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TRADITIONAL AND INNOVATIVE AGING TECHNOLOGIES OF DISTILLED BEVERAGES: THE INFLUENCE ON THE QUALITY AND CONSUMER PREFERENCES OF AGED SPIRIT DRINKS

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Abstract: Aging is one of the most important processes in the production of high-quality spirits, including whisky, brandy and cognac. The contact between wood and distillates is a crucial step for the migration of chemical compounds, which evoke the novel sensory properties of the final products. Novel taste is pleasurable for a vast group of consumers and depends on cultural preferences. In order to demystify the main chemical compounds for aroma contribution, connecting them with a sensory profile of aged spirits is a crucial step in hastening the very timeless process without decreasing the quality. Consumption patterns of spirit drinks have been influenced by changed consumers' preferences and increased availability of different types of spirits on the market. Consumers' choice of one type of spirit drinks over others is significantly shaped by extrinsic attributes and consumer-based factors, but the choice among different available options of the single type of spirit may be based on consumers' perception of its specific sensory attributes. Therefore, the combination of taste, aroma, color and other sensory attributes of a spirit drink can shape consumers' perceived quality of the spirit and impact the potential of its market success in general.

Key words: aging, distilled beverages, wood cask, cognac, whisky, brandy, sensory attributes, consumer preferences, perceived quality.

Introduction

The alcoholic beverages industry is one of the most important food sectors with constantly growing interest of the industrial as well as scientific society (Babor, 2009). One potential reason for that is the fact that the global alcoholic

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beverage market was estimated at almost 1.5 trillion dollars in 2018 (Statista, 2020). Another reason is that the global alcoholic beverage market also grows annually by 7.7%, which is driven by multiple factors, such as consumer preferences, changing lifestyles, and expansion on the untraditional markets, such as China (Statista, 2020). Additionally, modern research has confirmed that moderate consumption of alcohol enriched with phenolic compounds has multiple positive effects on consumer health (e.g. reduction of the risks of coronary heart disease, certain cancer types, stroke, the elimination of *Helicobacter pylori*, etc.) (Dasgupta and Klein, 2014; Veljović, 2016).

Given the diverse nature of alcoholic beverages, they can be classified into three general groups: beer, spirit drinks, and wine (Dasgupta and Klein, 2014). Spirits are alcoholic beverages with a minimum alcoholic strength by a volume of 15% (EU Commision, 2019). The production of spirits generally includes the fermentation of various agricultural products containing carbohydrates, a distillation of fermented mixture, aging, and blending (Awad et al., 2017). Besides aromatic compounds originating from raw materials, compounds composed during the aging process are important contributors to overall sensory quality, authenticity, and uniqueness of spirit drinks (Conner et al., 2003; Pecić et al., 2012b; Pecić, 2015; Śliwińska et al., 2015; Wiśniewska et al., 2016; Canas, 2017; Veljović et al., 2019a).

Alcoholic beverages have been consumed since ancient times, and their consumption represents a common segment of social gatherings, as well as the culture of eating (Maharjan, 2019). Preferences of alcohol beverages and patterns of alcohol consumption are largely influenced by cultural and social norms, as well as the traditions of different countries (Song et al., 2018; Podstawski et al., 2019; Veljović et al., 2019b; Zasimova and Kolosnitsyna, 2020). In European culture, the consumption of alcoholic beverages is considered to be socially acceptable in many contexts and has an important role in a diet (Cravero et al., 2020). There are differences in Western and Eastern patterns of consumption. For example, in the Western culture, three categories of consumption of alcoholic beverages exist: aperitifs or pre-meal drinks, mid-meal drinks, and digestive or after-meal drinks, while in the Chinese culture, alcoholic beverages are only consumed during meals (Song et al., 2018).

This manuscript deals with the world's most important aged distilled spirits – whisky, cognac, and brandy. The production steps of these spirits are very similar, and most producers maintain that cask maturation and blending make a crucial contribution to the final character as well as sensory profiles of these aged spirits (Wiśniewska et al., 2016; Winstel and Marchal, 2019; Smailagić al., 2021). Consequently, the main focus is put on traditional and modern aging technology and its influence on sensory quality as well as consumers' preferences.

Overview of selected aged spirits

Whisky

Whisky (or whiskey) is a distilled spirit drink produced in many parts of the world (Buglass et al., 2011). According to historical data, Ireland is the country of whisky origin, while the first published data about whisky distilling was found in the Annals of Clonmacnoise dated from the year of 1405. The necessary skills for whisky distillation were brought to Scotland by missionary monks, and the earliest record of whisky production in this country dates from 1494 (Power et al., 2020). From the United Kingdom and Ireland, distillation practice expanded to countries that have been largely influenced by European emigrants, such as Canada, India and Japan. Nowadays, the United States, Canada and Japan are included among major producers (Power et al., 2020). Although the whisky technology expanded to other countries, Irish and Scotch whiskies still remain the two most valued European, as well as world whiskies, with globally recognized geographical indication.

Whisky is also an economically important spirit drink with a projected revenue of more than 87 billion in 2020, with the highest rate in India (with 19.2%) (Statista, 2020). In order to protect and standardize the quality of the whisky, basic requirements are defined by the Council Regulation (EEC) No. 2019/787 of the European Union (EU) (EU Commission, 2019). Thus, whisky is produced by distillation of a mash made from malted cereals, with or without whole grains of unmalted cereals, fermented by the action of yeast (*Saccharomyces cervisiae*); and every distillation is carried out at less than 94.8% vol. Furthermore, the distillate has an aroma and taste typical for utilized raw materials. Aging of the final distillate is limited to at least three years in wooden casks not exceeding 700-liter capacity. However, the common commercial practice is that aging is much longer, sometimes even longer than 12 years (Roullier-Gall et al., 2020). Particularly for high-quality whisky, aging in a cask is longer than five years. Generally, the period from 15 to 21 years is considered to be the optimal period for aging malt whiskies, but, from the quality point of view, the longer period can be detrimental to overall quality (Buglass et al., 2011).

Brandy

Considering the brandy market at the global level, this broad segment, regulated by Food and Drug Administration (FDA) in the USA, includes spirit drinks produced from very different raw materials, such as wine, grapes or different fruits (e-CFR, 2021). Namely, the selection of raw materials depends on local character, cost price, and availability. Consequently, due to all differences among them, there are no unique legal definitions of brandies. As well as whisky, the brandy market is generally profitable, and the projected revenue of this alcoholic beverage segment amounts to more than 60 billion dollars in 2020. In global comparison, most revenue is generated in the United States (22.7%) (Statista, 2020).

Under EEC 2019/787 (EU Commission, 2019), brandy (*Weinbrand* in German-speaking countries) is defined as a spirit drink produced by wine distillation at less than 94.8% vol. alcoholic strength. According to the regulation, a fresh distillate is required to mature in oak casks. Depending on cask capacity, the maturation time of brandy must be at least one year in oak casks or for at least six months in oak casks with a capacity of fewer than 1000 liters. The minimum alcoholic strength by volume of brandy is limited to 36%.

According to EEC 2019/787, fruit spirits, pomace spirits, and even grape brandy are not included under the term brandy. European countries have a long tradition in the production of fruit spirits, often known as fruit brandies. According to EEC 2019/787 (EU Commission, 2019), fruit spirits are defined as alcoholic beverages produced by the distillation of fermented fresh fruits or their must, with or without stones. The used type of fruits depends on the production tradition and the region of origin. Although maturation is not strictly required for fruit spirits, local fruit spirits are traditionally aged in wood casks for many years. Unlike whisky, the type of casks and the duration of maturation are not defined according to the international or local regulation for fruit spirits (Mosedale and Puech, 1998; Canas, 2017). Moreover, an ingrained belief is that the quality of aged spirit increases with the pronged aging period in wood casks, lasting even more than a few decades.

Differently from EU regulation, U.S. legislation defined fruit brandies as an alcoholic distillate from the fermented juice, mash, or wine of fruit or the residue thereof (e-CFR, 2021). Additionally, if the brandy has been stored in oak containers for less than two years, it must be labeled as immature.

Cognac

Among aged wine spirits, especially notable is a type known as cognac, produced in the Charentes region, nearly all of Charente Maritime, and some neighboring communities in Southwest France (Ferrari et al., 2004; Lurton et al., 2012). The production of cognac dates back to the 16th century and with the strictly regulated process (Canas, 2017). Thus, cognac is produced by twice distilling white wines produced in designated growing regions, also known as the Cognac region. After the distillation and during the aging process, the product is also called *eau de vie*, which means “a water of life” (Buglass et al., 2011).

As previously mentioned, for brandy, the wine spirit must be aged for at least one year or six months (Wiśniewska et al., 2016). However, cognac is a wine spirit with geographical indications, so the aging period lasts for at least two years. The importance of the cognac aging period is officially recognized under "Product specification for the cognac or *eau-de-vie* de cognac or *eau-de-vie* des Charentes controlled appellation of origin, and designations" based on the length of aging of the youngest eau-de-vie in the blend" (Official Journal of the French Republic, 2018). According to this decision, different official labels of cognac are defined due to different years of aging, as summarized in Table 1.

Table 1. The minimum age of cognac wine spirits.

Term	The star numbers	The aging years*
3 Etoiles, Sélection, VS, De Luxe, Very Special and Millésime	Compte 2	at least 2-year aging
Supérieur, Cuvée Supérieure and Qualité Supérieure	Compte 3	at least 3-year aging
V.S.O.P., Réserve, Vieux, Rare, Royal and Very Superior Old Pale	Compte 4	at least 4-year aging
Vieille Réserve, Réserve Rare, and Réserve Royale	Compte 5	at least 5-year aging
Napoléon, Très Vieille Réserve, Très Vieux, Héritage, Très Rare, Excellence, and Suprême	Compte 6	at least 6-year aging
XO, Hors d'âge, Extra, Ancestral, Ancêtre, Or, Gold, Impérial, Extra Old, XXO, and Extra Extra Old	Compte 10	at least 10-year aging starting
XXO, and Extra Extra Old	-	wine spirits that have been aged for at least 14 years.

*starting from 1 April, the year after the harvest.

Aging process

Wood packaging has been used in winemaking since pre-Christian times (Le Floch et al., 2015). In almost the same design since the Celts, wood casks have been used as the most reputable packing material for exclusive alcoholic beverages (Viriot et al., 1993; Zhang et al., 2015). Since distillation practice had not been common knowledge until the 15th century, the wood casks were first used exclusively as wooden containers for wine. After the commercialization of distillation, wood cask utilization for distillate aging became standard practice. Generally, in the early days of cask aging, the quality of cask was not of particular interest, so producers used any available cask (Buglass et al., 2011). During the centuries, the purpose of cask expanded beyond storing, so producers and consumers have come to recognize multiple benefits of aging in a wooden cask and its impact on the quality of the final spirit, mainly on sensory attributes.

The importance of the cooperage industry is proven by the value of global export, which is estimated at more than one billion dollars in 2020 (TradeMap, 2020). Furthermore, France and the United States were the dominant exporters with 51.2% and 23.1% of the total value, respectively. These data are expected since the main regions of famous oaks for cooperage have traditionally been France and the USA (Mosedale and Puech, 2003). According to TradeMap data (TradeMap, 2020), in 2020, the most dominant global importers of wood casks, which are used for aging of whisky, cognac and brandy, were the United States, the United Kingdom, France and Ireland.

Generally, the aging process has been highlighted as a critical step for producing high-quality spirits (Canas, 2017). From a legal point of view, the most prominent aged alcoholic beverages within the EU are protected from counterfeit and fraud by definitions and statements within the EEC 2019/787 (EU Commission, 2019). Thus, the basic requirement for the majority of famous aged spirits is strictly defined by law, with the main focus on the minimum aging time as well as the cask type. Furthermore, under protection by geographic origin (e.g. whisky, cognac, etc.), the regulation additionally defines the origin and quality of materials used for cask production. In many regions, the aging process also broadly refers to "traditional practices" experience and know-how that local professionals have developed over many years. This knowledge is transmitted traditionally by generations and represents a part of the specific cultural identity and cultural heritage of the regions. The geographic origin also represents an important factor of brand identity and market differentiation (Kostić-Stanković and Cvijović, 2017).

Different types of wood are used in cask production, and the selection mostly depends on the local tradition. Taking into account the differences among wood species, oaks are the most often utilized for cask production due to unquestionable superior mechanic, physical and chemical properties (Viriot et al., 1993; Smailagić et al., 2019). Out of 250 species of the genus Quercus, the following types of the oak tree, *Quercus petraea* L. (*Q. sessiliflora*) — the sessile Oak and *Quercus pedunculata* (*Q. robur*) — the pedunculate Oak in Europe, and *Quercus alba* in North America, are mostly used.

Cognac is a spirit with geographical indication, thus wooden casks are produced from particular types of oak: fine-grained Tronçais or coarser-grained Limousin, *Quercus petraea* (sessile oak) or *Quercus robur* (pedunculate oak) (Official Journal of the French Republic, 2018). Depending on the country of origin, different wooden casks are used for whisky aging. In the USA, the whisky must be aged in new, charred casks produced from white oak (Qian et al., 2019). In Scotland, reused casks used for whisky aging are of either American oak (Bourbon casks), European oak (usually Sherry casks) or rejuvenated oak (Halliday, 2004). Differently from cognac and whisky, brandy can be aged in cask produced from local oaks as well as alternative wood species (e.g. mulberry, black locust, white ash, plum, cherry, elm, etc.).

As global demand for wood casks is constantly increasing, woodcutting of all old trees (e.g. oaks are older than hundred years) have a negative effect on the environment and also threaten the future of the cooperage industry due to the non-availability and high cost of oak timbers (Smailagić et al., 2019). Thus, the International Organization of Vine and Wine (OIV) approved the use of wood fragments, including wood staves, chips or sticks, to hasten the spirits aging process (Coldea et al., 2020; Smailagić et al., 2021). Evermore, another novel trend is the utilization of alternative wood species from the local region, such as Eastern Europe.

Due to the significant time and cost differences inherent between aging in casks and with alternative methods, the final aged spirit drinks must have similar sensory attributes, mainly pleasurable and common for consumers.

Sensory analyses of aged spirits

Aged spirits are a complex alcohol-water mixture with great complexity and numerous ingredients, with the concentration that varies within an average of 0.001–1.0% (v/v). The determination of aged spirit quality is a complex problem. Besides its chemical composition, the sensory profile is generally the most important parameter for high-quality spirits, whereas aromatic compounds are the main constituent of their sensory profile. Even more, their contents, odor attributes, and thresholds are primary factors that affect the sensory quality of all alcoholic spirits, including aged spirits. Aromatic compounds can be classified into four groups: primary, secondary, tertiary and quaternary (Tešević et al., 2005; Pecić et al., 2011; Canas, 2017). The primary compounds originate from the raw material, concentrated in the inner layer of fruit skin, while grain and agricultural materials are not a rich source of aromatic compounds. In the fermentation process, the distillation and aging processes form, evoke or concentrate secondary, tertiary and quaternary aromatic compounds, respectively. All production steps have an influence on the sensory characteristics of the product, but, in standardized industrial production, the aging parameters (the maturation time and the kind of wood cask) are the main factor that defines uniqueness and its most valuable specifications.

After distillation, fresh distillates are often characterized by raw, pungent odor and taste, and consequently, they are not appropriate for consumption (Christoph and Bauer-Christoph, 2007; Pecić et al., 2012a). Thus, the fresh distillate must be aged in a wooden cask in order to create the characteristic sensory attributes (Pecić, 2015; Veljović et al., 2014). During the aging in wooden casks, the hundreds of volatile compounds derived from the wooden cask contribute to the aroma of the spirit during the aging process (Caldeira et al., 2006a). Taking into account the complexity of the aged spirit, generally, it can be pointed out that only a few compounds have the key influence on sensory perception (Pecić et al., 2016;

Tsakiris et al., 2014). Main volatile aroma compounds originated from the toasted wood include cis-β-methyl-γ-octalactone and trans-β-methyl-γ-octalactone ("whisky lactone"), vanillin, guajacol, eugenol, cresols, and other phenolic compounds. These compounds contribute to oak wood and vanilla-like flavor. A recent study has found that quercotriterpenosides, natural sweet compounds extracted from oak wood during aging soften the aroma of fresh distillates (Marchal et al., 2011; Marchal, et al., 2015). Besides the influence on overall sensory quality, the presence of particular chemical compounds, such as scopuletin, is considered as a proof of maturation in oak casks (Tsakiris et al., 2014). From a chemical point of view, the volatile compound profile of aged spirits (e.g. cognac and whisky) is almost the same qualitatively, but quantitatively, it is significantly different (Ferrari et al., 2004).

Besides the difference in the origin of wood material, Granja-Soares et al. (2020) have found that the innovative aging process undoubtedly has a greater influence on wine spirit quality than the type of wood. On the other hand, the sensory characteristics of developed aged spirits must be acceptable for sensory evaluators as well as consumers. The sensory evaluators mark the analyzed samples from a qualitative or/and quantitative point of view. For qualitative evaluation, the sensory experts describe carefully selected descriptors based on the sensory characteristics of particular spirits. The main sensory descriptors for aged spirits are woody/smoky, vanilla, toasty, caramel and spicy (Buglass et al., 2011).

Despite the extensive use of wood fragments, the regulation of the quality, labeling, and technical process has still not been considered on local or higher levels. Spirits with protected geographic designation have strict regulations, and alternative aging methods are forbidden (Schwarz et al., 2020). However, as previously mentioned, multiple factors have a strong influence on the increased utilization of alternative aging methods in the alcoholic beverage industry. Thus, recent scientific studies open the novel fields, having a strong connection between practical experience and the optimization of these processes in order to develop aged spirits of the same or ever-higher quality. In due course, it is possible that alternative aging methods may become accepted and, after a further time, become traditional, like cask aging. After all, consumers will give the final judgment of developed products, but cheaper products will represent an important market advantage and a more financially attractive business.

Attributes that influence the consumption of spirits

Multiple factors influence the multisensory perception of flavor and overall positive attitudes towards spirits. These factors are generally divided into two groups – intrinsic and extrinsic. Intrinsic factors include internal traits of the spirit itself, like taste, aroma, color, mouthfeel and aftertaste, while extrinsic factors are related to packaging, brand name, label, price, origin, marketing activities or external environment (Lee et al., 2000; Wang et al., 2019a). Both groups of factors have their impact on beverage liking and consumption. The type of alcoholic spirits preferred for consumption may also depend on situational variables (Calvo-Porral and Levy-Mangin, 2019; Pierguidi et al., 2019; Pierguidi et al., 2020), as well as psychological factors (consumers' personality traits), prior experience and expectations (Lee et al., 2000) and individual differences in taste responsiveness (Pierguidi et al., 2019; Pierguidi et al., 2020). The influence of these factors is presented in Figure 1.

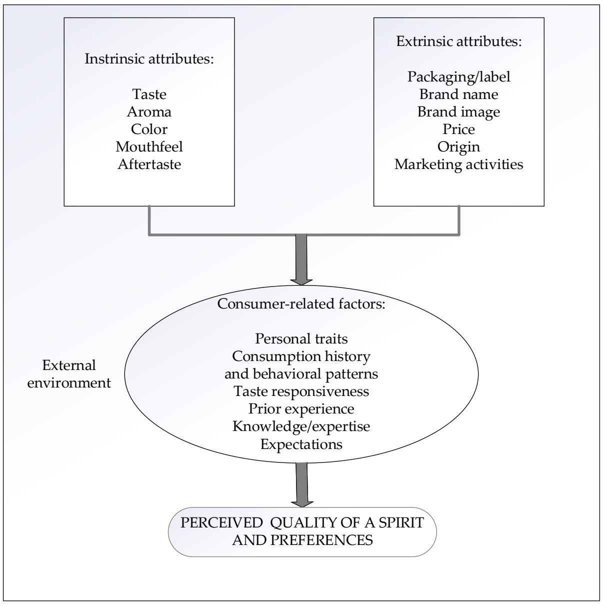

Figure 1. Groups of factors that influence consumers' preferences for alcoholic spirits.

Besides consumer-related factors, preferences of spirits are also stimulated by specific attributes of a beverage. Attributes related to taste and smell are most often taken into consideration when examining consumer preferences towards beverages (Rajić et al., 2018). In other words, the consumption of certain beverages is driven by the sensations it provides (Fiches et al., 2016). Among different consumer expectations, satisfying sensory quality is considered the key success factor for the appreciation of a product (Fiches et al., 2016). For such reason, it is necessary to analyze make an analysis of consumers' perceptions of certain sensory attributes and preferences towards alcoholic spirits (Glenk et al., 2012). Changing certain sensory attributes may result in the changed perception, and thus, the overall evaluation of a product. For example, varying the scent or color of beverages can influence the perception of their aroma. There is empirical evidence of a link between sensory properties and emotions, namely, sensory attributes act as sensory drivers of emotions, consequently leading to product (dis)liking and positive or negative affective attitudes (Spinelli and Jaeger, 2019). By obtaining data through sensory perception during the consumption of an alcoholic spirit, consumers use pattern recognition processes, which means using sensory data to constitute a holistic mental image in specific regions of the brain. As a result, they produce a flavor recognition based not only on sensory data obtained at the time of consumption but also information from long-term, short-term and sensory memory systems (Lee, 2000). This will provide valuable input for the development of novel spirits which should contain desirable sensory attributes. The identification of sensory attributes that can deliver a notion of perceived taste and drive liking of a product is important for producers in terms of developing novel products that will have greater potential to stimulate consumer satisfaction (Farah et al., 2017; Wang et al., 2019b). It will enable greater market segmentation, optimization of manufacturing processes (Cravero et al., 2020), marketing strategies for new products, reformulation of existing ones, and formulation of quality control programs (Farah et al., 2017). For such reasons, research of consumers' preferences, and the identification of key sensory attributes based on the olfactory and gustatory impression, are prerequisites for a novel product launching (Rozin and Hormes, 2010). Identifying the most significant drivers of consumption enables a better predictability of consumer behavior in different markets, which, additionally, enlarges the potential for further market expansion (Veljović and Krstić, 2020).

Sensory marketing of spirits and its impact on consumers' perception and preferences

Consumers' individual experience during eating and drinking is based on various sensations, including taste, smell and touch (Rozin and Hormes, 2010; Redondo et al., 2014). As Bachmanov et al. (2003) noted, taste, olfaction, and chemosensory irritation are three independent sensory systems that enable the perception of flavor. Anetoh et al. (2020) noted that visual, gustatory, tactile, and olfactory attributes of beverages significantly influence the purchase intentions of consumers. "In addition to its composition, the overall perceived flavor of a food is mainly impacted by the way in which volatile aroma compounds are released in the mouth and transported to the olfactory receptors in the nose during food consumption" (Déléris et al., 2011). As a result, consumer preferences significantly depend on the sensory attributes of food and drinks and flavor perception (Le Berre et al., 2007; Holt et al., 2008).

Considering the importance of sensory attributes in driving consumption, the concept of sensory marketing has been developed and implemented. Sensory marketing has gained great importance as an effective marketing approach to influence consumers (Haase and Wiedmann, 2018). It is based on creating appeals that are able to stimulate visual, olfactory, haptic, auditory, and gustatory sensory systems in a better way than is the case with traditional marketing. The incorporation of such stimuli in marketing and sales programs is often done in the food industry (Vukmirović et al., 2018). Sensory marketing has proven to be especially influential for various experiential products such as beverages (Biswas et al., 2010; Kellershohn, 2018). Krishna (2012) defined sensory marketing as "marketing that engages the consumers' senses and affects their perception, judgment and behavior". Hultén (2015) has noted that the effectiveness of sensory marketing lies in its potential to affect consumption activities, so sensory marketing is based on using implicit marketing appeals that stimulate subconscious triggers that characterize consumers' perceptions of abstract notions of products, such as their quality and sophistication. By triggering customer senses, it represents an effective way to stimulate consumers to purchase/consume products that evoke certain sensations (Krishna, 2012). In order to develop proper sensory marketing activities and appeals, as well as to evaluate the obtained results, it is necessary first to assess consumers' perception of sensory cues of a certain alcoholic spirit. In the literature, there are various scales developed for this purpose. For example, Haase and Wiedmann (2018) developed a holistic scale for the measurement of the sensory perception of consumers. As stated by Cangussu et al. (2020), "sensory analysis objectively characterizes foods and beverages through the analysis of information perceived by the human senses". In the process of the sensory evaluation process, "blind-tastings" of consumers and experts are commonly used, which aim to enable participants to express their perception of taste and preferences based on intrinsic attributes and prior experience (Lawless and Heymann, 2010; Wang et al., 2019a). Perceived taste and liking are individually shaped, and they depend on the perceived intensity of taste and flavor (Samant et al., 2017). Generally, such marketing strategies are created to promote the intrinsic properties of the spirit more than emphasizing extrinsic attributes such as brands and labels (Maharjan, 2019). As sensory marketing has been developed, it goes beyond the traditional five sensory systems and their influence on product evaluations. For example, Biswas et al. (2019) extended the concept of sensory marketing by studying the effects of the vestibular system (responsible for balance and posture) on taste perceptions. They concluded that when eating/drinking in a standing (contrary to sitting) posture, consumers evaluate the taste of foods and beverages as less pleasant.

Sensory analysis may be based on employing different methods such as discrimination testing if the goal is to determine whether the product differs from other product(s), and to perform descriptive analysis in order to determine the way it differs regarding specific sensory attributes; or sorting or projective mapping if the goal is to determine the way certain product differs from competitors holistically without reconsidering differences in specific sensory attributes. The nine-point hedonic scale ranging from extreme liking to extreme disliking is used most commonly for this purpose. Consumer testing is preferably conducted as blind testing, so the focus is put on the effects of intrinsic attributes (color, odor, taste, mouthfeel, and aftertaste) on product liking and consumers' choice so that they can are observed isolated from the effects that extrinsic attributes would have (if the price, the label, the origin would be indicated) (Heymann and Ebeler, 2016).

Sensory attributes of alcoholic spirits and their impact on consumers' preferences

There is empirical evidence that sensory characteristics drive consumer preferences of spirits and can be used for differentiation in relation to the competition. Raz et al. (2008) examined the influence of four groups of factors: color intensity, flavoring, label type and pack size, and found out that color intensity and flavoring, which represent intrinsic factors, are the main drivers of consumer preferences, while other two, which represent extrinsic factors, have a lesser effect on consumers' preferences. In their research, Monteiro et al. (2017) have found out that consumer evaluations of beverages are driven by aroma strength, color intensity and balance between sweetness and acidity. For alcoholic beverages, the aroma is found to significantly contribute to chemosensory perception and appreciation, so the quality of these beverages is to a large extent linked to aromatic richness and complexity (Le Berre et al., 2007; Holt et al., 2008; Fiches et al., 2014). Flavor plays an important role in accepting or rejecting alcoholic spirits (Bachmanov et al., 2003). Because of that, so-called flavor wheels have become popular means to illustrate the flavors that are likely to be perceived when drinking spirits like whisky or brandy, which are used for the purpose of training sensory assessors or communicating with marketing and sales departments and consumers (Lee et al., 2001; Piggott and Macleod, 2010). Spence and Wan (2015) found out that sensory qualities of the spirit can be enhanced by other factors, one of which is the shape of the glass. A glass that consumers find to be proper can enhance their perception of the sensory and hedonistic qualities of the spirit.

Cravero et al. (2020) determined three groups of customers in relation to their preferences of beverages based on investigating the individual responsiveness to various oral sensations that alcoholic and non-alcoholic beverages provoke. These groups are: "spirit-lovers" – the smallest group, mainly consisting of male consumers, aged 30–45, who enjoy consuming alcoholic beverages of any kind, especially spirits, more than other segments; “beer/wine lovers” – the group that consists of older consumers of both genders; “mild-drink lovers” – the group that includes mainly women, aged 18–29, who demonstrate a lower consumption of alcohol but like alcoholic drinks with an intensely sweet taste and/or mixers that moderate the perception of ethanol.

Ethanol is considered to be the defining component of all alcoholic beverages, which, due to its physiochemical properties, has a tremendous influence on flavor perception and chemosensory evaluation of beverages, including distilled spirits. There is plenty of empirical evidence that changes in ethanol concentration can have an impact on alcoholic beverage flavor perception in terms of taste, aroma and mouthfeel (Le Berre et al., 2007; Boothroyd et al., 2012; King et al., 2013; King and Heymann, 2014; Ickes and Cadwallader, 2017; Ramsey et al., 2018). It has been shown that the dilution of whiskies to 23% ABV for “nosing” in the presence of long-chain ethyl esters is likely to change aroma perception (Boothroyd et al., 2012). When examining the role of ethanol in the aroma of whisky, Poisson and Schieberle (2008) emphasized the “masking effect” of ethanol, especially regarding fruity aroma, since an aroma model with a lower level of ethanol demonstrated a more expressed fruitier note as the complete model.

Distilled spirits, such as whiskies and brandies, are valued by consumers for the richness of their aroma and changes during product consumption (Glenk et al., 2012). Because of that, the aroma and flavor of whisky, cognac and other distilled spirits are critical factors of consumer acceptance, and therefore, must be regularly evaluated and controlled by conducting sensory analysis (Piggott and Macleod, 2010). As Poisson and Schieberle (2008) noted, whisky’s characteristic is a unique aroma based on a combination of smoky, malty odors with a characteristic sweet, vanilla-based flavor note. Lee et al. (2000) defined a set of 16 compounds of whisky flavor standard (namely: acetic acid (sour), diacetyl (buttery), dimethyl trisulphide (sulphury), ethyl hexanoate (fruity-appley), ethyl laurate (soapy), furfural (grainy), geraniol (floral), guaiacol (smoky), hexanal (grassy), iso-amyl acetate (fruity-banana), iso-valeric acid (sweaty), maltol (sweet), phenyl ethanol (floral), vanillin (vanilla), 4-vinyl guaiacol (spicy) and whisky lactone (coconut)) that were recognized by 90% of assessors in their analysis. However, some authors pointed out the important influence of extrinsic attributes on the evaluation of the overall quality of the whisky, which means that the perception of whisky quality, as a result of the synergistic and holistic perceptual process, is “more than the sum of its component perceptions” (Wang et al., 2019a). Piggott et al. (1990) emphasized that differences in consumer perceptions of flavors of different types of whisky may be a result of perceptions of non-sensory attributes. According to their research findings, malt whisky was made clearly distinctive in relation to standard and deluxe blended whiskies and clustered together with brandy and liqueurs by female consumers. Authors noted that, in the case of female consumers, who generally consume whisky significantly less than male consumers and possess little knowledge of the product, the appreciation of the finer whiskies is possibly developed primarily based on their image and not on intrinsic attributes.

Maharjan (2019) noted that brandy is a wide spirit category that includes a large number of different types of spirits, so it is necessary to explore what drives consumers' preferences and choices of certain types of brandy. The study of Fiches et al. (2014) emphasized the impact of aroma perception on the global sensory image of brandies. They concluded that differences in perception of different French grape brandies appeared to be based on differences in their volatile composition, which depends on aroma formation and steps in manufacturing processes, like fermentation and distillation. Fiches et al. (2016) studied the origin of temporal perception during the consumption of five brandies with different aging and qualities by applying sensory analysis. The results of the temporal sensory analysis demonstrated common perception sequences for all brandies related to taste and trigeminal sensations, while different aromatic sequences were emphasized between products, based mainly on their aging. Similar release patterns were noted in all cases, even though higher intensities were determined for esters in aged brandies, as they were present at higher levels. Additionally, the overall perception of brandies could be influenced by aroma compounds from wood which interacts with other perceptions. The impact of certain compounds of brandy flavor on the perceived quality was also confirmed in the literature. The compounds like toasted, woody, vanilla, body, flavor persistence and spicy were found to be significantly correlated with brandy quality, while the tails, green and caoutchouc (rubber) characters appeared to be negatively correlated with brandy quality. Also, the complexity of brandy flavor appeared to have a highly significant influence on quality. There is a certain flavor evolution that happens in brandy over the period of five years of maturation, so the intensity of aroma notes such as vanilla, woody, caramel, toasted, and smoke increases over time and may reach equilibrium after four years of maturation (Caldeira et al., 2006b). Louw and Lambrechts (2012) pointed to the empirical evidence that the majority of sensory modifications of brandies occur during the first three years of maturation in wood. Caldeira et al. (2006b) have concluded that the flavor complexity of brandies consistently increases for the period of at least the first five years of maturation in new oak barrels. On the other hand, alcoholic and glue-like attributes show a decrease over time, while attributes like dried fruits, smooth, tails and caoutchouc/rubber may not be uninfluenced by the maturation process. The findings of Caldeira et al. (2010), who applied sensory analysis to evaluate the effects of chestnut and oak barrels on the sensory attributes of Portuguese brandies, indicate that smoky aroma stands out as an important attribute that contributes to the perception of brandy quality.

The research conducted by Song et al. (2018) had the goal to provide valuable information for the creation of marketing communication strategies for cognac brands tailored for American and Chinese consumers, based on different perceptions of the importance of different attributes. They found out that, in the case of American consumers, marketing appeals should be focused on the sensation and hedonistic character of cognac, including its taste, luxury feature and informal social settings where it is most often consumed. On the other hand, Chinese customers value most the social utilitarian functions of cognac and appreciate cognac brand more if it is associated with European culture, elitist lifestyle and business occasions for consumption.

Conclusion

The aging process has been highlighted as a key step for producing high-quality spirit drinks. Although other methods for aging are frequently used in practice, the regulation of the quality, labeling, and technical process is still not considered on local or higher levels. Spirits with protected geographical indications have strict regulations, and alternative aging methods are forbidden. Multiple factors have a strong influence on the increased utilization of alternative aging methods in the alcohol beverage industry. Recently, scientific studies have opened novel fields, making a strong connection between practical experience and optimization of these processes in order to develop aged spirits of the same or even higher quality.

The consumption of alcoholic beverages derives from ancient times, and today, it represents a common element of many social occasions and the culture of eating. Consumers react to the organoleptic properties of alcoholic beverages with their senses, so the perception of sensory information leads to the overall evaluation of the quality of the spirit. Identifying the key sensory attributes that drive the liking of a spirit is valuable in the process of the development of novel products, as well as for creating effective marketing appeals that have the potential to attract customers and stimulate purchasing and consumption. The identification of sensory attributes of distilled spirits, like whiskies, brandies and cognac, famous for the richness of their aroma and flavor, represents a critical factor for understanding consumer preferences, and therefore, it must be regularly performed by applying sensory analysis.

Finally, consumers will give the final judgment of developed aged spirits, but cheaper products will represent an important market advantage and a more financially attractive business. In due course, it is possible that alternative aging methods may become accepted and, after a further time, become traditional, like cask aging.

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TRADICIONALNE I INOVATIVNE TEHNOLOGIJE SAZREVANJA DESTILATA: UTICAJ NA NJIHOV KVALITET I SKLONOST POTROŠAČA PREMA SAZREVANIM ALKOHOLNIM PIĆIMA

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R e z i m e

Sazrevanje je jedan od najvažnijih procesa proizvodnje visokokvalitetnih alkoholnih pića, uključujući viski, rakiju i konjak. Kontakt drveta i destilata je presudan korak za migraciju hemijskih jedinjenja koja evociraju nova senzorna svojstva konačnih proizvoda. Novi ukus je ugodan za vrlo široku grupu potrošača i zavisi od kulturološki uslovljenih preferencija. Da bi se demistifikovala glavna hemijska jedinjenja, koja doprinose aromi, njihovo povezivanje sa senzornim profilom alkoholnih pića, koja su starila u buradima je presudan korak za ubrzanje vrlo dugotrajnog procesa, bez smanjenja kvaliteta. Na obrasce konzumiranja alkoholnih pića uticali su promenjene sklonosti potrošača i povećana dostupnost različitih vrsta alkoholnih pića na tržištu. Izbor jedne vrste alkoholnih pića u odnosu na druge značajno je oblikovan spoljašnjim atributima pića i faktorima koji zavise od samih potrošača, ali izbor između različitih dostupnih opcija jedne vrste alkoholnog pića može se zasnivati na potrošačkoj percepciji njegovih specifičnih senzornih atributa. Stoga, kombinacija ukusa, arome, boje i drugih senzornih atributa alkoholnih pića može da oblikuje percipirani kvalitet od strane potrošača i generalno utiče na potencijal njihovog tržišnog uspeha.

Ključne reči: sazrevanje, destilati, drvena burad, konjak, viski, rakije, senzorni atributi, preferencije potrošača, percepirani kvalitet.

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THE PERFORMANCE OF NEW EARLY MATURING PRO-VITAMIN A MAIZE (*ZEA MAYS* L.) HYBRIDS IN THE DERIVED SAVANNA AGRO-ECOLOGY OF NIGERIA

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Abstract: Maize (*Zea mays* L.) is a staple food for millions of people across the globe, and it supplies more than 30% of total dietary calories. However, the normal endosperm lacks a sufficient quantity of the nutritive precursor of vitamin A. To achieve food security and avert malnutrition, there is a need to adopt the cultivation of the early multiple stress-tolerant pro-vitamin A maize hybrid. The objective of this study was to assess the agronomic performance and yield of the newly developed maize hybrids. Fifteen improved maize hybrids and one commercial hybrid used as a local check were evaluated in a randomized complete block design with two replications for two years at the Ladoke Akintola University of Technology Teaching and Research farm in Ogbomoso, Nigeria. Hybrids exhibited significant variation ($P < 0.01$) for grain yield, number of days to anthesis and silking, ear height and husk cover. Across the years, the grain yield of hybrids ranged between 4,780.8 kg ha^{-1} (PVAEH-19) and 7,886.9 kg ha^{-1} (PVAQEH-1), with a mean of 6,354.2 kg ha^{-1}. PVAEH-15 ranks the best on the basis of superiority in grain yield, early flowering and tight husk cover. Fourteen hybrids out-yielded the local check (4,947.2 kg ha^{-1}), and five hybrids had a significant ($P < 0.05$) yield advantage of > 26% over the local check. The consistent performance of PVAEH-15 and PVAEH-16 in the two years of evaluation indicates potential for the adaptability of the hybrids to the agro-ecology. Farmers' adoption of these maize hybrids will boost maize production and prevent malnutrition in the derived savanna agro-ecology of Nigeria.

Key words: adaptation, agronomic traits, evaluation, grain yield, malnutrition.

Introduction

Maize (*Zea mays* L.) is a staple crop and source of calories, proteins, vitamins and minerals. It accounts for an average of 15–20% of the daily calories in the diets

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of inhabitants of sub-Saharan Africa (SSA) and is the source of income for smallholder farmers (FAOSTAT, 2016). Maize adapts to different environments and serves as an important feed, fodder and industrial crop due to its popularity across regions (Randjelovic, 2011). It has been forecasted to become the crop with the highest production by 2025, and the demands will be doubled by 2050 (Rosegrant et al., 2008). The development and deployment of improved maize cultivars by international and national research institutes assured increased maize productivity in the savanna agro-ecologies.

The savanna agro-ecologies of Nigeria have great potential for food production because of their high solar radiation favouring maize production (Bello et al., 2012). Like the rainforest region, the derived savanna experiences adequate annual precipitation and ample solar radiation as the Guinea savanna. These weather conditions result in a suitable environment for agricultural production. In spite of the growing reputation of maize as a chief income earner for resource-limited farmers in SSA over the last few decades (Fakorede et al., 2003; FAOSTAT, 2016), its yields on smallholder farmers' fields remain low owing to diverse abiotic and biotic stresses (drought, heat waves, low soil nitrogen (low-N), foliar diseases, insect infestations and *Striga hermonthica* parasitism) among which drought is the most disturbing (Hao et al., 2011; Mir et al., 2012).

In the tropics, maize cultivation occurs mainly under rainfed conditions and is usually exposed to random drought, which results in crop losses and, occasionally, a total crop failure. This situation is worsened by the rising impact of global climate change, compelling maize production into marginal, drought-prone zones (Bello et al., 2012). Terminal drought during grain-filling growth phases can be devastating in maize breeding as a result of enhancing leaf senescence, reduction in leaf gas exchange parameters, chlorophyll content of the plant and consequently a reduction in grain yield (Habuš-Jerčić et al., 2018). With the occurrence of random drought in the derived savanna, early maturing maize genotypes that can avoid drought and other stress factors at flowering could be important in reducing losses (Olaoye et al., 2009; Hussain, 2011). Early maturing maize varieties can be beneficial in various cropping systems like intercropping and mixed cropping by competing less for moisture, light, and nutrients than the late-maturing varieties. Their planting period can also be adjusted, thereby aiding multiple planting cycles in a season to lessen the risk of losing a single crop to weather hazards (Pswarayi and Vivek, 2008). The unpredictable changes in environmental conditions affect the performance of maize genotypes. Thus, evaluating the performance of new maize hybrids in a specific agro-ecology is essential.

Furthermore, maize varieties of standard grain quality have a deficiency in amino acids (lysine and tryptophan) and micronutrient supplements (pro-vitamin A), which may result in widespread malnutrition. Micronutrient deficiency, also known as hidden hunger, is a health condition caused by the lack of essential vitamins and minerals required by the human body in small quantities (Nguyen et al., 2014). Vitamin A deficiency (VAD) has been established as a serious public health problem worldwide (Tsegaye Demissie et al., 2009; Akhtar et al., 2013). The menace of VAD is more pronounced in the developing economies of the world, where it is mainly caused by the inadequate consumption of foods that are rich in vitamin A (Tsegaye Demissie et al., 2009). In Africa, it has affected 54 million children and 4 million women (WHO, 2009; Mason and Shrimpton, 2010). β-carotene is a precursor of vitamin A and enhancing their concentration in maize grain enables better absorption of mineral nutrients (Kravić et al., 2014). However, maize may be used as a vehicle to tackle this deficiency through the utilization of improved quality varieties with the crop biofortification approach (Miller and Welch, 2013). Therefore, the adoption of early multiple stress-tolerant, pro-vitamin A (PVA) maize hybrid for cultivation by farmers will boost maize nutrient availability, productivity and income.

The maize improvement programme of the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, possesses a genetically variable maize germplasm. They develop and maintain diverse genetic resources, which are useful sources of resistance and/or tolerance to biotic and abiotic stresses, higher grain yield potential, improved quality, earliness and wide adaptation. Improved genetic materials from the Institute's breeding programmes are disseminated to partners as either regional or international trials. The evaluation of the improved genotypes for adaptability and yield potential in the diverse growing environments will determine their suitability for cultivation by farmers in the agro-ecologies. Therefore, it is pertinent to assess the newly developed early maturing PVA enhanced maize hybrids for their reactions to other stress factors that may be unique to the derived savanna agro-ecology and also to identify hybrids that can replace existing cultivars for cultivation in farmers' fields. The objective of this study is, therefore, to assess the agronomic performance and yield of the early multiple stress-tolerant PVA enhanced maize hybrids, with the view to identify hybrids cultivated in the derived savanna agro-ecology of Nigeria.

Materials and Methods

Genetic materials

Sixteen (16) hybrid varieties comprising fifteen (15) multiple stress-tolerant PVA maize hybrids belonging to the early maturing group, which was originally part of international trials developed by the maize improvement programme (MIP) of IITA Ibadan, Nigeria, and a popular farmers' commercial hybrid, Oba Super 6, which is well adapted to the Savanna agro-ecologies, were used in this study (Table 1).

The hybrids were evaluated during the main growing seasons of 2018 and 2019 at the Teaching and Research (T&R) Farm of the Ladoke Akintola University of Technology (LAUTECH), Ogbomoso (8°10′N, 4°10′E, and altitude 341 m above sea level). The location is in the derived savanna agro-ecology of Nigeria. The annual mean rainfall of the experimental site ranges between 1,000 and 1,200 mm, while the daily temperature is between 28°C and 30°C. The soils are characterized as alfisol, which is generally low in nitrogen. The rainfall data for the years of the experiment (Figure 1) was obtained from the weather station situated at the Faculty of Agricultural Sciences, LAUTECH, Ogbomoso.

Table 1. The list of genetic materials used in this study.

Entry	Hybrid	Grain colour	Origin
1	PVAEH-14	Orange	IITA
2	PVAEH-15	Orange	IITA
3	PVAEH-16	Orange	IITA
4	PVAEH-17	Orange	IITA
5	PVAEH-18	Orange	IITA
6	PVAEH-19	Orange	IITA
7	PVAEH-20	Orange	IITA
8	PVAEH-21	Orange	IITA
9	PVAEH-22	Orange	IITA
10	PVAEH-23	Orange	IITA
11	PVAEH-24	Orange	IITA
12	PVAQEH-1	Orange	IITA
13	PVAEH-25	Orange	IITA
14	PVAQEH-2	Orange	IITA
15	Check(RE)	Yellow	IITA
16	Oba super 6	Yellow	Local Check

PVAEH = Pro-vitamin A early hybrid; PVAQEH = Pro-vitamin A QPM early hybrid; RE = Reference entry.

The experiment for each year was established in the first week of June when the rains have become steady. The sixteen hybrids were planted each year in a randomized complete block design (RCBD) with two replications. Each plot was a double 5-m row spaced 0.75 m apart with 0.50-m spacing between plants within each row. Three seeds were planted per hole and were later thinned to two plants per stand 2 weeks after sowing to attain the optimum population density of 53,333 plants ha^{-1}. NPK 15-15-15 fertilizer was applied at the rate of 60 kg N, 60 kg P, and 60 kg K per hectare at the time of sowing. Urea (45% N) was applied 4 weeks after sowing as top-dressing at the rate of 60 kg N ha^{-1} to achieve a total of 120 kg N ha^{-1} recommended for maize production in the zone. A mixture of herbicides including gramoxone (post-emergence) and primextra (pre-emergence) was applied at the rate of 5.0 l ha^{-1} at sowing, and manual weeding was subsequently done to keep the experimental plots weed-free.

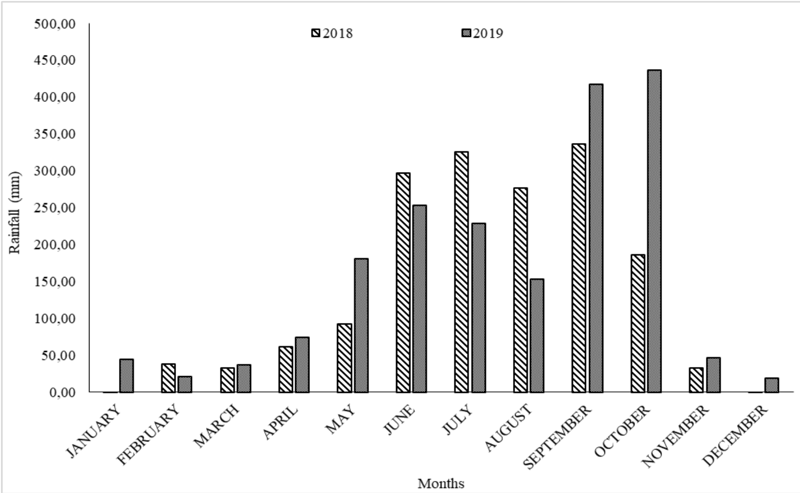

Figure 1. The monthly rainfall distribution pattern for Ogbomoso in 2018 and 2019.
Source: LAUTECH weather station, Ogbomoso, Nigeria.

Data collection and analyses

For each plot in each year's experiment, data were taken on the following traits: anthesis dates were recorded as the number of days from sowing to pollen shed for 50% of the plants in a plot; silking dates were taken as the number of days from sowing to silk emergence for 50% of the plants in a plot; anthesis-silking interval (ASI) was then calculated as the difference between silking and anthesis dates; plant height was measured in centimeters (cm) as the distance from the base of the plant to the height of the first tassel branch; ear height was also measured in cm as the distance from the base of the plant to the node bearing the upper ear; plant aspect was visually scored on a scale of 1–5, where 1 = excellent overall phenotypic appeal and 5 = poor overall phenotypic appeal; husk cover was visually rated on a scale of 1–5, where 1 = husks tightly arranged and extended beyond the ear tip and 5 = ear tips exposed; ear aspect was also visually assessed on a scale of 1–5, where 1 = clean, uniform, large, and well-filled ears, and 5 = rotten, variable, small, and partially filled ears; number of ears per plant was calculated as the ratio of number of harvested ears to number of harvested plants; grain yield measured in kg ha^{-1} was extrapolated from field weight and grain moisture recorded at harvest and was adjusted to 15%.

A separate analysis of variance (ANOVA) was performed on the data collected on an individual year basis. The ANOVA results of 2018 and 2019 data show moderate heritability estimates (0.35–0.83) and a low coefficient of variation

(2.34–24.26%) for all traits measured, thereby justifying the analysis across the years. The data for the two years were pooled for combined ANOVA, year and replications were considered as random factors, whereas the hybrids were considered as fixed effects. Entry means were generated for each trait and were separated using Fisher's protected least significant difference test (LSD) at $P < 0.05$ according to Steel and Torrie (1980). All analyses were performed using PROC GLM, in SAS (SAS Institute, 2011). A rank summation index (RSI) (Mulumba and Mock, 1978) was constructed to determine the overall performance of each entry. The index was obtained by ranking each entry for grain yield, number of days to anthesis, number of days to silking and tight husk cover. The 16 genotypes were ranked from the lowest to the highest for each trait, and RSI was calculated by summing the ranks to select the top five outstanding maize hybrids. Thus, the lowest index value obtained by an entry would be 4.0 if it was superior for all four traits.

Results and Discussion

The combined ANOVA revealed that year was a significant ($P < 0.01$) source of variation for all measured traits, and its sums of squares, expressed as percentages of the corrected total sums of squares, accounted for 3–49% of the total variation for all agronomic traits measured. On the other hand, the mean square of hybrid x year interaction was significant ($P < 0.05$) only for number of days to anthesis, suggesting that the hybrids displayed consistent performance over the years of evaluation, therefore aiding the identification of potentially high-yielding hybrids for the location. Previous authors have identified superior hybrids based on the absence of significant interaction between the hybrids and year for grain yield in maize (Menkir et al., 2014; Abera et al., 2016). The mean square of hybrids differed significantly ($P < 0.05$ / 0.01) for grain yield, number of days to anthesis and silking, ear height and husk cover. The observed variations may be a result of the diverse genetic makeups and backgrounds of the parental materials used in their formation. The coefficient of variation (CV) was > 20% only for ASI, ear aspect and husk cover ratings (Table 2).

Considering the traits that showed significant variation, the year of 2018 was the most favourable for the expression of grain yield potential. Although the amount of rainfall was evenly distributed in both years, the year of 2018 had higher rainfall between June and August (Figure 1) which were crucial periods for growth, flowering and grain filling. Hence, grain yield varied between 7,509.4kg ha^{-1} (PVAEH-19) and 11,349.3 kg ha^{-1} (PVAEH-23) with a mean of 9,272.9 kg ha^{-1}. PVAEH-23 had the highest grain yield potential, which differed significantly ($P < 0.05$) from 9 of the early maturing PVA maize hybrids. All the early maturing PVA maize hybrids out-yielded the local check (6,656 kg ha^{-1}), but only 8 hybrids had a significant ($P < 0.05$) yield advantage of > 25% over the local check. The hybrids shed pollen between 46 and 58 days, and number of days to silking was between 52 and 62 days after sowing (DAS) with PVAEH-16 and PVAEH-15 as the earliest for both traits. The hybrids also had vigorous growth, with ears placed at an average of 105.1 cm and a mean husk cover rating of 2.3. Incidentally, PVAEH-23, which had the highest grain yield, also was superior for tight husk cover (Table 3). The abundant soil moisture at anthesis and silking in 2018 allowed each hybrid to express their yield potential. The hybrids flowered earlier and had a shorter ASI than the check. The early flowering results in early seed set, grain filling and maturity, which are important for drought escape (Shavrukov et al., 2017; Senapati et al., 2019). Lower ear height in comparison to the local check was desirable because plants with higher ear placement are usually more prone to root and stalk lodging.

Table 2. Combined mean squares for grain yield and other agronomic traits of the evaluated maize hybrids.

Source	df	Grain yield (kg ha^{-1})	Anthesis (days)	Silking (days)	Anthesis -silking interval (days)	Plant height (cm)	Ear height (cm)	Number of ears per plant	Husk cover (1-5)	Plant aspect (1-5)	Ear aspect (1-5)
Year (Y)	1	318647490.5***	7.6*	74.4**	34.5**	36247.4***	47006.2***	2.3**	18.1***	93.8***	6.9***
Replicate	1	68705325.7***	18.5**	103.8***	44.6**	15848.7***	6353.2***	0.1	0.1	24.0***	0.8
Hybrid (H)	15	3882455.8**	204.2***	16.2***	4.4	189.9	172.1*	0.3	0.5*	0.4	0.5
H × Y	15	1972515.7	4.4*	2.8	4.2	203.4	87.7	0.3	0.2	0.2	0.4
Error	32	1393889.5	2.2	6.2	4.7	195.7	114.0	0.2	0.4	0.5	0.3
CV		18.8	2.9	4.5	37.4	8.7	14.1	9.1	22.2	18.8	21.7

*, **, *** indicate mean squares significant at 0.05, 0.01 and 0.001 probability levels, respectively.

On the other hand, the highest amount of rainfall in 2019 was between September and October towards the end of the grain filling period, and this resulted in a grain yield range of 2,961.8kg ha^{-1} (PVAEH-19) to 5,863.1 kg ha^{-1} (PVAQEH-1) with a mean of 4,370.9 kg ha^{-1}. PVAQEH-1 had the highest grain yield potential, which differed significantly ($P < 0.05$) from five of the early maturing PVA maize hybrids, while the same hybrid (PVAEH-19) with the lowest yield in the previous year was still the poorest in terms of yield potential in 2019. Twelve hybrids had higher grain yield than the local check (3,808.0 kg ha^{-1}), but only one hybrid (PVAQEH-1) had a significant ($P < 0.05$) yield advantage of 35% over the local check (Table 3). Number of days to anthesis was between 49 and 54 DAS, while silking dates varied between 54 and 63 DAS with PVAEH-16 as the earliest for both traits. The hybrids had a reduced mean ear height of 54.7 cm and a mean husk cover rating of 3.2, with PVAEH-17, PVAEH-18 and PVAEH-23 hybrids with the lowest husk cover rating (2.7).

Table 3. The mean performance of maize hybrid traits with significant variations from the two years of evaluation.

Hybrid	2018				
	Grain yield (kg ha-1)	Anthesis (days)	Silking (days)	Ear height (cm)	Husk cover (1–5)
PVAEH-14	8106.7	51.0	57.0	104.5	2.3
PVAEH-15	11093.4	47.5	52.5	111.5	2.3
PVAEH-16	8362.7	46.0	54.5	95.0	2.3
PVAEH-17	8192.0	51.5	55.5	100.0	2.0
PVAEH-18	8618.7	50.5	55.0	107.0	2.3
PVAEH-19	7509.4	51.0	54.5	104.5	2.8
PVAEH-20	9216.0	49.5	54.0	99.0	2.8
PVAEH-21	8960.0	51.0	53.5	108.0	2.3
PVAEH-22	7594.7	50.5	55.0	102.0	2.3
PVAEH-23	11349.3	50.5	54.5	106.5	1.5
PVAEH-24	8362.7	51.0	55.5	101.0	2.3
PVAEH-25	9386.7	49.0	53.5	103.0	2.3
PVAQEH-1	10922.7	52.5	58.5	113.0	2.3
PVAQEH-2	10752.0	51.0	55.0	116.0	2.3
Check(RE)	10666.7	49.5	53.0	105.5	2.8
Minimum	7509.4	46.0	52.5	95.0	1.5
Maximum	11349.3	52.5	58.5	116.0	2.8
Grand mean	9272.9	50.1	54.8	105.1	2.3
LSD (0.05)	2190.4	3.0	2.8	13.5	1.1
Local check	6656.0	58.0	61.5	113.0	1.8
Hybrid	2019				
	Grain yield (kg ha-1)	Anthesis (days)	Silking (days)	Ear height (cm)	Husk cover (1–5)
PVAEH-14	5137.8	52.3	59.7	50.4	3.0
PVAEH-15	3808.0	49.0	57.0	58.4	3.0
PVAEH-16	4533.3	48.7	54.3	55.6	4.0
PVAEH-17	3868.4	50.3	58.0	64.8	2.7
PVAEH-18	4291.6	52.3	59.3	57.5	2.7
PVAEH-19	2961.8	51.7	59.7	49.4	3.7
PVAEH-20	4231.1	51.0	56.7	54.7	3.0
PVAEH-21	3445.3	52.0	57.0	60.3	3.7
PVAEH-22	4352.0	53.0	58.3	57.2	3.7
PVAEH-23	4714.7	52.0	59.0	49.2	2.7
PVAEH-24	4835.5	52.0	57.3	57.0	3.0
PVAEH-25	3928.9	52.0	58.3	33.0	3.7
PVAQEH-1	5863.1	52.3	60.0	61.7	3.0
PVAQEH-2	5319.1	51.0	58.0	55.4	3.0
Check(RE)	4835.6	52.7	57.3	56.8	3.0
Minimum	2961.8	48.7	54.3	33.0	2.7
Maximum	5863.1	53.0	60.0	64.8	4.0
Grand mean	4408.4	51.5	58.0	54.7	3.2
LSD (0.05)	1775.7	2.1	4.2	19.5	1.1
Local check	3808.0	53.3	62.3	69.4	3.0

Other agronomic traits from each year of the evaluation showed disparity for all traits measured (Table 4). In the first year of evaluation, the flowering parameters were earlier, the hybrids had shorter ASI with a corresponding higher grain yield and number of ears per plant, taller plant and ear heights, lower husk cover, plant aspect and ear aspect ratings in comparison to the second year of the evaluation. Moreover, the grain yield of 11,349.3 kg ha^{-1} by PVAEH-23 in 2018 was more than twice the mean grain yield recorded (4,370.8 kg ha^{-1}) in 2019 and close to double the mean grain yield of the top hybrid (5,863.1 kg ha^{-1}) in 2019. Also, the commercial local check (Oba Super 6) showed instability for grain yield with a difference of 43% between the two years of the evaluation. The growth of the male and female flowers and their synchrony, which ensures good nicking, are dependent on the weather and edaphic features of the trial location. As a reflection of the weather pattern, growth and maturation progressions in 2018 were desirable in comparison to 2019. During the growing season of 2019, we experienced an unpredicted change in the rainfall pattern of Ogbomoso and its environs, which resulted in the form of random drought.

Table 4. Effects of years on the mean performance of grain yield and other measured agronomic traits of the evaluated PVA maize hybrids.

Traits	2018		2019		Mean±Standard error		Mean difference
	Min.	Max.	Min.	Max.	2018	2019	
Grain yield (kg ha^{-1})	7509.4	11349.3	2961.8	5863.1	9272.9±345.9	4377.9±205.8	4895.0
Anthesis (days)	46.0	52.5	48.7	53.0	50.1±0.4	51.4±0.3	-1.3
Silking (days)	52.5	58.5	54.3	60.0	54.8±0.4	58.0±0.4	-3.3
Anthesis-silking interval (days)	2.5	8.5	5.0	8.0	4.6±0.4	6.6±0.3	-2.0
Plant height (cm)	188.0	220.0	115.4	146.6	201.7±2.4	132.9±2.3	68.8
Ear height (cm)	95.0	116.0	33.0	64.8	105.1±1.4	54.6±2.1	50.5
Husk cover (1–5)	1.5	2.8	2.7	4.0	2.3±0.1	3.2±0.1	-0.9
Plant aspect (1–5)	2.0	2.8	4.3	5.7	2.3±0.1	4.9±0.1	-2.6
Ear aspect (1– 5)	2.0	2.8	2.0	3.3	2.3±0.1	2.7±0.1	-0.4
Number of ears per plant	1.0	1.1	0.6	0.9	1.0±0.0	0.8±0.0	0.2

Likewise, armyworm (*Spodoptera frugiperda*) infested maize fields during the rainy season of 2019, causing serious devastation, which was unprecedented. The above exigencies contributed to the significant reduction in grain yield and poor agronomic performance of the maize hybrids evaluated in 2019. Consequently, the mean performance of all measured traits in the two years of the evaluation was adversely affected.

From the combined entry means over the two years, the grain yield of hybrids ranged between 4,780.8kg ha^{-1}(PVAEH-19) and 7,886.9 kg ha^{-1}(PVAQEH-1) with a mean of 6,354.2 kg ha^{-1} (Table 5). Across the years, PVAQEH-1 had the highest yield, all of the early maturing PVA maize hybrids except for PVAEH-19 out-yielded the local check (4947.2 kg ha^{-1}), and five hybrids had a significant ($P < 0.05$) yield advantage of > 26% over the local check. The mean difference between the flowering dates of the hybrids and the local check was around 4–5 days, whereas ASI was just one day. Other measured traits of the hybrids were comparable to the local check except for ear height which was lower. The mean grain yield of 6.3 t ha^{-1} reported in this study is a reduction in yield expectation over the years. The disparity between the yields obtained in 2018 and 2019 is responsible for the lower average yields. The average hybrid maize grain yield between 8 and 10 t ha^{-1} has been previously reported under disease-free conditions in maize breeding (Ininda et al., 2006; Adebayo et al., 2014). Hence, the genetic potentials of the hybrids were influenced by the year variation, as having been similarly identified in previous studies as a cause of a possible yield reduction (Beyene et al., 2012; Chabala et al., 2015; Jaya et al., 2020).

The agronomic traits that showed significant variability among the hybrids evaluated were used to rank their performance. These desirable agronomic traits are essential in determining the suitability and adaptability of the hybrid to the derived savanna agro-ecology. Across the years, the rank summation index based on the aforementioned traits shows that PVAEH-15 ranked best and PVAQEH-2 ranked 5th, although PVAEQH-1 gave the highest grain yield (7,886.9) across the years. In 2018, three of the hybrids listed among outstanding hybrids constituted the top five across the years, whereas, in 2019, four of the hybrids listed among superior hybrids constituted the top five across the years. Ranking based on each year shows that both years had two hybrids (PVAEH-15 and PVAEH-16) in common listed among the top five (Table 6). Although several PVA open-pollinated varieties and hybrids have been released for commercialization in SSA, their agronomic performance differs across several production environments, but adaptability to the specific environment will determine suitability for farmers' cultivation. It is imperative to note that the top five hybrids across the years (PVAEH-15, PVAEH-16, PVAEH-20, PVAEH-23 and PVAQEH-2) were also among the outstanding hybrids listed from each year of the evaluation based on superiority in grain yield, flowering traits and husk cover ratings. In spite of the disparity in the distribution and amount of rainfall in the two years of evaluation, the consistent performance of PVAEH-15 and PVAEH-16 across the years indicates potentials for adaptability of the hybrids to the agro-ecology, especially as they also out-yielded the local check. These hybrids can be especially important for small-scale farmers, providing stable food production from year to year. Hence, the adaptability of these outstanding hybrids to the growing environment will enhance sustainable productivity, and these early maturing PVA maize hybrids may be used to replace existing cultivars in the derived savanna agro-ecology of Nigeria.

Table 5. The combined mean performance for grain yield and other agronomic traits of the evaluated maize hybrids.

Hybrid	Grain yield (kg ha^{-1})	Anthesis (days)	Silking (days)	Anthesis-silking interval (days)	Plant height (cm)
PVAEH-14	6325.3	51.8	58.6	6.8	150.6
PVAEH-15	6722.1	48.4	55.2	6.8	172.6
PVAEH-16	6065.1	47.6	54.4	6.8	165.6
PVAEH-17	5597.9	50.8	57.0	6.2	163.2
PVAEH-18	6022.4	51.6	57.6	6.0	163.3
PVAEH-19	4780.8	51.4	57.6	6.2	158.6
PVAEH-20	6225.1	50.4	55.6	5.2	153.4
PVAEH-21	5651.2	51.6	55.6	4.0	162.3
PVAEH-22	5649.1	52.0	57.0	5.0	158.0
PVAEH-23	7368.5	51.4	57.2	5.8	156.6
PVAEH-24	6246.4	51.6	56.6	5.0	155.8
PVAEH-25	6112.0	50.8	56.4	5.6	163.0
PVAQEH-1	7886.9	52.4	59.4	7.0	166.3
PVAQEH-2	7492.3	51.0	56.8	5.8	153.0
Check(RE)	7168.0	51.4	55.6	4.2	167.7
Minimum	4780.8	47.6	54.4	4.0	150.6
Maximum	7886.9	52.4	59.4	7.0	172.6
Grand mean	6354.2	50.9	56.7	5.8	160.7
LSD (0.05)	1503.0	1.9	3.2	2.8	17.8
Local check	**4947.2**	**55.2**	**62.0**	**6.8**	**167.0**

Hybrid	Ear height (cm)	Husk cover (1 – 5)	Plant aspect (1 – 5)	Ear aspect (1– 5)	Number of ears per plant
PVAEH-14	72.0	2.7	3.6	2.4	0.9
PVAEH-15	79.6	2.7	3.5	2.7	0.8
PVAEH-16	71.3	3.3	4.0	2.6	0.9
PVAEH-17	78.9	2.4	3.6	2.7	0.8
PVAEH-18	77.3	2.5	3.9	2.4	0.9
PVAEH-19	71.4	3.3	4.3	2.9	0.9
PVAEH-20	72.4	2.9	4.0	2.7	0.9
PVAEH-21	79.4	3.1	4.1	2.7	0.9
PVAEH-22	75.1	3.1	3.6	2.5	0.9
PVAEH-23	72.1	2.2	3.8	2.0	1.0
PVAEH-24	74.6	2.7	4.0	2.6	0.9
PVAEH-25	61.0	3.1	4.1	2.9	0.9
PVAQEH-1	82.2	2.7	3.5	2.3	1.0
PVAQEH-2	79.6	2.7	4.3	2.5	0.9
Check(RE)	76.3	2.9	3.8	3.1	1.0
Minimum	61.0	2.2	3.5	2.0	0.8
Maximum	82.2	3.3	4.3	3.1	1.0
Grand mean	74.9	2.8	3.9	2.6	0.9
LSD (0.05)	13.6	0.8	0.9	0.7	0.1
Local check	**86.8**	**2.5**	**4.4**	**3.2**	**0.8**

Table 6. The ranking of early maturing PVA maize hybrids based on traits with significant variations.

S/N	Hybrid	Grain yield (kg ha^{-1})	Anthesis (days)	Silking (days)	Husk cover (1-5)	Rank summation index
	Hybrid (2018 and 2019 combined)					
1	PVAEH-15	6722.1	48.4	55.2	2.7	15
2	PVAEH-16	6065.1	47.6	54.4	3.3	23
3	PVAEH-20	6225.1	50.4	55.6	2.9	24
4	PVAEH-23	7368.5	51.4	57.2	2.2	25
5	PVAQEH-2	7492.3	51.0	56.8	2.7	27
	Mean of top 5	6774.6	49.8	55.8	2.8	
	Grand mean	6354.2	50.9	56.7	2.8	
	LSD (0.05)	1503.0	1.9	3.2	0.8	
	Hybrid (2018)					
1	PVAEH-15	11093.4	47.5	52.5	2.3	9
2	PVAEH-23	11349.3	50.5	54.5	1.5	18
3	PVAEH-16	8362.7	46.0	54.5	2.3	22
4	PVAEH-25	9386.7	49.0	53.5	2.3	23
5	Check(RE)	10666.7	49.5	53.0	2.8	27
	Mean of top 5	10171.7	48.5	53.6	2.2	
	Grand mean	9272.9	50.1	54.8	2.3	
	LSD (0.05)	2190.4	3.0	2.8	1.1	
	Hybrid (2019)					
1	PVAEH-20	4231.1	51.0	56.7	3.0	20
2	PVAEH-15	3808.0	49.0	57.0	3.0	21
3	PVAEH-16	4533.3	48.7	54.3	4.0	22
4	PVAQEH-2	5319.1	51.0	58.0	3.0	22
5	PVAEH-17	3868.4	50.3	58.0	2.7	23
	Mean of top 5	4352.0	50.0	56.8	3.1	
	Grand mean	4408.4	51.5	58.0	3.2	
	LSD (0.05)	1775.7	2.1	4.2	1.1	

Conclusion

Variations among the 15 early maturing multiple stress-tolerant PVA maize hybrids were attributed to grain yield, number of days to anthesis and silking, ear height and husk cover rating. The superior hybrids, viz. PVAEH-15, PVAEH-16, PVAEH-20, PVAEH-23 and PVAQEH-2, identified in this study, combined desirable agronomic traits and could increase maize yield and solve malnutrition problems. Consequently, these superior hybrids that flowered and matured early with high yield potential and tight husk cover may, if adopted, escape moisture stress and are therefore recommended for sustainable production in the derived savanna agro-ecology.

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UČINAK NOVIH RANIH HIBRIDA KUKURUZA (*ZEA MAYS* L.) OBOGAĆENIH PROVITAMINOM A U USLOVIMA IZMENJENE SAVANE U NIGERIJI

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R e z i m e

Kukuruz (*Zea mays* L.) je glavna namirnica za milione ljudi širom sveta i čini više od 30% ukupnih kalorija u ishrani. Međutim, normalnom endospermu nedostaje dovoljna količina prekursora vitamina A. Da bi se postigla prehrambena sigurnost i sprečila neuhranjenost, potrebno je da se usvoji gajenje ranog višestrukog hibrida kukuruza obogaćenog pro-vitaminom A tolerantnog na stres. Cilj ove studije bio je da se proceni agronomski učinak i prinos novorazvijenih hibrida kukuruza. Petnaest poboljšanih hibrida kukuruza i jedan komercijalni hibrid, koji je korišćen kao lokalna kontrola ocenjeni su u potpuno slučajnom blok dizajnu sa dva ponavljanja tokom dve godine na naučno-istraživačkom imanju Tehnološkog univerziteta Ladoke Akintola u Ogbomosu u Nigeriji. Hibridi su pokazali značajne varijacije ($P < 0{,}01$) u pogledu prinosa zrna, broja dana do cvetanja, visine klipa i ovojnih listova klipa. Tokom godina, prinos zrna hibrida kretao se između 4.780,8 kg ha^{-1} (PVAEH-19) i 7.886,9 kg ha^{-1} (PVAQEH-1), sa srednjom vrednošću od 6.354,2 kg ha^{-1}. PVAEH-15 se pokazao kao najbolji na osnovu prinosa zrna, ranog cvetanja i čvrstih ovojnih listova klipa. Četrnaest hibrida je nadmašilo lokalnu kontrolu (4.947,2 kg ha^{-1}), pet hibrida imalo je značajnu ($P < 0{,}05$) prednost u prinosu od > 26% u odnosu na lokalnu kontrolu. Dosledan učinak PVAEH-15 i PVAEH-16 tokom dvogodišnje procene ukazuje na potencijal hibrida da se prilagode lokalnim uslovima. Usvajanje ovih hibrida kukuruza od strane poljoprivrednika, povećaće proizvodnju kukuruza i sprečiti neuhranjenost u uslovima izmenjene savane u Nigeriji.

Ključne reči: adaptacija, agronomske osobine, procena, prinos zrna, neuhranjenost.

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GENETIC VARIABILITY AND SELECTION CRITERIA OF SOME SESAME GENOTYPES FOR THEIR AGRONOMIC TRAITS AND SEED QUALITY

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Abstract: The identification of genetic variation, mean performance, and selection criteria for twelve sesame genotypes is required for the genetic enhancement of agronomic traits and seed quality. Thus, using a randomized complete block design with three replications, these genotypes were evaluated in a field trial at the Kafr-El-Hamam Agricultural Research Station, Agricultural Research Center, Sharkia Governorate, Egypt, and laboratory experiments at the Seed Technology Research Department, ARC, Giza, Egypt, during the two consecutive seasons of 2018 and 2019. For earliness in flowering, N.A.$_{130}$ and Shandweel$_3$ were the most promising sesame genotypes, while N.A.$_{114}$ and RH_1F_3 had the heaviest weight of seed plant^{-1} and one or more yield-related traits, and NA_{114}, Shandweel$_3$, and Zahar$_{12}$ had the best seed quality traits. Furthermore, Shandweel$_3$ and M_1A_{12} had the highest proportion of seed oil, Shandweel$_3$ and Zahar$_{12}$ had the largest amount of oleic acid, N.A.$_{114}$ and RH_1F_3 had the highest content of linoleic acid, and Zahar$_{12}$ and N.A.$_{114}$ had the highest proportion of linolenic acid. Seed weight plant^{-1} can be improved through selecting genotypes having the lengthiest fruiting zone, more branches and capsules, and the high electrical values of seed conductivity, accelerated aging germination as demonstrated by selection criteria. Moreover, the oleic acid proportion had the greatest direct and indirect effect on seed oil content, demonstrating its relevance as sesame oil quality selection criteria.

Key words: direct and joint effects, fatty acid compositions, phenotypic and genotypic correlation, *Sesamum indicum* L.

Introduction

Sesame (*Sesamum indicum* L.) is one of the oldest and most significant oilseed crops worldwide, not only in Egypt (Bhattachary et al., 2014). It is a major

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industrial crop as well as a nutritious food source. There is a significant disparity between oil output and consumption in Egypt. The development of genotypes with high seed and oil yield potential is deemed required to close this significant gap. As a result, much emphasis must be placed on improving the genetic yield of sesame genotypes, which may be achieved by determining the degree of genetic diversity in breeding materials. This information will assist sesame breeders in selecting the best breeding approach for their sesame crop development program. In this regard, Fahmy et al. (2015), Abd EL-Satar et al. (2016), Teilep et al. (2018), Anbanandan (2018), Bhuiyan et al. (2019), Sultana et al. (2019), Pavani et al. (2020), and Abdelsatar et al. (2020) found that significant genetic variability had the greatest effect on improving yield and its components. Furthermore, yield components have a positive impact on seed yield. As a result, investigating the relationship between seed yield and its components, as well as identifying the direct and indirect effects of yield components on seed yield will help in improving it directly. Moreover, Sultana et al. (2019) and Abdelsatar et al. (2020) reported that yield components had a positive effect on seed yield.

Seed germination and seedling vigor are two factors that determine a seed's ability to germinate rapidly and uniformly and develop into healthy seedlings under a wide range of conditions. Farmers' most common difficulties are a low sesame germination rate and poor seedling establishment (Khare and Bhale, 2016). Poor seedling vigor is one of the primary causes of poor germination and irregular seedling establishment (Khan et al., 2017). As a result, seed quality parameters such as germination % and vigor index affect yield by influencing plant population density, which includes field emergence, spatial arrangements, and crop duration (Khare and Bhale, 2016).

Therefore, the current investigation was designed to study mean performance, genetic parameters and selection criteria represented in correlation and path analyses at both phenotypic and genotypic levels of some sesame genotypes for agronomic traits and seed quality.

Materials and Methods

Site description

During the two consecutive summer seasons of 2018 and 2019, a field experiment was conducted at the Experiment Farm of the Kafr-El-Hamam Research Station, Zagazig, Sharkia Governorate, Agricultural Research Center, Egypt (30° 58'N, 31° 50'E).

Experimental design

The experiment was laid out in a randomized complete block design with three replications. After harvesting wheat in both seasons, each genotype was sown in five ridges with a ridge length of 4 m spaced at 60 cm between ridges and 20 cm from hill to hill. Tested sesame genotypes, *i.e.* $N.A_{52}$, M_2A_5, $Shandweel_3$, M_1A_{12}, NA_{32}, RH_1F_3, NA_{114}, RH_6F_6, NA_{130}, $Zahar_{12}$, $H_{88}A_2$ and M_2A_{24}, were received from the Department of Oil Crops Research, Field Crop Research Institute, Agricultural Research Center, Egypt.

Agricultural practices

Sesame genotype seeds were hand-planted in 60-centimeter-wide ridges at the 20-centimeter spacing between hills. In both seasons, this was done during the first week of June. At 15 days following planting, plants of the sesame genotypes under investigation were thinned to maintain two plants $hill^{-1}$. Other cultural practices were used in accordance with the recommendations.

Data collected

Agronomic traits:

Days to 50% flowering (days) were recorded on the basis of the number of plants in the plot. Plant height (cm), length of fruiting zone (cm), number of branches $plant^{-1}$, number of capsules $plant^{-1}$, weight of 1000-seed (g), and seed weight $plant^{-1}$(g) were all measured on ten competitive plants randomly selected from the 2nd and the 4th ridges. Seed yield per m^2 was determined from plants in each plot's central ridge and converted to seed yield in kg per hectare.

Seed quality: During the 2018 and 2019 seasons, seed quality testing for several seed quality parameters was done at the Seed Technology Research Department, ARC, Giza, Egypt.

Germination test: Seedlings were counted according to ISTA (1993) international criteria based on normal seedlings. The percentage of germination was determined using the Krishnasamy and Seshu's methodology (1990). The seed vigor index (S.V.I.) was computed using Copeland's (1976) formula:

S.V.I. = (Number of germinated seeds (first count) / Days to the first count) + (Number of germinated seeds (final count) / Days to final count), with the first count made after 3 days of germination.

Seedling evaluation: According to the rules of the Association of Official Seed Analysis, normal seedlings were used for seedling evaluation (AOSA, 1983). After a six-day germination test, the seedling shoot and root lengths were measured. The shoots and roots were also dried for 72 hours at 70 degrees Celsius. Seedling vigor index was computed using ISTA's (1985) formula: Seedling vigor index = seedling length (cm) × germination percentage.

Accelerated aging: The seeds were maintained in an aging chamber for three days at 45°C and 100% relative humidity. The seeds were dried in the sun after aging, and the percentage survival of the seeds was measured using a standard germination test at 25 degrees Celsius, and the mean normal seedling percentage was computed using AOSA guidelines (1983).

Electrical conductivity test: The electrical conductivity of the leachate was determined using the techniques outlined by ISTA (1999). Fifty seeds of each cultivar were weighed to 0.001g, put in plastic cups with 250 ml of distilled water, and kept at 25°C for four sub-samples. The electrical conductivity of the leachates was measured using an EC metre after 24 hours. The average values were given in $Scm^{-1}g^{-1}$.

Seed oil content and its quality

Crude oil percentage: According to AOSA (2000), crude oil percentage was measured using the Soxhlet apparatus with hexane as the solvent. A Hewlett Packard gas chromatograph model 5890 with a cabowa × Hp 20 M column was used to examine the methyl esters of fatty acids.

Fatty acid compositions: Fatty acid compositions were determined in samples of roughly 50 g of air-dried seeds of each genotype that were picked at random from two replications and finely ground for chemical composition estimation.

Statistical analysis

For all examined traits in field and laboratory trials, an analysis of variance was performed using a randomized complete block design with three replications according to Gomez and Gomez (1984). After confirming that the error variance for the studied traits was homogeneous using the Hartley's (1950) F-max test technique, a combined analysis of variance was conducted over two seasons. Genotypic and phenotypic coefficients of variation were estimated as described by Burton and DeVane (1953). The estimate of broad-sense heritability (h^2_b) was done by the formula suggested by Hansen et al. (1956). Moreover, the genetic advance as percent of the mean was performed according to Johnson et al. (1955). For the identification of selection criteria, the phenotypic and genotypic correlation coefficient was computed according to Weber and Moorthy (1952). Moreover, phenotypic and genotypic path analysis was computed as described by Dewey and Lu (1959).

Results and Discussion

Mean performance
Agronomic traits

Significant variations were found among the twelve sesame genotypes in terms of most seed weight $plant^{-1}$ and related traits (Table 1), showing that there was enough genetic diversity to effectively select better or preferred genotypes. The earlier study by Singh et al. (2020) found similar results.

Table 1. The agronomic performance of twelve sesame genotypes across 2018 and 2019 summery seasons.

Genotypes	Days to 50% flowering (day)	Plant height (cm)	Fruiting zone length (cm)	Branch number	Capsule number	1000-seed weight (g)	Seed weight plant^{-1} (g)	Seed yield hectare^{-1} (kg)
N.A.$_{52}$	64.00	188.60	128.08	5.38	280.48	5.35	48.57	1761.67
M_2A_5	57.00	184.60	120.83	4.88	251.65	4.65	45.42	1543.52
Shandweel$_3$	53.50	163.07	68.83	1.53	227.43	3.55	37.47	1233.98
M_1A_{12}	55.67	162.55	78.83	3.57	197.98	3.60	38.52	1390.60
N.A. $_{32}$	54.00	167.67	90.23	6.00	230.58	4.53	42.78	1389.17
RH_1F_3	57.67	185.07	141.62	5.45	261.12	5.53	48.62	1562.14
N.A. $_{114}$	65.00	192.85	117.93	6.37	300.20	5.47	56.13	1569.71
RH_6F_6	56.17	177.00	108.90	4.55	219.55	4.75	44.98	1501.14
N.A.$_{130}$	53.00	180.77	111.80	5.17	286.15	4.47	46.88	1213.26
Zahar$_{12}$	58.17	175.27	143.22	6.13	307.45	4.88	47.07	1934.69
$H_{88}A_2$	57.33	190.03	124.55	5.60	258.40	5.37	46.12	1579.88
M_2A_{24}	55.83	175.45	109.08	4.65	218.63	4.50	42.67	1415.55
LSD 5%	1.27	3.04	2.85	0.22	4.28	0.47	1.42	19.38
LSD 1%	1.72	4.13	3.87	0.30	5.82	0.63	1.93	26.33

The earliness of genotypes in days to 50% flowering (Table 1) was detected in N.A.$_{130}$ (53.00 days), followed by Shandweel$_3$ (53.50 days). The shortest plant height (Table 1) was obtained by M_1A_{12} (162.55 cm), followed by Shandweel$_3$ (163.07 cm). Zahar$_{12}$ (143.22 cm) and RH_1F_3 (141.62) possessed the longest fruiting zone length (Table 1). N.A.$_{114}$ (6.37) followed by Zahar$_{12}$ (6.13) had more branches plant^{-1} (Table 1). More capsules plant^{-1} (Table 1) were generated by Zahar$_{12}$ (307.45), followed by N.A.$_{114}$ (300.20). The heaviest weight of 1000 seeds (Table 1) was achieved by RH_1F_3 (5.53 g), followed by N.A.$_{114}$ (5.47 g). Consequently, N.A.$_{114}$ (56.13 g) followed by RH_1F_3 (48.62 g) possessed the heaviest weight of seed plant^{-1}(Table 1). Moreover, the highest seed yield hectare^{-1}(Table 1) was obtained by Zahar$_{12}$ (1934.68 kg ha^{-1}) followed by N.A.$_{52}$ (1761.67 kg ha^{-1}).

Seed quality:

Germination traits:

The results revealed highly significant differences between sesame genotypes with regard to all studied traits (Table 2). Meanwhile, N.A.$_{114}$ (96.67) achieved higher standard germination %, followed by M_2A_5 (96.17), $Shandweel_3$ (96.00) and $Zahar_{12}$ (95.33) genotypes, respectively. RH_6F_6 (91.17) and $N.A._{32}$ (92.67), on the other hand, had lower standard germination percentages. These variations in sesame genotypes might be ascribed to genetic impacts on sesame seed germination ability. The seed vigor index findings in Table 2 showed the same normal germination percent patterns, with $N.A._{114}$ (48.33), M_2A_5 (48.03), $Shandweel_3$ (48.00), and $Zahar_{12}$ (47.89) having the highest seed vigor index. On the other hand, $N.A._{32}$ (44.50) and RH_6F_6 (44.75) gave the lower value of this trait. These results mostly took the same trend of seed weight plant^{-1}and its attributes and seed oil content traits. $Zahar_{12}$ (80.50) had the greatest value of accelerated aging germination % in Table 2, followed by M_2A_5 (78.50) and $H_{88}A_2$ (78.00), without any significant differences between them. These results indicated that these genotypes could be tolerant to bad storage or environment conditions. Meanwhile, RH_6F_6 (62.33) and M_1A_{12} (62.33) had a lower proportion of accelerated aging germination.

Table 2. The performance of twelve sesame genotypes for seed quality traits across 2018 and 2019 summery seasons.

Genotypes	Seed quality traits								
	Germination traits				Seedling traits				
	Standard germination %	Seed vigor index	Accelerated aging germination %	Electrical conductivity μScm^{-1}g^{-1}	Root length (cm)	Shoot length (cm)	Seedling length (cm)	Seedling dry weight (mg)	Seedling vigor index
$N.A._{52}$	93.50	45.92	64.50	122.05	5.84	2.60	8.44	4.86	787.77
M_2A_5	96.17	48.03	78.50	109.94	6.23	2.57	8.80	4.96	845.61
$Shandweel_3$	96.00	48.00	71.33	100.18	6.46	2.63	9.09	5.35	872.82
M_1A_{12}	93.67	45.94	62.33	123.96	6.84	2.66	9.50	8.46	888.42
$N.A._{32}$	92.67	44.50	73.67	124.73	6.33	2.41	8.74	5.66	810.88
RH_1F_3	95.50	45.81	68.83	119.25	6.07	2.65	8.73	5.42	832.87
$N.A._{114}$	96.67	48.33	75.67	103.47	6.41	2.73	9.15	5.59	883.96
RH_6F_6	91.17	44.75	62.33	114.64	6.45	2.45	8.91	6.54	811.96
$N.A._{130}$	92.67	45.89	64.67	111.85	6.06	2.71	8.77	4.99	812.16
$Zahar_{12}$	95.33	47.89	80.50	102.75	6.22	2.89	9.12	5.86	869.14
$H_{88}A_2$	91.83	45.64	78.00	134.60	6.13	2.42	8.55	6.28	784.66
M_2A_{24}	94.33	45.72	67.33	121.98	6.26	2.57	8.83	5.85	832.88
LSD 5%	2.26	1.41	3.29	7.93	N.S	0.25	N.S	0.70	55.24
LSD 1%	3.07	1.92	4.47	10.78	N.S	0.34	N.S	0.96	75.08

The electrical conductivity (EC) is more often employed to determine seed vigor of crops because, as seed degradation advances, cell walls become less stiff and more water-permeable, enabling cell contents to escape into solution with the water and increasing electrical conductivity. $Shandweel_3$ (100.18), $Zahar_{12}$ (102.75) and $N.A._{114}$ (103.47) recorded the lower EC values, respectively, without any differences between them (Table 2). However, the high EC values were recorded in $H_{88}A_2$ (134.60), followed by $N.A._{32}$ (124.730). Standard germination percent, seed vigor index, and accelerated aging germination % were among the seed viability and vigor outcomes that were usually in the opposite direction of the forms provided. The results are in agreement with those reported by El Shakhess, Samar et al. (2008), Eraky, Hania et al. (2010) and Ahmed, Fadia et al. (2013).

Seedling traits:

On the one hand, the data in Table 2 revealed no significant variations between genotypes in both radical and seedling length traits. Shoot length, seedling dry weight, and seedling vigor index traits, however, showed highly significant variations among genotypes. The longest shoot length was found in $Zahar_{12}$ (2.89 cm), followed by $N.A._{114}$ (2.73 cm), $N.A._{130}$ (2.71 cm), $Shandweel_3$ (2.63 cm), and M_2A_5 (2.57 cm). Meanwhile, the short root length was given by $N.A._{32}$ (2.41 cm.) and $H_{88}A_2$ (2.42 cm.). The higher seedling dry weight came from M_1A_{12} (8.46 mg), while the lower seedling dry weight came from $N.A._{52}$ (4.86 mg). M_1A_{12} (888.42), $N.A._{114}$ (883.96), $Shandweel_3$ (872.82), and $Zahar_{12}$ (869.14) had the highest seedling vigor index values, whilst $H_{88}A_2$ (784.66) had the lowest. Other traits such as seed weight $plant^{-1}$ and its attributes, germination, and seedling traits followed a similar trend as these results.

Seed oil content and its quality

Again, highly significant differences in seed oil contents and fatty acid compositions were found among examined sesame genotypes (Table 3), suggesting that sesame genotypes have large genetic variability that allows for the successful selection of favorable genotypes. Mohanty et al. (2020) observed similar findings.

According to the sesame breeder, the best genotypes have low total saturated fatty acid compositions along with high total unsaturated fatty acid compositions. $Shandweel_3$ (7.53 %), followed by M_1A_{12} (7.54 %), had a low percentage of palmitic acids (C16:0), and $N.A._{114}$ (4.22%), followed by $N.A._{130}$ (4.23%), had a low proportion of stearic acids (C18:0). On the other hand, a high proportion of seed oil was detected in $Shandweel_3$ (60.08%), followed by M_1A_{12} (56.27%). $Shandweel_3$ (45.90%), followed by $Zahar_{12}$ (45.67%), was found to have the highest content of oleic acids (C18:1). The highest proportion of linoleic acids (C18:2) came from $N.A._{114}$ (43.79 %), followed by RH_1F_3 (43.45%). The highest content of linolenic acids (C18:3) was achieved by $Zahar_{12}$ (0.74 %), followed by $N.A._{114}$ (0.72 %).

Table 3. The performance of twelve sesame genotypes for seed oil content and its quality across 2018 and 2019 summery seasons.

Genotypes	Seed oil content	Fatty acid composition %					TS%	TU%	TS/TU ratio
		Saturated fatty acids		Unsaturated fatty acid					
		Palmitic C16:0	Stearic C18:0	Oleic C18:1	Linoleic C18:2	Linolenic C18:3			
N.A.$_{52}$	46.42	9.46	4.34	41.15	43.20	0.65	13.80	85.00	0.162
M_2A_5	47.92	9.28	4.62	43.77	42.87	0.53	13.89	87.17	0.159
Shandweel$_3$	60.08	7.53	5.51	45.95	41.26	0.27	13.03	87.47	0.149
M_1A_{12}	56.27	7.54	5.73	45.27	40.06	0.34	13.27	85.67	0.155
N.A.$_{32}$	54.80	8.65	5.13	44.67	41.82	0.42	13.78	86.91	0.159
RH_1F_3	46.56	9.51	4.46	43.17	43.45	0.65	13.96	87.28	0.160
N.A.$_{114}$	46.48	10.30	4.22	43.62	43.79	0.72	14.52	88.13	0.165
RH_6F_6	48.64	7.60	4.75	44.53	42.23	0.47	12.35	87.23	0.142
N.A.$_{130}$	46.30	10.53	4.23	41.59	40.56	0.32	14.76	82.47	0.179
Zahar$_{12}$	49.04	7.79	5.54	45.67	41.35	0.74	13.33	87.76	0.152
$H_{88}A_2$	47.27	9.36	4.54	43.70	42.79	0.58	13.90	87.07	0.160
M_2A_{24}	49.48	8.69	4.91	44.25	41.88	0.46	13.60	86.58	0.157
LSD 5%	1.08	0.20	0.10	1.88	1.27	0.03	0.23	2.38	0.01
LSD 1%	1.47	0.27	0.13	2.55	1.73	0.04	0.31	3.23	0.01

TS = Total saturated fatty acids TU = Total unsaturated fatty acids

Genetic parameters for agronomic traits and seed quality

The phenotypic (PCV) and genotypic (GCV) coefficients of variation, heritability in the broad sense (h^2_b), and expected genetic advance as percent mean for seed weight plant^{-1} and its related traits were computed to gain a better understanding of the extent of genetic variability for twelve sesame genotypes, as shown in Table 4. For all traits studied, PCV was slightly greater than GCV, indicating that the environment had a little effect on their expression. In the same line, Bhuiyan et al. (2019) and Abdelsatar et al. (2020) found that the differences between genotypic and phenotypic components of variance were narrow for investigated traits, indicating that phenotypic variation had a large genetic component in nature. Saravanan et al. (2020) also found that seed weight plant^{-1}, the number of branches per plant, and the number of capsules per plant had higher PCV and GCV values.

Consequently, selection for these traits would be successful in improving these breeding materials. Fruiting zone length, capsule number plant^{-1}, seedling vigor index and seed oil content had high PCV and GCV, while electrical conductivity, accelerated aging germination, plant height, branch number plant^{-1}, and seed weight plant^{-1} had moderate PCV and GCV, while the remaining traits had drastically reduced PCV and GCV.

Most studied traits have high heritability in the broad sense, indicating that a genotype can be recognized by its phenotypic performance, allowing for more effective selection to improve these traits.

As demonstrated in Table 4, heritability estimates combined with expected genetic advance as percent of the mean are usually more effective in predicting genetic gain under selection than heritability estimates alone, as validated by Johnson et al. (1955). High values of heritability coupled with high (more than 20%) values of genetic advance (as % of mean) were detected for fruiting zone length, branch number, capsule number, 1000-seed weight, seed weight plant^{-1}, palmitic, stearic and linolenic acid contents. As a result of the significance of additive gene effects in the inheritance of these traits, selection for these traits would be successful. In the same sense, Umamaheswari et al. (2019) and Abdelsatar et al. (2020) found that plant height at maturity, number of branches per plant, number of capsules per plant, length of the capsule, number of seeds per capsule, 1000-seed weight, and seed weight plant^{-1} had high heritability and high genetic advance as percent of the mean. This might be due to additive gene action influencing the expression of these traits; as a result, simple selection would likely be efficient in improving these traits. Moreover, Saravanan et al. (2020) found that the number of branches per plant and 1000-seed weight had a high heritability as well as a high genetic advance as percent of the mean. For days to 50% flowering, plant height, seedling dry weight, electrical conductivity, accelerated aging germination, seed oil content, and total saturated/total unsaturated ratio, high heritability combined with moderate (10–20%) expected genetic advance as percent of the mean were recorded, indicating that these traits appear to be controlled by both additive and non-additive gene actions. The variability study of Mohanty et al. (2020) indicated high to moderate genetic advance as percent of the mean for traits like plant height, days to first flowering, days to 50% flowering, days to maturity, number of productive branches plant^{-1}, height of the 1st capsule, number of productive capsules per plant, number of seeds per capsule, biological yield per plant, harvest index, 1000-seed weight, stearic acid, linolenic acid, linoleic acid, oleic acid, palmitic acid, oil content, oil yield per plant and seed weight plant^{-1}(g). This study indicates the preponderance of an additive gene effect, which will help to make the selection in an early segregating generation. However, high heritabilities coupled with low (less than 10%) expected genetic advance as percent of the mean were recorded for standard germination, root length, shoot length, seedling length, seed vigor index, seedling vigor index, oleic acid, linoleic, total saturated and total unsaturated fatty acids. This indicated that an increased influence of environment on these traits and thus the selection procedures involving progeny testing are recommended for these traits. Similar results were found by Mourad et al. (2019), who recorded that the expected genetic advance ranged from 2.28% for standard germination to 22.31% for seedling dry weight.

Table 4. Genetic parameters for agronomic traits and seed quality across 2018 and 2019 summery seasons.

Parameter	Agronomic traits						
	Days to 50% flowering	Plant height	Fruiting zone length	Branch number	Capsule number	1000-seed weight	Seed weight $plant^{-1}$
PCV	8.42	20.06	158.48	11.89	163.57	3.46	18.08
GCV	8.10	19.46	157.64	11.77	162.73	2.93	17.56
h^2_b	0.96	0.97	0.99	0.99	0.99	0.85	0.97
GA 5%	7.54	20.74	47.35	2.71	72.36	1.22	9.95
GAM%	13.17	11.62	42.28	54.89	28.57	25.87	21.90

Parameter	Seed quality traits								
	Germination traits				Seedling traits				
	Standard germination	Seed vigor index	Accelerated aging germination	Electrical conductivity	Root length	Shoot length	Seedling length	Seedling dry weight	Seedling vigor index
PCV	1.59	1.61	21.50	35.78	0.73	0.44	0.61	2.17	80.30
GCV	0.96	1.11	19.73	29.47	0.15	0.15	0.17	1.26	37.88
h^2_b	0.60	0.69	0.92	0.82	0.21	0.35	0.27	0.58	0.47
GA 5%	2.64	2.13	12.78	18.94	0.16	0.13	0.23	0.72	43.67
GAM%	2.81	4.60	18.09	16.36	2.52	5.08	2.56	12.98	5.22

Parameter	Oil quality traits								
	Seed oil content	Fatty acid composition %					TS%	TU%	TS/TU ratio
		Saturated fatty acids		Unsaturated fatty acids					
		Palmitic C16:0	Stearic C18:0	Oleic C18:1	Linoleic C18:2	Linolenic C18:3			
PCV	14.10	4.28	1.97	2.26	1.37	1.64	1.04	1.43	0.019
GCV	13.83	4.23	1.95	1.33	0.92	1.62	0.99	0.67	0.017
h^2_b	0.98	0.99	0.99	0.59	0.67	0.99	0.96	0.47	0.90
GA 5%	9.30	2.17	1.09	2.10	1.83	0.32	1.29	1.87	0.02
GAM%	18.62	24.53	22.58	4.78	4.35	63.31	9.41	2.16	11.08

TS = Total saturated fatty acids TU = Total unsaturated fatty acids

PCV: Phenotypic coefficient of variability, GCV: Genotypic coefficient of variability, h^2_b: Broad-sense heritability, GA 5%: Genetic advance, GAM% of means: Genetic advance as percent of the mean.

Selection criteria

Phenotypic and genotypic correlations

Seed weight plant^{-1} and its related traits

Phenotypic and genotypic correlations were estimated between seed weight plant^{-1} and its related traits for 12 sesame genotypes based on the average of 2018 and 2019, as presented in Table 5. Seed weight plant^{-1} was positively and significantly or highly significantly correlated with its related traits, *i.e.* days to 50% flowering, plant height, fruiting zone length, branch number, capsule number and 1000-seed weight at phenotypic and genotypic levels.

Table 5. Phenotypic (above diagonal) and genotypic (below diagonal) correlations of 12 sesame genotypes for seed weight plant^{-1} and its related traits across 2018 and 2019 summery seasons.

Traits	X_1	X_2	X_3	X_4	X_5	X_6	X_7
Days to 50% flowering (X_1)	1.000	0.796**	0.590*	0.465	0.548	0.740**	0.088
Plant height (X_2)	0.825**	1.000	0.878**	0.666*	0.759**	0.899**	0.061
Fruiting zone length (X_3)	0.608*	0.889**	1.000	0.832**	0.907**	0.891**	0.112
Branch number (X_4)	0.482	0.682*	0.838**	1.000	0.685*	0.826**	0.056
Capsule number (X_5)	0.560	0.772**	0.911**	0.687*	1.000	0.726**	0.138
1000-seed weight (X_6)	0.804**	0.952**	0.921**	0.864**	0.757**	1.000	0.063
Standard germination (X_7)	0.096	0.099	0.133	0.088	0.172	0.061	1.000
Root length (X_8)	-0.529	-0.569	-0.700*	-0.719**	-0.553	-0.619*	-0.406
Shoot length (X_9)	0.274	0.080	0.238	0.235	0.589*	0.090	-0.011
Seedling length (X_{10})	-0.408	-0.538	-0.597*	-0.617*	-0.287	-0.583*	-0.415
Seedling dry weight (X_{11})	-0.600*	-0.311	-0.148	0.073	-0.220	-0.248	0.364
Seedling vigor index (X_{12})	-0.381	-0.505	-0.539	-0.582*	-0.191	-0.571	0.186
Seed weight plant^{-1} (X_{13})	0.753**	0.911**	0.855**	0.799**	0.807**	0.935**	0.225

Traits	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
Days to 50% flowering (X_1)	-0.233	0.157	-0.163	-0.538	-0.130	0.707*
Plant height (X_2)	-0.333	0.041	-0.308	-0.304	-0.273	0.882**
Fruiting zone length (X_3)	-0.375	0.124	-0.315	-0.140	-0.259	0.840**
Branch number (X_4)	-0.358	0.116	-0.302	0.061	-0.266	0.780**
Capsule number (X_5)	-0.295	0.336	-0.149	-0.202	-0.091	0.785**
1000-seed weight (X_6)	-0.308	0.019	-0.292	-0.236	-0.257	0.882**
Standard germination (X_7)	-0.125	0.007	-0.119	0.334	0.258	0.159
Root length (X_8)	1.000	-0.146	0.915**	-0.176	0.844**	-0.266
Shoot length (X_9)	-0.248	1.000	0.266	-0.097	0.258	0.153
Seedling length (X_{10})	0.895**	0.209	1.000	-0.211	0.928	-0.196
Seedling dry weight (X_{11})	-0.349	-0.278	-0.480	1.000	-0.079	-0.154
Seedling vigor index (X_{12})	0.726**	0.181	0.816	-0.279	1.000	-0.129
Seed weight plant^{-1} (X_{13})	-0.518	0.290	-0.390	-0.131	-0.266	1.000

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

This indicates that selection will be more successful for a long period to 50% flowering, tall height, long fruiting zone length, more branches, more capsules, and the heaviest weight of 1000 seeds.

These findings were confirmed by Roy and Pal (2019), Umamaheswari et al. (2019), and Abdelsatar et al. (2020), who found that the number of branches per plant, number of capsules per plant, number of seeds per capsule, and weight of 1000-seeds per capsule were strongly related to sesame yield.

As a result, these traits may be used to select advanced sesame lines with higher seed yields. Furthermore, these traits might be used as selection criteria for improving sesame seed yield in the future agricultural system. Similarly, Saravanan et al. (2020) indicated that yield per plant had a significant positive correlation with the number of capsules per plant followed by 1000-seed weight, plant height and the number of branches per plant. Furthermore, the positive and significant or highly significant phenotypic and genotypic correlation was detected among the studied traits, *i.e.* days to 50% flowering, plant height, fruiting zone length, branch number, capsule number and 1000-seed weight at phenotypic and genotypic levels. This demonstrated that selecting for any of the previous traits would immediately enhance the others, particularly seed weight plant^{-1}. As a result, these traits might be used as indications for achieving desired genetic improvements in sesame seed weight plant^{-1}.

Seed oil content and its quality

Phenotypic and genotypic correlations were estimated between seed oil content and its contents of fatty acid composition for 12 sesame genotypes based on the average of 2018 and 2019 summer seasons as presented in Table 6. Seed oil content was positively and significantly or highly significantly correlated at both levels with the proportion of stearic and oleic acids on the one hand. On the other hand, a negative and valuable correlation at both levels was observed between seed oil content and the proportion of palmitic acid and linoleic acid. Moreover, fatty acid composition exhibited various trends of association among them. However, a highly significant negative phenotypic and genotypic correlation of the proportion of palmitic acid was detected with stearic acid along with oleic with linoleic and linolenic acids.

While significant positive associations of the proportion of stearic acid with oleic acid content along with the proportion of linoleic acid were noticed, an unsaturated fatty acid with the proportion of linolenic acid at both phenotypic and genotypic levels was observed. In the same sense, Khayambashi and Asadi-Gharneh (2020) showed a negative correlation between saturated and unsaturated fatty acid contents. Moreover, they showed that arachidic acid was positively correlated with stearic acid ($r=0.8$; $p<0.05$). In addition, palmitic acid was negatively correlated with oleic acid ($r=-0.78$; $p<0.05$).

Table 6. Phenotypic (above diagonal) and genotypic (below diagonal) correlations of 12 sesame genotypes for seed oil content and its contents of fatty acid composition across 2018 and 2019.

Traits	Seed oil content	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Seed oil content	1.000	-0.700*	0.810**	0.615*	-0.508	-0.662*
Palmitic	-0.711**	1.000	-0.874**	-0.702*	0.438	0.318
Stearic	0.824**	-0.885**	1.000	0.721**	-0.571	-0.370
Oleic	0.791**	-0.897**	0.949**	1.000	-0.265	-0.172
Linoleic	-0.638*	0.518	-0.734**	-0.478	1.000	0.646*
Linolenic	-0.674*	0.317	-0.375	-0.247	0.781**	1.000

*, ** Significant at 0.05 and 0.01 levels of probability, respectively.

Phenotypic and genotypic path analyses

Seed weight plant^{-1} and its related traits

The phenotypic and genotypic path analyses were used to separate phenotypic and genotypic correlations into direct and joint effects, with seed weight plant^{-1} as a dependent variable and yield-related traits as independent variables, as shown in Table 7 and Figure 1. A critical perusal of phenotypic and genotypic path analyses revealed that root length had the highest positive direct effects (P=3.700, G=1.866) on seed weight plant^{-1}, followed by plant height (P=1.061, G=1.642), shoot length (P=1.094, G=0.773), seedling length (P=0.905, G=0.556), capsule number (P=0.688, G=1.429) and branch number (p=0.555, G=1.171).

The high positive direct effects of the previously mentioned traits, in addition to their highly significant correlation coefficient with seed weight plant^{-1}, indicated that the direct selection through these traits would be effective for sesame improvement. Moreover, the direct impacts of fruiting zone length on seed weight plant^{-1} were negative and insignificant, despite a positive and significant phenotypic and genotypic correlation with seed weight plant^{-1}. Consequently, the indirect effect of fruiting zone length through plant height (P=0.931, G=1.460) had a positive effect on improving seed weight plant^{-1} of these materials than direct effect of fruiting zone length.

The high positive phenotypic and genotypic indirect effects on seed weight plant^{-1} were detected for days to 50% flowering through plant height (P= 0.844, G=1.354), plant height through branch number (P=0.369, G=0.798), capsule number (P=0.522, G=1.103), fruiting zone length through branch number (P=0.462, G=0.982) and capsule number (P=0.623, G=1.301), branch number via plant height (P=0.706, G=1.119) and capsule number (P=0.471, G=0.981), capsule number via plant height (P=0.805, G=1.268) and branch number (P=0.380, G=0.804), 1000-seed weight via plant height (P=0.953, G=1.563), branch number (P=0.458, G=1.012) and capsule number (P=0.499, G=1.081), root length via seedling length (P=0.508, G=3.873), shoot length through plant height (P=0.043, G=0.132), branch number (P=0.065, G=0.275) and capsule number (P=0.231, G=0.842), seedling length (P=0.422, G=1.236), seedling dry weight (P= 0.187, G=0.306) and seedling vigor index (P=0.348, G=1.115) through fruiting zone length, and seedling vigor index via seedling length (P=0.516, G=3.531). It is apparent from the above-mentioned results that the preferred improvement of seed weight plant^{-1}can be achieved through selecting genotypes having the long fruiting zone length, more branches plant^{-1}, more capsules plant^{-1}, the heaviest weight of 1000 seeds, the longest root length, shoot length and seedling length, the heaviest dry weight of seedling and the highest index of seedling vigor. These results agreed with those of Umamaheswari et al. (2019), who reported that the traits of plant height at maturity, number of capsules per plant and number of seeds per capsule directly influenced the seed weight per plant.

Table 7. Phenotypic (P) and genotypic (G) path analyses of twelve sesame genotypes for seed weight plant^{-1} and its related traits across 2018 and 2019 summery seasons.

		DF	PH	FZL	BN	CN	TSW	SG
DF	P	**-0.283**	0.844	-0.790	0.258	0.377	0.292	0.092
	G	**0.382**	1.354	-1.259	0.564	0.800	-0.946	-0.267
PH	P	-0.225	**1.061**	-1.177	0.369	0.522	0.355	0.064
	G	0.315	**1.642**	-1.841	0.798	1.103	-1.120	-0.276
FZL	P	-0.167	0.931	**-1.340**	0.462	0.623	0.352	0.117
	G	0.232	1.460	**-2.071**	0.982	1.301	-1.084	-0.369
BN	P	-0.132	0.706	-1.115	**0.555**	0.471	0.326	0.059
	G	0.184	1.119	-1.735	**1.171**	0.981	-1.017	-0.245
CN	P	-0.155	0.805	-1.215	0.380	**0.688**	0.286	0.144
	G	0.214	1.268	-1.886	0.804	**1.429**	-0.890	-0.477
TSW	P	-0.209	0.953	-1.194	0.458	0.499	**0.395**	0.066
	G	0.307	1.563	-1.907	1.012	1.081	**-1.177**	-0.168
SG	P	-0.025	0.065	-0.150	0.031	0.095	0.025	**1.048**
	G	0.037	0.163	-0.275	0.103	0.245	-0.071	**-2.776**
RL	P	0.066	-0.353	0.503	-0.199	-0.203	-0.121	-0.131
	G	-0.202	-0.935	1.449	-0.842	-0.790	0.728	1.128
SHL	P	-0.044	0.043	-0.167	0.065	0.231	0.008	0.007
	G	0.105	0.132	-0.493	0.275	0.842	-0.106	0.031
SL	P	0.046	-0.327	0.422	-0.167	-0.103	-0.115	-0.124
	G	-0.156	-0.883	1.236	-0.723	-0.410	0.686	1.153
SDW	P	0.152	-0.322	0.187	0.034	-0.139	-0.093	0.350
	G	-0.229	-0.511	0.306	0.085	-0.314	0.291	-1.010
SVI	P	0.037	-0.290	0.348	-0.147	-0.063	-0.102	0.270
	G	-0.146	-0.829	1.115	-0.681	-0.273	0.672	-0.517

Table 7. Continued.

		RL	SHL	SL	SDW	SVI	r
DF	P	-0.434	0.121	-0.090	-0.001	0.322	0.707
	G	4.814	-1.207	-1.764	-0.075	-1.643	0.753
PH	P	-0.622	0.032	-0.171	-0.001	0.675	0.882
	G	5.184	-0.354	-2.326	-0.039	-2.176	0.911
FZL	P	-0.700	0.096	-0.175	0.000	0.642	0.840
	G	6.372	-1.049	-2.583	-0.018	-2.320	0.855
BN	P	-0.669	0.090	-0.168	0.000	0.657	0.780
	G	6.545	-1.036	-2.671	0.009	-2.506	0.799
CN	P	-0.550	0.260	-0.083	-0.001	0.225	0.785
	G	5.034	-2.597	-1.242	-0.027	-0.823	0.807
TSW	P	-0.574	0.015	-0.162	-0.001	0.636	0.882
	G	5.635	-0.395	-2.524	-0.031	-2.460	0.935
SG	P	-0.233	0.005	-0.066	0.001	-0.637	0.159
	G	**3.700**	0.048	-1.796	0.045	0.802	0.225
RL	P	**1.866**	-0.113	0.508	0.000	-2.088	-0.266
	G	-9.106	**1.094**	3.873	-0.044	3.127	-0.518
SHL	P	-0.273	**0.773**	0.148	0.000	-0.638	0.153
	G	2.261	-4.408	**0.905**	-0.035	0.781	0.290
SL	P	1.707	0.206	**0.556**	-0.001	-2.296	-0.196
	G	-8.153	-0.922	4.326	**-0.060**	3.516	-0.390
SDW	P	-0.329	-0.075	-0.117	**0.003**	0.195	-0.154
	G	3.179	1.227	-2.078	0.125	**-1.202**	-0.131
SVI	P	1.576	0.200	0.516	0.000	**-2.473**	-0.129
	G	-6.611	-0.800	3.531	-0.035	4.308	-0.266
Residual effect					P		0.268
					G		0.170

DF: Days to 50% flowering, PH: Plant height, FZL: Fruiting zone length, BN: Branch number, CN: Capsule number, TSW: 1000-seed weight, SG: Standard germination, RL: Root length, SHL: Shoot length, SL: Seedling length, SDW: Seeding dry weight, SVI: Seed vigor index, r: Correlation of yield related traits with seed weight plant^{-1}

Moreover, Saravanan et al. (2020) revealed that the number of capsules per plant had a highly positive direct effect on yield per plant. So, the selection based on these traits such as the number of capsules per plant, plant height, 1000-seed weight and the number of branches per plant would be a benefit for crop improvement. The residual effect at the phenotypic and genotypic levels was 0.268 and 0.170, indicating that independent traits included in the phenotypic and genotypic path analyses explained 73.23% and 82.98% of the total variance in seed weight plant^{-1}, respectively. The largest residual effects of phenotypic and genotypic path analyses revealed that the existence of other traits not included in the current study was linked with the greatest influence on seed weight plant^{-1}.

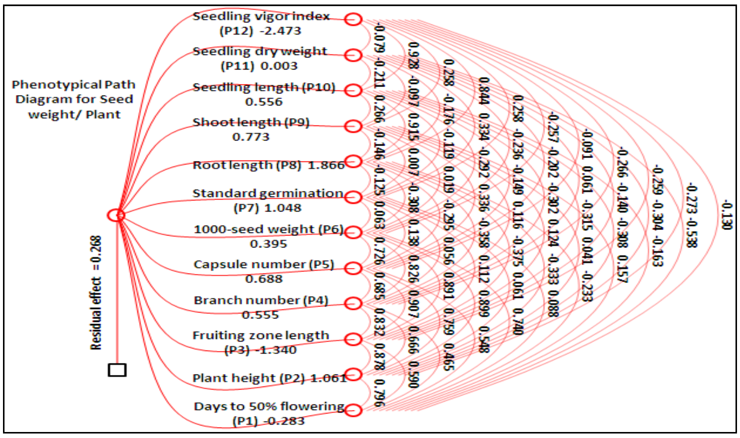

Figure 1a. The Phenotypical Path Diagram for Seed weight/plant.

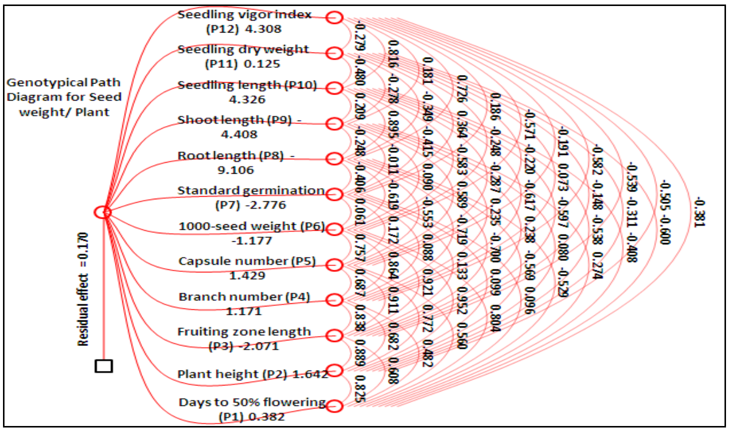

Figure 1b. The genotypical Path Diagram for Seed weight/plant.

Seed oil content and its quality

The phenotypic and genotypic path analyses were used to split phenotypic and genotypic correlations into direct and joint effects to identify interrelationships between seed oil content and its contents of the fatty acid composition. As indicated in Table 8 and Figure 2, the seed oil content was regarded as a dependent variable, whereas oil proportions of fatty acid composition were considered independent variables.

Oleic acid content had a positive direct impact (P=0.1081, G=2.0683), and there was a correlation at both levels (P=0.615*, G=0.791**). This demonstrates that seed oil content is influenced by oleic acid. Furthermore, oleic acid content has a significantly positive indirect impact via its association with linolenic acid content (P=0.0998, G=0.0649) and stearic acid content (P=0.0779, G=1.9637). These findings suggest that increasing the oleic fatty acid component of these materials effectively increases oil content. The residual effect was 0.378 and 0.426 at phenotypic and genotypic levels, respectively. This indicated that independent variables included in the phenotypic and genotypic path analyses explained 62.17 and 57.43 percent of the overall variance in seed oil content, respectively. The largest residual effects of phenotypic and genotypic path analyses revealed that the existence of other traits not included in the current study was linked with the greatest influence on seed oil content.

Table 8. Phenotypic and genotypic path analyses of twelve sesame genotypes for seed oil content and its contents of fatty acid composition across 2018 and 2019 summery seasons.

		Palmitic C16:0	Stearic C18:0	Oleic C18:1	Linoleic C18:2	Linolenic C18:3	Correlation with seed oil content
Palmitic	P	**0.1292**	-0.6982	-0.0759	0.1293	-0.1840	-0.6996
C16:0	G	**0.1680**	1.4315	-1.8552	-0.3722	-0.0834	-0.7113
Stearic	P	-0.1129	**0.7991**	0.0779	-0.1686	0.2144	0.8099
C18:0	G	-0.1487	**-1.6171**	1.9637	0.5279	0.0986	0.8245
Oleic	P	-0.0907	0.5758	**0.1081**	-0.0782	0.0998	0.6148
C18:1	G	-0.1507	-1.5353	**2.0683**	0.3436	0.0649	0.7907
Linoleic	P	0.0566	-0.4566	-0.0286	**0.2951**	-0.3743	-0.5078
C18:2	G	0.0870	1.1873	-0.9884	**-0.7190**	-0.2052	-0.6382
Linolenic	P	0.0410	-0.2958	-0.0186	0.1907	**-0.5792**	-0.6620
C18:3	G	0.0533	0.6070	-0.5106	-0.5615	**-0.2627**	-0.6745
Phenotypic residual					0.37831		
Genotypic residual					0.42568		

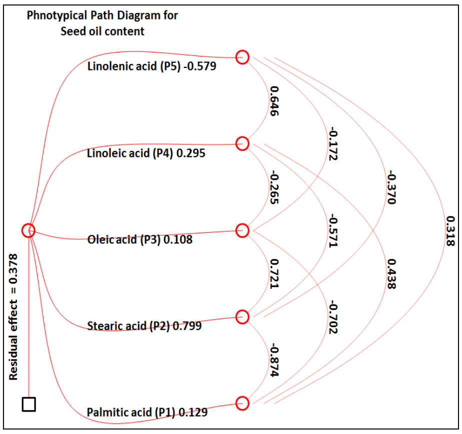

Figure 2a. The phenotypical Path Diagram for Seed oil content.

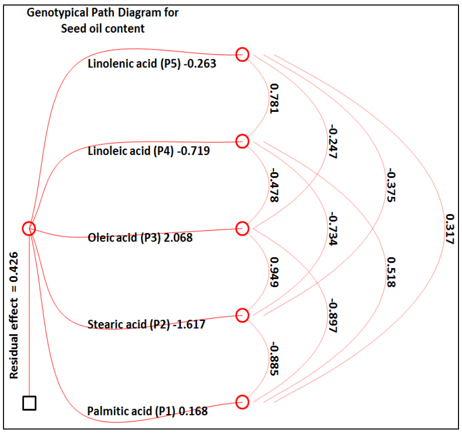

Figure 2b. The genotypical Path Diagram for Seed oil content.

Conclusion

In conclusion, all studied traits showed a significant genetic diversity among genotypes, indicating the possibility of improving sesame yield and oil quality. As a result, selection within this population or hybridization among members of this population can result in genetic improvement in seed weight plant^{-1} and oil quality for assessed genotypes.

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GENETSKA VARIJABILNOST I KRITERIJUMI ZA IZBOR NEKIH GENOTIPOVA SUSAMA U POGLEDU NJIHOVIH AGRONOMSKIH OSOBINA I KVALITETA SEMENA

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R e z i m e

Identifikacija genetske varijabilnosti, srednjih performansi i kriterijuma selekcije za dvanaest genotipova susama je potrebna radi genetskog poboljšanja agronomskih osobina i kvaliteta semena. Tako su, koristeći potpuno slučajni blok dizajn sa tri ponavljanja, ovi genotipovi ocenjeni u terenskom ispitivanju u Poljoprivrednoj istraživačkoj stanici Kafr-El-Hamam, Poljoprivrednog istraživačkog centra, Guvernorat Šarkija u Egiptu, i laboratorijskim eksperimentima na Odseku za istraživanje tehnologije semena, PIC, Giza, Egipat, tokom dve uzastopne sezone 2018. i 2019. U pogledu ranog cvetanja, $N.A._{130}$ i $Shandweel_3$ su bili najperspektivniji genotipovi susama, dok su $N.A._{114}$ i RH_1F_3 imali najveću masu semena po biljci i jednu ili više osobina povezanih sa prinosom. NA_{114}, $Shandweel_3$ i $Zahar_{12}$ su imali najbolji kvalitet semena. Pored toga, genotipovi $Shandweel_3$ i M_1A_{12} su imali najveći udeo ulja u semenu, $Shandweel_3$ i $Zahar_{12}$ su imali najveću količinu oleinske kiseline, $N.A._{114}$ i RH_1F_3 su imali najveći sadržaj linolne kiseline, a $Zahar_{12}$ i $N.A._{114}$ su imali najveći udeo linolne kiseline. Masa semena po biljci može se poboljšati odabirom genotipova koji imaju najduži period plodonošenja, više grana i kapsula, visoke vrednosti električne provodljivosti semena i ubrzano klijanje, što je pokazano kriterijumima za odabir. Osim toga, udeo oleinske kiseline imao je najveći direktan i indirektan uticaj na sadržaj ulja semena, pokazujući njegovu relevantnost kao kriterijuma za izbor kvaliteta susamovog ulja.

Ključne reči: direktni i udruženi uticaji, sastav masnih kiselina, fenotipska i genotipska korelacija, *Sesamum indicum* L.

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THE SUITABILITY OF APRICOT FOR DRIED FRUIT PRODUCTION BY THE COMBINED TECHNOLOGY

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Abstract: The apricot is considered as one of the most delicious temperate fruit, a highly appreciated stone fruit and a valuable raw material for processing. The Republic of Serbia is one of the leading apricot producers in Southeast Europe, but the assortment is limited by a small number of cultivars harvested, mostly in the ripening season of “Magyar kajszi”. In order to introduce the most suitable cultivars in the production, having high yield and high quality for consumption and various forms of processing, introduced and domestic cultivars have been intensively studied. In Serbia, apricots are mostly marketed fresh and processed for jams and spirits, but demand for high-quality dried fruits is increasing. To preserve the nutritional and sensory quality of fresh apricots, choosing the best drying technique is significant, and the most preferred technique is the reduction of moisture through convective drying. The aim of the paper was to compare the potential of the apricot cultivars “Magyar kajszi”, “Novosadska rodna”, “NS-4” and “NS-6” for dried fruit production by two-phase technology – combined osmotic and convective drying, as well as the profitability of apricot drying on small family farms. Cultivars “NS-4” and “Novosadska rodna” were found to be suitable for combined drying technology. The highest score in the sensory evaluation of the dried apricots was given to “NS-4”, and then to “Novosadska rodna”. The results indicate that the combined osmotic and convective drying of apricot rather than selling fresh fruits can be a profitable and important added value tool for small family farms.

Key words: fruit, osmotic and convective drying, profitability, *Prunus armeniaca.*

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Introduction

The apricot (*Prunus armeniaca* L.) is considered as one of the most delicious temperate fruits, highly appreciated for its taste and aroma. Apricot characteristic flavour is a complex of sugars, organic acids, phenolic compounds, and volatiles, among others, which differ greatly among cultivars (Roussos et al., 2016). Apricots are rich in carbohydrates, minerals and β-carotene (Drogoudi et al., 2008). Due to harmonised chemical composition, apricots are appreciated stone fruits and a valuable raw material for further processing by drying (Milić and Vukoje, 2008). Apricots are mainly grown in the Mediterranean Basin and regions with moderate climate including ex-Soviet Union countries, Iran, China, Japan, South Africa and the United States (Asma, 2007). Turkey (16.6% of worldwide production) has been the leading producer in the last 10 years, according to the FAO (2020).

The Republic of Serbia is one of the leading apricot producers in Southeast Europe, with an average annual production of 30.000 t (FAO, 2020). The apricot assortment in Serbia is characterised by a small number of cultivars having a short period of maturation (Milatović et al., 2012). Most apricots are harvested in the season of "Magyar kajszi", which is the most grown cultivar, or ten days afterwards. To improve the assortment, the creation of new domestic cultivars conducted 30 years ago resulted in eleven new apricot cultivars released so far. In order to introduce the most suitable cultivars in the production, having high yield and high quality for consumption and various forms of processing, introduced and domestic cultivars have been intensively studied (Milatović et al., 2012, 2015; Rahović et al., 2013).

Apricot is a climacteric fruit, and while it is fresh, it cannot be stored for a long time, partly due to a high respiration rate and a rapid ripening process. Drying is one of the oldest techniques to prolong the shelf life of foods. It is a complex technological method that reduces the moisture level to preserve the natural characteristics of fruit so that the final product has high-quality physical, chemical, structural, mechanical and organoleptic characteristics. For its biochemical structure, the apricot is considered very suitable for drying. It features a high content of provitamin A, vitamin C, as well as a complex of other vitamins that are beneficial to human organisms (Pavkov et al., 2009). In order to preserve the nutritional and sensory quality of fresh apricots, it is necessary to choose the most suitable drying technique (air-drying, vacuum drying or freeze-drying) and optimise the drying conditions (Sablani, 2006). The most preferred technique is the reduction of moisture through convective drying (Mundada et al., 2010), but applied as the sole technological drying operation produces dried apricots of unsatisfactory quality. Using combined drying technology with osmotic drying as one of the fundamental technological operations rectifies this problem (Babić et al., 2006; Riva et al., 2005). In 2002, The Faculty of Agriculture in Novi Sad began developing a new technology of combined drying of fruits (Babić and Babić, 2003; Babić et al., 2005), comprising osmotic and convective drying. Osmotic drying is one of the possible methods for preparing fruits for convective drying and was traditionally used to improve the nutritive and sensory quality of fruits (Peiro-Mena et al., 2006). It reduces the negative influence of heat on flavour and colour, inhibits the browning of enzymes and decreases energy costs (Khan, 2012). Osmotic dehydration is a method used to partially remove water from plant tissues by immersion in a hypertonic sugar and/or salt solution to reduce the moisture content of foods before the actual drying process. This technique enhances the mass transfer rate and shortens the duration of drying time. Also, the quality of osmotically dehydrated products is better, and shrinkage is considerably lower as compared to products dried conventionally. Moreover, the air incorporated in the porous structure of the tissue leaves the tissue after immersion that provides a larger surface area for osmotic drying (Ramaswamy and Van Nieuwenhauzen, 2002). This technique helps to conserve the overall energy relative to other drying procedures.

In Serbia, apricots are mostly marketed fresh, but also, the dominant markets for domestic apricots are distilleries. Recently, there has been an increasing demand for high-quality dried fruits. Drying of apricots is economically justified, especially when performed in dryers suitable for family farms (Milić et al., 2007; Vukoje and Pavkov, 2010). Combined drying on family farms can be very profitable, engaging 2–3 family members at the same time over the year.

The aim of the research was to compare the potential for combined (two-phase) drying of some newly released apricot cultivars and the most often planted "Magyar kajszi", and to select the ones whose fruits can be used for dry apricot production. Also, we analysed the possibility of increasing family farm profitability by switching from selling fresh apricots to on-farm fruit processing and selling dry apricots, having added value.

Materials and Methods

Plant material

Apricot cultivars "Magyar kajszi", "Novosadska rodna", "NS-4" and "NS-6" were studied for three years. Fruits were collected in the orchard in full production. The trees were grafted onto Myrobalan seedlings (*Prunus cerasifera*), with the plum cultivar "Stanley" used as an interstock and planted at a spacing of 5×4 m. The orchard was under irrigation and was maintained using standard management practices, including disease and pest control. The fruits were harvested when the ground colour changed to yellow-green, and fruit firmness was still high. After harvesting, a sample of 30 fresh fruits, of each cultivar, was taken in order to determine the initial weight and moisture content. Weight was measured on an analytical balance, while moisture content was determined by the thermal-gravimetric method.

Drying

Drying of apricot fruits was carried out at the Laboratory for Bio-systematic Engineering, Department of Agricultural Technique, Faculty of Agriculture, Novi Sad. The flow chart of apricot drying is presented in Figure 1.

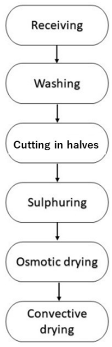

Figure 1. The flow chart of apricot drying.

The fresh fruit was washed under a water stream and spread in a single layer for drying. Too ripe or immature ones were eliminated from further processing. After washing, 5 kg of fruit was cut along the suture, the stone was removed, and the end of the petiole of the fruit was cut off. For the purpose of monitoring the changes in the moisture content of the apricot halves, a laboratory dryer and an analytical balance were used. The analytical balance was used to measure the weight of empty dishes and the weight of dishes containing fresh samples. The dishes with the samples were then put into the laboratory dryer, previously heated to 80°C. The weight of the dishes with dried samples was also determined. The moisture of the halves was calculated as the difference in the weight of the samples before and after drying, according to the following equation:

$$\omega = \frac{(m_0 - m_p) - (m_1 - m_p)}{(m_0 - m_p)} \times 100 \quad (1)$$

where:

ω – the moisture of the halves [%];

m_0 m_1 – the weight of the material and the dish [g] before and after drying;

m_p – the weight of an empty dish [g].

Then the halves that had been placed in a plastic woven container were treated with 2 g kg^{-1} of powdered sulfur dioxide. The chamber was closed airtight. Sulphuring lasted for four hours, and after that, the batch was unloaded from the chamber. All apricot halves were manually removed and placed in a single layer in order to collect surface moisture by tissue.

The preparation of the osmotic solution with the sucrose concentration of 50°Bx comprised the preparation of the fresh solution or adjusting the used one. Per 10 kg of apricot halves, the fresh osmotic solution was prepared by dissolving 20 kg of sucrose in 40 l of distilled water, while for adjusting sucrose concentration in already used osmotic solution, 350 g of sucrose (on average) was used. The osmotic solution was then heated to 50°C in the osmotic dryer. The drying lasted for 2 hours, then the weight of the halves was measured. Convective drying using the laboratory dryer “IVA-2” lasted for 24 hours at the temperature of 50°C. After 24 hours, the halves were taken out of the dryer and the weight of the halves was measured.

The descriptive sensory evaluation of the dried apricots was conducted by scoring: for colour – max 7, aroma – max 4, taste – max 4, and attractiveness – max 5. Sensory evaluation was conducted on the sample of five halves per cultivar by five independent experts.

Data analysis

Data for all measurements were expressed as average values. The obtained results were processed by ANOVA in the statistic program STATISTICA Version 6.0 for Windows (Stat Soft Inc., Tulsa, Oklahoma). The LSD test was used to detect significant differences ($p \leq 0.05$) between the values. The economic analysis of the profitability of drying apricot includes a compilation analysis for drying different apricot cultivars using the same equipment.

Results and Discussion

Fruit ripening is associated with several phenomena such as changes in respiration, ethylene production, soluble solids, sugars and beta-carotene contents (Dinnella et al., 2006). The ripening induced texture softening, which is associated with pectin depolymerisation and solubilisation. The ripening phase had a significant influence on the drying characteristics of apricot fruits, and the maturity grading before drying is an essential step to ensure the homogeneous drying process and its efficiency (Deng et al., 2019). Based on the results of Bureau et al. (2006) and Egea et al. (2006), the fruits for drying were harvested at the phase closer to the full ripening, when they had a small area of straw-green skin and hard texture. Before and during fruit drying, a change in moisture content was observed.

As shown in Table 1, the highest content of moisture in fresh fruit was found in “NS-6” (89.39%) and the lowest in “NS-4” (86.25%). After osmotic drying, the loss of moisture was highest in “Novosadska kasnocvetna” amounting to 2.95% and the lowest in “NS-4” (1.94%).

Table 1. The moisture content in fresh and dried apricot fruits (%).

Cultivar/selection	Moisture of fresh fruit	Moisture after osmotic drying	Loss of moisture after osmotic drying	Moisture after convective drying	Loss of moisture after convective drying
NS–4	86.25a*	84.31a	1.94b	36.37a	49.88a
NS–6	89.39a	87.32a	2.07b	35.87a	53.52a
N. rodna	87.94a	85.54a	2.40b	36.00a	51.94a
N. kasnocvetna	88.62a	85.67a	2.95a	35.42a	53.20a
Magyar kajszi	87.82a	85.27a	2.55b	36.92a	50.90a

*Different letters in the same column denote a significant difference according to the LSD test, $p < 0.05$.

Total moisture after combined drying ranged from 35.42% (“N. kasnocvetna”) to 36.92% (“Magyar kajszi”). Convective drying resulted in the highest moisture loss in “NS-6” (53.52%) and “Novosadska kasnocvetna” (53.20%), without any statistically important differences. Compared to “Magyar kajszi”, all the cultivars except for “NS-4” had a higher loss of moisture, which means they are more suitable for processing by using the combined method of drying. The moisture content in the dried fruits is a very important trait since it affects the taste (Rahović 2006; Rahović et al., 2013) and shrinkage (Janjai et al., 2009). Meteorological factors, especially precipitation, directly influence harvest duration and moisture content in fruits during fruit ripening (Đurić et al., 2005).

As shown in Table 2, the amount of dry fruit produced depended on the cultivar and ranged from 4.6 (“NS-4”) to 5.7 kg (“Novosadska kasnocvetna”).

Table 2. The weight of finally dried fruits and the drying ratio.

Cultivar/selection	Weight of dry fruit (g) produced from 5 kg of fresh fruit	Dry fruit yield (%)	Weight of fresh fruit per 1 kg of dry fruit (kg)
NS–4	1084.71a*	21.69a	4.6a
NS–6	921.34a	18.43a	5.4a
N. rodna	1027.38a	20.55a	4.9a
N. kasnocvetna	884.17a	17.68a	5.7a
Magyar kajszi	962.02a	19.24a	5.2a

*Different letters in the same column denote a significant difference according to the LSD test, $p < 0.05$.

“NS-4” and “Novosadska rodna” showed better results and were more suitable for drying in comparison to “Magyar kajszi” although a statistical difference among cultivars for the fresh/dry ratio was not observed. The dry fruit yield of evaluated cultivars was slightly lower than observed by Akça et al. (1999) for 15 apricot cultivars widely grown in Turkey that varied between 19.36% and 29.80%.

Descriptive sensory evaluation

Maintaining natural colour in dried food products is very important as the visual appearance is one of the first judgments made by consumers. Colour, size, gloss, shape, etc. form the appearance and represent a valuable indicative parameter used in quality control. One of the most challenging aspects of drying is performing the process to produce an attractive colour for the final product. An osmotic dehydration pre-treatment can improve the colour attributes in plant materials, as confirmed by Cano-Lamadrid et al. (2017) in their study on pomegranate arils. Considerable changes in the physical structure of the product, such as a reduction in volume, can occur during the drying process. The application of osmotic drying using sucrose as the first step during drying reduced the shrinkage and improved the rehydration capacity and sensory evaluation (Cano-Lamadrid et al., 2017).

The sensory evaluation of the finally dried fruits obtained from the tested apricot cultivars is expressed in scores and given in Table 3. The highest score for all the properties was given to the dried fruits of “NS–4“, followed by “Novosadska rodna”, “NS-6”, and “Magyar kajszi”, whereas the lowest score was given to “Novosadska kasnocvetna”.

Table 3. The descriptive sensory evaluation of finally dried apricot fruits.

Cultivar/Selection	Colour	Aroma	Taste	Attractiveness	Total score
NS–4	5.3a*	3.2a	3.4b	3.8ab	15.8b
NS–6	4.9a	3.0a	3.2b	3.5abc	14.6ab
N. rodna	5.6b	2.9a	2.9a	3.8ab	15.2ab
N. kasnocvetna	5.5a	2.9a	2.4a	3.2c	13.7ab
Magyar kajszi	4.8a	3.0a	2.8a	3.2c	13.8a

*Different letters in the same column denote a significant difference according to the LSD test, $p < 0.05$.

A statistically important difference confirmed that colour, taste and attractiveness are genotype-dependent. In line with the results of Inserra et al. (2017) that conclude that the sulphuring treatment significantly decreases the aroma compound profile of the dried apricots, scores varied in a small range and were not statistically different.

Economic analysis of drying apricots

Apricots are dried in the period from mid-July to mid-August. After that period, usually fruits with later ripening compared to apricot are dried, so it can be assumed that the equipment will be used for drying plums, apples and other fruits.

Table 4. The economic analysis of drying apricots.

No	Item	Rationale	Total cost
1	Fresh apricots	The capacity of dryers is 80 kg h^{-1}; for two shifts (16 hours per day), one can process 38,400 kg of fresh apricots per month. The price for 1 kg of fresh apricots (kg) – 0.98€	37,632 €
2	Sugar	Approximately 1500 kg for preparation of osmotic solution with the sucrose concentration of 50°Bx and adjustment after each loading. The price per 50kg of sugar – 26.72€	802€
3	Energy	The total energy consumption for two shifts (16 hours per day) is 1,200 kWh^{-1} per month. Energy cost – 0.376 € per kWh^{-1+}.	451.2 €
4	Labour	2 employees are needed for one shift (4 employees for 2 shifts^{++}). One seasonal worker salary is 400 € per month	1,600 €
5	Equipment maintenance	The maintenance of both driers is 20 € per month§.	20 €
6	Depreciation	The drying process is carried out with two types of drying machines: osmotic and conventional. The price for an osmotic dryer is 3,000 €, while the price for a conventional dryer is 4,000 €. The lifespan of a dryer was estimated to be twenty-five years with zero salvage value. It is assumed that the equipment will be used for drying other products around the year, and costs allocated to apricot drying are therefore set at 50%.	140 €
7	Interest	Taking into account the 2% annual interest rate, it is assumed that the equipment will be used for drying other products around the year, and costs allocated to apricot drying are therefore set at 50%.	70 €
8	Total cost per season		40,715.2 €
9	The quantity of “NS-4” dried apricots produced in a season		8,347.82 kg
	The market value of “NS-4” dried apricots produced in a season*		47,976.47 €
	The profit from drying “NS-4” apricots		7,261.27 €
10	The quantity of “Magyar kajszi” dried apricots produced in a season		7,384.61 kg
	The market value of “Magyar kajszi” dried apricots produced in a season		42,387.66 €
	The profit from drying “Magyar kajszi” apricots		1,672.46 €
11	The quantity of “Novosadska kasnocvetna” dried apricots produced in a season		6,736.84 kg
	The market value of “Novosadska kasnocvetna” dried apricots produced in a season		38,669.46 €
	The profit from drying “Novosadska kasnocvetna” apricots		-2,045.74 €

*(market price for 1 kg of dried apricots is 5.74 €), $^{+}$Osmotic dryers use 2 kWh^{-1} while convective dryers use 0.5 kWh^{-1}, $^{++}$The estimates have been made from practical experience, §The information provided by the dryer suppliers of both dryers.

The period of equipment depreciation is 25 years, with no salvage value left in the equipment. In this analysis, the equipment was used in two eight-hour shifts. Different ratios, fresh vs. dried, have mainly caused differences in profitability of three different cultivars, ranging from 4.6 ("NS-4"), 5.2 ("Magyar kajszi") to 5.7 ("Novosadska kasnocvetna"). Based on economic analysis, a decision was made about which apricot cultivars were profitable to dry and which cultivar achieved the highest profit. According to the results from Tables 2 and 4, one can draw a conclusion that choosing the right apricot cultivar for drying is crucial. "NS-4" has the most favourable fresh-to-dry conversion rate and gives high profits per month (7,261.27 €), while "Magyar kajszi" has a moderate conversion rate, and one can make additional profits of 1,672.46 € if apricot fruits are dried instead of sold fresh. "Novosadska kasnocvetna" has an unfavourable conversion rate, so it is not suitable for drying and results in a loss of 2,045.74 €.

Conclusion

Based on the data provided in this research, it can be concluded that the highest content of moisture was found in the cultivar "NS-6" (89.39%) and the lowest in "NS-4" (86.25%) (measured using the thermal gravimetric method). Cultivars "NS-4" and "Novosadska rodna" are suitable for drying with a combined drying method since 4.6 and 4.9 kg of fresh apricots, respectively, are needed to obtain 1 kg of dried fruit. The highest score in the sensory evaluation of dried apricots was given to "NS-4". Furthermore, the application of osmotic drying using sucrose as the first step during drying reduced the shrinkage and improved the rehydration capacity, as well as the sensory quality.

Drying apricots rather than selling fresh apricots, can be a profitable and important added value tool for small farms. According to the study, there is a significant difference between the profitability of drying of different cultivars. Therefore, choosing cultivars with better conversion rate can increase profitability of fruit drying.

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POGODNOST KAJSIJE ZA SUŠENJE KOMBINOVANOM TEHNOLOGIJOM

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R e z i m e

Kajsija je jedna od najcenjenijih kontinentalnih vrsta voćaka čiji se plodovi konzumiraju kao stono voće ili se upotrebljavaju kao vredna sirovina za preradu. Republika Srbija je jedan od lidera u Jugoistočnoj Evropi u proizvodnji kajsije, ali je ponuda ograničena na mali broj sorti koje sazrevaju u vreme kad i „Mađarska najbolja”. U cilju uvođenja u proizvodnju novih sorti koje se odlikuju visokim rodom, kao i kvalitetom za stonu upotrebu i različite vidove prerade, sprovode se intenzivna istraživanja introdukovanih i novostvorenih domaćih sorti. Kajsija se u Srbiji uglavnom prodaje u svežem stanju, ali je i potražnja za sušenim plodovima u porastu. Kako bi se sačuvala nutritivna svojstva i senzorne karakteristike svežih plodova, veoma je važan izbor tehnike za sušenje, a najčešće korišćeno je konvektivno. Cilj istraživanja bio je da se uporedi potencijal sorti kajsije „Mađarska najbolja”, „Novosadska rodna”, „NS-4” i „NS-6” za sušenje primenom dvofazne tehnologije, odnosno kombinacijom osmotskog i konvektivnog sušenja, kao i da se utvrdi profitabilnost primene ove tehnologije na porodičnim poljoprivrednim gazdinstvima. Sorte „NS-4” i „Novosadska rodna” pokazale su najbolje rezultate i pogodnost za sušenje kombinovanom metodom. Najviše ocene za senzorsku evaluaciju suve kajsije dobile su „NS-4”, a zatim „Novosadska rodna”. Rezultati ukazuju na to da je sušenje kajsije kombinovanom tehnologijom, odnosno primenom osmotskog i konvektivnog sušenja profitabilnije od prodaje svežih plodova, kao i da na malim porodičnim gazdinstvima može biti značajan alat za stvaranje dodatne vrednosti poljoprivrednih proizvoda.

Ključne reči: plod, osmotsko i konvektivno sušenje, profitabilnost, *Prunus armeniaca.*

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HAEMATOLOGICAL INDICES AND SERUM BIOCHEMISTRY OF BROILER CHICKEN FINISHER FED DIETS CONTAINING DRIED AVOCADO PEAR SEED (*PERSEA AMERICANA*) MEAL

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Abstract: The general acceptability of plants with proven records of medicinal values in the tropics in recent times has necessitated the use of dried avocado pear in the broiler diet and its possible effects on haematological variables and biochemical indices. The study focused on haematological and biochemical responses of broilers to varying levels of the inclusion of dried avocado pear seeds. The inclusion levels were 0% of the dried avocado pear seed meal as a control, 2.5%, 3.5%, 4.5% and 5.5%. The experiment lasted for eight weeks: four weeks for the starter phase (for the acclimatization of the birds and the maturation of their GIT) and four weeks for the test trials (the finisher phase). The result showed significant differences ($P<0.05$) in the haematological parameters, which implied that the inclusion of the dried avocado pear seeds in broilers' diets had a positive influence on platelets, lymphocytes, monocytes, eosinophils and heterophils. The presence of lymphocytes indicated the adequate production of antibodies, which could prevent opportunistic infections, as was observed during the experimental trials with birds without the test ingredients. The dried avocado pear seed had a positive influence on aspartate aminotransferase (AST), albumin (ALB), total protein (TP), triglyceride and high-density lipoprotein (HDL). It could be concluded from this study that avocado pear seed has significant effects on improving the haematological and serum characteristics of broiler birds, with the highest values recorded in T4 (4.5%) and T5 (5.5%), respectively.

Key words: broiler birds, haematology, high-density lipoprotein, total protein, dried avocado pear seed.

Introduction

Poultry production has been identified as the fastest means of bridging the protein deficiency gap, especially in developing countries. This is because poultry remains one of the most efficient converters of food to animal protein as it is

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known to have a short gestation interval and can multiply quickly. Broiler birds have been widely reported to be a good converter of feed to meat without any religious barriers (Haveenstein et al., 1994). Poultry has achieved its pride of place due to its superior economic importance occasioned by egg production (Laseinde, 2007). Poultry meat and eggs are beginning to substantially contribute to ameliorating animal protein insufficiency in many African countries. However, not much can be said of poultry without a mention of feed.

A greater percentage of the total feed produced in Nigeria is majorly poultry feed, according to Agbede (2019). The sharp increase in the demand for poultry products in recent times, especially in Nigeria, has been attributable to the growth in numbers of fast-food restaurants whose major menu source in urban centres is chicken (Akinnusotu et al., 2018). Feeds and feeding play a very important role in poultry farming as it determines the profit of the business. The poultry industry in Nigeria is faced with the challenges of limited/non-availability of conventional feed ingredients (Agbede, 2019). Hence, a search for alternative feedstuffs that could reduce the cost of feed production becomes a relevant factor. The use of unconventional feed sources like crop residues and agro-industrial by-products has been seen as an alternative solution to the problem of feed crises in poultry production (Agbede, 2019; Igbasan, 2019). A suggestion has been made by Akinsanmi et al. (2020) on the need for partial or complete replacement of costly feed ingredients with less costly non-conventional ones.

Conventional feed ingredients such as maize and soybean have become inadequate for the production of animal products, especially from poultry, as a result of an undue competition between man and livestock over the available feed ingredients, which have resulted in the high cost of feed. This scenario is common in developing nations. However, soybean meal (SBM) and groundnut cake, which are the commonly used plant protein sources in the poultry diet, have become extremely expensive in the last decade, especially in developing countries. Therefore, the search for alternative plant protein sources, which are cheap and locally available, has become an urgent subject to poultry nutritionists (El-Hussieny et al., 2001).

Olorede et al., (1999) reported that feed alone accounted for about 70% of the total cost of poultry production. However, the introduction of avocado seed in poultry diets suggests a future hope for some neglected plant products in the global economy. Aside from the useful protein profiles attributed to avocado seed, Dembitsky et al. (2011) explicitly described the importance of the plant product as a provider of folic acid and appreciable amounts of calcium, potassium, magnesium, sodium, phosphorus, sulfur and silicon, as well as vitamins E, B1, B2 and D. Avocado commonly referred to as the African pear (*Dacryodes edulis*) is a well-known plant in West Africa. The fruits are edible, and the bark, leaves, stem and roots are used for local medicine against diseases associated with the vital organs of the human body (Neuwinger, 2000; Jirovetz et al., 2003). The numerous potentials of avocado seed remain unexploited, however, the industrial use of the seed, if fully utilized, can bring about a drastic reduction in the prices of conventional raw materials such as groundnut cake, soybean meal and other oil seeds used for the production of livestock feed. The determination of blood components by laboratory tests is an important procedure to assist in the diagnosis of various poultry diseases and disorders.

Thus, it is important to know these variations when assessing clinical blood parameters in birds. Also, Genilson et al. (2020) argue that, in Brazil, there is insufficient information at both reference levels for haematological and biochemical parameters for broilers, which makes this study more relevant, and it is essential to draw a blood profile from birds in different experimental situations.

Materials and Methods

Experimental site

The research was carried out at the Poultry Unit of the Teaching and Research Farm, Osun State University, College of Agriculture, Ejigbo Campus. The farm is located on latitude 7º54'N and longitude 4º18'E and 4º54'E at an altitude of 426 m above sea level (Wikipedia-Ejigbo, 2012). Ejigbo is located in the middle portion of 35 km to the north-east of Iwo, 30 km from Ogbomosho in the north and about 24 km east to Ede.

Plant sample collection
The source of avocado pear seeds

Ripe avocado pear pods were obtained from various towns within Osun State. The pods were cut open to gain access to the seeds for further processing. The seeds were chopped into smaller pieces to make the drying process faster and ensure that the seeds were completely dried. After chopping, the seeds were dried in a room away from direct sunlight in order to keep the nutrient profile intact and also until a constant weight was achieved and there was a total reduction in moisture content. The dried seeds were ground (pulverized) using a hammer mill, after which they were incorporated into the feed at various inclusion levels.

Experimental birds
Preparation before arrival

Disinfection, screening and fumigation of the brooding pen had been done before the broiler chicks were brought in, which served as a biosecurity measure.

The nylon screening was removed after 48 hours of fumigation to allow the escape of any residual gases (fumigants).

The arrival of birds

On arrival, the chicks were graded, i.e. unboxed, counted, isolated from weak ones while the active ones were kept in the already prepared pen. Also, the birds were given a solution of glucose and vitamins to serve as an anti-stress agent.

Experimental procedure

Two hundred day-old broiler chicks were used for the experiment. These birds were obtained from a reputable farm in Osogbo, Osun State. The chicks were brooded for fourteen (14) days on a deep litter system using 200-watt electricity bulbs as a source of heat. From 0 to 4 weeks, the chicks were group-fed for acclimatization and the development of the GIT prior to the inclusion of the test ingredient at the finisher phase. The feeding trial was between days 28–56. The chicks, which had already been randomly selected and assigned to five treatments, were replicated three times, ten (10) birds were allocated to each replicate, making a total of 30 birds per treatment. Vaccination and medication programs were administered based on the standard procedure laid down at the University Teaching and Research Farm. Both routine and occasional management practices were thoroughly carried out with strict hygiene measures.

The feed compositions at both starter and finisher phases are shown in Table 2 below. Water was supplied *ad-libitum* throughout the experiment, and avocado pear seeds at varying levels (0%, 2.5%, 3.5%, 4.5%, and 5.5%) were added to their diet at the finisher phase, respectively.

Experimental treatments and experimental design

The following dietary treatments were employed, with the experimental birds being completely randomized in their respective pens. The test ingredient (avocado pear seed) was incorporated into the basal diet. The birds were allotted to the treatments, as illustrated below:

Treatment 1 – Control (0% of avocado pear seed);
Treatment 2 – (2.5% of avocado pear seed);
Treatment 3 – (3.5% of avocado pear seed);
Treatment 4 – (4.5% of avocado pear seed);
Treatment 5 – (5.5% of avocado pear seed).

Table 1. Normal physiological ranges of some biochemical and haematological components for broilers.

Parameters	Reference range
Haematological components	
Haemoglobin (g/dl)	10.2–15.1
Red blood cells ($\times 10^6$uL)	2.5–3.5
PVC %	22–35
WBC ($\times 10^4$u)	1.2–3.0
Heterophils (%)	1.5–4.0
Basophils (%)	Rare
Platelet ($\times 10^6 \mu l^{-1}$)	1.5–3.2
Lymphocyte (%)	45–70
Monocytes (%)	5.0–10
Eosinophils (%)	1.6–6.0
Biochemical components	
Total protein (mg/dl)	3–4.9
Cholesterol (mg/dl)	129–297

Source: Jain (1993) as cited by Aeanwanich et al. (2004).

Table 2. The gross composition of the experimental diets at both starter and finisher phases.

	Finisher diet					
Ingredients	0%	2.5%	3.5%	4.5%	5.5%	Starter diet
Maize	50.00	47.50	47.50	47.50	47.50	50.00
Wheat offal	15.50	14.50	15.00	12.00	10.00	8.90
GNC	15.00	15.00	15.50	16.00	16.00	10.00
SBM	15.00	16.00	15.00	15.50	16.50	24.50
Fish meal	0.00	0.00	0.00	0.00	0.00	3.00
DCP	0.10	0.10	0.10	0.10	0.10	0.20
Bone meal	3.00	3.00	3.00	3.00	3.00	2.50
Methionine	0.35	0.35	0.35	0.35	0.35	0.25
Lysine	0.35	0.35	0.35	0.35	0.35	0.00
Broiler premix	0.30	0.30	0.30	0.30	0.30	0.25
Salt	0.40	0.40	0.40	0.40	0.40	0.40
APS	0.00	2.50	3.50	4.50	5.50	0.00
Total	100.0	100.0	100.0	100.0	100.0	100.0

Sample collection for serum and haematological parameters

At the termination of the experiment (8 weeks), the feed was withdrawn 12 hours prior to blood collection. Two birds were selected from each replicate, making a total of six birds per treatment. Then, 5 ml of blood was drawn from each bird through the jugular vein using a hypodermic needle and syringe; blood samples from each bird were released into pre-labelled sample bottles containing ethylene diamine tetra-acetic acid (EDTA) as an anti-coagulant. The collected blood samples were used for the determination of haematological parameters. The PCV was estimated by spinning about 75ul of each blood sample in heparinized capillary tubes in a haematocrit micro centrifuge for 5 minutes, while the total red blood cell count (RBC) was determined using normal saline as the diluting fluid. The haemoglobin concentration (HBC) was estimated using the cyanomethaemoglobin method. Similarly, the erythrocyte sedimentation rate (ESR) of the blood was determined as described by Lamb (1981).

Some blood samples were also collected in test tubes without EDTA for serum analysis. The blood contained in the bottles without the anti-coagulant was allowed to stand in the test tube rack in the laboratory in a slanting position for about 6 hours. The serum separated from each blood sample was then decanted after centrifugation at 2,000 rpm for four minutes. The serum was kept deep frozen prior to further studies. The sera were analyzed for serum biochemical indices. The total protein was determined by the Biuret method of Reinhold (1953) using a commercial kit (Randox Laboratories Ltd, UK), while albumin value was obtained by the bromocresol green method according to Doumas and Bigg (1971). The globulin and albumin/globulin ratio were determined according to the method of Coles (1986). The free cholesterol was determined by Nonane extraction and enzymatic colorimetric methods, respectively, using commercial test kits (Quimica clinica applicada, S.A), while the serum enzymes alanine amino-transferase (ALT) and aspartate amino-transferase (AST) were obtained using the Randox laboratories Ltd, UK test kits and read in the spectrophotometer.

Statistical analysis

All data on haematological variables and serum biochemistry were subjected to one-way analysis of variance (ANOVA) using the statistical analysis system (SAS Version 9.1, 2008). Where significant differences were separated, Duncan's multiple range tests of the same statistical package (Duncan, 1975) were used.

Results and Discussion

Haematological parameters

The haematological parameters (Table 3) showed significant ($P<0.05$) differences in all the blood components at different levels of avocado pear seed meal inclusion, except in PCV, Hb, WBC, RBC and BA. The value of the platelet decreased as the inclusion level increased up to T3 ($3.5\times10^6\mu l^{-1}$). Except in T4, which had an increase of about $1.44\times10^6\mu l^{-1}$ as its value against T3. The PCV results across the whole treatments showed they supported values elicited in Table 1. However, there were no significant differences ($P>0.05$) between T4, T2 and T3.

The highest platelet value was recorded in birds under T1 (0%) with the value of $1.79 \times 10^6 \mu l^{-1}$, while the least was found in T5. LYM obtained in this study recorded the highest values in T3. However, T2 and T3 had 64.50% and 69.50%, respectively, as their values. However, there was no significant (P>0.05) difference between T1 and T5 and between T2 and T4, with T5 being the least. The HET content showed T5 had the highest value, followed by T1 and T2, and the least values were found in T4 and T3. There was a reduction in the value of HET up to T4 (4.5%). However, there were similarities between T1, T2 and T4. The least value was found in T3. Values obtained in MON showed that T4 and T5 were the highest in the monocyte content of the blood, followed by T2 and T1, and the least in T3. However, there was no significant difference (P>0.05) between T1 and T2 in the monocyte content. Values obtained in EOS showed that T1 had the highest value, followed by T2 and T3, and the least value was found in T5. Also, there were similarities between T2, T3 and T4. Basophil had the highest value in T1, T2 and T5, which had no significant difference (P>0.05) between them, with T3 and T4 having the lowest value. The results from the study on basophils supported the findings of Jain (1993) as cited by Aeangwanich et al. (2004) in Table 1.

Table 3. The effect of avocado pear seed at varying inclusion levels on haematological indices of broiler birds.

Parameters	T1 (0%)	T2 (2.5%)	T3 (3.5%)	T4 (4.5%)	T5 (5.5%)	±SEM
PCV %	25.00	25.00	24.50	27.00	26.00	0.90
HBC (g/dL)	8.33	8.47	8.07	9.27	8.95	0.38
WBC ($\times 10^4$u)	14975.00	16900.00	17675.00	18125.00	14325.00	1200.35
Platelet	179000.00^{a}	159500.00^{ab}	133000.00^{ab}	144000.00^{ab}	108500.0^{b}	15512.36
LYM %	61.00^{b}	64.50^{ab}	69.50^{a}	66.00^{ab}	60.00^{b}	2.29
HET %	31.00^{ab}	27.50^{ab}	24.00^{b}	26.50^{ab}	33.00^{a}	2.46
MON %	3.00^{bc}	3.50^{bc}	2.50^{c}	4.00^{ab}	4.50^{a}	0.43
EOS %	4.50^{a}	4.00^{ab}	4.00^{ab}	3.50^{ab}	2.50^{a}	0.56
RBC ($\times 10^6$uL)	2.17	2.71	2.28	2.97	2.73	0.36
BA %	0.50	0.50	0.00	0.00	0.50	0.22

^{abc} means in the same row with different superscripts are significantly different (P<0.05). PCV = packed cell volume, RBC = red blood cell, HBC = haemoglobin count, WBC = white blood cell, LYM = lymphocyte, HET = heterophils, MON = monocytes, EOS = eosinophils and BA = basophils.

Serum biochemistry

The main effect of avocado pear seed on the serum indices of broiler chicken is shown in Table 4. There were no significant differences (P>0.05) between ALT, CHOL and ALP. There were differences (P<0.05) in the result obtained for AST across the treatments. T1 and T5 had the highest value and T3 had the lowest value. The result decreases from T1, T5, T4 and T3, respectively, with T3 having the lowest value. The similarity was noticed between T2 and T4 and also between T1 and T5. T2 had the highest value for TP, followed by T2 and T3, respectively, with T1 and T4 having the lowest value. The similarity was noticed between T1 and T4, also between T2, T3 and T5. T5 had the highest value for the albumin content of the blood, followed by T3 and T2, respectively, with T1 having the least value. There was no significant difference (P > 0.05) between T2 and T3. T2 had the highest value (0.93 g/dL) for globulin, followed by T3 and T1, respectively (0.78 and 0.76 g/dL). The lowest value was recorded in T4 (0.48g/dL). There were similarities between T1, T3 and T5. TG was affected (P< 0.05) by the inclusion of avocado pear seed. T5 had the highest value and the lowest value followed by T2, and the similarity was noticed between T1 and T4 and also between T2 and T3 with SEM (4.12). The HDL value was found to be the highest in T3 and the lowest in T4. The similarity was noticed between T1 and T5, and also between T2 and T3 with SEM (1.24).

Table 4. The effect of dried avocado pear seed at various inclusion levels on serum characteristics of broiler birds.

Parameters	T1 (0%)	T2 (2.5%)	T3 (3.5%)	T4 (4.5%)	T5 (5.5%)	±SEM
AST(IU/l)	178.52^{a}	152.09^{ab}	117.97^{b}	150.52^{ab}	177.74^{a}	11.75
ALT(IU/l)	20.79	22.67	13.03	14.98	22.25	3.24
Cholesterol (mg/dl)	114.83	132.07	111.91	82.07	97.59	16.79
Total protein (g/dl)	2.60^{b}	3.25^{a}	3.08^{a}	2.63^{b}	3.16^{a}	0.10
ALB (g/dl)	1.84^{c}	2.32^{ab}	2.30^{ab}	2.15^{b}	2.48^{a}	0.08
GLOB (g/dl)	0.76^{ab}	0.93^{a}	0.78^{ab}	0.48^{b}	0.68^{ab}	0.10
TRG (mg/dl)	116.37^{b}	56.04^{c}	66.22^{c}	115.07^{b}	130.97^{a}	4.12
HDL (mg/dl)	36.86^{ab}	37.74^{a}	38.45^{a}	33.39^{b}	36.56^{ab}	1.24
ALP (IU/l)	436.07	446.95	492.37	464.13	506.11	3.67

^{abc} means in the same row with different superscripts are significantly different (P<0.05). T1–T5 = treatments, TRG = triglyceride, LDL = low-density lipoprotein, HDL = high-density lipoprotein, AST = aspartate amino-transferase, ALT = alanine amino-transferase; CHOL = cholesterol, TP = total protein, GLO = globulin, ALB = albumin, ALP = alkaline phosphatase.

Blood represents a means of assessing the clinical and nutritional health status of the animal in feeding trials (Aletor and Egberongbe, 1992) and according to Togun and Oseni (2005), haemoglobin indices such as RBC, WBC, PCV and Hb have been found useful for disease prognosis and for therapeutic as well as feed stress monitoring. The result from this study could help determine the health status of the birds as it reveals the numbers and morphological status of the cellular components that make up the blood, which is often described as factors necessary for the diagnoses and monitoring of diseases according to the Merck manual (2012).

Lymphocytes, PCV, eosinophils, WBC and platelet values obtained in this study were within the normal ranges reported in the literature for chickens (Aeangwanich et al., 2004). The result indicated that avocado pear seed meal did not have any negative effects on blood formation. The platelet values obtained ranged from 1.09 to $1.79\times10^6 \mu l^{-1}$. The lowest values were recorded in T3, and the highest was recorded in T1. The values obtained were within the range (1.5–$3.2\times10^6 \mu l^{-1}$), as buttressed by Aeangwanich et al. (2004). The values recorded for the PCV for the experimental birds ranged from 24.50 to 27.00%. Birds fed 4.5% APS meal recorded the highest value (27.00%), which was higher than the control diet, and this again was corroborated by Akinduro et al. (2017), wherein in a related study, it was revealed that certain medicinal herbs have the tendency to improve haematological parameters in animals.

However, there was no significant difference (P>0.05) in the values of PCV obtained. The PCV values obtained were within the range (22–35%) reported by Aeangwanich et al. (2004). The WBC values recorded for the experimental birds ranged from 1.43 to $1.81\times10^4 \mu l$. Birds fed the 4.5% APS meal recorded the highest value ($1.81\times10^4 \mu$), which was higher than those on the control diet, which could help explain the immunity potential of the dried avocado seed, even though there was no significant difference (P>0.05) in the values of WBC obtained. The WBC values obtained were within the range (1.2–$3.0\times10^4 \mu$) as reported by Aeangwanich et al. (2004).

The values recorded on the lymphocyte level for the experimental birds ranged from 60.00 to 69.50%. Birds fed the 3.5% APS meal recorded the highest value (69.50%), which was significantly ($P < 0.05$) higher than those in the control diet and the treatments. The lymphocyte levels obtained for the birds fed the T3 diet being generally higher than for those fed the other diets imply that the APS fed at 3.5% increased the lymphocyte level in the animal's blood, thereby increasing the level of their immunity, as lymphocyte is a type of white blood cell that functions as part of the immune system and responds to foreign invaders in the animal body. The lymphocyte values obtained were within the range (45–70%), as reported by Aeangwanich et al. (2004).

The values recorded in the monocyte level for the experimental birds ranged from 2.50 to 4.50%. The highest value was obtained in T5 with 4.50%, and the lowest value was obtained at T3 with the value of 2.5%. The result contradicted the report by Aeangwanich et al. (2004), whose value ranges from 5.0% as the lowest value compared to 10.00% as the highest value. This means that the APS decreases the level of monocyte in their blood, which brought about a decline in the adaptive immunity of the animals. The values obtained for eosinophils ranged from 2.5% to 4.5%, where T2 and T3 had the same values of 4.00%, and T5 had the lowest value of 2.5%. The result was within the range (1.6–6.0%), as reported by Aeangwanich et al. (2004).

The serum biochemical indices showed AST, blood albumin and blood were not adversely affected by feeding broiler with avocado pear seed. Most blood proteins are formed in the liver, and plasma protein synthesis is usually reduced in severe liver damage or prolonged protein deficiency (Duke, 1975), a situation which has been explicitly defined by the results of this study. According to Aro et al. (2012), the concentration of biochemical substances in the serum changes in abnormal conditions and, therefore, aids in disease diagnosis. Usually, total proteins, albumin, urea, creatinine, and cholesterol analyses are used for the renal function test, while sodium, potassium, chloride, bicarbonate, alkaline phosphate, aspartate amino-transferase (AST), alkaline amino-transferase (ALT) and bilirubin analyses are used to assess the functions of the liver.

Conclusion

It could be concluded from the study that dried avocado pear seeds have a significant effect on the haematological content of broilers, with the highest value recorded in T4 (4.5%) and T5 (5.5%). The study also revealed that T2 (2.5%) had a significant effect on the serum characteristics of broiler birds, hence the improved quality and general wellbeing noticed during the trial exercise. It was also discovered that T2 had high records of TP, ALB, GLOB, ALT, HDL, and ALP amongst all other treatments, which could have been a result of the inclusion of the test ingredient.

Also, the lymphocyte value obtained showed that the APS assisted in the production of antibodies for proper immune function.

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HEMATOLOŠKI INDEKSI I SERUMSKA BIOHEMIJA TOVNIH BROJLERA HRANJENIH OBROKOM SA BRAŠNOM SEMENA AVOKADA (*PERSEA AMERICANA*)

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R e z i m e

Upotreba biljaka sa dokazanim lekovitim svojstvima u tropskim oblastima u poslednje vreme zahtevala je upotrebu osušenog avokada u ishrani brojlera i njegove moguće uticaje na hematološke varijable i biohemijske indekse. Studija se fokusirala na hematološke i biohemijske odgovore brojlera na različite količine osušenog semena avokada. Udeo ovog hraniva u obroku je bio 0% osušenog semena avokada kao kontrole, 2,5%, 3,5%, 4,5% i 5,5%. Ogled je trajao osam nedelja: četiri nedelje za početnu fazu (za aklimatizaciju ptica i sazrevanje njihovog gastrointestinalnog trakta) i četiri nedelje za probna ispitivanja (završna faza). Rezultat je pokazao značajne razlike ($P<0,05$) kod hematoloških parametara, što implicira da je uključivanje osušenog semena avokada u ishranu brojlera imalo pozitivan uticaj na trombocite, limfocite, monocite, eozinofile i heterofile. Prisustvo limfocita ukazuje na adekvatnu proizvodnju antitela, što bi moglo sprečiti oportunističke infekcije, kao što je primećeno tokom oglednih ispitivanja sa pticama bez ispitivanih sastojaka. Osušeno seme avokada imalo je pozitivan uticaj na aspartat aminotransferazu (AST), albumin (ALB), ukupne proteine (TP), trigliceride i lipoproteine visoke gustine (HDL). Iz ove studije se moglo zaključiti da seme avokada značajno utiče na poboljšanje hematoloških i serumskih karakteristika brojlera, pri čemu su najveće vrednosti zabeležene kod T4 (4,5%) odnosno T5 (5,5%).

Ključne reči: brojleri, hematologija, lipoprotein visoke gustine, ukupni protein, osušeno seme avokada.

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UTICAJ KLIMATSKIH PROMENA NA POTREBE PRIRODNIH TRAVNJAKA ZA VODOM U SRBIJI

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Sažetak: Usled povećanja temperature vazduha sve dužeg vegetacionog perioda i promenljivih količina padavina poslednje dve decenije, livade i pašnjaci Srbije sve češće ostaju bez dovoljno vode za regeneraciju. Cilj ovog rada je da preko pet reprezentativnih lokaliteta sagleda uticaj klimatskih promena na raspoloživost vode za prirodne travnjake na području Srbije. Za analizu buduće promene klimatskih uslova na teritoriji Republike Srbije korišćeni su rezultati ansambla od devet regionalnih klimatskih modela iz baze EURO-CORDEX. Za svaki od 9 modela je izračunat deficit/suficit vode, na kraju za najverovatniju vrednost deficita vode uzeta je medijalna vrednost za svaki proučavani vremenski period. Referentni period je 1986–2005, budući periodi su: 2016–2035 (*bliska budućnost*), 2046–2065, (*sredina veka*) i 2081–2100 (*kraj veka*). Analize su urađene za dva izabrana scenarija emisija gasova staklene bašte: RCP4.5 i RCP8.5. Vegetacija prirodnih travnjaka će biti izložena povećanom riziku od suša. Nedostatak vode se očekuje već krajem maja, kada se iscrpe zalihe vode u zemljištu, i trajaće sve do prvih značajnijih kiša u septembru. Po oba scenarija, očekuje se smanjenje raspoloživih voda do 7% u bliskoj budućnosti. Po scenariju RCP4.5 od sredine do kraja veka očekuje se povećanje deficita vode između 10,7% i 24,2%. Nepovoljniji, mada verovatniji scenario RCP8.5, prikazuje da će povećanje nedostatka vode sredinom veka varirati od 4% do 14%, a do kraja veka između 28,4% i 41,9%. Otpornost na sušu će se razvijati prirodnom raznolikošću i širenjem vrsta otpornih na visoke temperature i oskudicu vode na uštrb osetljivih trava, pogotovo u sušnijem delu Srbije na plićim zemljištima.
Ključne reči: prirodni travnjaci, navodnjavanje, klimatske promene, suša.

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Uvod

Travnjaci su najčešći tip korišćenja zemljišta u mnogim evropskim zemljama, posebno u zapadnoj Evropi ili u planinskim zemljama srednje i južne Evrope, zauzimajući 30–40% evropskog poljoprivrednog područja (Simić et al., 2019). Travnjaci pokrivaju manje produktivna zemljišta na centralnom Balkanu, koja predstavljaju veliki udeo u ukupnim poljoprivrednim površinama u Srbiji (19,5%), Crnoj Gori (80%), Bosni i Hercegovini (> 50%). Prema važećim statističkim podacima iz 2019. godine, trajni travnjaci u Srbiji pokrivaju 676,36 hiljada hektara (livade se nalaze na 350, a pašnjaci na 326 hiljada hektara), dok se površine pod sejanim livadama procenjuju na oko 50.000 ha (Sokolović et al., 2018; Republički zavod za statistiku, 2019). Prema dostupnim statističkim podacima produkcija livada na nivou Srbije je u proseku svega 2,3 tha^{-1} suve materije, a pašnjaka oko 2 tha^{-1}. Uočava se konstantno smanjenje površina pod travnjacima u Srbiji uz veoma nizak prinos krme. Uz socio-ekonomske razloge za ove promene, veliki uticaj imaju i klimatske promene kroz smanjenje padavina i neregularnost distribucije tokom vegetacione sezone.

Travnjaci su neizmerno značajni za očuvanje kvaliteta zemljišta i vode. Višegodišnje trave formiraju gusti pokrivač sa žiličastim korenovim sistemom koji poboljšava stopu infiltracije više od drugih gajenih ratarskih kultura, a efikasnom potrošnjom smanjuje ispiranje azota. Takođe, svojim gustim sklopom travni pokrivač smanjuje gubitak vode isparavanjem i površinsko oticanje, a samim tim sprečava pojavu vodne i eolske erozije (Suttle et al., 2007).

Generalno, produkcija travnjaka, uključujući pašnjake i livade, ograničena je sunčevim zračenjem, temperaturom, stresom vode, dostupnošću hranljivih sastojaka i upravljanjem ispašom/kosidbom. Većina ograničenja vezanih za vodu, hranljive sastojke i upravljanje može se poboljšati – iako to nije uvek ekonomski isplativo – ali sunčevo zračenje i spoljne temperature ne mogu, što su vrlo važni aspekti klimatskih promena (Hutchinson et al., 2000).

IPCC (2014) predviđa značajne klimatske promene koje mogu imati velike uticaje na vodne resurse, a samim tim i na upravljanje vodama i poljoprivrednu proizvodnju. Klimatske promene uzrokuju lanac problema, koji zahtevaju integrisani pristup utvrđivanja faktora koji ograničavaju prinos, a koji će verovatno imati veliki uticaj na ukupnu poljoprivrednu proizvodnju u budućnosti. Gotovo da nema sumnje da će klimatske promene zahtevati kratkoročno i dugoročno prilagođavanje korišćenja zemljišta i upravljanja vodama (Hansen et al., 2006). Nažalost, na to ukazuju činjenice da je već uočen trend povećanja srednje godišnje temperature vazduha tokom poslednje dekade (2007–2016. godine) za 0,87–0,92°C u odnosu na predindustrijsku eru prošlog veka. Ovo povećanje je izraženije na severnoj hemisferi u odnosu na južnu. Projekcije porasta globalne srednje temperature vazduha su od 1,4°C do 1,8°C u zavisnosti od scenarija emisije gasova sa efektom staklene bašte. Na području Srbije, izmerene promene daleko prevazilaze globalne i iznose 1,2°C za period 1996–2015, u odnosu na 1961–1980. Najveći porast, od 1,8°C, zabeležen je tokom letnje sezone. U budućnosti se mogu očekivati dalja povećanja koja, u zavisnosti od scenarija emisije GSB, mogu dostići do 1,0°C u bliskoj budućnosti, 2,0°C sredinom veka i čak 4,3°C, krajem veka (prema scenariju RCP8.5) u odnosu na referentni period 1986–2005. godine (Vuković et al., 2018). To sve ukazuje na neophodnost proučavanja uticaja klimatskih promena na sadašnje prirodne travnjake (Olesen et al., 2011). Tome u prilog idu rezultati istraživanja u kojima je ustanovljeno da toplotni talasi i suše veoma negativno utiču na prirodne travnjake na području kontinentalne klime u Panonskoj niziji, koja uključuje Mađarsku, Srbiju, Bugarsku i Rumuniju. Stoga je povećanje proizvodnje biomase uz održavanje ili smanjenje količine vode koja se koristi, tj. povećanje efikasnosti korišćenja vode (EKV), od najvećeg interesa. Kombinovanje vrsta trava različitih funkcionalnih grupa i sa različitim funkcionalnim osobinama moglo bi da igra ključnu ulogu u ovom pogledu (Hofer et al., 2016).

Craine et al. (2013) su u svojim istraživanjima ustanovili da se fiziološka tolerancija na sušu deseterostruko razlikovala među 426 vrsta trava. Trave su dobro raspoređene i klimatski i filogenetski, što ukazuje da većina prirodnih travnjaka verovatno sadrži veliku raznolikost tolerancije na sušu. Shodno tome, lokalne vrste mogu pomoći u održavanju funkcionisanja ekosistema kao odgovor na promenljive režime suše, a da ne zahtevaju migracije vrsta trava na velike razdaljine. Dalje, fiziološki tolerantne vrste na sušu imale su veće stope razmene vode i ugljen-dioksida od netolerantnih vrsta, što ukazuje da ozbiljne i dugotrajne suše mogu promeniti floristički sastav prirodnih travnjaka.

Istraživanjima uticaja ektremnih klimatskih pojava (suše, toplotnih talasa, promene u topljenju snega, itd.) na travnjake u različitim ekosistemima Italije, došlo se do zaključka da je suša imala najozbiljniji efekat na biljke, pogotovo u zajednicama sa mnogo vrsta dok su toplotni talasi imali manji efekat ako su biljke bile dobro snabdevene vodom. Preklapanje različitih ekstremnih klimatskih pojava (npr. suša povezana sa toplotnim talasima) je najčešće sinergijski negativno delovalo, što se ispoljava i na povećano propadanje biljaka (Orsenigo et al., 2014).

Kako su prirodni travnjaci sačinjeni od velikog broja različitih biljnih vrsta u kojima dominiraju predstavnici trava, najverovatnije se mogu očekivati različite reakcije na suše u budućnosti. Cilj ovoga rada je da se ustanovi uticaj klimatskih promena u Srbiji na potrebu prirodnih travnjaka za vodom, kao i da se predvidi verovatnoća pojave trajanja ekstremnih temperaturama (Tmax > 30°C) u periodu dužem od 30 dana, kao i verovatnoća pojave dâna bez snega i ekstremno niskih temperatura (Tmin < -17°C) koje mogu negativno uticati na pojedine vrste trava.

Materijal i metode

Izabrano je pet reprezentativnih lokaliteta koji predstavljaju veće agroekološke makroceline Srbije (Rimski Šančevi, Valjevo, Kragujevac, Negotin i Leskovac) za analiziranje uticaja klimatskih promena na potrebu prirodnih travnjaka za vodom na području čitave Srbije.

Za izračunavanje parametara vezanih za buduće klimatske promene korišćen je multi-model ansambl rezultata 9 regionalnih klimatskih modela iz baze EURO-CORDEX, čija je rezolucija 0,1 po geografskoj dužini i širini. Rezultati modela su sa statistički korigovanom greškom modela (engl. *bias*) na dnevnom nivou za srednje, maksimalne i minimalne dnevne temperature i dnevne sume padavina. Detaljan opis korekcije je opisan u Vuković et al. (2015). Korišćeni scenariji budućih emisija gasova sa efektom staklene bašte (GSB) izabrani su u skladu sa Petim izveštajem Međuvladinog panela o klimatskim promenama – *Representative Concentration Pathway* (RCP) (IPCC, 2014). Izabrana su dva scenarija za koje se pretpostavlja da obuhvataju najverovatniji opseg mogućih budućih ishoda: RCP4.5 po kome će emisije GSB doseći maksimum oko 2040. godine, posle čega će se porast stabilizovati, i scenariju RCP8.5, po kome se porast emisija gasova staklene bašte nastavlja kroz 21. vek. Veza emisije GSB i deficita vode se ogleda preko porasta temperature vazduha a samim tim i porasta potencijalne evapotranspiracije tj. potrebe travnjaka za vodom i smanjenja padavina.

Za svaki od 9 modela je izračunat deficit vode, a na kraju za najverovatniju vrednost deficita vode uzeta je medijalna vrednost za svaki proučavani vremenski period. Kao ilustracija velikih varijacija u modelu, pored medijane biće prikazane i maksimalne i minimalne vrednosti koje daju pojedini modeli. Odabir perioda za analizu budućih promena klime je u skladu sa Petim izveštajem Međuvladinog panela o klimatskim promenama. Referentni period je 1986–2005, a budući periodi su: 2016–2035 (*bliska budućnost*), 2046–2065 (*sredina veka*) i 2081–2100 (*kraj veka*).

Potrebe prirodnih travnjaka za vodom, odnosno nedostatak vode ili neto norma navodnjavanjem (In) su izračunati metodom vodnog bilansa. Metod vodnog bilansa je podrazumevao izračunavanje referentne evapotranspiracije (ETo) metodom FAO Hargreaves–Sammani (HS) (Allen et al., 1998), i evapotranspiracije travnjaka (ET), gde je uzet u obzir koeficijent kulture (kc) i padavina (P) na mesečnom nivou. U proračunu vodnog bilansa, uzeta je u obzir i sposobnost zemljišta da zadrži vodu (θ) koju trave mogu koristiti u beskišnom periodu, dakle:

$$ET = ETo \cdot kc \qquad (1)$$

$$In = ET - P \pm \Delta\theta \qquad (2)$$

Poznato je da metoda HS u klimatskim uslovima Srbije daje veće vrednosti i do 28% kada se za proračun koriste mesečne vrednosti minimalne i maksimalne temperature vazduha (Trajković, 2005), i da je bolje primenjivati korigovanu metodu za područje Srbije (Trajković, 2007). Novija pak istraživanja zasnovana na dnevnim vrednostima ulaznih podataka pokazuju da su odstupanja manja, pogotovo u vegetacionom periodu (Marković, 2012). Uzimajući u obzir izveštaje o osmotrenim promenama klime u Srbiji i buduće projekcije klimatskih uslova (Djurdjević et al., 2018), koje ukazuju da će područje Srbije biti toplije i aridnije (sa ekstremnim temperaturama preko > 30°C u trajanju preko mesec dana), tako da se opravdava primena metode HS za izračunavanje vodnog deficita, što potvrđuju istraživanja Todorović et al. (2013). Dakle, izvesne greške pri proceni ET početkom veka su moguće, ali se one minimiziraju krajem veka.

Vodni bilans je izračunat za svaki model ponaosob za svaku godinu istraživanja (1986–2100), a zatim je kao najverovatnija vrednost uzeta medijana dobijenih rezultata za svaki posmatrani lokalitet. Pored medijane, takođe su prikazane i maksimalne i minimalne vrednosti koje daju pojedini modeli, koje služe kao ilustracija o odstupanju između pojedinih modela. Na ovakav način se izbegava favorizovanje blažeg ili oštrijeg uticaja klimatskih promena na potrebe useva za vodom i opstanak travnatih vrsta uopšte.

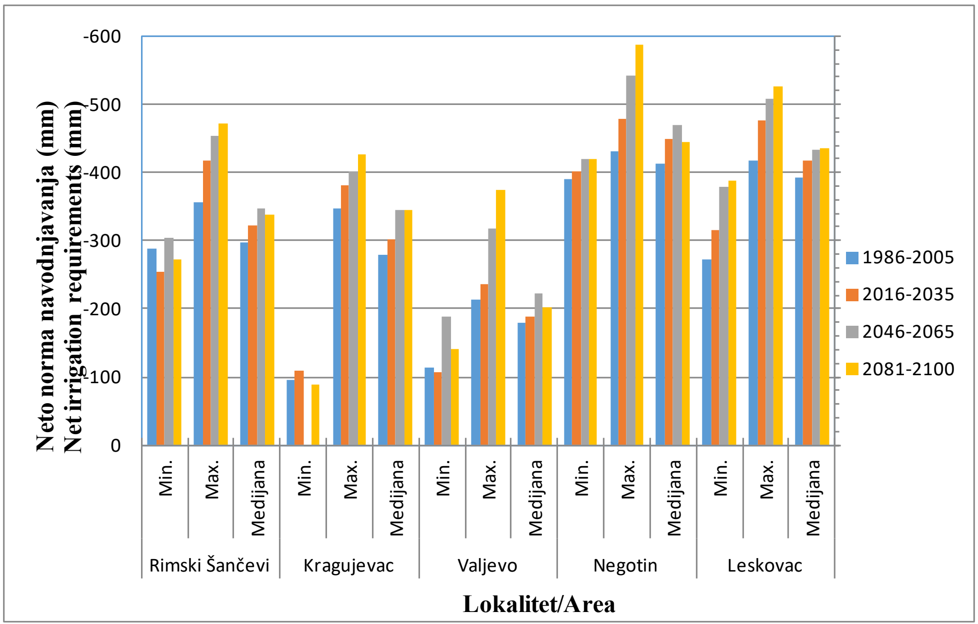
Pored vodnog bilansa izračunata je verovatnoća pojave ekstremnih temperatura vazduha u trajanju dužem od 30 dana u toku vegetacionog perioda trava (Tmax > 30°C) i u periodu zimskog mirovanja (Tmin < -17°C) i trend promena da bi se utvrdio mogući uticaj na opstanak pojedinih vrsta u izmenjenom temperaturnom režimu. Ukoliko se toplotni režim naruši, neke višegodišnje trave u kombinaciji sa dugotrajnom sušom teško opstaju. Na primer, trave tipa C_3 mogu lako podneti niske temperature, ali svega nekoliko dana mogu podneti ekstremno visoke (Tmax > 30°C), a ukoliko one potraju 3–4 nedelje može doći do propadanja trava (Puhalla et al., 2010).

Rezultati i diskusija

Scenario RCP4.5 i RCP 8.5

Na slici 1 su prikazani deficiti vode za prirodne travnjake na pet proučavanih lokaliteta po scenariju RCP4.5. Jasno se uočavaju velike varijacije u vrednostima koje daju pojedini modeli od devet proučavanih. Na svim područjima razlika između minimalnih i maksimalnih vrednosti može dostići od 30% do 50% vrednosti deficita (povoljniji rezultat) u istom posmatranom periodu. Na primer, na Rimskim Šančevima deficit vode sredinom veka bi iznosio 303 mm po jednom modelu, a po drugom čak 453 mm. Kao verovatna vrednost zbog toga je uzeta medijalna vrednost devet modela koja za taj period iznosi 347 mm.

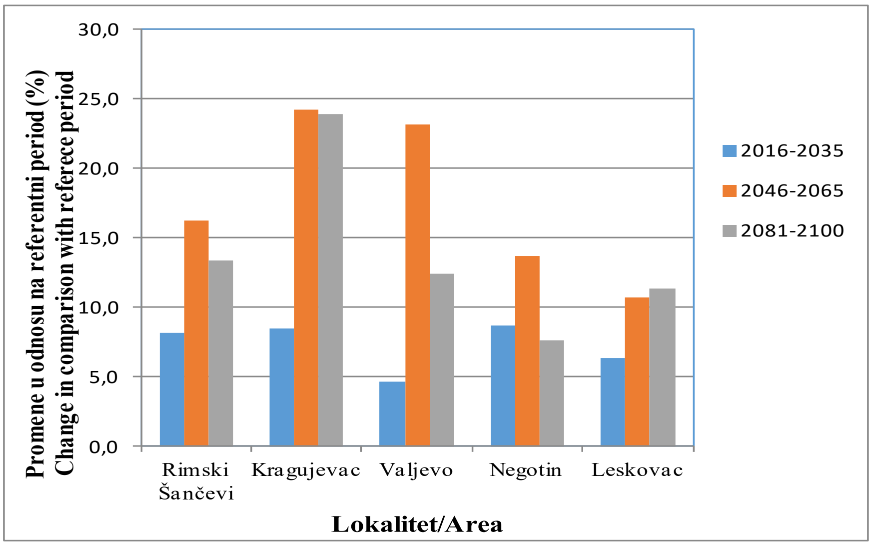
Na svim lokalitetima se uočava trend povećanja deficita vode. U referentnom periodu prosečan deficit prirodnih travnjaka za vodom iznosi 312 mm, s tim što je najniža vrednost dobijena na području Valjeva (180 mm), a najviša na području Negotina (413 mm). U bliskoj budućnosti i sredinom veka uočava se trend povećavanja za po jednu normu zalivanja, dakle povećanje za prosečno 24 mm i 51 mm, redom. S obzirom na to da je po ovom scenariju povećanje emisije GSB sporije, temperaturni i padavinski režim se neće bitnije menjati od sredine veka, a samim tim i neto norme navodnjavanja.



Slika 1. Neto norma navodnjavanja prirodnih travnjaka po scenariju RCP 4.5.
Figure 1. The net irrigation requirement of natural grasslands under the RCP 4.5 scenario.

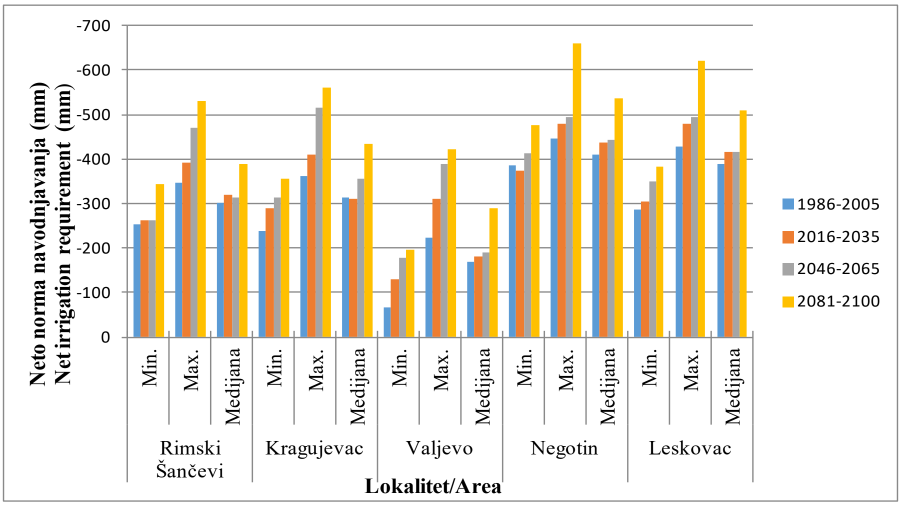
Iako se na prvi pogled čini da se norme navodnjavanja neće značajnije menjati, treba napomenuti da nedostatak vode u Negotinu od 470 mm vode ukazuje na redovnu pojavu dugotrajnih suša, što predstavlja rizik po prirodne travnjake da se ne oporave posle obilnih jesenjih kiša, što posebno važi za one vrste trava čiji je uobičajeni period letnje dormancije na travnjaku kraći.

Na slici 2, prikazane su procentualne promene neto norme navodnjavanja u odnosu na referentni period (1986–2005). U bliskoj budućnosti povećanje varira od 4,7% u Valjevu do 8,7% u Negotinu, što se smatra uobičajenom standardnom varijacijom. Međutim, sredinom veka, povećanje deficita će biti najmanje na području Leskovca (10,7%), a najveće na području Kragujevca (24,2%). Nešto manje vrednosti će se javiti do kraja veka (7,7% u Negotinu do 23,9% u Kragujevcu). Na prvi pogled se može reći da povećanje od, na primer, 10,7% nije veliko za područje Negotina, ali ako su tamo deficiti znatno veći nego u drugim područjima, onda je jasno da će se situacija značajno pogoršati u i ovako najsušnijem delu Srbije.



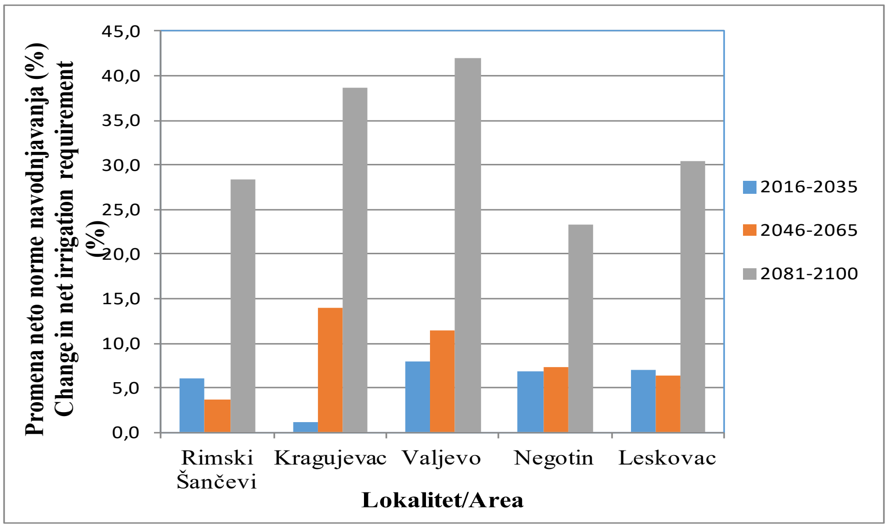
Slika 2. Promena neto potreba za navodnjavanjem (%) po scenariju RCP4.5.
Figure 2. The percentual variation in irrigation water requirements under the RCP4.5 scenario.

Na slici 3 prikazane su neto norme navodnjavanja za prirodne travnjake po scenariju RCP8.5. Kao i u prethodnom scenariju (RCP4.5), uočavaju se značajne razlike u neto normama navodnjavanja po modelima. Na primer, u referentnom periodu deficit vode na području Valjeva po jednom modelu je 66 mm, a po drugom 223 mm, dok je medijalna vrednost 168 mm, što se podudara sa osmotrenim vrednostima deficita vode u pomenutom periodu (Avakumović et al., 2005). Nešto manje razlike se dobijaju na ostalim područjima. Na primer, na lokalitetu Negotin najniža vrednost je 385 mm, dok je najviša 447 mm, a medijalna 410 mm. Iz dobijenih podataka jasno je da je medijalna vrednost merodavna za dalje prognoze potreba prirodnih travnjaka za navodnjavanjem. Medijalne vrednosti deficita vode po svim modelima na posmatranim područjima iznose 333 mm, 343 mm i 430 mm u bliskoj budućnosti, sredinom i krajem veka, redom. Najniži deficiti se očekuju na području Valjeva 182 mm, 190 mm, 290 mm, a najveći na području Negotina 438 mm, 443 mm i 535 mm, u bliskoj budućnosti, sredinom i krajem veka, redom.



Slika 3. Neto potreba prirodnih travnjaka za navodnjavanjem po scenariju RCP 8.5.
Figure 3. The net irrigation requirement of grasslands under the RCP 8.5 scenario.

Daleko nepovoljniji scenario u pogledu vodnog režima prirodnih travnjaka je RCP8.5, po kome se očekuju značajno veći deficiti vode, naročito krajem veka. Iako je procentualno povećanje najmanje na području Negotina (23,3%), to područje će biti najviše pogođeno sušom (slika 4).



Slika 4. Promena neto potreba za navodnjavanjem (%) po scenariju RCP8.5.
Figure 4. The percentage of variation in net irrigation requiremetns under the RCP8.5 scenario.

Naime, kad su veliki deficiti vode, onda i malo povećanje je mnogo veće nego na nekom području gde su deficiti u referentnom periodu mnogo manji. Na primer, na području Negotina se deficit povećava za 125 mm, dok se na lokalitetu Valjevo povećava za 121 mm. Dakle, posmatrati samo relativno povećanje nije dovoljno da bi se ocenio negativan uticaj suše na neko područje, već je neophodno šire, sveobuhvatnije posmatranje. U svakom slučaju, promene deficita vode za 41,9%, na primer za Valjevo, svakako će izazvati ozbiljnu reakciju ekosistema travnjaka.

Sušni period

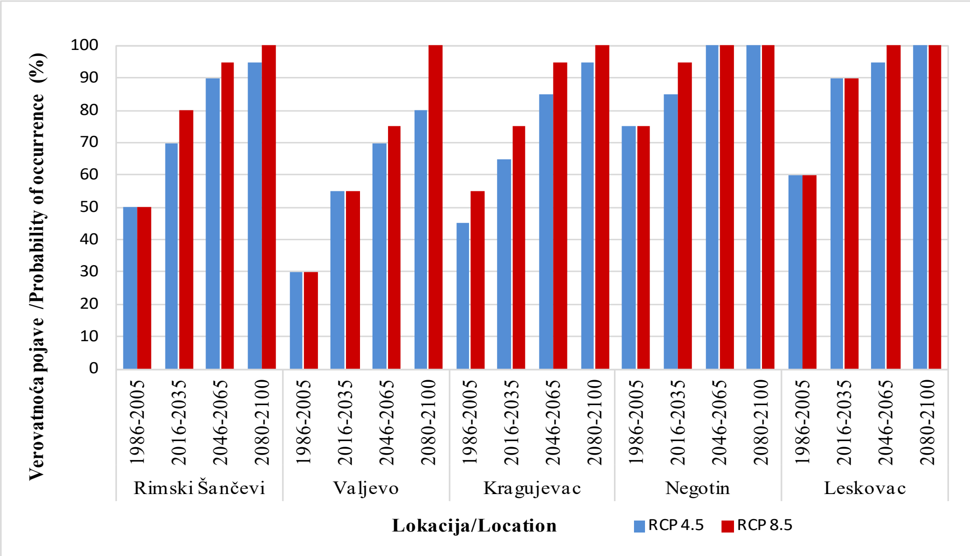
Dužina sušnog perioda je od velikog značaja za održivost ekosistema prirodnih travnjaka, ali i broj dana sa ekstremnim temperaturama, kako sa visokim tako i sa niskim, kao i izostanak snežnog pokrivača, itd.

U tabeli 1 su prikazane verovatnoće pojave broja sušnih dana po lokalitetima. Iz podataka se vidi da će broj sušnih dana početkom veka biti najmanji na području Valjeva (97), a najveći na lokalitetu Negotin (107). Sredinom i krajem veka po scenariju RCP4.5 doći će do povećanja broja sušnih dana za 2 na svim područjima. Sličan broj dana se može očekivati i po scenariju RCP8.5, s tim što se krajem veka broj sušnih dana povećava 9 dana za Valjevo i od 5 do 7 dana na ostalim lokalitetima.

Tabela 1. Simulirani broj sušnih dana po lokalitetima.
Table 1. The number of days without rain.

Scenario	Period	Rimski Šančevi	Valjevo	Kragujevac	Negotin	Leskovac
RCP 4.5	1986–2005	101	95	100	106	101
	2016–2035	101	97	101	107	102
	2046–2065	103	99	103	109	105
	2080–2100	103	99	103	108	105
RCP 8.5	1986–2005	100	94	100	106	102
	2016–2035	101	96	101	106	101
	2046–2065	102	99	103	108	104
	2080–2100	106	103	107	111	109

Veza uticaja ekstremnih vremenskih pojava ekstremnih temperatura (verovatnoće pojave ekstremno visokih temperatura > 30°C u trajanju dužem od 30 dana), suše i broja sušnih dana su prikazane na slici 5. U referentnom periodu vidimo da je verovatnoća da ovako ekstremne temperature traju preko mesec dana variraju od 30% za lokalitet Valjevo, do 60% na lokalitetu Leskovac. U bliskoj budućnosti verovatnoće da će se ovako visoke temperature javiti rastu na svim područjima i variraju od 55% za Valjevo do 90% za Negotin i Leskovac, da bi sredinom i krajem veka praktično to postala redovna pojava (verovatnoća od 95% do 100%), pogotovo po scenariju RCP8.5.



Slika 5. Verovatnoća pojave (%) maksimalne dnevne temperatura vazduha > 30°C u trajanju od preko 30 dana na proučavanom području po dva scenarija RCP 4.5 i RCP 8.5.

Figure 5. The probability of the occurrence (%) of the maximum daily air temperature (> 30°C) for more than 30 days at selected locations, under RCP4.5 and RCP8.5 scenarios.

Verovatnoća pojavljivanja veoma niskih temperatura u toku zimskog dela godine je na istraživanim lokalitetima u referentnom periodu varirala od 15% za Rimske Šančeve, Valjevo i Kragujevac do 25% za Leskovac. U bliskoj budućnosti mogu se očekivati samo manje promene ovih verovatnoća po oba scenarija. Polovinom i krajem veka se po scenariju RCP4.5 može očekivati smanjenje verovatnoće na 5% do 10% na svim lokalitetima. Prema scenariju RCP8.5 polovinom veka verovatnoća pojavljivanja niskih temperatura će biti 10% na svim lokalitetima, dok se krajem veka takvi događaji ne očekuju (tabela 2).

Verovatnoća pojavljivanja veoma niskih temperatura koje su u isto vreme praćene golomrazicom, odnosno pojavljuju se bez formiranja snežnog pokrivača je očekivano manja (tabela 3). U Valjevu ovakvih događaja nije bilo u referentnom periodu, jer su obično niske temperature bile praćene formiranjem snežnog pokrivača, što se očekuje i u budućnosti, dokle god se tako niske temperature budu javljale. Na ostalim lokalitetima verovatnoća pojavljivanja niskih temperatura sa golomrazicom u referentnom periodu i bliskoj budućnosti je oko 5%, dok se do sredine i kraja veka očekuje da se ovakvi događaji više ne javljaju, naročito prema scenariju RCP8.5.

Tabela 2. Verovatnoća pojave Tmin < -17°C u toku zime (%).
Table 2. The probability of the occurence of Tmin < -17°C during winter (%).

Scenario	Period/Lokalitet	Rimski Šančevi	Valjevo	Kragujevac	Negotin	Leskovac
RCP4.5	1986–2005	15	15	15	20	25
	2016–2035	10	15	15	15	25
	2046–2065	5	10	5	5	15
	2081–2100	10	5	5	10	5
RCP8.5	1986–2005	15	15	15	15	25
	2016–2035	15	15	15	20	20
	2046–2065	10	10	10	10	10
	2081–2100	0	0	0	0	0

Dobijeni rezultati jasno ukazuju na to da će vegetacija prirodnih travnjaka biti izložena promeni klimatskih uslova, čestoj suši i čestoj pojavi ekstremno visokih temperatura. Nedostatak vode se očekuje već krajem maja, kada se iscrpe zalihe vode u zemljištu, i trajaće sve do prvih značajnijih jesenjih kiša, odnosno kada priliv vode bude dovoljan da se ostvari proces regeneracije biljaka i proces evapotranspiracije.

Tabela 3. Verovatnoća pojave Tmin < -17°C bez snežnog pokrivača u toku zime (%).
Table 3. The probability of the occurrence of Tmin < -17°C without snow cover during winter (%).

Scenario	Period/Lokalitet	Rimski Šančevi	Valjevo	Kragujevac	Negotin	Leskovac
RCP4.5	1986–2005	5	0	5	5	5
	2016–2035	5	0	0	5	0
	2046–2065	0	0	0	0	5
	2081–2100	0	0	0	5	0
RCP8.5	1986–2005	0	0	5	5	5
	2016–2035	10	0	5	5	5
	2046–2065	0	0	0	0	0
	2081–2100	0	0	0	0	0

Proučavanjem trendova osmotrenih klimatskih parametara u periodu 1961–2017, uočeno je da se temperatura vazduha povećava za 0,36°C po deceniji, ali da akumulirane padavine nemaju izraženi i jednoznačan trend u prostornoj i sezonskoj analizi. Uočeno je povećanje padavina za 7 mm, ali ovi rezultati nisu statistički značajni. Međutim, analizom sezonskih padavina došlo se do rezultata da se one smanjuju tokom letnjih meseci (Djurdjević et al., 2018).

Iako će biti padavina tokom leta, one često neće biti dovoljne da prokvase zemljište do potrebne dubine kako bi se travnjaci održavali u životu i obezbedila regeneracija pojedinih vrsta. Opšte je poznato da padavine manje od 8 mm nisu efektivne ako se jave posle sušnog perioda, jer se najveći deo tih padavina zadrži na lišću (čak i suvom lišću) i u površinskom delu zemljišta odakle pri visokim letnjim temperaturama ispare istog ili sledećeg dana (Doorenbos i Pruitt, 1984), dok su padavine od 25 mm do 30 mm efektivne svega oko 60% (što znači da u zemljište dospe svega 15–18 mm), i one mogu prokvasiti zemljište do desetak centimetara. Ukoliko su padavine učestale, i manje količine mogu biti efektivne. S obzirom na to da se očekuje povećani broj sušnih dana i povećanje ekstremno visokih temperatura vazduha, opstanak travnjaka će u mnogome zavisiti od visine padavina u toku leta koje će obezbediti održavanje korenovog sistema u periodu prinudne hibernacije.

Istraživanja na globalnom nivou (Stuart-Haëntjens et al., 2018) ukazuju da je otpornost prirodnih travnjaka na ekstremne suše i njihov oporavak u korelaciji sa srednjim godišnjim sumama padavina. S obzirom na to da se sume padavina neće bitnije menjati na području Srbije, po ovim istraživanjima se može očekivati opstanak prirodnih travnjaka i pored povećanja deficita vode.

Mogući uticaji klimatskih promena na prirodne travnjake u Srbiji

U budućnosti se mogu očekivati dalja povećanja temperatura vazduha i to od 1,0°C, 2,0°C i 4,3°C, u bliskoj budućnosti, sredinom i krajem veka redom u odnosu na referentni period 1986–2005, po scenariju RCP8.5 (Vuković et al., 2018). Ovakve projekcije porasta temperature mogu imati i dobre i loše strane. Dobre strane se mogu očekivati samo na višim nadmorskim visinama, kada se usled otopljavanja može očekivati duži vegetacioni period. Uz nepromenjene varijacije padavina mogu se očekivati i viši prinosi biomase (Orsenigo et al., 2014).

Međutim, više pokazatelja po ovim istraživanjima ukazuje na to da se usled klimatskih promena mogu očekivati negativni uticaji. Na primer, suša u kombinaciji sa toplotnim talasima utiče na produkciju biomase u letnjem periodu, ali ne i u prolećnom. Takođe, utiče i na mortalitet mladih biljaka, biljaka u razvoju, pa čak i stasalih (razvijenih) biljaka. Stepen uvenuća svakako zavisi ne samo od stepena suše već i od biljne vrste i njene tolerantnosti na ekstremne uslove (C_3 ili C_4), kao i plodnosti zemljišta. Porast temperature može povećati fotosintezu trava tipa C_3 za 30%, ali ne i C_4, kojima veće temperature mogu pogodovati većem rastu (Volenec i Nelson, 2017), ali će im lišće i stabla biti slabijeg kvaliteta. Povezanost sa vodnim stresom će kod biljaka na travnjaku uticati na izduženje korena, u potrazi za vlagom.

Verovatnoća pojave ekstremnih temperatura vazduha u dužem trajanju u sadejstvu sa sušnim uslovima, što se očekuje u Srbiji može dovesti do ugrožavanja opstanka travnih biljnih vrsta (McDowell et al., 2011; Craine et al., 2013; Griffin-Noland i Knapp, 2018), a posebno vrsta severnog umerenog klimata kao što su: *Lolium perenne* (engleski ljulj), *Lolium multiflorum* (italijanski ljulj), *Phleum* *pratense* (mačji rep), *Dactylis glomerata* (ježevica), *Festuca pratense* (livadski vijuk), *Poa pratensis* (prava livadarka), *Bromus inermis* (bezosni vlasen), *Alopecurus pratensis* (lisičji rep) i druge, koje su izuzetno osetljive na ovakve klimatske prilike. Sve ove višegodišnje travne vrste čine veoma brojne komponente, neretko edifikatore, biljnih asocijacija prirodnih trajnih travnjaka, odnosno glavne komponente i nosioce prinosa sejanih travnjaka za proizvodnju kabaste stočne hrane na livadama i oranicama Srbije (Sokolović et al., 2013).

Istovremeno, one se veoma razlikuju prema otpornosti na hladnoću, pa je mačji rep otporniji od bezosnog vlasena, a on je otporniji od ježevice. Prema otpornosti na izmrzavanje, trave tipa C_3 se razlikuju, od ekstremno otpornih, kao što su rosulje, koje izdržavaju i temperature ispod -30°C, preko prave livadarke, koja izdržava u zavisnosti od sorte i uslova sredine, od -20 do -30°C, do nešto osetljivijeg visokog vijuka, koji izdržava do -15°C i relativno osetljivog engleskog ljulja, koji strada u rasponu od -5°C do -15°C (Bertrand et al., 2013).

Bezosni vlasen je tolerantniji na sušu od ježevice i prave livadarke, jer je dubljeg korena i ima pristup većoj zapremini zemljišta (Volenec i Nelson, 2017). Višegodišnje trave tipa C_3 se takođe razlikuju i po odgovoru na toplotni stres, pa visoki vijuk pokazuje visoku tolerantnost, prava livadarka dobru, dok engleski ljulj i rosulje imaju zadovoljavajuću otpornost. S druge strane, obična livadarka (*Poa trivialis*) je neotporna na toplotni udar (DaCosta i Huang, 2013).

Duži sušni periodi uslovljavaju letnju dormanciju trava, tako da slabije štite zemljište od erozije i bujica koje mogu nastati usled jakih letnjih kiša. Pored toga, podložno je uticaju požara, a samim tim i ubrzanoj potencijalnoj sukcesiji biljnih asocijacija i izmeni prirodnog sintaksona. Višegodišnja izloženost nepovoljnim klimatskim uslovima može čak dovesti i do dezertifikacije (Kosmas et al., 2003), što se sve može očekivati u Srbiji s obzirom na očekivanu dugotrajnost sušnog perioda i visokih tempeatura.

Istraživanja sprovedena na više ekozona ukazuju na to da će klimatske promene na područjima umerenih stepa (u koje se po prikazanoj klasifikaciji nalazi i naša zemlja) uticati na smanjenje produkcije biomase, pre svega zbog suše i povećane evapotranspiracije (Hossain i Li, 2020). Ovi podaci su u saglasnosti s dobijenim rezultatima o povećanju potreba travnatog pokrivača za vodom.

Eksperimentalna istraživanja sprovedena u mediteranskim uslovima potvrđuju da uticaj suše u kombinaciji sa visokim temperaturama negativno utiče na preživljavanje nekih trava. Naime, Severmutlu et al. (2011) su ustanovili da visoki vijuk, kao trava koja pripada tipu C_3 ulazi u period dormancije sredinom jula, a oporavak se ostvaruje na 70% biljaka na jednom području, dok se na drugom području ne oporavlja uopšte. S obzirom na to da će sušni period početi već u maju, a trajaće do septembra na svim područjima Srbije, po pitanju suše klima sve više nalikuje mediteranskoj.

S druge strane, i pored mogućnosti pojave niskih temperatura od -17°C, sa ili bez snežnog pokrivača, očekivanja su da će travnjaci dobro podnositi takve niske temperature, usled fiziološke osnove dominantnih vrsta na travnjaku – trava. Inače, na području Srbije se javljaju trave tipa C_3 koje skladište u ćelijskim vakuolama ugljeni hidrat fruktan, što im daje značajnu otpornost na oštećenja od niskih temperatura. Uz takve trave se javljaju i prilično tolerantne višegodišnje leguminoze dobro razvijenog korena (lucerka, crvena detelina, esparzeta...), koje akumuliraju skrob u hloroplastima i smanjuju disanje, dočekujući niske temperature spremne za preživljavanje. Veće probleme od veoma niskih temperatura mogu imati u proleće, kada se često smenjuju pozitivne dnevne temperature sa niskim noćnim, što može provocirati metaboličke procese u biljkama i izazvati oštećenja osetljivih vrsta.

Zaključak

Ova istraživanja su nagovestila velike promene koje će uslediti do kraja veka, ako se obistine projekcije date preko 9 klimatskih modela. Povećanje deficita vode, kao i ekstremnih temperatura i dužina sušnog perioda nagoveštava da su moguće promene u ekosistemu, što otvara niz pitanja kako prilagoditi korišćenje prirodnih travnjaka u budućnosti i kako zadržati/sačuvati floristički sastav trava. Dobijeni rezultati ukazuju na neophodnost obavljanja višegodišnjih eksperimentalnih istraživanja uticaja dužine sušnog perioda i ekstremnih temperatura na održivost prirodnih travnjaka.

Više temperature će uticati na skraćivanje perioda od nicanja do cvetanja. U toplijem klimatu sa manje padavina, biljke će na travnjacima imati ubrzano razviće. Biljke će biti kraće i težiće da cvetaju ranije. Radi očuvanja kvaliteta krme, to će zahtevati češće košenje.

Niske temperature ni do sada nisu imale značajniji uticaj na prirodne travnjake, ali će se rizik od stresa izazvanog niskim temperaturama ili opasnost od izmrzavanja još smanjivati.

S ozbirom na izvesno povećanje deficita vode, proizvodnja biomase uz povećanje efikasnosti korišćenja vode biće od najvećeg interesa u budućnosti, posebno za oplemenjivače. Kombinovanje vrsta trava različitih funkcionalnih grupa i sa različitim funkcionalnim osobinama, kao i tolerantnih sorti, moglo bi da igra ključnu ulogu u obezbeđenju dovoljno hrane za ispašu.

Zahvalnica

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THE IMPACT OF CLIMATE CHANGE ON THE WATER REQUIREMENT OF GRASSLANDS IN SERBIA

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A b s t r a c t

Due to the air temperature increase, longer growing seasons and erratic rainfalls in the last two decades, natural grasslands like meadows or pastures grow in unfavourable climatic conditions that disable the regeneration. The aim of this work is to assess the impact of climate changes on the water requirement of grasslands in Serbia. The results of ensembles of nine regional climate models from the EURO-CORDEX database were used to analyse future climatic conditions. As the most probable value, the median of scores obtained for each ensemble member was considered. The period of 1986–2005 was used as the reference. The time slices in future periods are: 2016–2035 (the near future), 2046–2065 (the mid-century) and 2081–2100 (the end of the century). Analyses were conducted for two scenarios of GHG emissions: RCP4.5 and RCP8.5. Permanent grasslands will be more prone to drought risks in the future. Water shortage could be expected at the end of May when the water stored in the soil will be depleted by the duration of drought until September heavy rains. According to both scenarios, an increment of water requirement of 7% could be expected in the near future. The RCP4.5 scenario projects an increase in the water requirement in the range of 10.7–24.2% from the mid to the end of the century. The less favourable but more realistic RCP8.5 scenario projects a water need increment in the range from 4% to 14 % in the mid-century and 28.4–41.9% toward the end of the century. Recent research indicates that drought resistance will be developed through natural diversity and the spread of species resistant to high temperatures and water scarcity.

Key words: permanent grasslands, irrigation, climate change, drought.

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Sažetak
Sažetak je kratak informativni prikaz sadržaja članka koji čitaocu omogućava da brzo i tačno odredi njegovu relevantnost. U interesu je autora da sažetak sadrži termine koji se koriste za indeksiranje i pretraživanje. Sažetak ne sme da sadrži reference. Sastavni delovi sažetka su cilj istraživanja, metode, rezultati i zaključak. Sažetak treba da ima od 200 do 250 reči. Reč „Sažetak“ piše se boldovano i uvlači jednim tabulatorom, nakon čega slede dve tačke, a zatim tekst sažetka.

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

tabulatorom. Nakon toga slede dve tačke, a zatim nabrajanje ključnih reči malim slovima, sa tačkom na kraju. Treba izbegavati korišćenje ključnih reči koje se nalaze u naslovu rada. Ključne reči se dostavljaju na srpskom i engleskom jeziku posle sažetaka na oba jezika.

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.

Zahvalnica

Zahvalnica treba da sadrži naziv i broj projekta, odnosno naziv programa u okviru koga je rad nastao, kao i naziv institucije koja je finansirala projekat ili program.

Literatura

Poglavlje „Literatura" treba da sadrži samo radove citirane u glavnom tekstu. Rad citiran u tekstu treba da sadrži prezime autora i godinu. Ako citat obuhvata jednog autora on se navodi kao Jalikop (2010) ili (Jalikop, 2010). Kada citat obuhvata dva autora on se navodi kao Sadras i Soar (2009) ili (Sadras i Soar, 2009). Ako se u tekstu citiraju više od dva autora posle prezimena prvog autora navodi se skraćenica „et al.", a zatim godina. Ovakav citat navodi se kao Lehrer et al. (2008) ili (Lehrer et al., 2008). Ako se za određeni problem istovremeno citira više radova onda se oni hronološki nabrajaju. Odvajanje većeg broja citiranih radova van

zagrade vrši se zarezom (,) a u zagradi tačkom i zarezom (;). Ako se citiraju dva ili više rada istog autora oni moraju biti poređani prema hronološkom redu (1997, 2002, 2006, itd.). Ukoliko se određeni autor pojavljuje nekoliko puta u istoj godini, dodaju se slova (2005a, b, c, itd.). Citate ličnih komunikacija i neobjavljenih podataka treba izbegavati, osim ako je to apsolutno neophodno. Takvi citati bi trebali da se pojave samo u tekstu (npr. Brown, lična komunikacija), ali ne i u spisku referenci.
Literatura koja je citirana u tekstu navodi se u spisku referenci u originalnom obliku, po abecednom redu, bez numeracije. Ako se citira veći broj radova istog autora najpre se navode radovi kada je autor sam, a zatim kada su prisutna dva i više autora. Ako se u nekoj od ovih kategorija javlja veći broj radova, treba ih hronološki srediti po godinama (1997, 2002, 2006, itd.), a ako se u istoj godini javlja veći broj radova dodaju se slova (2005a, 2005b, 2005c, itd.). Literaturni podatak treba da sadrži: prezime autora, početno slovo imena, godinu izdanja u zagradi, naslov rada, naziv časopisa, volumen i broj stranica (prva-poslednja). Prilikom citiranja knjiga navodi se izdavač i mesto izdavanja. Redovi svake reference posle prvog reda moraju biti uvučeni. U časopisu se koristi APA - Publication Manual of the American Psychological Association citatni stil.

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.

Izveštaj

Ballard, J. (1998). *Some significant apple breeding stations around the world*. Selah, Washington.

Veb sajt

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

Rezime

Rezime na srpskom jeziku (za radove napisane na engleskom jeziku) ili na engleskom jeziku (za radove napisane na srpskom jeziku) navodi se na kraju rada i treba da ima od 200 do 250 reči. Ispred osnovnog teksta rezimea, navodi se naslov rada, puno ime, srednje slovo i prezime svih autora i naziv i adresa ustanove autora. Naslov „Rezime“ piše se razmaknuto i centrirano. Nakon naslova sledi jedan razmak, a zatim tekst rezimea, uvučen jednim tabulatorom. Neposredno nakon teksta rezimea, navode se ključne reči, sa tačkom na kraju. E-mail adresa autora za kontakt navodi se ispod crte, pri dnu stranice.

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 uslovom da se ti izrazi navedu u punom obliku prilikom prvog pominjanja, sa skraćenim oblikom u zagradi. Vrednosti od 1 do 9 mogu se izražavati slovima, a ostali brojevi isključivo numerički.

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.

Nakon objavljivanja rada, autoru za kontakt će biti poslat jedan primerak časopisa.
Mole se svi budući saradnici da rad pripreme prema datom uputstvu, kako bi olakšali rad redakcije časopisa. Ukoliko se rad ne pripremi po navedenom uputstvu neće biti prihvaćen za objavljivanje.

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