONT	INCS	WMO	
Nymphs	June 25	8.80±0.45a	4.20±0.24b	1.60±0.17c	166.17**
	July 11	12.80±0.65a	3.80±0.47b	3.20±0.44b	105.80**
	July 26	10.20±0.60a	3.80±0.32b	2.40±0.17c	216.17**
	August 10	6.20±0.44a	3.20±0.36b	1.40±0.11c	51.88**
	August 25	12.80±0.75a	4.60±0.29b	3.00±0.11c	92.13**
	September 10	8.20±0.43a	2.80±0.24b	2.20±0.16b	52.84**
	Summer	9.83±0.51a	3.73±0.34b	2.30±0.14c	64.58**
Adults	June 25	4.20±0.21a	2.40±0.20b	1.20±0.08c	12.67**
	July 11	3.40±0.32a	1.60±0.35b	1.20±0.25b	25.75**
	July 26	4.60±0.38a	2.20±0.27b	1.20±0.12c	38.17**
	August 10	5.40±0.30a	3.20±0.21b	1.40±0.12c	75.25**
	August 25	3.60±0.21a	1.80±0.13b	1.20±0.14c	33.43**
	September 10	6.80±0.31a	2.80±0.20b	2.20±0.18b	85.27**
	Summer	4.67±0.33a	2.33±0.22b	1.40±0.14c	28.51**

‡Different letters in each row indicate a significant difference between the treatments; *indicates that the effect of the treatments was statistically significant at a 1% probability level ($p<0.01$); CON: control treatment; INCS: insecticide treatment; WMO: water-washing and mineral oil treatment.

Summer

As can be seen in Table 2, the application of the studied treatments significantly affected the population of the different developmental stages of *P. pentagona* in summer ($p<0.01$). On June 25, the lowest number of live nymphs and

adults counted among the treatments was obtained for the water-washing + mineral oil treatment with the averages of 1.60 and 1.20 individuals per 10 square centimetres of bark, respectively, which was significantly different from the other treatments (Table 3). According to the results, on July 11 and September 10, the lowest number of different developmental stages of WPS was counted in the water-washing + mineral oil treatment, but no significant difference was observed between this treatment and the treatment with insecticides (Table 3). The results of mean comparisons on July 26, August 10 and 25 showed that the water-washing + mineral oil treatment caused a significant decrease in the density of the population of nymphs and adults of *P. pentagona* compared to the other treatments (Table 3).

Autumn

The results of variance analysis in this season showed that applying the studied treatments had a significant effect on the control of the different developmental stages of WPS ($p<0.01$) (Table 4). According to the mean comparison on September 25, the lowest number of WPS nymphs was obtained for the water-washing + mineral oil treatment with a significant difference compared to the other treatments, but no significant difference was observed between the water-washing + mineral oil treatment and the insecticide treatment in terms of the adult population although the lowest number of WPS adult was obtained for the water-washing + mineral oil treatment (Table 4). On October 13 and November 1, the lowest number of nymphs and adults of *P. pentagona* was obtained for the water-washing + mineral oil treatment with a significant difference compared to the other treatments.

Table 4. Mean comparison of the nymphs and the adult population of *P. pentagona* affected by the treatments on the different sampling dates in the autumn of 2021.

Developmental stage	Sampling date	Mean±SE‡			F-value
		CONT	INCS	WMO	
Nymphs	September 25	5.80±0.37a	2.80±0.16b	1.40±0.19c	63.17**
	October 13	3.00±0.26a	1.80±0.16b	1.00±0.15c	21.71**
	November 1	2.80±0.23a	1.80±0.13b	0.60±0.07c	26.00**
	November 15	1.40±0.14a	1.00±0.10ab	0.60±0.06b	4.00*
	Autumn	3.25±0.22a	1.85±0.12b	0.90±0.11c	17.26**
Adults	September 25	4.00±0.25a	2.20±0.30b	1.40±0.27b	17.73**
	October 13	3.00±0.21a	2.00±0.19b	1.00±0.10c	7.50**
	November 1	5.00±0.27a	2.80±0.15b	1.00±0.11c	86.00**
	November 15	3.80±0.25a	2.40±0.13b	0.80±0.06c	28.17**
	Autumn	3.95±0.25a	2.35±0.18b	1.05±0.11c	21.66**

‡Different letters in each row indicate a significant difference between the treatments; ** and * indicate that the effect of the treatments was statistically significant at the 1% and 5% probability levels, respectively ($p<0.01$ and $p<0.05$); CON: control treatment; INCS: insecticide treatment; WMO: water-washing and mineral oil treatment.

The results of comparing the average population of nymphs on November 15 showed that no significant difference was observed between the water-washing + mineral oil treatment and the insecticide treatment due to the decrease in pest density on this date, but it should be noted that there was a significant difference between the population of nymphs in water-washing + mineral oil and control treatments. This is despite the fact that the observed difference between the control and insecticide treatments was not significant (Table 4).

Comparison of the efficacy of water-washing + mineral oil and insecticides in the control of *P. pentagona* on different sampling dates

Considering that the first date of the application of insecticides was on May 5, 2021, therefore, the trend of changes in the efficacy of water-washing + mineral oil in controlling the population of WPS nymphs from February 4 to April 27, 2021 is shown in Figure 1, and the efficiencies of water-washing + mineral oil and insecticides were compared with each other from May 11, 2021 to the end of the experiment.

As can be seen, the efficacy of this treatment increased from February 4 (48.33%) to April 27 (84.76%), 2021 (except for March 19, 2021). Also, the changes in the efficiency of the water-washing + mineral oil treatment in the control of the population of WPS adults showed that the efficiency increased from February 4 to April 13, 2021 (except for April 1, 2021), so that it increased from 56.00% to 83.73%, although a slight decrease in efficiency was observed on April 27, 2021, reaching an average of 79.11% (Figure 2).

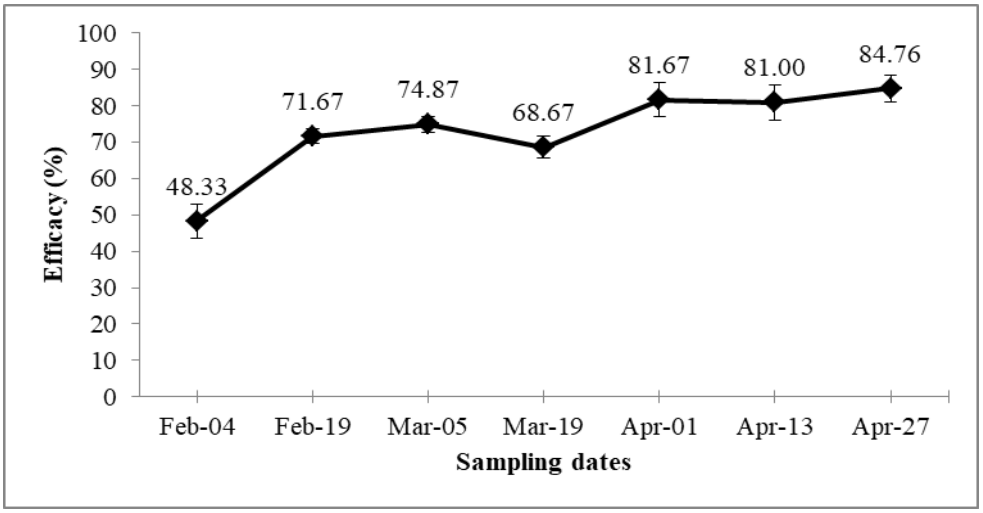

Figure 1. The efficacy of the water-washing + mineral oil treatment in controlling the nymphs of *P. pentagona* on the different sampling dates before applying the insecticides.

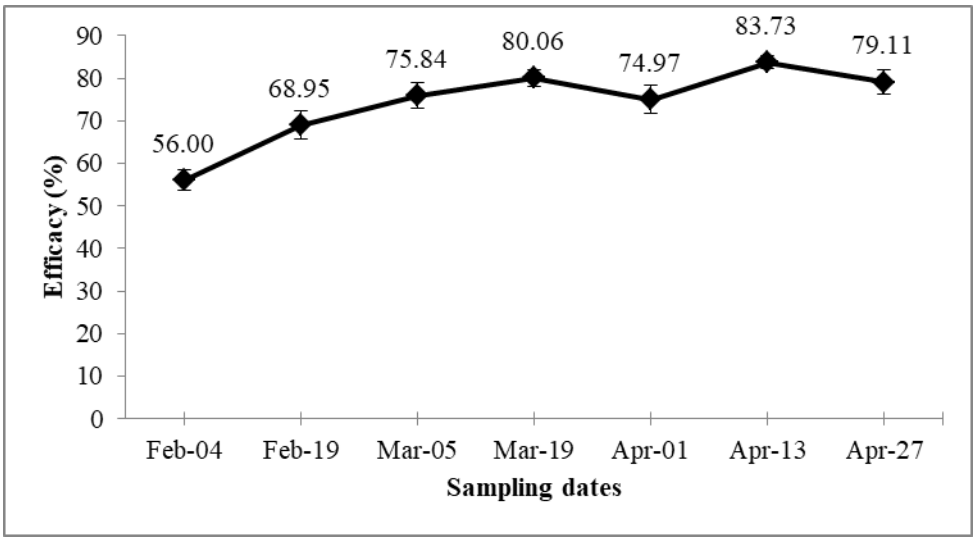

Figure 2. The efficacy of the water-washing + mineral oil treatment in controlling the adults of *P. pentagona* on the different sampling dates before applying the insecticides.

Spring

Based on the results of the t-test on May 11, 2021 (Table 5), there is a significant difference between the treatments in terms of efficiency in controlling WPS nymphs ($p<0.01$), but the difference between their effectiveness in controlling the adult was not significant ($p>0.05$). According to the mean comparison between the treatments, the water-washing + mineral oil treatment was more effective compared to the insecticide treatment in controlling the WPS nymphs, but despite a non-significant difference between the efficacy of these two compounds on control of WPS adult, the efficiency of water-washing + mineral oil was higher than that of the insecticide (Table 5).

The results of the t-test on May 25 and June 10, 2021 indicated that there was a statistically significant difference between the treatments in terms of efficacy in controlling WPS nymphs at the 1% probability level ($p<0.01$), while their efficiency in controlling the adult of *P. pentagona* showed a significant difference at the 5% probability level ($p<0.05$). The mean comparison of the efficiency of the two treatments on these dates showed that the water-washing + mineral oil treatment was significantly more effective compared to the insecticide treatment in controlling the nymphs and the adult of this pest (Table 5). The mean comparison of the treatments during the spring season showed that the water-washing + mineral oil

treatment was significantly more effective compared to the insecticide treatment in controlling the different stages of growth and emergence of *P. pentagona* (Table 5).

Table 5. Mean comparison of the efficacy of the treatments in controlling nymphs and adults of *P. pentagona* on the different sampling dates in the spring of 2021.

Developmental stage	Sampling date	Mean (%)±SE‡		t-value
		INCS	WMO	
Nymphs	May 11	67.72±2.16b	77.49±2.34a	3.84**
	May 25	64.05±2.58b	80.27±2.50a	4.51**
	June 10	59.33±2.67b	76.33±2.60a	4.56**
	Spring	63.70±2.31b	80.25±3.17a	4.46**
Adults	May 11	66.33±3.33a	75.33±2.44a	1.53ns
	May 25	51.00±3.40b	73.00±3.39a	3.04*
	June 10	50.00±2.26b	68.10±3.71a	2.94*
	Spring	55.78±2.64b	75.71±3.09a	3.32*

‡Different letters in each row indicate a significant difference between the treatments; ns indicates non-significance; ** and * indicate the significance at the 1% and 5% probability levels ($p<0.01$ and $p<0.05$), respectively; INCS: insecticide treatment; WMO: water-washing and mineral oil treatment.

Summer

As can be seen in Table 6, there was a significant difference between the treatments in terms of efficiency in controlling nymphs and adults of *P. pentagona* at the 1% probability level on June 25, 2021 ($p<0.01$). The mean comparison of the efficiency of two treatments on this date showed that the water-washing + mineral oil treatment was significantly more effective compared to the insecticide treatment in controlling nymphs and adults, respectively (Table 6). Based on the results of the t-test on July 11 (Table 6), no significant difference was observed between the treatments in the control of WPS nymphs ($p>0.05$), while the treatments showed a significant difference in terms of their efficiency in controlling the WPS adult. According to the mean comparison results, the water-washing + mineral oil treatment was more effective compared to the insecticide treatment in controlling the nymphs and the adults. A non-significant difference between the two treatments in controlling nymphs may be attributed to the application of insecticides for the second time on July 6, resulting in a higher efficiency than on the previous dates and reducing the difference with the water-washing + mineral oil treatment (Table 6).

The results of the t-test on July 26, August 10 and 25, 2021 showed that there was a significant difference between the treatments in terms of efficacy in controlling nymphs and adults of *P. pentagona* ($p<0.05$). The mean comparison of the efficiency of the two treatments on these dates showed that the water-washing + mineral oil treatment was always significantly more effective compared to the insecticide treatment in controlling nymphs and adults (Table 6).

Table 6. Mean comparison of the efficacy of the treatments in controlling nymphs and adults of *P. pentagona* on the different sampling dates in the summer of 2021.

Developmental stage	Sampling date	Mean (%)±SE‡		t-value
		INCS	WMO	
Nymph	June 25	52.22±1.26b	81.83±2.72a	9.72**
	July 11	70.50±1.67a	74.93±2.82a	1.35ns
	July 26	67.79±2.27b	76.46±2.22a	5.35**
	August 10	49.14±3.15b	77.90±2.71a	6.92**
	August 25	64.01±2.15b	77.13±3.80a	3.31*
	September 10	66.40±3.31a	73.76±3.27a	1.84ns
	Summer	61.68±3.42b	77.00±3.30a	6.12**
Adults	June 25	44.00±2.15b	69.00±2.50a	3.86**
	July 11	53.33±2.24b	65.00±2.08a	3.57**
	July 26	52.00±2.05b	72.67±3.88a	3.33*
	August 10	40.67±2.67b	74.00±3.52a	6.35**
	August 25	50.00±2.27b	66.67±2.56a	2.39*
	September 10	58.69±2.81a	67.38±3.02a	2.11ns
	Summer	49.78±2.41b	69.12±2.55a	4.44**

‡Different letters in each row indicate a significant difference between the treatments; ns indicates non-significance; ** and * indicate the significance at the 1% and 5% probability levels ($p<0.01$ and $p<0.05$), respectively; INCS: insecticide treatment; WMO: water-washing and mineral oil treatment.

Based on the results of the t-test on September 10 (Table 6), there was no significant difference between the treatments in terms of efficiency in controlling nymphs and adults of *P. pentagona* ($p<0.05$). Despite a non-significant difference between the treatments, the mean comparison of the efficiency of the two treatments showed that the water-washing + mineral oil treatment was more effective than the insecticide treatment in controlling the nymphs and the adults although this difference was not statistically significant (Table 6). This non-significant difference observed between the efficiency of the treatments can be due to the application of insecticides for the third time on August 21, which reduced the difference between the efficiency of these two treatments. Based on the mean comparison of the treatments in the summer season, the efficacy of water-washing + mineral oil in controlling the nymphal and adult stages of *P. pentagona* was significantly higher than that of the treatment with insecticides (Table 6).

Autumn

The results of the t-test presented in Table 6 show that on September 25 and October 13, there was a significant difference between the treatments in terms of efficiency in controlling the WPS nymphs and the adult at the 1% and 5% probability levels, respectively ($p<0.01$ and $p<0.05$).

The mean comparison of the efficiency of the two treatments on these dates also showed that the water-washing + mineral oil treatment was significantly more effective in controlling nymphs and adults compared to the insecticide treatment

(Table 7). The results of the t-test on November 1 and 15, 2021 also showed that there was a significant difference between the treatments in terms of efficiency in controlling nymphs and adults of *P. pentagona* at the 1% probability level ($p<0.01$). The mean comparison of the efficiency of two treatments on this date also showed that the efficiency of the water-washing + mineral oil treatment was significantly higher than that of the insecticide treatment in controlling nymphs and adults (Table 7). The mean comparison of the treatments in the summer season revealed that the efficacy of the water-washing + mineral oil treatment was significantly higher than that of the insecticide treatment in controlling the nymphal and adult stages of *P. pentagona* (Table 7).

Table 7. Mean comparison of the efficacy of the treatments in controlling nymphs and adults of *P. pentagona* on the different sampling dates in the autumn of 2021.

Developmental stage	Sampling date	Mean (%)±SE‡		t-value
		INCS	WMO	
Nymphs	September 25	51.43±2.47b	76.29±3.11a	5.33**
	October 13	40.00±2.12b	65.00±2.08a	4.33**
	November 1	36.67±2.33b	80.00±3.16a	4.91**
	November 15	20.00±1.72b	60.00±2.71a	6.79**
	Autumn	37.03±2.26b	70.32±3.13a	4.61**
Adults	September 25	46.33±2.54b	63.67±3.12a	3.63*
	October 13	36.67±2.05b	63.33±2.65a	3.34*
	November 1	44.00±2.45b	79.67±2.33a	12.79**
	November 15	36.33±2.16b	77.67±3.74a	5.57**
	Autumn	40.83±2.33b	71.09±2.19a	5.22**

‡Different letters in each row indicate a significant difference between the treatments; ** and * indicate the significance at the 1% and 5% probability levels ($p<0.01$ and $p<0.05$), respectively; INCS: insecticide treatment; WMO: water-washing and mineral oil treatment.

The trend of changes in the efficacy of water-washing + mineral oil and insecticide in the control of different developmental stages of WPS showed that the efficiency of water-washing + mineral oil in controlling nymphs decreased with a very slight slope, while the insecticide efficiency continued to decrease despite three foliar sprayings at different intervals. Comparing the efficiency of these two treatments revealed that the efficiency of water-washing + mineral oil was higher than that of insecticides on all the dates (Figure 3). The trend of changes in the effectiveness of the two compounds in relation to the control of the WPS adult was somewhat similar to that of the nymphs, although the efficacy of the water-washing + mineral oil treatment increased relatively on November 1, 2021. Comparing the efficiency of two treatments indicated that the water-washing + mineral oil treatment was more efficient than insecticides (Figure 4).

Scale insects are the most important agricultural pests on perennial plants and can cause serious damage to fruit trees. The wax coating in most species of scale

insects protects them effectively from contact insecticides, so these compounds are only effective against newly hatched nymphs (Prakash and Patil, 2018). Currently, due to the special climatic conditions of the north of Iran that are favourable for the development of scale insects, chemical pesticides are used to control WPS as well as other scale insects (Sharifi et al., 2020). In recent decades, the widespread use of various chemical insecticides, which have a broad spectrum and are very stable, has plunged humanity into a crisis. One of the solutions to this problem is the use of bio-based and low-risk insecticides (Danae Toos et al., 2013). However, scale insects are often controlled using mineral oils and insecticidal soaps that dissolve the waxy coating, suffocate and finally kill them (Dreistadt et al., 2007; Soliman et al., 2007). In many cases, the results have shown that mineral oils are able to control pests at a level equivalent to that of chemical insecticides. For example, spraying boxwoods with the mineral oil controlled the Euonymus scale, *Unaspis euonymi* (Comstock) (Hemiptera: Diaspididae) as well or even better than synthetic pesticides such as pyrethroids and acephate and chlorpyrifos (both of organophosphate insecticides) (Gholamzadeh-Chitgar et al., 2018; Raupp et al., 2001).

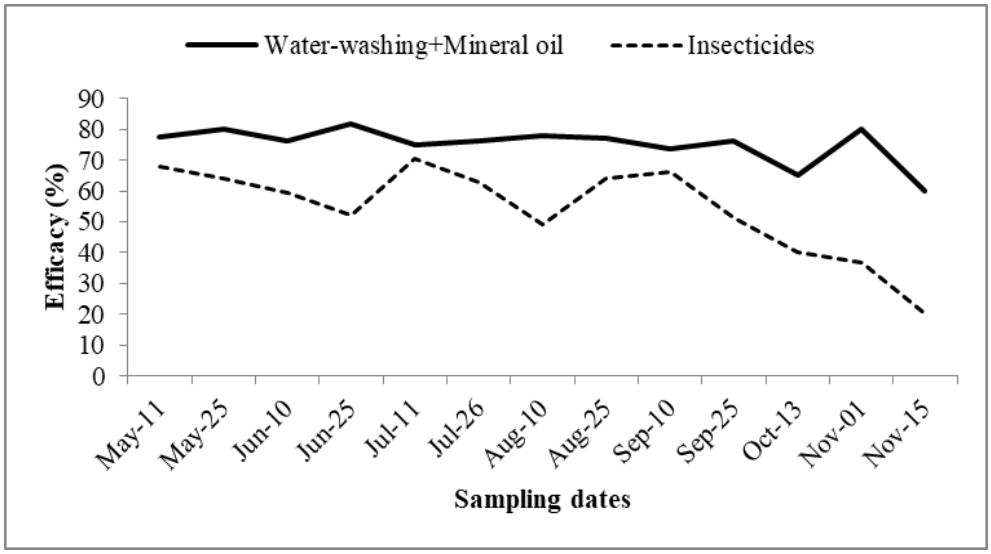

Figure 3. The trend of changes in the efficacy of water-washing + mineral oil and insecticides in the control of WPS nymphs during the sampling dates.

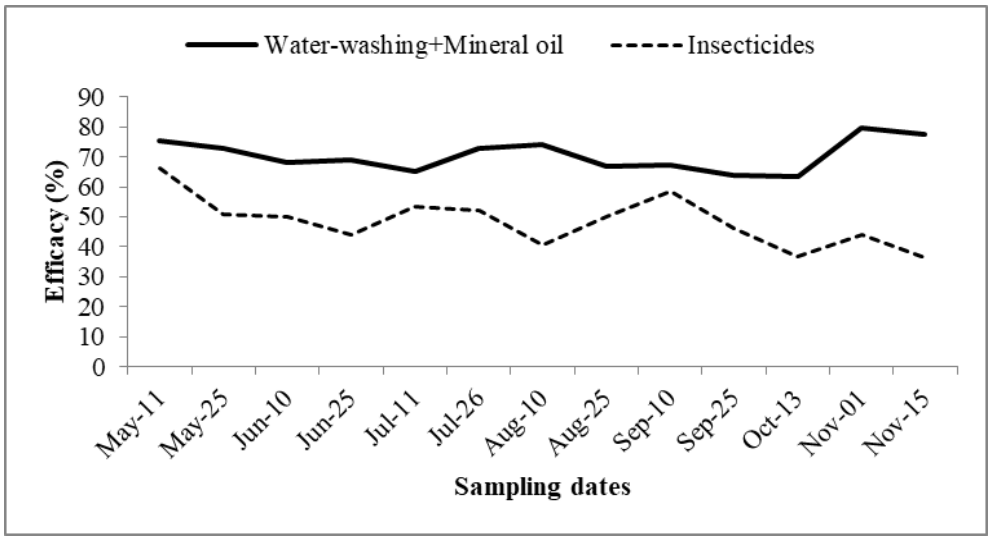

Figure 4. The trend of changes in the efficacy of water-washing + mineral oil and insecticides in the control of WPS adults during the sampling dates.

The results of the present study show that spraying the trees once with mineral oil in winter provided better control of the population of nymphs and adults of *P. pentagona* than spraying three times with the insecticides ethion and chlorpyrifos. Considering the significant activity of this pest in peach orchards in spring and summer, we focus on the results obtained in these two seasons. The results of the current research in spring show that the use of water-washing + mineral oil in the winter control against the WPS had a significant effect on reducing the population of nymphs and adults of this pest in peach orchards, so that this treatment caused a decrease of more than 80% (average of 80.25% and range of 76.33–84.76%) in the population of nymphs and more than 75% (average of 75.71% and range of 68.10–83.73%) in the adult population. The results after the application of insecticides on May 11 also showed that foliar spraying by using the insecticides resulted in a reduction of more than 65% in the population of nymphs and adults compared to water-washing + mineral oil (reduction of more than 75%). On May 25, the reduction rate of the population of nymphs and adults caused by the insecticides was 64.05% and 51.00%, respectively, which was significantly different compared to water-washing + mineral oil (the decreases of 80.27% and 73%, respectively). The results obtained on June 10 showed that the reduction of the pest population due to the application of the insecticides (59.33% and 50.00% for nymphs and adults, respectively) was significantly lower than that caused by applying water-washing + mineral oil (76.33% and 68.10% for nymphs and adults, respectively).

Based on the results obtained in summer, the range of efficiency of water-washing + mineral oil in reducing the population of nymphs and adults was 73.76–81.83% and 65–74%, respectively, and the average was 77.01% and 69.12%, respectively, while the range of effectiveness of insecticides used on the above developmental stages was 49.14–70.50% and 40.67–58.69%, respectively, and the average was 60.84% and 49.78%, respectively. According to the six dates of sampling in summer, only on two dates, i.e., July 11 and September 10, 2021, no significant difference was observed between the efficiency of water-washing + mineral oil and insecticides in controlling nymphs and adults of *P. pentagona*, but on the other four dates, there was a significant difference between the efficiency of these treatments. It is worth noting that on all the sampling dates in this season, the efficiency of water-washing + mineral oil in controlling nymphs and adults was higher than that of insecticides. In the research conducted by Mafi Pashakolaei et al. (2015), it was revealed that the treatments of brushing the tree trunks and spraying with mineral oil were effective at a rate of 2.5% (73.61%), spraying twice with mineral oil at 2.5% intervals of one month (60.75%) and spraying once with mineral oil at a rate of 2.5% (57.63%) caused the highest mortality in overwintering adult females of *P. pentagona* within 60 days after treatment. These researchers have stated that for a successful integrated control against the mulberry scale, it is recommended to prune the branches infested by the pest at the appropriate time, brush the tree trunks along with spraying mineral oil at a rate of 2.5% in winter. In the present study, applying water-washing + mineral oil at a rate of 5% in winter had a significant efficacy in controlling the WPS population in spring, summer and even in autumn, which is consistent with the findings of the above study.

Bazrafshan et al. (2010) studied the effect of five insecticides, diazinon, azinphosmethyl, chlorpyrifos, methoxyfenozide, spinosad, and emulsifiable mineral oil on the female WPS adults by the dipping method in laboratory conditions in Iran and showed that only the mineral oil has moderate toxicity to *P. pentagona*, and that it can be used as an alternative to insecticides or along with them due to its less harmful effects on humans and the environment. The results reported by Gholamian et al. (2013) showed that spraying with chlorpyrifos + mineral oil at a rate of 1% and mineral oil spraying at a rate of 2% caused the highest mortality in the overwintering generation of *P. pentagona* on kiwifruits and oil spraying at a rate of 0.5% had the minimum control effect on this pest. The results of the present study also showed the significant effect of mineral oil spraying at a rate of 5% on the control of the WPS, so that on the sampling dates, applying mineral oil along with water-washing caused the greatest decrease in the population of nymphs and adults of *P. pentagona*.

Research conducted in Carolina's orchards showed that winter oil spraying against WPS on peach trees resulted in a 93% reduction in the pest population

(Meyer and Nalepa, 1991). Smith (1969) also found that spraying overwintering WPS females twice with mineral oil at a rate of 3% at two-week intervals can destroy 100% of the pest population. The research conducted in the Qalyubia governorate of Egypt on the nymphs and adults of *P. pentagona* in field conditions showed that the mineral oils used (misrona oil 85% mayonnaise and alboleum oil 80% mayonnaise) were more effective against *P. pentagona* populations than neem extracts and fenitrothion 50%EC after five weeks of application. The mineral oils reduced the pest population by 89% (misrona oil) and 88.3% (alboleum oil), while fenitrothion and neem extracts were ranked next with 79.3% and 66.4% efficacy, respectively (Kwaiz et al., 2009).

Zhuang et al. (2015) stated that the mineral oil "EnSpray 99" showed good efficacy against the first nymphal instars of the WPS, *P. pentagona*, and its residues prevented the settlement of mobile nymphs or crawlers for approximately 12 days after oil application. The mineral oil spraying was safe and had no phytotoxicity when applied to kiwifruits to control this scale insect for the first generation of nymphs (4–18 days after fruit set). Also, the application of 1% mineral oil to the first nymphal instars of the first generation and the second generation reduced the number of fruits infested by *P. pentagona*.

The results of the studies conducted on the efficiency of mineral oils in controlling other scale insects were also positive. In the study conducted on *U. euonymi*, it was reported that spraying boxwood with mineral oil to control the first nymphal instars of *U. euonymi* by using emulsifiable oil and mayonnaise oil at rates of 0.5% and 0.7% showed efficiencies of 22.5% and 42.6%, and 30.2% and 40.6%, respectively (Gholamzadeh-Chitgar et al., 2018). The laboratory results of the study by Ghaffari Lashkenari and Damavandian (2013) regarding the response of the female adult of *Chryaomphalus dictyospermi* Morgan (Hemiptera: Diaspididae) to concentrations of 0.5%, 0.75%, 1%, 1.2%, and 1.5% showed that this scale insect can be controlled by mineral oil, and the most appropriate rate of mineral oil to control *C. dictyospermi* female adult is between 1.138% and 1.663%. Xiao et al. (2016) showed that spraying mineral oil (SuffOil-X®) three times on cycads and camellia caused a 90.36% and 100% decrease in the populations of *Aulacaspis yasumatsui* Takagi and Fioriniatheae Green (Hemiptera: Diaspididae) over 3–4 and 5 months, respectively. In Chile, Sazo et al. (2008) found that spraying mineral oil once at a rate of 1% reduced up to 73.94% and 88.10% of the population of the first generation of nymphs of the San Jose scale, *Diaspidiotus perniciosus* Comstock (Hemiptera: Diaspididae) on almond and apple trees, respectively, while two sprays with mineral oil caused a decrease of 91.49% and 80.95% in the population of nymphs on almond and apple trees, respectively. Quesada and Sadof (2017) reported that, in the field conditions, horticultural oil had 90% and 40% efficacy when applied to the first nymphal instars and adults of pine needle scale (*C. pinifoliae*) and oleander scale (*A. nerii*), respectively. These

results show that mineral oil has a significant efficiency in controlling the different developmental stages of the scale insects, and the findings of the present study are in agreement with these results.

Conclusion

Considering the severe and widespread damage caused by *P. pentagona* in peach orchards of northern Iran, many efforts have been made to control this pest using conventional chemical pesticides, while suppressing the population of the 2nd and 3rd instar nymphs of WPS and female adults is difficult due to developing a waxy armour on their body. The results of the present study show that winter control by a single water-washing and mineral oil spraying at a rate of 5% reduced the WPS population on peach trees in the spring and then reduced the damage caused by this pest in the following seasons, i.e., summer and autumn, so that no chemical insecticides need to be used in these seasons. Since mineral oil is less dangerous for humans and safe for natural enemies of the pests, pollutes the environment much less compared to synthetic pesticides, and no pest resistance to this compound has been observed, it can be used to control this pest, minimising the use of chemical insecticides.

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KOMBINACIJA MINERALNOG ULJA I ISPIRANJA VODOM KAO EFIKASAN NAČIN SUZBIJANJA *PSEUDAULACASPIS PENTAGONA* (TARGIONI-TOZZETTI) (HEMIPTERA: DIASPIDIDAE)

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R e z i m e

Ova studija imala je za cilj da proceni efikasnost zimskog suzbijanja ispiranjem vodom u kombinaciji sa mineralnim uljem u poređenju sa ponovljenom primenom insekticida u suzbijanju *Pseudaulacaspis pentagona* (Targioni-Tozzetti) u zasadima breskve u provinciji Mazandaran. Eksperiment je sproveden po potpuno slučajnom dizajnu sa tri tretmana i pet ponavljanja u zasadu breskve koji se nalazi u selu Makran, grad Miandorud: (1) hlorpirifos (Chlorpyrifos-methyl Kavosh®, 40% EC) i etion (Ethion Kavosh®, 47% EC) u koncentraciji od 2 L/1000 L vode, (2) ispiranje vodom + mineralno ulje (Volk Kavosh®, 90% EC) u odnosu 5% (V/V), i (3) kontrola (bez prskanja). Rezultati su pokazali da postoji značajna razlika u efikasnosti između tretmana ispiranjem vodom u kombinaciji sa mineralnim uljem u poređenju sa hemijskim insekticidima u suzbijanju *P. pentagona*. Ispiranje vodom i prskanje mineralnim uljem pokazalo je efikasnost od 80,25% u suzbijanju nimfi odnosno 75,71% u suzbijanju odraslih jedinki *P. pentagona* tokom prolećne sezone. Efikasnost pomenutog tretmana u smanjenju populacije nimfi i odraslih ženskih jedinki tokom letnje sezone iznosila je 77,00%, odnosno 69,12%. Zabeležena je efikasnost od 70,32% u suzbijanju populacija nimfi i 71,09% u suzbijanju odraslih jedinki ovog štetnog insekta prilikom ispiranja vodom u kombinaciji sa mineralnim uljem tokom jesenje sezone. S druge strane, efikasnost insekticida na nimfe i odrasle jedinke iznosila je 63,70% i 55,78% u proleće, 61,68% i 49,78% u leto, te 37,03% i 40,83% u jesen. Kao rezultat toga, nalazi su pokazali da zimsko suzbijanje sa jednom primenom tretmana ispiranjem vodom u kombinaciji sa mineralnim uljem ima višu i značajnu efikasnost nego tri primene hemijskih insekticida.

Ključne reči: bela breskvina štitasta vaš, mineralno ulje, hemijski insekticid, efikasnost.

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EFFECTS OF ADDED GROUND CORN GRAIN ON THE NUTRITIONAL VALUE AND PROTEIN DEGRADABILITY OF AN ENSILED MIXTURE OF COMMON VETCH AND OATS

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Abstract: The aim of the study was to determine the effects of the addition of 5% or 10% of ground corn grain (CG) on the ensiling properties, nutritional value, and protein degradability of a forage mixture of common vetch and oats (VO). The addition of CG significantly increased the dry matter content of the silages ($p<0.01$), while the crude protein (CP) content decreased by 4.7% and 9.3% in the VO+5% CG and VO+10% CG treatments, respectively. The addition of CG to ensiled forage resulted in higher values of lactic acid concentration (4.5% and 6.8%), especially when the proportion of milled grain was higher ($p<0.05$), and the pH of the silages was significantly lowered ($p<0.01$). The use of ground CG in ensiled legume-cereal forage provided higher net energy (NE) concentration values, which were significant ($p<0.05$) for NE for meat production. The ammonia-N concentration (protein fraction A1) was significantly lower ($p<0.05$) in the VO+5% CG and VO+10% CG treatments (15.8% and 21%, respectively), and also the soluble protein (CP fraction A2) by 8.2% and 12.1% ($p<0.01$). Protein degradability was affected by the supplementation of ensiled forage with CG ($p<0.05$ for Kp=5%/h and $p<0.01$ for Kp=8%/h), with the lowest degradability observed in VO+10% CG silages. It is suggested that the supplementation of vetch-oat forage with ground corn grain, especially at a higher proportion (10% *vs*. 5% of wet weight), has a favorable effect on fermentation parameters, the proportion of rumen undegradable protein (RUP) in CP, and the nutritional value of the obtained silage.

Key words: corn, legume-cereal silage, protein fractions, protein degradability, fermentation parameters.

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Introduction

Common vetch (*Vicia sativa* L.) is an annual legume commonly used in forage mixtures with cereal small grains, such as oats (*Avena sativa* L.) under rainfed conditions. The vetch-oat mixture is characterized by the highest forage dry matter (DM) yield and a higher CP content compared to the vetch-barley and vetch-triticale mixtures (Nájera et al., 2016). The ensiled mixture of common vetch and oats has the highest CP content, compared to mixtures of common vetch and barley, wheat, triticale or rye, also with the lower values for neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Balabanli et al., 2010). This is another reason for the high rate of silage obtained with common vetch and oat intercrop.

Good silage fermentation depends on the rapid proliferation of lactic acid bacteria, which mainly ferment water-soluble carbohydrates. Legumes and legume-cereal forages are difficult to preserve because of their low water-soluble carbohydrate content (Kristensen, 1992). The buffering effect of legumes may be an additional constraint to rapid acidification (Cussen et al., 1995) in legume crops and legume-cereal bi-crops. Obtaining quality silage and avoiding losses during ensiling can be achieved by treating with silage additives such as carbohydrate sources that stimulate fermentation (McDonald et al., 1991). In general, the addition of fermentable carbohydrates results in the accelerated growth of lactic acid bacteria, the more rapid development of acidic conditions and an early elimination of coliform bacteria (Kung et al., 2003). Corn grain contains adequate water-soluble carbohydrates for fermentation to lactic acid, has a low buffering capacity, and a high dry matter and energy content (Topps and Oliver, 1993). The inclusion of legumes in grass forage raises the pH and ammonia nitrogen of silages, while the increase in pH and NH_3-N content is lower in the silages treated with the additive – ground corn (Sibanda et al., 1997). According to the report by Weiss and Underwood (2009), the addition of grain to the hay-crop forage increases the energy and dry matter (DM) content of the silage.

Forages, especially legumes, are an important source of protein for ruminants, but their protein is often poorly utilized because it is extensively degraded during ruminal fermentation, and this may be the most limiting factor for high quality forage legumes (Tremblay et al., 2003). The changes in protein quality during ensiling of legumes and grass forages can affect intake, protein utilization and productivity of dairy and beef cattle (Guo et al., 2008). During ensiling, plant endopeptidases catalyze proteolytic reactions converting most of the soluble forage protein to non-protein nitrogenous (NPN) compounds (Nsereko and Rooke, 2000). Supplementing ensiled forage with a source of readily fermentable carbohydrates can result in a greater pH reduction than in untreated silages and also in a lower NH_3–N concentration (Jones, 1988; McDonald et al., 1991; Adesogan et al., 2004).

Although there is much information on the effects of numerous additives on mono-crop silages, little is known about the suitability of ground corn grain as an additive for legume-cereal bi-crop silages. The aim of this study was to measure the effects of adding ground corn grain on improving the fermentation process in silages and on the nutritional value and CP degradability of an ensiled forage mixture of common vetch and oats.

Material and Methods

Common vetch (*Vicia sativa* L. cv. Novi Beograd) and oats (*Avena sativa* L. cv. Rajac) were intercropped at respective seed rates of 70 and 30 kg/ha in late March 2022 in a field located in the western region of Serbia, in the vicinity of Loznica (44°53′ N, 19°49′ E) on loamy soil. The field was fertilized with 30 t/ha of cow manure, which was incorporated before plowing in the fall, and with 100 kg/ha of compound fertilizer (N, 15; P, 15; K, 15) before sowing. The area has a continental, semi-arid to semi-humid climate. The temperature and precipitation for April, May and June 2022 were 11.3, 18.7 and 23.2°C and 57.8, 31.2 and 171.5 mm, respectively.

The forage of vetch and oats was harvested when the vetch formed first pods (end of the third week of June), with a rotary mower about 5 cm above ground level. The cut herbage was left to wilt overnight *in situ*, and after the wilting period the plant material was chopped to about 1.5 cm particle length with a forage chopper. The wilted and chopped forage was ensiled untreated (VO) or after treatment with 50 or 100 g/kg (wet weight) of ground corn grain (VO + 5% CG or VO + 10% CG). The dried corn grains were ground in a hammer mill (2-mm sieve size) before being mixed with the chopped, wilted legume-cereal plant material. The forage was preserved using a small-scale silage fermentation system. All feeds were ensiled without the use of inoculants in anaerobic glass jars with a capacity of 1.5 l, each jar containing 650 to 700 g of forage mass. The silages were stored at room temperature (22–29°C) for 3 months. Five replicates each of untreated and treated silage were prepared to obtain a total of 15 laboratory silos. Representative samples of the wilted vetch-oat herbage were frozen (-20°C) for subsequent laboratory analysis.

The chemical analysis was conducted in the Laboratory of Animal Nutrition at the Faculty of Agriculture of the University of Belgrade. The samples of wilted plant material and silages were dried for 48 h at 50°C in a forced-air oven for chemical composition analysis. All samples were ground through a 1-mm sieve on a small sample cutting mill (Kinematica PX-MFC 90D). The ground samples were analyzed according to the official methods (AOAC, 2002). The analytical DM content of the samples was determined by drying at 105°C for 16 h (method 967.03), the ash content by combustion at 600°C for 2 h (method 942.05), the CP

content by the Kjeldahl method (method 2001.11), the ether extract content by extraction with diethyl ether (method 920.39), the crude fiber content by the Henneberg and Stohmann method (method 978.10), the NDF content was determined using heat-stable α-amylase (method 2002.04) and the ADF content according to the method 973.18. The water extracts of the ensiled forage were analyzed for pH (Owens et al., 1999) (Table 1).

Table 1. The chemical composition (g/kg DM) of the vetch-oat forage and corn grain used for ensiling.

Ingredient	Vetch-oat forage	Ground corn grain
Dry matter	287.6	874.6
Crude protein	134.3	86.9
Ether extract	35.1	35.8
Neutral detergent fiber	617.8	109.6
Acid detergent fiber	465.2	39.1
Crude fiber	345.1	33.2
Nitrogen-free extract	370.8	833.4
Ash	114.7	10.7

The CP was divided into five fractions (A1, A2, B1, B2 and C) based on ruminal degradation rates according to the Cornell Net Carbohydrate and Protein System – CNCPS v6.5 (Higgs et al., 2015). Within the determined fractions, A1 represented ammonia (as CP equivalents), A2 – soluble true protein (soluble protein minus A1), B1 was buffer insoluble protein minus neutral detergent insoluble protein (NDIP), B2 – NDIP minus acid detergent insoluble protein (ADIP) and ADIP – the C fraction. Rumen degradable protein (RDP) was estimated using digestion rate constants according to CNCPS v6.5 (Van Amburgh et al., 2015) with an assumed passage rate (Kp) of 5%/h and 8%/h (Sniffen et al., 1992).

The CVB (2018) model was used to estimate the concentration of net energy for lactation (NElac) and meat production (NEmeat) of silages in ruminant nutrition.

Analysis of variance using JASP v.0.15 (JASP Team, 2021) was performed to evaluate the effects of the level of ground corn grain addition on the chemical composition and nutritional values, as well as on the protein fractions and degradability of the ensiled mixture of common vetch and oats. The LSD test was used to estimate the significance of the differences between the means of the treatments. The effect of treatment was considered significant if $p<0.05$.

Results and Discussion

To investigate the effect of adding ground corn grain to ensiled vetch-oat forage on the chemical composition, fermentation parameters, protein degradability and nutritional value of the silages, the grain addition rates applied were within the range commonly used in previous studies with other cereals (Jones et al., 1990; Harrison et al., 1994).

The chemical analysis showed the good quality of the experimental silages (Table 2).

The addition of ground corn significantly increased the dry matter content ($p<0.01$). The obtained values for the higher DM content (9.1% and 21.9%) in ensiled vetch-oat forage treated with ground corn grain were expected due to the high DM content of CG. These results are consistent with earlier studies by Jones et al. (1990) in which ensiled ryegrass forage was supplemented with rolled barley. The increase in DM content may also contribute to less favorable conditions for undesirable fermentation and possibly promote the rapid proliferation of lactic acid bacteria (Jones, 1988). According to Pys et al. (2002), the addition of rolled grain to ensiled forage increases DM content and also acts as an absorbent additive.

The CP content decreased significantly ($p<0.05$) after the addition of 5% or 10% of ground corn grain (4.7% and 9.3%) to the ensiled vetch-oat forage, which can be attributed to the significantly lower protein content in the DM of the corn grain used compared to the vetch-oat forage.

Table 2. The chemical composition (g/kg DM) and the net energy content of the silages.

Ingredient	Silage						p-values
	VO	SEM	VO+5% CG	SEM	VO+10% CG	SEM	
Dry matter, %	299.4^{c}	1.9	326.5^{b}	0.6	365.1^{a}	0.3	<0.01
Crude protein	137.2^{a}	2.8	130.7^{b}	0.6	124.5^{c}	0.6	0.04
Ether extract	36.0	0.6	35.3	0.6	35.5	0.3	0.60
Neutral detergent fiber	636.0^{a}	3.9	595.6^{b}	2.8	576.7^{c}	2.1	<0.01
Acid detergent fiber	490.4^{a}	4.3	464.0^{b}	3.0	444.2^{c}	3.1	<0.01
Crude fiber	357.2^{a}	6.5	343.4	9.4	322.8^{b}	4.4	0.02
Nitrogen-free extract	354.3^{c}	1.5	371.2^{b}	2.0	395.8^{a}	1.8	0.02
Ash	115.3	0.6	114.4	0.3	114.0	0.3	0.13
Lactic acid	53.2^{b}	0.7	55.6	1.1	56.8^{a}	1.0	0.02
Acetic acid	26.3	1.1	28.2	1.3	27.8	1.0	0.46
Butyric acid	2.7	0.4	2.5	0.4	2.5	0.4	0.95
pH	4.58^{a}	0.02	4.39^{b}	0.02	4.28^{c}	0.03	<0.01
NElac, kJ/kg DM	5028.9	15.8	5043.4	16.2	5075.1	4.8	0.13
NEmeat, kJ/kg DM	4882.7^{b}	22.4	4906.3	23.7	4954.7^{a}	7.0	0.03

VO – common vetch-oat; VO+5% CG – common vetch-oat + 5% ground corn grain; VO+10% CG – common vetch-oat + 10% ground corn grain. $^{a, b, c}$ Values within the same row with different letter superscripts differ significantly ($p<0.05$).

The application of CG in vetch-oat forage at a dosage of 5% and 10% decreased ($p<0.01$) the concentration of neutral detergent fiber (NDF, 6.4% and 9.3%) and acid detergent fiber (ADF, 5.4% and 9.4%) in the silage, and in contrast, the content of nitrogen-free extract (NFE) was 4.8% and 11.7% higher ($p<0.05$). The obtained values could be fully explained by the lower fiber content of the added corn grain as a feed with a particularly high starch content. This is consistent with reports by Jones (1988) that the addition of ground oats or barley to ryegrass forage increases the silage DM and reduces the fiber content of the silage. Harrison et al. (1994) also found that the addition of barley increased the DM and starch content of ensiled alfalfa forage and decreased the fiber content (NDF and ADF).

The treatment of the ensiled forage with CG resulted in higher values for lactic acid concentration (4.5% and 6.8%), especially when the proportion of milled grain was higher ($p<0.05$). The concentrations of acetic and butyric acid did not differ significantly between the treatments. The effect of the addition of CG to the vetch-oat plant mass on the improvement of the fermentation quality of the obtained silages was demonstrated by the significantly lower pH values observed ($p<0.01$). The results obtained show that lactic acid and acetic acid were present in high concentrations, while butyric acid was present in very low concentrations. Since lactic acid is the major organic acid responsible for most of the pH reduction in silage, its presence is favored over other fermentation products in silage (Umana et al., 1991). The addition of ground CG at 5% and 10% of fresh weight resulted in a significantly greater pH reduction than with non-supplemented silage. The results of this study are consistent with the reports of Harrison et al. (1994) that the addition of rolled barley improved the fermentation of alfalfa by lowering the pH and reducing the acetate concentration. In general, a lower pH ensures better preservation and higher stability of the silage. This indicates that corn grain-treated vetch and oat forage has the potential to produce silages of acceptable quality. The effect of milled grain addition to ensiled forage probably cannot be attributed to the hydrolysis of the grain starch, and it is more likely that the 3–4% simple sugars present in the grain significantly affected fermentation or that the other carbohydrate fractions such as β-glucan were hydrolyzed to yield sugars for fermentation (Jones, 1988). The total content of readily fermentable simple sugars in dry corn kernels averages 4.15% (3.31% sucrose, 0.28% each of glucose, fructose, and raffinose) (Kereliuk et al., 1995).

The use of ground CG in ensiled legume-cereal forage provided higher values for net energy concentration (net energy for lactation – NElac and meat production – NEmeat), whereas NEmeat was significantly higher ($p<0.05$) in VO+10% CG silage. The increase in the net energy concentration of the supplemented silages is consistent with the lower fiber and the higher NFE content of these silages.

The crude protein fractions of the analyzed silages according to the Cornell Net Carbohydrate and Protein System are shown in Table 3.

Table 3. The CNCPS crude protein fractions (% CP) of the silages.

Fractions	Silage						p-values
	VO	SEM	VO + 5% CG	SEM	VO + 10% CG	SEM	
A1	14.53[a]	0.67	12.24[b]	0.65	11.48[b]	0.59	0.01
A2	49.86[a]	0.78	45.76[b]	0.62	43.85[b]	0.66	<0.01
B1	15.16[b]	1.66	23.15[a]	1.95	27.16[a]	1.90	<0.01
B2	12.28	0.12	12.13	0.50	11.03	0.54	0.12
C	8.17[a]	0.35	6.72[b]	0.26	6.48[b]	0.24	<0.01

VO – common vetch-oat; VO+5% CG – common vetch-oat + 5% ground corn grain; VO+10% CG – common vetch-oat + 10% ground corn grain. [a, b] Values within the same row with different letter superscripts differ significantly ($p<0.05$).

The NH_3-N concentration (protein fraction A1) was significantly lower ($p<0.05$, 15.8% and 21%) in silages where the ensiled forage was supplemented with 5% or 10% ground CG. Soluble protein (fraction A2) was also significantly lower ($p<0.01$) in silages treated with 5% or 10% CG (8.2% and 12.1%). The significantly higher values ($p<0.01$) for the moderately degradable protein fraction (B1) were found in ensiled vetch-oat forage with 5% or 10% CG added (52.7% and 79.2%). There were no significant differences in the content of the B2 fraction between the treatments. Protein fraction C, which is not available to the animals, was significantly reduced ($p<0.01$) by the addition of ground corn to the ensiled forage (17.8% and 20.7%).

The research results regarding the significant reduction in protein fractions A1 (NH_3-N) and A2 (soluble protein) when supplementing vetch-oat forage with CG are consistent with the findings of Harrison et al. (1994), where the addition of ground barley to the alfalfa forage prior to ensiling (in ranges of 50–150 g/kg wet weight) significantly affected fermentation and resulted in lower pH and lower levels of ammonia-nitrogen, acetate and propionate, while the amount of lactate was increased. According to Sibanda et al. (1997), silages treated with ground corn had a lower ammonia-N content than the control grass or grass-legume silages. Jones (1988) also found that the addition of ground oats or barley to ensiled ryegrass forage significantly improved fermentation and led to a significant reduction in the ammonia-N content and pH of the silages. Spörndly (1986) also reported that the addition of 5% oat flakes improved the fermentation quality of the silage, which was confirmed by the reduction in pH and ammonia-N content, this reduction being accompanied by a progressive increase in lactic acid content. The availability of readily fermentable carbohydrates may be a determining factor for the fermentation rate and the reduction of pH and proteolysis in silages (Adesogan et al., 2004). The addition of molasses to ensiled forage resulted in a greater pH reduction and a lower NH_3–N concentration than in silages without molasses (McDonald et al., 1991). This was probably due to the fact that a higher sugar concentration led to a rapid drop in pH, which inhibited the deamination and

decarboxylation of amino acids. The increased silage DM content could also reduce the soluble N content and improve the proportion of rumen undegradable protein (RUP) in the CP. Kung et al. (2018) report that ensiled forages with a lower DM content have higher concentrations of soluble N and NH_3-N than drier silages, as fermentation is more robust overall in the former.

Due to the reduced contents of fiber fractions (NDF and ADF) in ensiled vetch-oat with milled corn grain, the lower values of CP fractions connected with cell wall components (B2 and C) were observed. Accordingly, the supplemented silages showed increased values for the moderately degradable protein fraction (B1).

Protein degradability was affected by the treatment of the ensiled forage with CG ($p<0.05$ for Kp=5%/h and $p<0.01$ for Kp=8%/h), with the lowest degradability observed in ensiled forage with 10% ground CG (Table 4).

Table 4. The crude protein degradability (RDP, % of CP) of silages.

Silage	K_p			
	5%/h		8%/h	
	Mean	SEM	Mean	SEM
VO	76.84[a]	0.18	71.32[a]	0.23
VO+5% CG	76.52	0.10	70.38[b]	0.10
VO+10% CG	76.18[b]	0.12	69.79[c]	0.14
p-values	0.02		<0.01	

VO – common vetch-oat; VO+5% CG – common vetch-oat + 5% ground corn grain; VO+10% CG – common vetch-oat + 10% ground corn grain; Kp – ruminal passage rate. [a, b, c] Values within the same column with different letter superscripts differ significantly ($p<0.05$).

The protein degradation during ensiling results from the high activity of the cellular proteolytic enzymes of the plants and the process of bacterial deamination of free amino acids and amides (Vagnoni et al., 1997). The significantly lower CP degradability of silages with added milled corn grain could be due to the more effective restriction of the cellular proteolysis of the protein by a significant improvement in the lactic acid concentration and a stronger pH reduction (Charmley and Veira, 1990). Dried corn grain is characterized by a higher RUP content (45.4% CP) compared to other cereals (barley 36.8% and wheat 32.5% CP) (Chrenkova et al., 2018), which could also contribute to a higher proportion of RUP in supplemented silages. A higher RUP content in silages with corn grain ensures an improved biological value of the silage protein and a more efficient use of the consumed N (Dijkstra et al., 2013). It also increases the amounts of amino acids flowing from the rumen to the duodenum in ruminants.

Conclusion

The results of this study indicate that the addition of ground corn grain to common vetch-oat forage has the potential to provide well-preserved silage. When vetch-oat plant mass was ensiled with added corn grain, especially at higher levels (10% of fresh weight), the production of lactic acid dominated, resulting in a lower pH compared to the non-added forage. The net energy content of the silage was increased by adding milled grain before ensiling vetch-oat forage. The addition of ground corn grain to ensiled legume-cereal forage decreased the proportion of NH_3-N and soluble protein and improved the RUP to CP ratio of the silage. Considering the chemical composition and nutritional value, it is suggested that supplementation of vetch-oat forage with ground corn grain, especially at a higher proportion (10% *vs.* 5% of wet weight), has a favorable effect on fermentation parameters, the ratio of RUP to CP and the nutritional value of the silage obtained.

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EFEKTI DODAVANJA KUKURUZNE PREKRUPE NA HRANLJIVU VREDNOST I RAZGRADIVOST PROTEINA SILIRANE SMEŠE GRAHORICE I OVSA

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R e z i m e

Istraživanje je obavljeno u cilju utvrđivanja efekata dodavanja 5% ili 10% prekrupe zrna kukuruza (engl. *corn grain* – CG) na kvalitet, hranljivu vrednost, i razgradivost proteina silaže dobijene siliranjem smeše grahorice i ovsa (engl. *vetch-oat* – VO). Korišćenje prekrupe zrna kukuruza značajno je povećalo sadržaj suve materije u silaži ($p<0,01$), dok je smanjenje sadržaja sirovih proteina iznosilo 4,7% odnosno 9,3%, za tretmane VO+5% CG i VO+10% CG. Uključivanje prekrupe zrna kukuruza u siliranu biljnu masu smeše grahorice i ovsa rezultiralo je povećanjem koncentracije mlečne kiseline (za 4,5% i 6,8%), što je bilo i statistički značajno ($p<0,05$) pri većem učešću samlevenog zrna, kao i značajnim smanjenjem pH vrednosti silaža ($p<0,01$). Dodavanje samlevenog zrna kukuruza pri siliranju smeše leguminoze i žitarice, obezbedilo je veću koncentraciju neto energije u dobijenim silažama, pri čemu je ovo povećanje bilo značajno ($p<0,05$) za sadržaj neto energije za proizvodnju mesa. Koncentracija amonijačnog-N (A1 frakcija sirovih proteina) bila je značajno smanjena ($p<0,05$) kod tretmana VO+5% CG i VO+10% CG (15,8% odnosno 21%), a takođe je značajno smanjen (8,2% i 12,1%, $p<0.01$) i sadržaj rastvorljivog proteina (A2 frakcija sirovih proteina). Dodavanje kukuruzne prekrupe značajno je uticalo na razgradivost sirovih proteina u silažama ($p<0,05$ za Kp=5%/h, i $p<0,01$ za Kp=8%/h), pri čemu je najmanja razgradivost proteina utvrđena kod tretmana VO+10% CG. Može se zaključiti da dodavanje prekrupe zrna kukuruza pri siliranju biljne mase smeše grahorice i ovsa, naročito u većoj količini (10% naspram 5% silirane mase), ima pozitivan efekat na parametre fermentacije, učešće frakcije nerazgradivog proteina (engl. *rumen undegradable protein* – RUP) u sirovom proteinu, kao i na hranljivu vrednost dobijenih silaža.

Ključne reči: kukuruz, silaža smeše leguminoza i žitarica, frakcije proteina, razgradivost proteina, fermentacioni parametri.

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E-AGRAR PLATFORM: ASSESSMENT OF BENEFITS AND USAGE CHALLENGES FROM THE PERSPECTIVE OF BEEKEEPERS IN SERBIA

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Abstract: The aim of the research is to understand beekeepers' attitudes towards the usefulness and usage challenges of the new government electronic service in agriculture – eAgrar. This service was launched in 2023 by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia and the participation in this platform is mandatory for agricultural producers who want to participate in the national subsidy system. The data for this paper were collected during 2023 by using a structured online questionnaire. The number of respondents was representative (459), while purposeful random sampling ensured anonymity and credibility. Data processing included the application of descriptive statistics, the chi-square test of independence, and the Word Cloud tool. The majority of respondents (81.0%) think that they will benefit from the introduction of this platform, as it will make all administrative procedures faster, easier, and cheaper. For 64.7% of beekeepers, the platform is easy to use. About one-third of them find it somewhat challenging to use and rely significantly on the support of agricultural extension officers. Furthermore, there is a statistically significant positive correlation only between the respondents' level of education and the level of difficulties in using the eAgrar platform. The results of this study are expected to provide agricultural policymakers in Serbia with insights into different aspects of the practical application of the eAgrar platform and also contribute to enriching the scientific knowledge about the application of new technologies in agriculture.

Key words: e-government, agriculture, survey, Republic of Serbia.

Introduction

Digitalization in agriculture is a consequence of technological progress and the widespread process of globalizing economies and societies. According to the EC (2017), it is an essential tool for redesigning food production in the near future which helps to maintain, renew and strenghten rural communities, i.e. to transform villages into the so-called smart villages. Generally speaking, greater digitalization of agriculture increases its competitiveness and leads to a higher level of

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investment in this sector (Safiullin et al., 2021; Mushi et al., 2024a). Digitalization is mainly associated with the so-called Agriculture 4.0 technologies (robots, drones, IoT and alike), whose aim is to produce more high-quality food while investing fewer resources. One aspect of digitalization in the sector of agriculture refers to using various electronic platforms developed by governments (e-government, eAgrar, etc.) for registering agricultural producers, providing subsidies, trading agricultural products, monitoring production, etc.

The analysis of ICT application in agriculture, in over one hundred countries worldwide, has shown that the application of e-agriculture is still modest and in its early stages of development when compared to other sectors of economy (Alassaf and Szalay, 2020). Nevertheless, the usefulness of e-government in agriculture has already been confirmed in many rural areas in different countries. For instance, in Malaysia, rural inhabitants believe that the e-government system in agriculture results in better work performance, making them more productive and consequently leading to higher incomes (Kamarudin et al., 2021). Furthermore, e-government in agriculture in Bangladesh has led to significant improvements in the agriculture sector: farmers have gained access to vital agricultural information, market data and professional advice through the integration of information and communication technologies. This has resulted in increased productivity, lowered post-harvest losses, and improved resource management. However, insufficient digital literacy, along with the limited number of digital service centers and facilities, insufficiently developed internet network and lack of awareness about the advantages of e-agriculture are responsible for the adaptation and broader acceptance of e-agriculture in this country (Sheikh and Berenyi, 2023; Goedde et al., 2021; Emeana et al., 2020). Digital literacy has a particularly important place in the acceptance of e-agriculture, as many authors have pointed out (Bejaković and Mrnjavac, 2020; Emeana et al., 2020; Pogorelskaia and Várallyai, 2020; Mushi et al., 2024b).

E-government users in rural areas in different countries are generally satisfied with the service. Significant criteria that determine the level of satisfaction are accessibility and interaction, as well as usefulness and ease of use (Hoque and Al Kabir, 2024; Bournaris, 2020). These characteristics of e-government are the most important features of electronic systems which lead to their acceptance by the population. The more citizens perceive the application as useful and easy to use, the more positively they will evaluate it and use it more frequently (Chen and Aklikokou, 2020; Manoharan et al., 2021; Eweoya et al., 2021; Zhang and Zhu, 2021).

However, some recent studies show that satisfaction with electronic services in agriculture is not universal. For example, a study conducted in the dairy sector in Spain showed that the use of e-government was associated with difficulties such as complex procedures, which led to calls to customer service, visits to regional

agricultural offices or hiring authorized individuals (Vázquez-López and Marey-Perez, 2021). In Switzerland, where e-government adoption is obligatory and legally prescribed, farmers perceive it as an administrative burden which does not positively contribute to productivity and farm income, particularly in the case of family farms (Reissig et al., 2022).

In Serbia, the new information system/electronic platform for agriculture, known as eAgrar, is under the competence of the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. The platform started operating in the spring of 2023 with the aim of reforming the way of registering agricultural holdings and approving subsidies for farmers. The previously used Register of Agricultural Holdings, the related procedures and processes of incentive approval were established back in 2004, so many of the technological, software and procedural solutions were outdated. The old procedures were complicated, which led to delays in the approval and disbursement of incentives (Naled, 2023) and these were the reasons for introducing the new, modernized eAgrar platform in 2023. The eAgrar platform enables online registration of agricultural holdings, allows farmers to access and manage their farm data on a daily basis (including data changes and deletions), and allows online submission of registration applications and updating the applications for incentives in agriculture. It should be underlined that farmers are required to participate in the eAgrar system, meaning that the participation in this platform is mandatory for agricultural producers who want to participate in the subsidy system (national support measures for agriculture and rural development).

The main objective of the research in this paper is to examine the attitudes of agricultural producers in the beekeeping sector towards the new electronic agricultural service in Serbia – eAgrar. For the purposes of the research, the authors selected the population of beekeepers because beekeeping in Serbia has a long tradition and includes approximately 29,900 holdings managing about 1,103,000 bee colonies (SORS, 2019; SORS, 2023). In order to stimulate this production, the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia announces an annual competition for the allocation of subsidies per beehive. Given the new reality regarding the digitalization of agriculture, and the fact that the eAgrar platform is mandatory for beekeepers who want to participate in the subsidy system, it is necessary to understand how beekeepers perceive and accept the introduction of this system in agricultural production.

The study aims to show how beekeepers perceive and accept this digital platform, by analyzing their responses regarding its usefulness, usage challenges and adaptability to users' needs. Thus, by conducting an empirical study, the authors attempted to provide answers to the following initial hypotheses:

Ha0: The majority of beekeepers believe that the eAgrar application will bring benefits to their production.

Hb0: The majority of beekeepers find the eAgrar application easy to use and well-adapted to an average agricultural producer in Serbia.

The research was initiated by the authors' suspicion regarding the potential misunderstanding and rejection of different electronic services, digital tools and platforms by farmers in Serbia, bearing in mind their generally unfavorable age structure and low digital literacy. There was also a concern about accepting and understanding of the eAgrar platform in the beekeeping sector, since most beekeepers in Serbia are middle-aged or older people (between the ages of 41 and 65 years) and are mainly hobby beekeepers with apiaries of smaller production capacity (up to 90 production colonies).

The results of this study are expected to provide agricultural policymakers in Serbia with insights into different aspects of the practical application of the eAgrar platform. This would potentially help them to adjust the measures taken so far, improve the existing platform and create an optimal framework for the electronic service intended for farmers. In addition, the results will contribute to enriching the knowledge about the application of new technologies in agriculture, given that this is a new concept whose implementation is still in its early stages and there is an insufficient number of scientific studies on this topic.

Material and Methods

For the purposes of this research, data were collected using a survey questionnaire (employing Google forms), especially structured for the goals of this paper. The target group in the study was the population of beekeepers living in the area of the Republic of Serbia. The questionnaire was sent to them through the Union of Beekeeping Organizations of Serbia. The questionnaire was voluntary and anonymous, and the responses were to be provided from April to May 2023. Beekeepers received the questionnaire online, and valid responses were obtained from 459 of them. The sample characteristics are presented in the following table (Table 1).

In order to test the proposed hypotheses, the responses to the following four questions from the questionnaire containing a larger number of questions, were considered:

1. Do you think that you will benefit from eAgrar?
2. If you think that you will benefit, what benefits do you expect?
3. If you think that you will not benefit, what are the reasons for your opinion?
4. How difficult do you find using eAgrar?

The beekeepers also provided responses to the questions related to their place of residence, age, level of education and the number of bee colonies owned. These categorical variables were selected on the basis of the authors' experience, who

considered these to be the most significant parameters which can affect the respondents' opinion about the subject of the analysis. Gender was not considered as a variable since most beekeepers in Serbia are men, i.e. the percentage of women involved in beekeeping is almost negligible and is therefore unlikely to significantly affect the statistical analysis of the collected data.

Table 1. Sample characteristics.

Sample characteristics	Number, (%)
Region of living	459
Economically developed region: ➢ Belgrade region ➢ Vojvodina region	140 (30.5%)
Economically underdeveloped region: ➢ region of Šumadija and Western Serbia ➢ region of Southern and Eastern Serbia	319 (69.5%)
Age of beekeepers	457
➢ Up to 40	77 (16.8%)
➢ From 41 to 65	291 (63.4%)
➢ Over 65	89 (19.4%)
Education of beekeepers	459
➢ Primary school	18 (3.9%)
➢ Secondary school	224 (48.8%)
➢ College/faculty + Master's degree/PhD	217 (47.3%)
Number of beehives	459
➢ Up to 90	328 (71.5%)
➢ Between 91 and 150	77 (16.8%)
➢ Over 150	54 (11.8%)

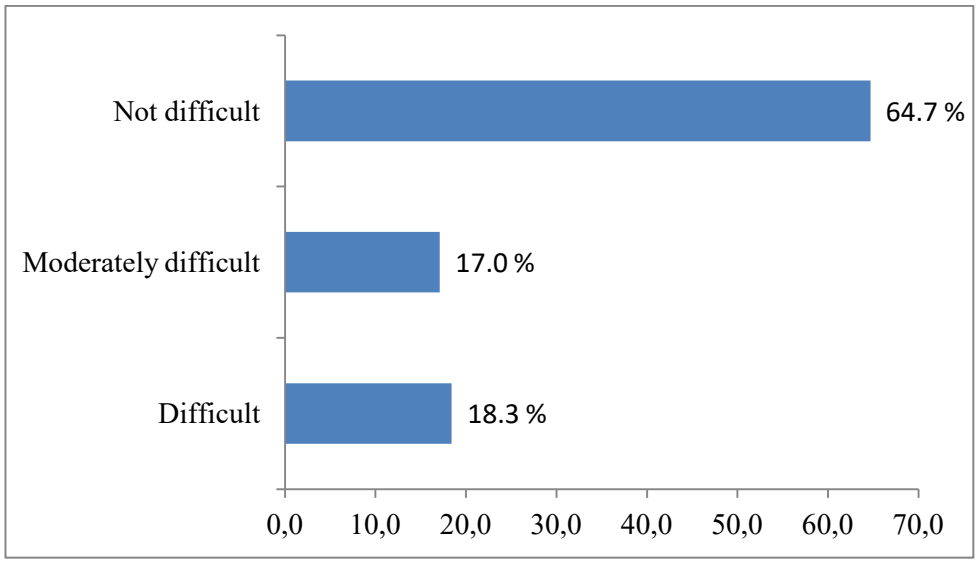
Source: Authors' presentation.

The statistical analysis of the data included the application of descriptive statistics and the chi-square test of independence, and it was conducted using the SPSS 21.0 software package (IBM, Chicago, USA), with the level of significance set at $p \leq 0.05$. The results are presented in both graphs and tables. In addition, the qualitative exploratory analysis tool Word Cloud was used for analyzing and presenting the responses to the question "If you think that you will benefit from it, what benefits do you expect?".

Results and Discussion

When answering the question "*How difficult do you find using eAgrar*?", the respondents could provide answers on the 5-step ordinal Likert scale, where: 1=not at all difficult, 2=a little difficult, 3=moderately difficult, 4=difficult, 5=very difficult. In order to facilitate the interpretation of the results, the responses were

divided into 3 categories: not difficult (responses 1 and 2 on the Likert scale), moderately difficult (response 3 on the Likert scale) and difficult (responses 4 and 5 on the Likert scale). A total of 459 respondents provided responses to this question. The data analysis indicates that the majority of the surveyed beekeepers, i.e. as many as 297 (64.7%) of them, thought that using this electronic platform was not difficult. Only 78 respondents (17.0%) found using eAgrar moderately difficult, while 84 (18.3%) found it difficult (Graph 1).



Graph 1. The difficulty of using the eAgrar platform, answer structure, 2023.
Source: Survey results. Authors' presentation.

The chi-square test of independence has been applied to find out whether there is a correlation between beekeepers' belief that they will benefit from eAgrar and their region of residence, age group, level of education and the number of bee colonies they own, i.e. whether there is a correlation between the challenges of using eAgrar and the selected variables. The results of the $\chi 2$ test showed that there was a statistically significant correlation only regarding the level of education and the challenges of using eAgrar, while the other variables had no significance. Therefore, based on the Pearson's chi-square values shown in Table 2, it can be concluded that there was a positive statistically significant correlation between the two studied variables ($\chi 2$ (4, 459)=16.551, p=0.002). The value of Cramer's V shows that the effect had a small size (Table 3).

Table 2. Value of the $\chi 2$ test for education and eAgrar usage challenges.

	Value	df	Asymptotic significance (2-sided)
Pearson's chi-square	16.551	4	.002
Likelihood ratio	15.321	4	.004
Linear-by-linear association	10.936	1	.001
N of valid cases	459		

Source: Output from SPSS 21.0 software package.

Table 3. Value of Cramer's V coefficient.

		Value	Approximate significance
Nominal by nominal	Phi	.190	.002
	Cramer's V	.134	.002
N of valid cases		459	

Source: Output from SPSS 21.0 software package.

By interpreting the values in the cross-tabulation table based on the adjusted residual values, it can be concluded that the percentage of respondents with primary and those with secondary level of education who found eAgrar difficult to use was higher than expected (if there were no correlations between the variables). On the other hand, the percentage of respondents with a higher level of education who described using eAgrar as difficult was lower than expected (Table 4).

Table 4. Cross-tabulation of education and the response to the question "How difficult do you find using eAgrar?".

			How difficult do you find using eAgrar?			Total
			Not difficult	Moderately difficult	Difficult	
Education	Primary school	Count	8	2	8	18
		%	44.4	11.1	44.4	100.0
		Adjusted residual	-1.8	-.7	**2.9**	
	Secondary school	Count	139	35	50	224
		%	62.1	15.6	22.3	100.0
		Adjusted residual	-1.2	-.8	**2.2**	
	College/faculty/ Master's degree/PhD	Count	150	41	26	217
		%	69.1	18.9	12.0	100.0
		Adjusted residual	1.9	1.0	**-3.3**	
Total		Count	297	78	84	459
		%	64.7	17.0	18.3	100.0

Source: Output from the SPSS 21.0 software package.

When it comes to the question "Do you think you will benefit from eAgrar?" the respondents could answer 1=Yes, I think I will benefit from it, 2=No, I do not think I will benefit from it. A total number of 459 respondents answered this question. The data analysis has revealed that the majority of those surveyed, i.e. as many as 372 individuals (81.0%), thought that they would benefit from this electronic platform, while only 87 respondents (19.0%) thought they would not benefit from it. There were various answers to the question "If you think that you will benefit from this, which benefits do you expect?". They were mainly associated with faster and easier procedures of registering and changing data about agricultural holdings, applying for subsidies, saving time and material resources, tracking the status of their holding, data accuracy, and particularly with their expectations regarding faster subsidy payments per beehive. Since their responses to this question were open-ended, the authors decided to take the advantages of the Word Cloud tool to analyze and visually represent the most prevalent words in the responses. The authors agreed to organize the beekeepers' responses according to the dominant words. This led to the conclusion that the most dominant word was FASTER, indicating that this is the most important characteristic of the electronic application. Apart from this word, the words EASIER and CHEAPER were also prevalent, while other words were used significantly less frequently (Diagram 1).

Diagram 1. Word Cloud for the question "If you think that you will benefit from it, what benefits do you expect?".

Legend: word FASTER – frequency 176; word EASIER – frequency 94; word CHEAPER – frequency 81; word EFFICIENT – frequency 30; word SIMPLER – frequency 26; word BETTER – frequency 7; word TRANSPARENT – frequency 7; word TIMELY – frequency 4; word ACCURATE – frequency 4; word AVAILABLE – frequency 3; word frequency less than 2 – EXPEDITIOUSLY, EFFECTIVELY, PROFESSIONAL, SAFER, USEFUL.

Only 47 beekeepers gave an answer to the question "If you think that you will not benefit from it, what are the reasons for your opinion?". After sorting their responses, it was concluded that the reasons for this opinion were mainly due to the complexity of the platform, which makes it difficult for users to work with it independently and urges them to ask for additional help. Other reasons included low digital literacy and technical problems with the platform. For younger beekeepers up to the age of 40, the greatest problem was the inadequate operation of the platform, i.e. the pages do not load quickly or cannot load at all, the system crashes, etc. The biggest issue for older beekeepers, particularly those older than 65, was the complexity of the system and their insufficient digital literacy. Beekeepers with a lower level of education thought that the system was complicated. On the other hand, those with a higher degree of education who believe they will not benefit from this platform stated that the greatest issues were the inadequate technical operation of the platform, as well as the complexity of use. It should be underlined that the eAgrar platform was launched in March 2023, and that the survey in this paper was conducted in April/May of the same year. Therefore, problems related to the technical functioning of the platform can be attributed to its early stages of operation, during which both farmers and platform developers were adapting to the new way of working.

The results of the conducted research show that both initial hypotheses are correct, i.e. the majority of beekeepers in Serbia thought that the new application in agriculture eAgrar was useful and easy to use. Namely, a vast majority of respondents in this research (as many as 81.0%) believed that they would benefit from the introduction of this platform, and 64.7% of them stated that they did not find it difficult to use. In general, the declared objectives of the creators of this electronic platform which primarily involve reducing paperwork and administration and accelerating different procedures (registering holdings, updating statuses and other agricultural data about agricultural holdings, processing subsidy applications and paying subsidies), have been achieved, since the majority of the respondents believed that these were the main advantages of the eAgrar platform. Therefore, the most important benefits were saving time and material resources (since time was no longer wasted while waiting in line, collecting documentation, etc.) The saved time can now be redirected towards working in the apiary, which can indirectly increase the productivity and profitability of production. This is in accordance with the studies of other authors conducted in rural areas of other countries, where inhabitants believe that e-government provides better work performance, makes them more productive and consequently increases their income (Kamarudin et al., 2021; Panganiban, 2019).

If usefulness and ease of use of the electronic platform are taken as the criteria for assessing the satisfaction with e-government in the sector of agriculture, it can be concluded that, on the whole, eAgrar users were satisfied with the service. This

aligns with the findings of the authors from other countries (Hoque and Al Kabir, 2024; Bournaris, 2020). However, it must be underlined that the use of eAgrar in Serbia is mandatory for all agricultural producers who want to be part of the subsidy system. The authors have the impression that the subsidies are an important motivator for beekeepers to engage in mastering this application. The usefulness of the application in this sense (easier and faster access to subsidies) is thus an extremely significant factor in mastering the use of the application, which is consistent with the research of Zhang and Zhu (2021).

Approximately one fifth of respondents thought that they would have no benefits from eAgrar. They stated that the main reasons for this were the inadequate technical operation of the application, the excessive complexity of the platform preventing beekeepers from using it independently, and the insufficient digital literacy of the users (beekeepers). For the dissatisfied users, the complexity of the platform and insufficient digital literacy represented the main reasons for requiring assistance from acquaintances or agricultural extension services. This can be correlated with a study conducted in some countries, where the use of e-government is connected with a greater engagement of producers in the search for agricultural extension officers and other professional services to help them overcome complex procedures, and they consider it an administrative burden (Vázquez-López and Marey-Perez, 2021; Sheikh and Berenyi, 2023; Reissig et al., 2022).

Conclusion

Beekeeping is a significant sector of agricultural production, primarily due to the importance of pollination in the ecosystem secured by bees, but also due to the economic benefits from selling honey and other bee products. In the area of Serbia, there are more than one million honey-bearing bee colonies, and almost 30,000 agricultural holdings involved in this production.

The digitalization of agriculture, which includes the implementation of e-government in the sector of agriculture (eAgrar platform), has also encompassed the beekeeping sector. This digital platform started operating in 2023 and is mandatory for all registered agricultural holdings that want to participate in the system of national subsidies.

The authors' research has shown that the majority of the surveyed beekeepers consider the eAgrar platform to be useful and that digitalization will make all administrative procedures in cooperation with the Directorate for Agrarian Payments of the Republic of Serbia faster, easier and cheaper. This consequently leads to saving time, which can be redirected to working in apiaries and improving the productivity of beekeeping production. In addition, the research has found that the majority of the surveyed respondents find the

platform easy to use, which indicates that it is well adjusted to end-users' needs. Also, the research has shown that education is a significant predictor of success in the implementation of the electronic platform, as education was the only categorical variable which showed significance in the evaluation of the challenges in using e-government in agriculture.

The study results provide agricultural policy makers with insights into the practical application of the new digital platform, thus creating the possibility for continuously developing and optimally adapting the platform to the needs of farmers. Beekeepers need to continuously acquire and develop their IT knowledge and skills in order to work efficiently and independently on the eAgrar digital platform. Users need time to become competent when using this platform, and developing digital knowledge and skills is of key importance for adapting to the new digital age.

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PLATFORMA E-AGRAR U POLJOPRIVREDI SRBIJE: OCENA KORISTI I TEŽINE KORIŠĆENJA SA STANOVIŠTA PČELARA

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R e z i m e

Cilj istraživanja usmeren je na razumevanje stavova pčelara u pogledu korisnosti i težine korišćenja novog vladinog elektronskog servisa u poljoprivredi – eAgrar. Ovu platformu pokrenulo je Ministarstvo poljoprivrede, šumarstva i vodoprivrede Republike Srbije 2023. godine, a učešće na njoj je obavezno za sve poljoprivredne proizvođače koji žele da budu u nacionalnom sistemu subvencija. Podaci za potrebe istraživanja u okviru ovog rada prikupljene su u periodu mart–april 2023. godine, putem struktuiranog onlajn anketnog upitnika (*Google forms*). Broj ispitanika bio je reprezentativan (459), a slučajno uzorkovanje garantovalo je anonimnost ispitanika i obezbedilo je kredibilitet istraživanja. Obrada prikupljenih podataka podrazumevala je primenu deskriptivne statistike, $\chi 2$ testa nezavisnosti i alata *Word Cloud*. Rezultati istraživanja su pokazali da većina ispitanika (81,0%) smatra da će imati koristi od uvođenja ove platforme, jer će sve administrativne procedure u poslovanju postati brže, lakše i jeftinije. Za većinu pčelara (64,7%) platforma je laka za korišćenje, dok se oko trećina njih ne snalazi najbolje, te je u značajnoj meri oslonjena na podršku poljoprivrednih savetodavaca. Rezultati $\chi 2$ testa nezavisnosti ujedno su pokazali da postoji statistički značajna veza između stepena obrazovanja ispitanika i teškoća u radu na platformi eAgrar. Očekuje se da će rezultati ove studije kreatorima poljoprivredne politike u Srbiji pružiti uvid u različite aspekte praktične primene platforme eAgrar, kao i doprineti obogaćivanju naučnih saznanja o primeni novih tehnologija u poljoprivredi.

Ključne reči: e-uprava, poljoprivreda, anketno istraživanje, Republika Srbija.

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ENVIRONMENTAL LITERACY AND BEHAVIOUR OF AGRICULTURAL PRODUCERS – PILOT STUDY

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Abstract: The environmental literacy of agricultural producers is extremely important for sustainable agriculture and environmental protection. In this paper, we examined the knowledge, education and environmental and agricultural literacy of individual farmers as well as their influence on their work in agricultural practice. The study was performed in an agricultural region in Vojvodina, Serbia. We used a self-designed questionnaire. The questionnaire was completed during an interview and personal visits to farmer's households. All agricultural producers in the examined region had 8 years of formal education and more than half had higher education; more than half also attended additional informal education in the field of agriculture and had very good knowledge of pesticide toxicity and its environmental impact. However, their behavior in managing waste and pesticide-contaminated water is inadequate. After rinsing spray tanks at home, more than half of farmers reported pouring contaminated water from the tank with pesticide residues into the yard or into the sewage system, without being aware of the environmental hazard. In addition, 74% of farmers knew the name of the active ingredient in a pesticide and 76% of them always read the instructions for use. However, more than 37% of respondents believe that using a slightly higher concentration is the only way to control pests. The level of education, as well as the knowledge on environmental threat of pesticides did not significantly affect the behavior of agricultural producers. Although they have a high level of knowledge about the pesticide management, they do not always apply it adequately in everyday practice. Additional environmental education on the implementation of theoretical knowledge in everyday practice is needed.

Key words: environmental literacy, agricultural producers, pesticide handling, implementation.

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Introduction

In recent years, the intensive use of pesticides has significantly increased the impact of pesticide residues on nature and on humans (Narayanan et al., 2022). The amount, improper selection of pesticides applied, and suboptimal pesticide handling are some of the current major issues associated with pesticide use, particularly in underdeveloped and developing countries (Aktar et al., 2009; Bhandari, 2014; Melanda et al., 2022). Several pesticides used in agriculture cause health problems in humans, the most serious being cancer and congenital malformations (Shah, 2021). The main sources of contamination are food, water, or exposure during agricultural work. Agricultural environmental pollution is particularly prevalent in countries, where pesticide management and safety measures do not follow intensive agricultural development (Sarkar et al., 2019). One of the principal reasons for the improper use of pesticides and the handling of pesticide residues is the insufficient knowledge (Endalew et al., 2022) or the inadequate implementation of knowledge into practice (Sai et al., 2019), meaning that agricultural behavior is inadequate from the perspective of environmental literacy. Environmental literacy is the knowledge of environmental concepts and issues; the attitudinal dispositions, motivation, cognitive abilities, and skills, and the confidence and appropriate behaviors to apply this knowledge to make effective decisions in a range of environmental contexts (Hollweg et al., 2011). Relevant studies have confirmed that environmental literacy could promote individuals to adopt responsible environmental behavior (Asteria, 2019; Biswas, 2020). Environmental literacy had a significant positive impact on individuals' environmental behavior (Yu et al., 2022).

From the perspective of agricultural production, agricultural literacy is a term that has been gaining popularity recently. According to Spielmaker et al. (2014), "an agriculturally literate person understands and can communicate the source and value of agriculture as it affects our quality of life". What does it mean to be agriculturally literate? It is an understanding of the relationship between agriculture and the environment, food, fiber, technology, and the economy (Nutrient for life, Canada, 2022). Frick et al. (1991) identified eleven concepts that encompass agricultural literacy: Environment, processing, policy, natural resources, animal production, societal significance, plant production, economic impact, marketing, distribution, and globalization (Frick et al. 1991).

Agricultural literacy is most often related to the citizens (Trexler, 2000; Hess and Trexler, 2011). Individual agricultural producers are assumed to have enough professional knowledge in the field of agricultural production and the environment. However, individual agricultural producers are not always professionally trained in agriculture, and their environmental literacy, i.e., the development of knowledge, attitudes, and skills necessary to make informed decisions concerning the

relationships between natural and urban systems, is most often at the level of the general population. Nevertheless, they cultivate most of the agricultural land and use the largest amount of pesticides.

In our study, we therefore investigated the environmental/agricultural literacy of individual agricultural producers in the agricultural area in Serbia based on the level of knowledge and appropriate behaviors to apply such knowledge to make effective decisions. We tried to analyze how familiar the farm workers are with the environmental toxicity of pesticides, to what extent they implement the general rules for the pesticide waste management in everyday practice, and to what extent their opinions, and probably also their actions agree with the claims for use.

Material and Methods

The study was performed among the agricultural products of the Bački Petrovac municipality, situated in South Bačka district in the Vojvodina region in 2019–2020. The municipality consists of 4 villages, three of which participated in the study – Bački Petrovac, Kulpin and Gložan. In recent years, in Bački Petrovac, similar to other Serbian regions, the number of small (up to 5 hectares) agricultural households has declined, and most family farmers have around 25 hectares. The number of registered agricultural households is 1313 (Republika Srbija, 2020). Traditionally, experts from the pharmaceutical industry and professors from the Faculty of Agriculture from nearby universities, mainly in Novi Sad, organize educational meetings attended by most farmers (additional education) every winter.

Questionnaire development and delivery

We used a self-designed questionnaire. The questionnaire consisted of 24 questions related to four sections. The first section was related to the sociodemographic characteristics of farmers, including sex, educational level, amount, and farming duration. The second section focused on farmers' knowledge on the influence of pesticides on wildlife. The third section included questions regarding pesticide residue management reading and following the label instructions, and ecological practices relating to storing and disposing of pesticides and empty containers. In the fourth section, we asked the farmers about the knowledge of the generic name of the active ingredient in the pesticide, reading the instructions and implementing them in the practice, and finally about the knowing the meaning of pictograms as the signs of danger.

The inclusion criteria for participants were willingness to participate, age between 20 and 70 years (the active age group of farm workers in the given region), and full-time or part-time farm workers. The exclusion criterion was the unwillingness to participate in the study. The questionnaire was completed in the

form of an interview and personal visits to the farmer's households. A total of 80 questionnaires were submitted. The questionnaires not completely fulfilled were not included in the analysis.

Data analysis

All data were coded, entered, and analyzed using SPSS version 20 (SPSS Inc) and Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA, USA). Results, expressed as frequencies and percentages, were conducted for all parameters obtained, and the chi-square test ($\chi 2$) was used to measure the possible association between nominal variables (level of education, farming years vs knowledge, attitudes and behavior of agricultural producers in practice) with Yates' correction for small samples. We used $\alpha \leq 0.05$ as a criterion for statistical significance.

Agricultural producers' attitudes, knowledge and behavior about pesticide knowledge influence on the environment, handling the pesticides, disposal practice, and equipment wash area were compared with formal and additional voluntary education about the safety and ecological aspects of handling the pesticides, amount and duration of land farming.

The ethical committee of the University of Health and Social Work of St. Elizabeth in Bratislava, Slovakia, and the Management of Local Associations of Agricultural Producers in the municipality of Bački Petrovac approved the study.

Results and Discussion

Seventy-eight out of 80 farmers fulfilled the questionnaire, indicating a full response rate of 97.5%. Most of the farmers were involved in the cultivation of corn, wheat, and soybeans.

Socio-demographic characteristics of the farmers

The respondents were mostly male (94.6%). There were no illiterate participants. All agricultural producers had at least eight years of formal education, 58.7% of them had 12 years, and 7.7% had 16 years of schooling at various universities. Of all participants, only 16 (13 with secondary school diploma and 3 with high school diploma) or 20.5% completed secondary or high school in agriculture. The majority of producers have been cultivating the land for more than ten years (83. 4%). Most of the agricultural producers cultivate between 5 and 25 hectares of the land (66.7%), 23% cultivate less than 5 hectares, 6 (7.69) cultivate between 25 and 50 hectares, while only two agricultural producers (2.56%) cultivate more than 50 hectares (Table 1).

Table 1. Demographic factors of respondents.

Gender	No.	%
Males	73	94.6
Females	5	6.4
Education		
Primary school	26	33.3
Secondary school	46	58.7
University/College	6	7.7
Field of education		
Agriculture	16	20.5
Other	62	79.5
Length of farming		
1–5 yr(s) of farming	5	6.4
6–10 yrs	8	10.2
> 10 yrs	65	83.4
Farming area (ha)		
Up to 5	18	23.07
Up to 25	52	66.7
Up to 50	6	7.69
> 50	2	2.56

The majority (70.2%) of the farm workers received further training in agriculture organized every winter in the form of educational meetings. The farmers with the lowest amount of farming land (up to 5 hectares) had the lowest ratio of attendance to the educational meetings (55.6%), farmers with up to 25 hectares had a participation rate of 78.8% while 21.1% of farmers did not attend additional educational activities. Furthermore, 83.3% of farmers with up to 50 hectares attended the additional educative meeting while farmers cultivating more than 50 hectares had 100% attendance at educational meetings (Table 2). The difference is statistically significant (X^2 7.99, $p<0.018$).

Table 2. Additional educational activities according to the farming area.

Additional education/ Amount of farming land							
5 ha		>25 ha		>50 ha		<50 ha	
Yes	No	Yes	No	Yes	No	Yes	No
No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
8 (44.4)	10 (55,6)	41 (78.8)	11 (21.1)	5 (83.3)	1 (16,16)	2 (100)	-
Total:		Yes 56 (71.8%)			No 22 (28.2%)		

Statistical significance: amount of farming/attendance (λ^2 4.73, X^2 7.99, $p<0.018$).

Environmental literacy – knowledge and behavior of farm workers

Farm workers' knowledge on environmental toxicity of pesticides

Farmers' interest and knowledge about pesticide environmental toxicity is shown in Table 3. When buying pesticides, 57.7% of farmworkers were interested in their environmental toxicity, 35.9% lacked the interest, while 6.4% answered "other". When asked about the length of time that pesticides can remain in the soil or water, 88.4% of farm workers knew that pesticides can remain in the soil and water for an extended period of time. Moreover, 94% of farm workers thought that pesticides were toxic to domestic and wild animals. The duration of farming significantly influenced this general awareness ($\lambda 2$ 4.73 $p \leq 0.05$). In addition, 91.0% of the farmers thought that pesticides can reach watercourses, while 6.4% believed that they remained on the surface. Furthermore, 97.6% of farmers believed that the pesticides entering the surface water could destroy fish and other wildlife, while only 2.4% were not concerned about it.

Table 3. Farmworkers' knowledge on the environmental toxicity of pesticides.

Question/variables	Yes No. (%)	No No. (%)
	No. (%)	
When buying pesticide do you ask about environmental toxicity?		
Yes, always, or read the instructions for use	45 (57.7)	
Mostly no	28 (35.9)	
Other	5 (6.4)	
Do you know that some pesticides can remain on soil and in water for > 1 yr**?**	69 (88.4)	9 (11.6)
Pesticides are toxic to domestic and wild animals (λ^2 4.73, $p \leq 0.05$) x farming years	79 (94)	5 (6.0)
Pesticides spilled on the ground		
Remain on the surface	5 (6.4)	
Reach a watercourse	71 (91)	
This is a small amount that is not harmful	0 (0.0)	
Other	2 (2.6)	
Pesticides that reach the surface water		
Can destroy fish and other wildlife	76 (97.6)	
Do not affect fish because only safe products are used	0 (0.0)	
Have not considered toxicity to fish and other wildlife	2 (2.4)	

P=0.8; 1.68; 0.79; 0.24; 0.2; NS. The level of education did not influence the answers (p=0.28, NS).

Pesticide residue management

The practice of farm workers in pesticide residue management is shown in Table 4. Most farmworkers did not spill pesticide residues after spraying at all (91%) or rarely (7.7%) in the field or watercourses. If they had leftover in spraying tanks, they usually sprayed it on the plants. All of them flushed tanks after spraying, 41% of farmers in the field, and 59% of farmers at home. Of the farmers who flashed the tank at home, 19.6% of farmers discharged the wastewater into the sewage system (down the drain), while most farmers throw out the wastewater in the yard (76%).

The empty pesticide packaging was thrown away in household waste by 16.7% of farmworkers (almost twice as many of them with primary than secondary education), while 82.1% of farmers put it in special containers.

Table 4. The practice of farm workers in disposal of pesticide residues.

Question	Variables	No. (%)
Do you spill unused pesticide in the surrounding watercourses (ditch, channel)?	Usually	1 (1.3%)
	Sometimes	0 (0.0%)
	Rarely	6 (7.7%)
	Never	71 (91 %)
Do you flush the tank after spraying?	Yes, in the field	32 (41%)
	Yes, at home	46 (59%)
	No	0 (0.0%)
Where do you discard the wastewater after flushing at home?	Down the drain	9 (19.6%)
	In the yard	35 (76%)
	Other	2 (4.4%)
Disposal of empty pesticide packaging	To garbage	13 (16.7%)
	Storage and transportation in special containers	64 (82.1%)
	Other	1 (1.2%)

p=0.1; 0.1; 0.057; 0.1; NS. The level of education did not influence the answers.

Knowledge of the generic name of the active ingredient in the pesticide, reading the instructions for use and implementing them into practice.

Only 74% of farmers know the name of active ingredient of a pesticide. When preparing the solution, 76% of farmers always read the instructions for use, 24% of farmers did not read the instructions for use, regardless of their education level. The reason: small letters (1), not understandable (1), boring (1), because I have already read it (3) (Table 5). Farmers who had been farming for more than ten years were significantly more likely to read the instructions than farmers who had been farming for less than five years (X^2 16.42 $p < 0.05$).

More than 37% of participants agreed with the claim that slightly higher concentrations than recommended were the only way to destroy pests. Formal or additional education did not significantly influence this statement.

Table 5. The knowledge of the generic name of the active ingredient in a pesticide, reading the instructions for use and implementing them into practice.

Topics	Yes	No
Farmers know the name of the active ingredient in the pesticide preparation	58 (74%)	20 (26%)
Farmers read the instructions for use before preparing the solution (λ^2 16.42, p.< 0.05 farming years)	59 (76%)	19 (24%)
Is using slightly higher concentrations than recommended the only way to destroy pests and weeds?	Strongly agree	17 (21.8%)
	Agree	12 (15.4%)
	Do not agree	38 (48.7%)
	Do not agree at all	7 (9.0%)
	Do not have an opinion	4 (5.1%)

P=0.8; 0.28; 0.14; NS. The level of education did not influence the answers.

In this study, we examined the knowledge of farmworkers on environmental toxicity, pesticide waste management practices, and willingness of the farmers to apply existing knowledge about pesticides in order to make effective decisions from the perspective of environment.

Some studies have revealed that environmental literacy has a significant positive impact on the environmental behavior of individuals (Yu et al., 2022). Nevertheless, the level of environmental literacy among individual, smallholder farmers, who cultivate most of the land in most countries, and who often do not have appropriate professional education in agriculture and ecology is not well known. However, they are the ones who use most of the pesticides and dispose of their residues and used packaging. The degree of their environmental literacy and the implementation of their knowledge are extremely important for sustainable agriculture. We therefore consider it very important to investigate the agricultural and ecological knowledge of these people.

In Serbia, family farms account for over 90% of agricultural land (Bogdanov, 2007; FAO, 2020). Most farmers cultivate 5–25 hectares of land, that is, most of them have developed small-scale family farming. An area of 25 hectares is enough to support a family in Serbia. In the majority of published studies, farmers cultivated from 5 to 25 hectares of land (Jallow et al., 2017; Adesuyi et al., 2018; Mubushar et al., 2019).

In our sample, all participants were formally literate, having completed primary school, and almost half of them had both secondary and tertiary education, although only 20% from the field of agriculture, indicating that agriculture was probably not their first career choice. The level of education is similar to the results from Greece, but much higher than the trials conducted among the farmworkers in some Asian or African countries (Damalas et al., 2017). A significant percentage of

our respondents also attended additional lectures in the field of modern agriculture. This was reflected in a good knowledge of the toxicity of pesticides to both living organisms and nature, and, based on their own statements, many of them showed concern for the environment.

As many as 57% of farmers were interested in the environmental toxicity of pesticides when purchasing pesticides, which is slightly more than half of the respondents. However, more than 90% of them were aware of the environmental toxicity of pesticides and their impact on wildlife. This is a better result than the result obtained in Malaysia, where about 74–76% of respondents with a similar level of education as in our survey gave correct answers to similar questions about the impact of pesticides on wildlife (Sabran and Abas, 2021).

In our survey, 91% of respondents stated that they never poured the remaining pesticide solution into the surrounding waterways. Although this is a high, and, in our opinion, satisfactory percentage, in neighboring countries, such as Greece, this percentage is even higher – 95%. While in Greece 49.3% of farmers dispose of unused pesticides on uncultivated land, in our survey as many as 59% of farmers washed out the tanks at home, and discharged the contaminated water into the sewage system or into the yard. In both cases, the pesticides reach groundwater and pollute it (Karasmanaki et al., 2021). Pesticides spilled in the yard most often end up in underground watercourses and pollute them. The situation is similar for spills into the sewage system, where the pesticides reach surface waters (Novaković et al., 2018). Although 90% of farmers stated that pesticides can enter the surrounding watercourses via the land, this practice shows that they do not sufficiently apply the existing knowledge. The probable explanation is that they are not completely aware that spilling in the yard or in the sewerage system is associated with the pollution of underground watercourses, because the handling of used packaging is very responsible, and more than 80% of farmers keep the used packaging and take it to special containers.

In our survey, 76% of agricultural producers regularly read the instructions for the use of pesticides. This is especially important for the preparation of the corresponding concentrations. However, only 57% of them agreed that the proposed concentrations were sufficient to achieve the effect and 37.2% believed that a higher concentration should be used. Although this is still not optimal, it represents a significant improvement compared to 2004. A group of authors led by Strubenhoff (2004) participated in a project on the use of pesticides in the Danube basin, in which it was found for the farmworkers from Serbia “they do not respect the proposed time of application of pesticides, apply pesticides later than it is proposed one, even 2–3 times higher in some cases”. This is the consequence of insufficient knowledge and education in the field of pesticides. Our study has shown that the education and a satisfactory level of knowledge can change the behavior of farmers in this field.

It is interesting to note that the level of additional education in the field of pesticides did not significantly affect the behavior of farmers. This is consistent with Karapandžin (2018). He has claimed that the adoption of environmental measures by farmers in Vojvodina does not depend on the level of education, nor on additional education, but contrary to Šarković et al. (2016), who have found that the level of formal education has a direct impact on the reduction of harmful environmental practices, provided that any infrastructure allows it. However, when talking about environmental literacy, it is an outcome of environmental education, not only formal education or education from the field; and only in this way can it provide a solid foundation for future environmental responsiveness and help in the transition towards more sustainable societies and healthy living (Usha Shri and Tiwari, 2021). According to Gifford and Sussman (2012), the environmental attitudes vary by age, gender, socio-economic status, ethnicity, degree of urban areas, personality, experience, education and knowledge about the environment, and education is one of the most important factors influencing the environmental awareness. In our study, only the length of farming experience had a significant impact on farmers' knowledge, showing that, in addition to education, experience in this branch is of crucial importance for acquiring knowledge.

Conclusion

In this paper, we investigated the knowledge and environmental literacy of farmers from Serbia, an agricultural region. We concluded that the farmworkers were familiar with the environmental toxicity of pesticides, and that they had good environmental and agricultural knowledge. They applied some of the knowledge well – particularly in terms of the application of recommended doses and dealing with empty pesticide packaging and pesticides, but not with pesticide-contaminated water. After rinsing the spray tank at home, the waste water was spilled into the yard, from where it entered the underground watercourses. In addition, 74% of farmers knew the name of the active ingredient in a pesticide, and 76% of them always read the instructions for use. However, more than 37% of respondents believed that using a slightly higher concentration was the only way to control pests. There is still a lack of fully applying the knowledge into practice that would be environmentally friendly. Additional environmental education in the form of repeated courses and lectures is needed to better understand water flows and environmental pollution so that people are able to navigate the environment and agriculture.

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EKOLOŠKA PISMENOST I PONAŠANJE POLJOPRIVREDNIH PROIZVOĐAČA – PILOT STUDIJA

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R e z i m e

Ekološka pismenost poljoprivrednih proizvođača je izuzetno važna za održivu poljoprivredu i zaštitu životne sredine. U radu smo ispitali znanje, obrazovanje i ekološku i poljoprivrednu pismenost kod individualnih poljoprivrednika kao i njihov uticaj na rad u poljoprivredi. Studija je sprovedena u poljoprivrednom regionu, u Vojvodini, Srbija u opštini Bački Petrovac, sa značajnim udelom poljoprivrednih proizvođača, putem upitnika. Svi poljoprivredni proizvođači u ispitivanom regionu imali su 8 godina formalnog i više od polovine visokoškolskog obrazovanja; više od polovine je takođe pohađalo dodatno neformalno obrazovanje iz oblasti poljoprivrede, i imalo je veoma dobro znanje o toksičnosti pesticida i njihovom uticaju na životnu sredinu. Međutim, njihovo ponašanje u upravljanju otpadnim, pesticidima zagađenim vodama je neadekvatno. Nakon ispiranja rezervoara za prskanje kod kuće, više od polovine farmera je prijavilo da prosipa zagađenu vodu iz rezervoara sa ostacima pesticida u dvorište ili u kanalizaciju, a da nisu bili svesni opasnosti po životnu sredinu. Pored toga, 74% poljoprivrednih proizvođača zna ime aktivne supstance u pesticidu, i 76% njih uvek čita uputstvo za upotrebu. Međutim, više od 37% ispitanika smatra da je korišćenje malo više koncentracije jedini put za suzbijanje štetnika. Nivo obrazovanja, kao i znanja o ekološkoj ugroženosti pesticida nisu značajno uticali na ponašanje poljoprivrednih proizvođača. Iako imaju visok nivo znanja o upravljanju pesticidima, ne primenjuju ga uvek na adekvatan način u svakodnevnoj praksi. Potrebno je dodatno ekološko obrazovanje o primeni teorijskih znanja u svakodnevnu praksu.

Ključne reči: ekološka pismenost, poljoprivredni proizvođači, primena pesticida, implementacija.

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Books

Steel, R.G.D., & Torrie, J.H. (1980). *Principles and procedures of statistics*. New York: McGraw-Hill Book Company.

Book chapter

Bell, R.L., Quamme, H.A., Layne, R.E.C., & Skirvin, R. M. (1996). Pears. In J. Janick & J.N. Moore (Eds.), *Fruit breeding, Volume I: Tree and tropical fruits.* (pp. 441-514). New York: John Wiley and Sons, Inc.

Proceedings
Behera, T.K., Staub, J.E., Behera, S., Rao, A.R., & Mason, S. (2008). One cycle of phenotypic selection combined with marker assisted selection for improving yield and quality in cucumber. In M. Pitrat (Ed.), *Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceae* (pp. 115-121). Avignon, France.

Thesis
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Web site
Platnick, N.I. (2010). The world spider catalog, version 10.5. *American Museum of Natural History*. Retrieved February 12, 2016, from http://research.amnh.org/entomology/spiders/catalog/index.html

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The summary in Serbian is given at the end of the paper and should comprise 200 to 250 words. Before the main text of the summary, as well as in English, the title of the paper, first name, middle initial(s) and last (family) name of all authors and the names and addresses of affiliations should be given. The title of the summary is centred and written separately. Below the title, the text of the summary should follow, without any indentation, and immediately after the text of the summary, the key words are given with the full stop at the end. The e-mail address of the corresponding author should be given at the bottom of the page.

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Only standardised abbreviations should be used in the paper. Measure units should be expressed using International System of Units (SI). The abbreviations can be used for other expressions provided these expressions are stated in the full form when appear for the first time with the abbreviated form in the brackets. Values from 1 to 9 can be written in letters, but others numerically.

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The complete nomenclature (chemical and biochemical, taxonomical, genetic etc.) must be adjusted to international codes and commissions, such as *International Union of Pure and Applied Chemistry, IUPAC-IUB Combined Commission on Biochemical Nomenclature, Enzyme Nomenclature, International Code of Botanical Nomenclature, International Code of Nomenclature of Bacteria* etc.

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All formulae and equations in the paper should be worked out by means of the programme "WORD Equation". An ample space should be left around the formulae for the sake of visibility. Subscripts and superscripts should be clear. Greek letters and other non-Latin symbols should be explained when they are first used. The meaning of all symbols should be given immediately after the equation where these symbols are first used. Equations should be numbered by Arabic numerals, serially in brackets, at the right-hand side. Each equation must be mentioned in the text as Eq. (1), Eq. (2), etc.

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Ključne reči
Ključne reči su termini ili fraze koje najbolje opisuju sadržaj članka za potrebe indeksiranja i pretraživanja. Broj ključnih reči može biti od 3 do 10. Navode se ispod sažetka. Naslov „Ključne reči“ piše se boldovano i uvlači jednim

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Uvod

Uvod treba da sadrži informacije o dosadašnjim istraživanjima po navedenom pitanju i šta se datim istraživanjem želi postići. Prilikom osvrta na literaturu, navesti autora i godinu, a autora citirati u spisku literature. Naslov „Uvod“ piše se sa prvim velikim slovom, centrirano i boldovano, nakon čega sa jednim razmakom ispod naslova sledi tekst uvoda poravnat po levoj i desnoj margini. Svaki novi pasus uvlači se jednim tabulatorom. Ova pravila važe i za sva ostala poglavlja.

Materijal i metode

Materijal i metode treba izložiti jasno uz objašnjenje svih primenjenih postupaka u radu. Opšte poznate metode izložiti kratko, a detaljnije ih objasniti ukoliko se odstupa od ranije objavljenih postupaka. Za radove eksperimentalnog karaktera obavezno navesti način statističke obrade podataka. U ovom poglavlju, kao i u poglavlju „Rezultati i diskusija“, po potrebi se mogu dati i određena podpoglavlja.

Rezultati i diskusija

U poglavlju „Rezultati i diskusija“ interpretiraju se podaci dobijeni na osnovu zapažanja i izvršenih eksperimenata. U komentaru rezultata treba se pozivati na literaturu koja se navodi na kraju rada, čime se obezbeđuje poređenje dobijenih rezultata sa dosadašnjim saznanjima u toj oblasti.

Zaključak

U zaključku treba ukratko navesti najznačajnije rezultate dobijene u radu. Izbegavati nabrajanje svih rezultata istraživanja sa ponavljanjem brojčanih vrednosti koje su prethodno već navedene u poglavlju „Rezultati i diskusija“. Zaključak ne sme da sadrži reference.

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Primeri navođenja referenci su sledeći:

Periodičan časopis
Gvozdenović, S., Saftić Panković, D., Jocić, S., & Radić, V. (2009). Correlation between heterosis and genetic distance based on SSR markers in sunflower (Helianthus annuus L.). *Journal of Agricultural Sciences*, *54*, 1-10.

Knjiga
Steel, R.G.D., & Torrie, J.H. (1980). *Principles and procedures of statistics*. New York: McGraw-Hill Book Company.

Poglavlje u knjizi
Bell, R.L., Quamme, H.A., Layne, R.E.C., & Skirvin, R.M. (1996). Pears. In J. Janick & J.N. Moore (Eds.), *Fruit breeding, Volume I: Tree and tropical fruits.* (pp. 441-514). New York: John Wiley and Sons, Inc.

Zbornik
Behera, T.K., Staub, J.E., Behera, S., Rao, A.R., & Mason, S. (2008). One cycle of phenotypic selection combined with marker assisted selection for improving yield and quality in cucumber. In M. Pitrat (Ed.), *Proceedings of the IXth EUCARPIA meeting on genetics and breeding of Cucurbitaceae* (pp. 115-121). Avignon.

Teza
Singh, N.K. (1985). *The structure and genetic control of endosperm proteins in wheat and rye*. University of Adelaide.

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Veb sajt
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Tabele
Tabele obeležene arapskim brojevima (1, 2, itd.) praćene naslovom treba da se nalaze na odgovarajućem mestu u tekstu, u fontu 9. Maksimalna širina tabela treba da bude 13 cm. One treba da budu jasne, što jednostavnije i pregledne. Treba izbegavati vertikalne crte, a broj kolona ograničiti tako da tabela ne bi bila preširoka. Takođe, treba izbegavati nepotrebnu upotrebu horizontalnih crta. Naslov tabele, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom iznad tabele. Ispod tabele treba dati detaljno objašnjenje skraćenica, simbola i znakova korišćenih u samoj tabeli. Svaka tabela mora biti pomenuta u tekstu.

Ilustracije
Svi grafikoni, dijagrami i fotografije treba da se nazovu „Slika“ (1, 2, itd.). Prilažu se na odgovarajućem mestu u tekstu. Grafikone i dijagrame treba uraditi fontom 9, u crno-beloj tehnici i sa maksimalnom širinom od 13 cm. Voditi računa da oni budu čitki i jasni i nakon redukcije veličine. Za svaki grafikon i dijagram treba obezbediti detaljnu legendu bez skraćenica. Fotografije moraju biti visokog kvaliteta da bi se tehnički mogle dobro reprodukovati. Prilažu se u „TIF“ ili „JPG“ formatu, u crno-beloj tehnici. Naslov ilustracije, poravnat po levoj i desnoj margini, sa tačkom na kraju, navodi se sa jednim razmakom ispod ilustracije. Svaka ilustracija mora biti pomenuta u tekstu.

Skraćenice i jedinice
U radu treba koristiti samo standardne skraćenice. Merne jedinice treba izražavati u internacionalnom sistemu jedinica (SI). Kod navođenja jedinica posle broja treba da stoji razmak (osim za % i °C). Skraćenice se mogu koristiti i za druge izraze pod

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Nomenklatura

Celokupna nomenklatura (hemijska i biohemijska, taksonomska, genetička itd.) mora biti usklađena sa međunarodnim kodeksima i komisijama, kao što su *International Union of Pure and Applied Chemistry, IUPAC-IUB Combined Commission on Biochemical Nomenclature, Enzyme Nomenclature, International Code of Botanical Nomenclature, International Code of Nomenclature of Bacteria* itd.

Formule

Sve formule i jednačine u radu moraju biti urađene pomoću programa „Word Equation". Pri pisanju formula, radi preglednosti, ostaviti dovoljno praznog prostora oko same formule. Subskripti i superskripti treba da budu jasni. Prilikom pisanja jednačina treba dati smisao svih simbola odmah posle jednačine u kojoj se simbol prvi put koristi. Jednačine treba da budu numerisane arapskim brojevima, serijski u zagradama, na desnoj strani linije. Svaka jednačina mora biti pomenuta u tekstu kao Eq. (1), Eq. (2), itd.

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