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Research Article

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EVALUATION OF EMPLOYEE POSITIONS BY DIFFERENT ERGONOMIC RISK ANALYSIS METHODS IN MANUAL HARVESTING OF HAZELNUTS

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ABSTRACT

In this study, working postures during the manual harvesting of hazelnuts were analyzed with four different ergonomic risk assessment methods, namely REBA, AWBA, OWAS, and RULA, and the differences between them were revealed. The most appropriate method for manual harvesting activities was determined. Hand harvesting of hazelnuts; It consists of three main workstations: shaking the branches by hand, collecting them manually from the branches, and containing them manually from the ground. There are three different ways of sitting in the hand-harvesting of hazelnuts: standing on knees, bending over, or cross-legged. During the manual harvest, the workers' movements at all workstations were observed and recorded with a camera. Images were analyzed using the ErgoFellow 2.0 program. As a result of the analysis, working postures that may cause musculoskeletal disorders (MSD) were determined. According to the analysis results, shaking the hazelnut by hand and harvesting from the branch by hand were risky compared to the other three analysis methods, except for the Ovako Working Posture Analyzing System (OWAS) method. In manual harvesting from the ground, high-risk scores were obtained in all working postures, Rapid Entire Body Assessment (REBA), Agricultural Whole-Body Assessment (AWBA), Rapid Upper Limb Assessment (RULA), and OWAS methods, and it was determined in the category of urgent action change. Among the ergonomic risk analysis methods, it can be said that AWBA is the analysis method that includes the closest positions of working postures in the manual harvest of hazelnuts.

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1. Introduction

Türkiye has 74.50% of the world's hazelnut planting areas, with approximately 700 thousand hectares. The production amount of in-shell hazelnut is about 665 thousand tons, and it meets 76% of the world hazelnut production. Hazelnut export is approximately 500 thousand tons, and it realizes 75% of the world's hazelnut export (TUIK, 2022). However, hazelnut is the sole source of income for approximately 500 thousand farmer families. Hazelnut can be grown economically up to 60 km inland from the coast and up to 750 m altitudes in the Black Sea Region. In hazelnut cultivation, the hearth planting method is generally applied. This method is the traditional planting method used in hazelnut production regions. Approximately 91% of the hazelnut production areas in Terme and Çarşamba counties of Samsun province have a dibbling planting system, and the remaining 9% have a row planting system (Beyhan and Sauk, 2018). The healthiest way to harvest hazelnuts is to shake the reached harvest maturity hazelnuts to the ground and collect the fallen hazelnuts. However, the harvesting method widely applied in the Black Sea Region is the manual harvesting of hazelnuts from the branch because the harvest is prolonged until the rainy periods and the drying problem. Hand harvesting of hazelnuts is one of the essential and labor-intensive work groups that need human labor in agricultural activities. Hand harvesting of hazelnuts in Turkish conditions requires 306 BIGh/ha. This figure constitutes 71% of the total working time for production and 55% of the production cost (İlkyaz, 1986). This situation significantly increases the hazelnut production cost and causes a labor-based labor requirement during harvest (Beyhan and Sauk, 2018). Despite significant technological developments, the agricultural sector is seen as one of the most challenging and dangerous sectors concerning occupational accidents and diseases. Musculoskeletal disorders (MSD) are frequently seen in employees due to the high number of human labor processes and the very different body postures of the employees. Accordingly, determining which body posture is riskier regarding employee health is an essential field of work in ergonomics. Work-related factors related to occupational musculoskeletal disorders and accelerating the discomfort process are considered ergonomic risk factors (Kır, 2015). Repetitive body movements (such as bending, twisting, squatting, reaching, and holding) during the hand-harvesting of hazelnuts cause MSD in the body's tendon, muscle, nerve, and soft tissue systems (Baş et al., 2018). Agricultural activities have a dynamic structure. For this reason, it is more difficult to systematically analyze the physical factors that workers working in the agricultural sector are exposed to compared to other sectors. When the studies in the literature are examined, it is seen that many studies are using ergonomic risk assessment methods in different agricultural activities and sectors. Das and Gangopadhyay (2015), in their study using the REBA and OWAS method, determined that the waist region was the most affected body area in potato growers. Aygün et al. (2018), in their study using REBA and RULA methods on the bodily load scores of workers in citrus orchards, determined that the most challenging jobs for the worker were cutting and harvesting sap on tree branches and carrying baskets full of citrus fruits on the back. Akalp et al. (2021), in their study where they analyzed the working postures of the workers working in the olive grove with the REBA method, found that the ergonomic risk analysis scores varied according to the workstation and the risk levels of the working postures were high and very high. Riemer and Bechar (2016), in their study using REBA and OWAS methods on the strains of agricultural workers working in the pepper and tomato harvest, determined that collecting by bending to the ground included high ergonomic risk while collecting by kneeling included moderate ergonomic risk. Zhang et al. (2019), in their study where they evaluated employee postures during apple picking using the RULA method, found that employees exhibited body postures that could cause MSD in 64% of the harvest time. Schuman (2002) found that the risk of back injury is caused by repetitive loads applied to the upper extremities and trunk, bending, twisting movements, and carrying repetitive overloads. Again, Kamble et al. (2022) found that in cotton picking by hand, the body postures of the workers, legs, shoulders, and lower back revealed MSD.

There is a need to analyze the employee postures during the manual harvest of hazelnuts with different methods and compare the results. Since the results of different risk assessment methods are not compared too much, different risk assessment methods were used in our study. Working in this direction; this study aimed to analyze the postures of employees in the manual harvest of hazelnuts with four different ergonomic risk assessment methods to determine the differences between them and to decide on the most appropriate method for evaluating the manual harvesting activities of hazelnuts, to determine the ergonomic risk scores that occur depending on the determination of the strains and loads that the workers are exposed to.

2. Materials and methods

2.1. Plant materials

This study was carried out in a farmer's orchard in Samsun province, Terme district (Figure 1). The characteristics of the hazelnut orchard where the collection trials were carried out are given in Table 1. The hazelnut orchard where the experiments were carried out has the Çakıldak hazelnut variety, which is widely grown in the region.

Figure 1. General view of the hazelnut orchard

Table 1. Characteristics of the hazelnut orchard where collection trials were carried out

Properties	Measurement Unit	Average Value
Harvest time		September 2022
Hazelnut planting		Hearth-like
Hearth planting dimensions		
Inter row	(m)	4.50
In row	(m)	4.50
Branch angle	(°)	57
Number of main branches in the hearth	(number)	19
Floor slope	(%)	1.15

2.2. Methods

The hazelnuts, which have reached harvest maturity, are either collected from the branch by hand or the branches are manually shaken and dropped to the ground by hand. Then, the collected hazelnuts are filled into baskets, and the hazelnuts in these baskets are transferred to sacks and taken to the threshing process. At these stages, employees have working postures that can cause MSD. Collecting operations carried out at ground level or above the shoulders outside the standard working areas are postures that may cause more MSD in employees. Within the scope of the study, three different workstations were observed; shaking the branches and harvesting by hand from the branch and the ground (Figure 2). Each workstation was observed separately in the hazelnut orchard, and video recordings and photographs were taken. Different working postures for each recorded workstation were analyzed using the ErgoFellow 2.0 program.

3. Results

3.1. Ergonomic risk analysis of body postures in shaking hazelnut branches

While shaking the hazelnut branches by hand, the body postures of the employees were examined, and their physical risk scores were determined. According to this; for REBA; the action level was determined as "3", the risk score was "8-10", the risk level was "high," and action status was determined in the category of "change needed soon." for AWBA; the risk score was determined as " 3" and the risk level was determined in the “high” category. For OWAS, " 2-Working postures have harmful effects on the musculoskeletal system. Ergonomic regulation will be needed for these postures soon". For RULA, While the risk score was found to be risky with "7", the action status was determined as "4" in the category of urgent action required.

Figure 2. Working postures in the manual harvest of hazelnuts

3.2. Ergonomic risk analysis of manual harvesting of hazelnut from branch

During the manual harvest of hazelnuts, the body postures of the employees were examined, and their physical risk scores were determined. According to this; for REBA; the action level was determined as "3", the risk score was "8-10", the risk level was "high," and action status was determined in the category of "change needed soon." for AWBA; the risk score was determined as "4" and the risk level was determined in the "very high" category. For OWAS, "1-Working postures have no harmful effects on the musculoskeletal system. There is no need for ergonomic regulation for these postures". For RULA, While the risk score was found to be risky with "7", the action status was determined as "4" in the category of urgent action required.

3.3. Ergonomic risk analysis of manual harvesting of hazelnut from the ground

The hazelnut harvesters' body postures (cross-legged, bending over, and kneeling) were examined, and their physical risk scores were determined. In the cross-legged collection process, none of the existing analysis methods fully covers the working postures of the employees. In the bodily risk analysis of employee postures, identical scores were obtained in all ways, such as cross-legged, bent over, and the collection of hazelnuts by standing on one's knees. According to this; for REBA; the action level was determined as "3", the risk score was "8-10", the risk level was "high," and action status was selected in the category of "change needed soon." For AWBA, the risk score was determined as "3," and the risk level was determined in the "high" category. For OWAS, "4-Working postures have significant detrimental effects on the musculoskeletal system. The necessary ergonomic arrangements for these postures should be made immediately". For RULA, While the risk score was found to be risky with "7", the action status was determined as "4" in the category of urgent action required.

4. Results and discussion

Ergonomics interests medicine, engineering, business scientists, and all branches of science. For this reason, many studies have been carried out on the subject, and analysis methods have been developed. It has been determined that working postures evaluated within the scope of our study may cause MSD in hazelnut farming workers.

According to the results, different risk assessment methods applied to the same workstations can give different results. Commonly used OWAS, REBA, and RULA methods do not cover all body postures developed in agricultural work. At the same time, it was determined that the analysis results obtained from the methods in some employee postures contradicted each other. The OWAS approach is inconsistent as it gives different results from the other techniques used in the study to analyze upper body extremities. Although the AWBA method, developed to fill this gap, includes 50 different body postures, it does not have some poses in hand-hazelnut harvesting. However, the analysis method that consists of the positions closest to the parts of the employees in the manual harvest of hazelnuts has been AWBA.

The use of technological developments in hazelnut mechanization will help reduce the discomforts related to the musculoskeletal system. The data obtained from this study can form the basis for future studies. Working body risk maps can be updated by analyzing different body postures in hand-harvesting hazelnuts with similar methods. Accordingly, the same body postures can be evaluated with more risk analysis methods, and hand-harvesting hazelnuts can determine the most appropriate risk assessment method.

Compliance with Ethical Standards

Conflict of Interest

As the author of article declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' Contributions

Hüseyin SAUK: Investigation, Conceptualization, Writing - original draft. **Kübra Meriç KALIN UĞURLUTEPE:** Formal analysis, Data curation.

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Review

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A REVIEW OF HEAVY METALS ACCUMULATION AND CONTROL IN ACTIVE AGRICULTURAL SOIL

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ABSTRACT

Agricultural soil is contaminated with dangerous heavy metals (HMs) from anthropogenic activities and natural processes. These HMs are passed to humans through the consumption of crops produced in the contaminated soil. Crop production in a contaminated field and irrigation with raw untreated sewage and industrial effluents exposed food crops to HMs contaminations. Consumption of foods contaminated with HMs can be dangerous due to their persistent nature and tendency to accumulate in human tissues. HMs contamination in humans can lead to serious health problems and, in severe cases, can cause death. This review article aimed to compile soil treatment methods reported to be effective in reducing HMs uptake by food crops in active agricultural fields, outline research gaps and suggest areas for future research. Soil treatment with biochar is the most effective control method reported, was found to mitigate the uptake of Cd, Cr, Pb, Zn, and Cu in different crops. Other control measures are the application of inorganic sorbents, chelating agents, and nanomaterials to soil and hydroponic water; the use of microorganisms and their products; gene modification of the food crop; and soil washing and filtration. The control methods reported in soil and the hydroponic solution were found to significantly lower Cd, Pb, Ni, Zn, Cu, Co, Cr, Mn, Hg, and Fe uptake in cereal grains and different types of vegetable and tuber crops.

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1. Introduction

The excessive use of HMs in chemical processing, agrochemicals, healthcare, cosmetics, and other domestic appliances continues to contaminate the environment (Paithankar et al., 2021). Contamination of agricultural soil and water with toxic HMs and metalloids from anthropogenic activities and natural processes is negatively affecting food safety and human health (Liu et al., 2018; Bhagwat, 2019; Wang et al., 2019; Edogbo et al., 2020; Khan et al., 2020a; Qadir et al., 2020; Zhang et al., 2020). Irrigation with raw wastewater poses a serious threat to environmental safety and public health (Rezapour et al., 2019). Food crops are prone to HMs contamination due to the exponential growth of environmental pollution (Afonne and Ifediba, 2020). Contamination of food crops by HMs is becoming a global challenge (Rai et al., 2019). The results of a meta-analysis conducted by Kumar et al. (2019b) showed that water bodies are highly contaminated with HMs and the global average concentrations of Cr, Mn, Co, Ni, As and Cd in the surface water exceed permissible limits approved by WHO. Food is the major pathway for human HMs contamination (Rehman et al., 2018b; Kumar et al., 2019a; Zhang et al., 2019; Huang et al., 2020b) and account for more than 99% of human contamination (Yu et al., 2019). Food contamination commonly occurs through contaminated water, soil, and air, and in very rare cases through leaching of utensils (Fung et al., 2018). HMs are very ubiquitous and inhibiting them completely from foods is nearly impossible (Bragotto, 2019).

Remediation of HMs contaminated soil can mitigate the transfer of HMs into the food chain (Rai et al., 2019). There is an urgent and necessary need for the removal of heavy metals from the environment, it is also crucial to stop the rampant discharge of these toxic metals into the environment (Ahmad et al., 2020). Remediation of contaminated agricultural fields through modification of soil conditions was reported to be effective in lowering HMs uptake in food crops. Most of the approaches reported lower the bioavailability of the HMs and make them inaccessible to the crops.

2. HMs Control Methods in Active Agricultural Fields

Rai et al. (2019) recommended the use of remediation techniques that are cost-effective and friendly to the environment. Phytoremediation is the cheapest remediation technique (Chen and Li, 2018; Dhaliwal et al., 2020), but has little applicability in active agricultural land (Table 1). Soil decontamination before cropping, policy measures, research, public awareness, and health risk assessments are the major control measures reported by Gupta et al. (2019). Low-cost adsorbents from agricultural waste, terrestrial and aquatic biomass, and soil and mineral deposits were also recommended by Joseph et al. (2019). There is an urgent need for the development of economically feasible and environment-friendly methods since conventional remediation techniques are associated with higher operational and maintenance costs, the production of secondary wastes, and soil degradation (Sharma et al., 2018; Vardhan et al., 2019; Varghese et al., 2019; Xu et al., 2019b). Combining techniques provides fruitful results, physiobiological and physiochemical methods improve removal efficiency at an economic cost (Sharma et al., 2018).

The common HMs control methods reported in food crop is the treatment of soil with biochar (Table 1) produced by subjecting the biomass to pyrolysis or gasification treatment (Huang et al., 2021); a process that generates product rich in organic carbon (Yaashikaa et al., 2020), with good porosity, significant surface area, and excellent water holding capacity (Godlewska et al., 2021). Biochars can be produced from all forms of wastes generated along the food supply chain (O'Connor et al., 2021). The use of biochar in horticulture was demonstrated at different levels and its suitability for large-scale agriculture was studied (Hu et al., 2020). Plant biochars are cheaper, more readily available, and less effective than animal-derived biochar (Nie et al., 2021). The properties of biochar depend on the feedstock composition, heating methods, and temperature (Yaashikaa et al., 2020; Ahmad et al., 2021). The effectiveness of biochar can be improved by modifying its physical and chemical properties through acid or alkaline treatment, oxidation, nitrogenation, sulfuration, composting, or physical treatments such as heating (Huang et al., 2021). Modification of biochar can improve grain qualities and lower their toxic accumulation capacity (Gao et al., 2021). Nie et al. (2021) reported that treating the soil with aged biochar enhances the oxygen-containing functional group of the biochar, improves soil organic carbon content and pH, and lowers Cd^{2+} and Zn^{2+} bioavailability.

The use of biochar in the amendment of HM-contaminated soil was reported by many researchers in the last three years at the application rate ranges between 0.75% to 7%. At this application rate, the uptake of Cd, Cr, Pb, Zn, Cu, Co, Ni, Mn, and Hg was successfully mitigated in spinach, maize, potato, lettuce, wheat, eggplant, cilantro, kale, tomato, and cabbage (Table 1). Biochar was also reported to lower Cd uptake from hydroponic water. Biochars from different plant materials were used to minimize metal uptake in food crops, their application modifies the biological and physicochemical properties of soil. Biochar minimizes plant metal uptake by increasing soil pH, surface area (Khan, et al., 2020a), complexation, adsorption, or co-precipitation (Wang et al., 2018). The modification reduces HMs mobility and their phytoavailability and also increases crop yield (Palansooriya et al., 2019) by improving soil fertility (Zhi et al., 2020), and the activities of soil enzymes (Naeem et al., 2021). A results compilation by (Chen et al., 2018) showed that biochar can reduce Cd, Pb, Cu, and Zn accumulation in a plant by 38, 39, 25, and 17% respectively. The effectiveness of biochar in mitigating HMs uptake depends on the type of biochar, the soil condition, the properties of the crop, and the nature of the HMs (Chen et al., 2018; Palansooriya et al., 2019).

Microorganisms, including endophytic bacteria, and their products reported to mitigate HMs uptake in food crops in both soil and hydroponic production (Table 1). Soil amendment with biochar and organic fertilizer increases soil microbial diversity (Zhaoxiang et al., 2020). Microorganisms accumulate HMs and reduce their bioavailability in soil. Xia et al. (2021) reviewed the HMs resistance mechanisms of microorganisms and their capability in the amendment of Cd and Cr contaminated soil. The effects of soil amendment on the activities of microorganisms depend on soil nutrients (Wu et al., 2021). Proteobacteria, Acidobacteria, and Chloroflexi showed strong resistance to HMs stress (Wang et al., 2019). *Streptomyces rimosus* biomass is an active bio-absorbent of Cd and Ni from wastewater (Yous et al., 2018). *Pseudomonas aeruginosa* demonstrates higher resistance to Cd with excellent bioaccumulation and bio-absorption capacity (Chellaiah, 2018). Engineered baker's yeast is an excellent As, Cr, and Cd accumulator (Sun et al., 2019). Ureolytic bacteria, *Stenotrophomonas rhizophila* (A323), and *Variovorax boronicumulans* (C113) demonstrate high affinity to Pb, Cd, and Zn and efficiently convert them into insoluble carbonate minerals in an in vitro experiment (Jalilvand et al., 2020). Li et al. (2021) reported the potential of *Weissella viridescens* ZY-6 in removing Cd from an aqueous solution. Qi et al. (2021) demonstrate the efficiency of mixed bacteria-loaded biochar in enhancing uranium and Cd immobilization in soil.

Other control methods reported in Table 1 are the application of inorganic sorbents, chelating agents, and nanomaterials to soil and hydroponic water, gene modification of food crops, and soil filtration. Clay minerals are effective, reliable, affordable, and sustainable soil and water HMs remediation materials (Otunola and Ololade, 2020). Chitosan possesses a high affinity to HMs and can efficiently eliminate HMs from contaminated water and soil (Pal et al., 2021). Nanomaterials have specific surface properties and excellent HMs absorption capacity (Borji et al., 2020) due to their ample active sites that increase the removal rate (Zhang et al., 2021a). They possessed great affinity to Cd and can safely be used in the amendment of Cd contaminated soil (Zhang et al., 2021b). Soil remediation using nanomaterials and the development of food crops with HMs limited uptake capacity through biotechnology can provide an efficient and economically viable solution to HM contamination issues (Kumar et al., 2019a). Carbon nanomaterials are potential candidates for HMs remediation due to their numerous functionality and modification simplicity (Baby et al., 2019). A nanocomposite made from copper iodide nanoparticles and acidophilic bacteria cultures demonstrates excellent decontamination ability for Cr and Zn (Akhtar et al., 2020). Amino-functionalized modified silica gel can efficiently remove Pb, Cu, and Cd from tea polyphenols with little effect on the catechins and antioxidants contents (Huang et al., 2020a). Modified cellulose-based adsorbents have wide application in the treatment of wastewater (Varghese et al., 2019). Soil washing of severely contaminated soil is cost-effective (Chen and Li, 2018) and an active control method when washing conditions are optimized to improve HMs solubility and availability (Yang et al., 2018). Soil washing using a chelating agent and filtration lower Cd content below a safe level (Xu et al., 2019b). Arsenic can be removed from contaminated soil by washing the soil with Na_2EDTA and ascorbic or oxalic acid (Wei et al., 2018). Drinking water treatment residues can be used in the treatment of wastewater polluted soil (Shen et al., 2019), and groundwater (Holmes et al., 2019). Removal of straws can minimize HMs accumulation since they contain much higher concentrations than the grains as reported by (Feng et al., 2020) in rice straw, (Xiang et al., 2020)

Table 1. Heavy metals control methods during food crop production

Treatment	Application-level/concentration	Effectiveness	Food Crop	Reference
Rice husk biochar	Addition of 1.0% in soil	Lower Cd bioavailability 74 % Minimized Cd uptake by 62 %	Wheat grains	(Rehman et al., 2018a)
Silver-grass biochar + chitosan	Addition of 0.75% each in wastewater	Reduces Cd, Cr, Co, Ni, and Pb uptake.	Eggplant	(Turan et al., 2018)
Sugarcane bagasse biochar	Addition of 7.0% in soil	Reduces Cr and Pb uptake	Lettuce	(Khan et al., 2020b)
Plantain peel biochar	Addition of 1.0% in soil	Lower Cd and Zn	Potato tubers	(Nzediegwu et al., 2019)
Polyacrylamide super absorbent polymer + plantain peel biochar	Addition of 1.0% in soil	Lower Cd, Cu, Pb, and Zn uptake	Potato tubers	(Dhiman et al., 2020)
Anaerobically digested food waste compost	2812.5 m^3ha^{-1}	Lower Ni and Pb uptake	Maize	(Ulm et al., 2019)
Cassava peel + Mexican sunflower composts	At 2.0 kg m^{-2}	Lower Pb uptake by 37.8	Maize	(Adejumo et al., 2018)
Sulfur application	Addition of 5.28 mM in soil or hydroponic solution	minimize Cd uptake and accumulation	Rice	(Cao et al., 2018)
Sorbent (Alginate, biochar, Sepiolite, Halloysite)	Addition of 2.5% in soil	Lower Zn uptake	Maize	(Strachel et al., 2018)
Plantain peel biochar	Addition of 1.0% in soil	Lower Zn uptake	Spinach	(Nzediegwu et al., 2020)
Corn stover biochar	Addition of 7.0% in soil	Lower Hg bioavailability in the soil	Spinach	(Zhao et al., 2021)
Brewery sludge biochar	Addition of 4.0% to the soil in a pot experiment	Lower conc. of Cd by 93 % in the shoot	Ethiopian kale	(Tsadik et al., 2020)
Rice straw biochar	Addition of 6.0% in the soil	Reduces Pb and Cu in shoot and root by 46 and 36%, and 77 and 58%, respectively	Tomato	(Rizwan et al., 2021)
Modified gangue	Application of 2.0 kgm^{-2}	Lower Cd uptake in shoot and root by 54.9–61.5% and 9.3–13.2% respectively	Lettuce	(Zhao et al., 2020)
Modified Attapulgite clay	50 g/Kg of contaminated soil	lower Cd Cr and Pb uptake	Chinese cabbage	(Xu et al., 2019a)
Zinc oxide	Addition of 100 mgL^{-1} in hydroponic solution	mitigate the uptake Cd and Pb	Spinach, parsley, and cilantro	(Sharifan et al., 2020)
Cerium oxide nanoparticles	Addition of 200 mgL^{-1} into Hoagland solution	Lower Cu, Mn, Zn, and Fe uptake	Sugar pea	(Skiba and Wolf, 2019)
N-acetylcysteine	Addition of 1 mM to a petri dish containing seed	Alleviate Cu, Hg, Cd, and Pb toxicity	Wheat seedlings	(Colak et al., 2019)
Bio-filtration	Cultivation on bio-filters	Significantly reduced Cu, Mn, Ni, Pb, and Zn concentrations	broad beans, kohlrabi, kale, lettuce, mint, mustard, radish, spinach, and sweet corn	(Ng et al., 2018)
Yak manure biochar modified with H_2O_2	1000 mgL^{-1} of HMs stock solution	Bind with Pb^{2+}, Cu^{2+}, Cd^{2+}, and Zn^{2+} and reduced their bioavailability		(Wang and Liu, 2018)
Cat manure + Spent coffee ground compost (1:3)	Addition of 5.0% to soil	Lower Zn, Cu, Cd, and Pb uptake	spinach	(Keeflee et al., 2020)
Endophytic bacteria, *Stenotrophomonas maltophilia* R5-5	Inoculation with 2^8 $cfumL^{-1}$ in a pot experiment	Significantly reduced Cd content	Rice	(Zhou et al., 2020)
microbial inoculant + garbage enzymes	Addition to the soil in a pot experiment	Minimize Cd uptake	Red sage	(Wei et al., 2020)
Bacillus megaterium N3 and *Serratia liquefaciens* H12	Addition of 60 mL of 10^8 cells mL^{-1} bacterial suspension into a pot	Minimizing Cd and Pb absorption	Chinese cabbage	(Han et al., 2020)
Ectomycorrhizal fungi	Root immersion of the seedling before transplanting into a pot	Lower translocation of Pb, Zn, Mn, As, Cr, Cd, and Cu	Massion's pine	(Yu et al., 2020)
Salicylic acid	Seedlings pre-treatment with 100 µM for 3 days	Reduced Cd accumulation	Tomato	(Jia et al., 2021)
Compost made from olive pomace (82 %) + poultry manure (10 %) + wheat straw (8 %)	50 $kgha^{-1}$	Lower Zn, Cu, Pb, Ni uptake	Organic emmer	(Diacono and Montemurro, 2019)
Hydroxyapatite/calcium silicate hydrate + wood biochar	Addition of 3.0% in soil	Lower Cd bioavailability	Water spinach	(Chen et al., 2020)

in sorghum stover, and (Zhou and Zhu, 2020) in rapeseed straw. The use of rice stubble after harvesting grain in a modified fish-rice system in removing Cd from contaminated paddy fields was reported by (Luo et al., 2021). Soil and hydroponic solution HMs control methods reported in Table 1 significantly lower Cd, Pb, Ni, Zn, Cu, Co, Cr, Mn, Hg, and Fe uptake in cereal grains, different types of vegetable and tuber crops.

3. Conclusion and Future Studies

The major factors that account for food crops HMs contamination are rapid urbanization, vigorous industrial activities, poor environmental policy, reluctance by the government to enforce environmental protection laws, poverty, food scarcity, and to a lesser extent illiteracy. Modifying soil conditions can discourage HMs uptake and accumulation in food crops since their bioavailability is favored by low soil pH and high organic matter content. Soilless farming secure crops from soil HMs contaminations, crops can only be contaminated from the atmospheric deposit when the system is operated in an urban area. The use of clean water, such as properly treated wastewater and clean underground water for irrigation can save soil and underground water from HMs contamination. Various control methods of HMs in food crops recently reported by researchers were discussed. These control methods involve the application of biochar, inorganic sorbents, chelating agent, nanomaterials, microorganisms, and their products to the soil and hydroponic solutions. Soil washing and filtration, and modification of the food crop genes were also reported. The control methods were found to significantly lower Cd, Pb, Ni, Zn, Cu, Cr, Mn, Hg, and Fe uptake in cereal grains, different types of vegetable and tuber crops. The article identified the following research gaps:

- Researchers pay more attention to the HM uptake mitigation effects of the various soil amendment techniques and show no interest in the aftermath of the soil alteration. The effects of the amendment on the soil chemical, physical and biological properties and the effects on the plant physiology, genetics, and chemical composition other than the metal content should be given due consideration in the future. Godlewska et al. (2021) reported that biochars are toxic to soil microorganisms at higher concentrations or when used without soil.
- Most of the soil amendment studies reported in recent years were conducted in a laboratory and greenhouse in a pot experiment. The effects of these techniques should be studied in large scale agriculture.
- Some researchers studied the effectiveness of the amends using artificial contamination where healthy soil is contaminated with the required dosage of metal contaminant. The effectiveness of these treatments will only be justified when studied in an active contaminated agricultural field.
- The residual effects of biochar application can be minimized by modifying the biochar, hence, researches should be conducted on the efficiency of modified biochars in different crops under different soil conditions.
- Amendment methods reported to be effective in a hydroponic system should be studied in soil agriculture.
- Little data was reported on preventing HMs uptake in fruits and nuts, these classes of foods are staple in some communities and deserve similar attention given to vegetables due to their similar nutritional functions.
- Development of HMs resistant varieties will certainly minimize HM consumption by both humans and animals.
- Understanding the properties of feedstock for biochar production and how burning conditions determine the qualities and properties of the biochar will assist in choosing the right stock and processing conditions that will produce biochar with the desired characteristics.

Compliance with Ethical Standards

Conflict of Interest

As the author of article declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' Contributions

Nura ABDULLAHİ: Conceptualization, literature search, original draft preparation. **Ernest Chukwusoro IGWE**: Supervision, literature search, writing-reviewing, and editing. **Munir Abba DANDAGO**: Supervision, literature search, writing- review, and editing. **Abdulkadir SANİ**: Supervision, writing- review, and editing. **Nasiru Bilkisu UMAR**: literature search, writing- review and editing.

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We humbly give consent for this article to be published.

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EFFECT OF PLANT GROWTH PROMOTING RHIZOBACTERIA ON THE VASE LIFE OF GERBERA FLOWERS

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ABSTRACT

In this study, the effects of three different bacterial isolates added to the vase solution on the vase life were investigated. All three bacterial isolates significantly increased the vase life of gerbera cut flowers. While the vase life of the flowers in the control solution was 3 days, this period reached up to 11 days in the flowers kept in the vase containing bacteria. Daily water uptake decreased with increasing time in vase in all treatments. Although there were some differences between treatments in terms of daily water uptake, it has been determined that bacteria application does not have a significant effect on water uptake. The relative fresh weight decreased with increasing time in the vase. For example, in the solution containing Z7 bacteria, which allows the flowers to live the longest, the flower weight, which was 89 g on August 11, decreased day by day and decreased to 68 g on August 23. Bacteria applications slowed the rate of decrease in fresh weight. *Bacillus cereus* found to be more effective than other bacterial isolates in slowing fresh weight decrease.

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1. Introduction

Cut flower, a group of ornamental plants with high added value, gained importance in the early 20th century and become a growing industry in many parts of the world. The cut flowers production area is increasing in Türkiye as well as in other countries of the world. In Türkiye, 1237.4 ha of the 5247.7 ha ornamental plants production area has been reserved for cut flowers production. In addition, 36 million dollars of the 80 million dollars revenue earned from the total ornamental plant exports in 2019 was obtained from the cut flowers. Cut flower production has the largest share (60.9%) in total ornamental plant production (Anonymous, 2020).

Gerbera sp., which belongs to the Asteraceae family, is used as a pot or cut flower (Minerva and Kumar, 2013), and is the most sold flower species in the Royal Flora flower auction of Netherlands, following important species such as rose, tulip, chrysanthemum and lily (Anonymous, 2017). The area reserved for Gerbera production in Türkiye is in the third following carnations and roses, while the amount of gerbera production is in the second place after cloves (TUIK, 2018).

The vase life of flowers is an important factor determining the commercial value of a flower (Kılıç and Yaman, 2020), and the long vase life increases the value of cut flowers in the domestic and foreign market. Therefore, storage and transportation methods should be improved to extend the durability of flowers. Enabling long-term durability will make a significant contribution to the economy in the cut flower sector. Genetic characteristics of the plant species, cultural processes, environmental conditions, flower cutting place, harvest time, water quality in the vase, microorganism activity in the water and the amount of toxic substances and post-harvest processes are effective on the vase life (Uzun et al., 1983).

The most important factor determining the vase life is the microorganism activities in the vase solution. Previous studies revealed that these microorganisms reduce the water intake by clogging the vascular bundles directly or with the substances they secrete (Elhindi, 2012; Lie et al., 2017), thus the water balance of the plants is wilted, and the vase life is shortened (Tuna, 2012). The treatments to reduce the formation of microorganisms in the vase solution are effective in prolonging the vase life of cut flowers (Safa et al., 2015; Khan et al., 2015; El-Sayed, 2018; Sharma et al., 2018). Some researchers have pointed out that the effect of bacteria on vase life varies depending on the type of bacteria (Van Doorn et al., 1991; Jacob and Kim, 2010; Carlson et al., 2015). Contrasting findings have been reported about the effects of microorganisms on vase life of cut flowers. Some researchers reported that bacteria in the vase solution have little or no effect on the vase life (Van Doorn et al., 1991;1995), while some revealed that the vase life can be extended by adding bacteria to the vase solution (Carlson et al., 2015; Naing et al., 2017).

Naing et al. (2017) claimed that bacteria with biocontrol agent properties can contribute to extend life of cut flowers by killing harmful bacteria formed in the vase solution. In this study, the effects of solutions containing *Bacillus cereus, Pseudomonas putida* and *Acinetobacter calcoaceticus* isolates, which can promote plant growth directly or by suppressing different disease factors (Imriz et al., 2014), on vase life of gerbera flowers were investigated.

2. Materials and methods

2.1. Plant materials

Gerbera flowers of Opera cultivar were used in the study. The stems of the harvested flowers were transported to the laboratory in a bucket full of water, cut at 45 cm lengths and placed in vases containing 250 ml of solution. In this study, the effects of 8 different vase solutions [distilled water as control, 4% vinegar (V), 108 cells/ml *Bacillus cereus* (Z7), 108 cells/ml *Bacillus cereus* + 4% vinegar (Z7+V), 108 cells/ml *Pseudomonas putida* (Z12), 108 cells/ml *Pseudomonas putida* + 4% vinegar (Z12+V), 108 cells/ml *Acinetobacter calcoaceticus* (Z13), 108 cells/*ml Acinetobacter calcoaceticus* + 4% vinegar (Z13+V)] on vase life of cut flowers were investigated. Sucrose (4%) was added to all solutions including the control. The bacterial isolates used were collected from different parts of healthy pepper plants in the pepper production areas of Tokat province. The isolated were identified by morphological, physiological, biochemical tests and MALDI- TOF

MS technique. The isolates, which were kept as stock cultures in the refrigerator, were grown on Nutrient Agar medium for 24 h at 27 °C. Bacterial suspension was prepared with sterile distilled water using the growing bacterial isolates. The density of suspensions was adjusted to 0.3 absorbance value (108 cells/ml density) under 600 nm light in a spectrophotometer. The study was set up in a randomized plot design with 3 replications and 3 plants in each replication. Cut flowers placed in the vases were stored at room temperature (25-26 °C).

2.2. Methods

The observations were carried out daily during the storage period, and the vase life, solution uptake of cut flower stalks and fresh weight ratio were recorded daily. The vase life refers the number of days from placement of flowers in a vase to the time that the flowers are wilting or the stem is bent more than 90º. The end of vase life for a treatment was considered when 2 out of 3 flowers in a repetition wilted or bend more than 90º. Water uptake (WU) was calculated using the amount of fresh water that per gram cut flower absorbs in two days.

$$SA = St\text{-}2 - St / A0$$

In the equation, St-2 is the amount of solution at two days ago (ml), St is the amount of solution on t day (ml), and Ao is the flower weight (g) measured at the beginning. Fresh weight ratio (FWR) was calculated using the following equation;

$$FWR = At/A0 \times 100$$

In the equation; At is the weight of a cut flower on t day; A0 is the initial weight of a flower.

The water uptake data, which had normal distribution and the variances were homogeneous, were subjected to variance analysis, and the mean values of the treatments were compared with the Duncan multiple comparison test. In contrast, the FWR values had non-normal distribution, therefore the FWR data converted to normal distribution by square root arsine transformation prior to the statistical analysis. Vase life values measured as the number of days were analyzed with the Kruskal-Wallis test, which is one of the nonparametric tests, and the mean values of the treatments were compared with the Bonferroni multiple comparison test.

3. Results

All three bacterial isolates added to the vase solution caused a significant increase in the vase life of gerbera cut flowers compared to the control. The vase life of cut flowers kept in the control solution was 3 days, while the vase life of the flowers in solutions containing Z7, Z12 and Z13 bacterial isolates were 11.3, 9.9 and 8.7 days, respectively (Figure 1). It has been determined that vinegar added to the vase solution causes an increase in the vase life of the flowers, although not as much as the bacteria application. The effects of bacteria in the solutions without vinegar were not seen in the solutions with vinegar. The effect of all three bacterial isolates tended to decrease in the vinegar medium compared to the vinegar-free medium. The flowers in the solution containing only Z7 bacteria had a vase life of 11.3 days, while the vase life of the same bacteria was only 6 days when applied with vinegar (Figure 1). A similar vase life was recorded in the other two bacterial applications with and without vinegar.

The water uptake of cut flowers was measured at two-day intervals. In all treatments, the highest water uptake occurred in the first two days. In the first two days of water uptake, Z7+V treatment received more water compared to Z7, Z12 and Z13 treatments. The differences in water uptake between other treatments in the first two days were not significant. The differences between other treatments, except for the between vinegar added (V) and control treatments were not significant on the 3rd and 4th days of the vase. The amount of water uptake between the treatments on the 5th and 6th days was slightly different, while the water uptake level in the later periods was similar in all treatments (Figure 2).

Total amount of water uptake in the Z7, Z12 and Z13 treatments during the waiting period in the vase was higher compared to the other treatments. The lowest total water uptake was recorded in the control.

The relative fresh weights in all treatments slightly decreased until the 4th day of vase life. The decrease in fresh weight of Z7+V and Z12+V treatments increased after the 4th day. The relative fresh weight of flowers in the Z7+V and Z12+VS treatments on the 6th day, which was the end of the vase life, decreased to 70 and 79.1%, respectively. The decrease in the relative fresh weight of Z13 and Z12 treatments increased after the 6th day. The relative fresh weight of cut flowers in Z13 treatment decreased to 69.9% at 8th day of the vase life. The flowers in Z12 maintained 55.9% of their initial weight at the 10th day of the vase life (Figure 3).

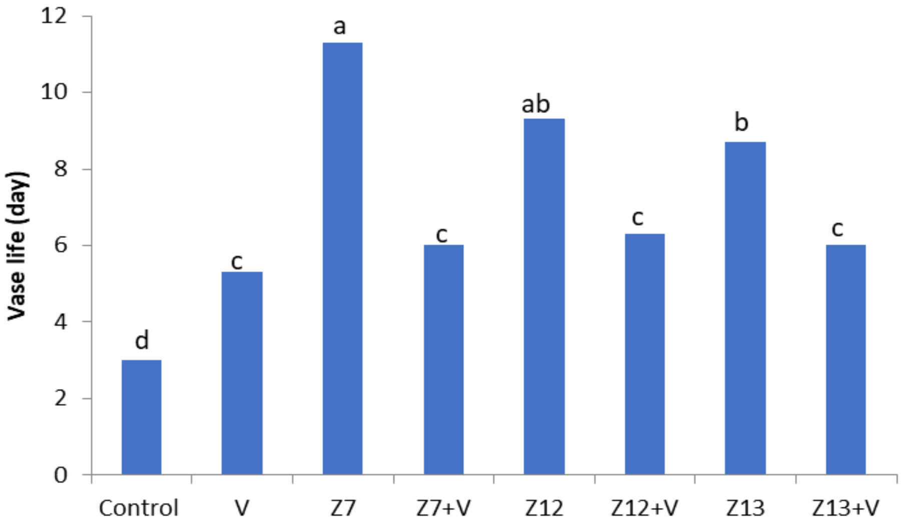

Figure 1. Effect of PGPRs on vase life in gerbera flower

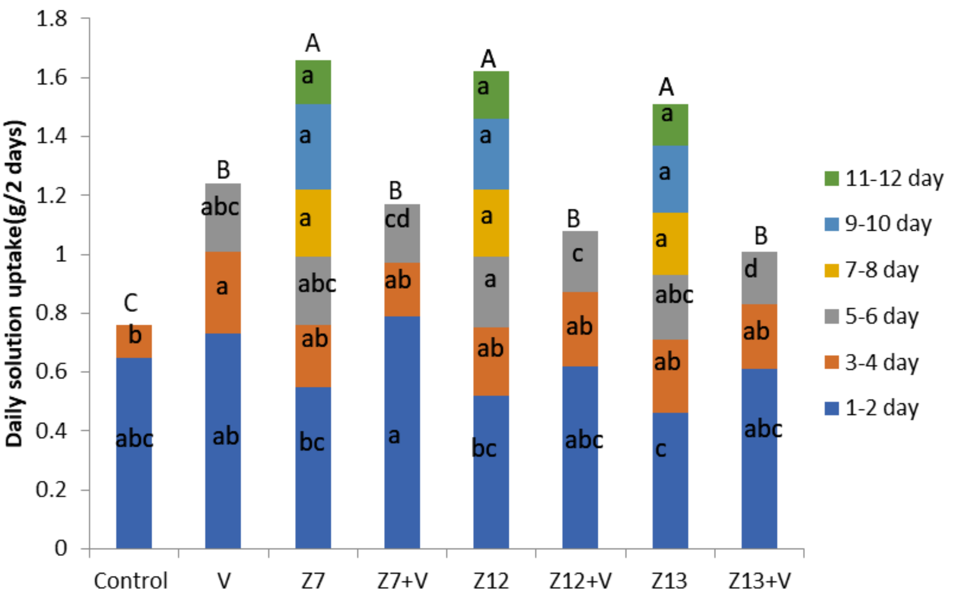

Figure 2. Two-day solution uptake of flowers kept in different solutions.

The difference between means of two-day water uptake, denoted by the same lowercase letter, is not significant.
The difference between the means of total water uptake indicated with the same capital letter is not significant.

4. Discussion

Quality loss in cut flowers has mostly been associated with clogging of the xylem vessels by microorganisms accumulating in the vase solution (Knee, 2000). The findings indicating that vase life can be increased with applications that will prevent the accumulation of microorganisms in the vase solution are in line find the aforementioned cause of quality loss in cut flowers (Mengüç et al., 1991). The increase in vase life with the vinegar application can be attributed to the bactericidal effect of vinegar (Fei et al., 2010) that reduced the amount of bacteria in the vase solution. Some studies reported that the bacteria accumulated in the vase solution shortens the vase life (Solgi et al., 2009; Hassan et al., 2014; Lie et al., 2017), while others revealed that some bacteria may increase the vase life of cut flowers (Carlson et al. 2015; Naing et al., 2017). In addition, Jacob and Kim (2010) indicated that the effect of microorganisms varies depending on the type of bacteria present in the solution. Similarly, all three bacteria used in the experiment extended the vase life of gerbera cut flowers. Naing et al. (2017) revealed that the E. cloacae bacteria applied to the vase solution increased the water uptake and vase life of cut flowers, and the researchers associated the results with the destructive effects of E. cloacae bacteria on the microorganisms in the vase solution. In this study, Total water uptake was higher in bacterial applications, however, a significant increase in daily water uptake due to bacterial applications was not detected. The result indicates that the increase in vase life caused by bacteria cannot be explained by the increase in water uptake alone. Naing et al. (2017) stated that the positive effect of E. cloacae bacteria on vase life of cut flowers may be related to the inhibition of ethylene synthesis, and/or increased antioxidant activity by the bacteria. Therefore, the positive effect on vase life recorded in this study may be related to the change in ethylene synthesis and antioxidant activity.

Co-application of the bacteria with vinegar decreased the efficiency of the bacteria. This may be due to acidic and bactericidal properties of the vinegar, which reduces the effectiveness of the bacteria. Similar to the results obtained from many other studies (Demircioğlu et al., 2018; Özbucak, 2021; Dündar et al., 2018), the fresh weight ratio decreased faster in treatments with a shorter vase life.

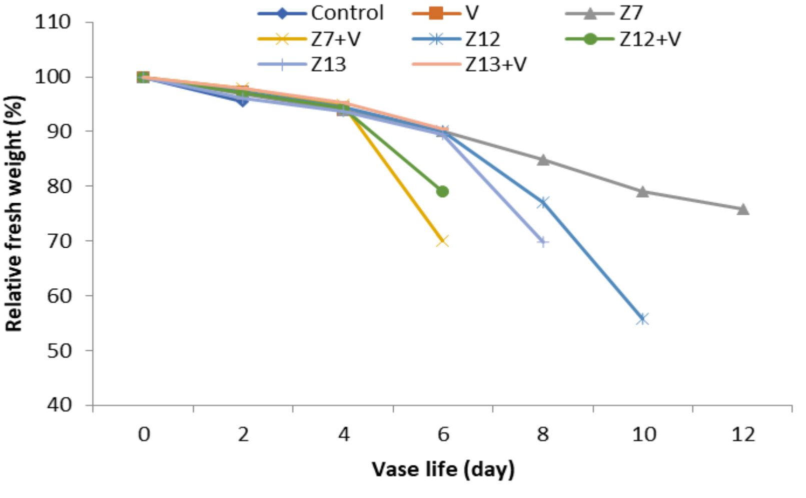

Figure 3. The relative fresh weights of cut flowers during the waiting period in the vase

5. Conclusion

All three bacteria significantly extended the vase life of gerbera cut flowers. The result revealed that bacteria can be used to extend the vase life of cut flowers. The effect of bacteria may vary depending on the plant species and the microorganism structure in the vase solution, therefore, further studies are needed to determine the appropriate bacterial strain or combination of races for each plant species. In addition, the information on the mechanism of the positive effect of some bacteria on the vase life is limited. The information obtained in the detailed studies can guide to develop new practical methods that will benefit the cut flower industry.

Compliance with Ethical Standards

Conflict of Interest

As the author of article declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' Contributions

Güzella YILMAZ: Investigation, Conceptualization, Writing - original draft. **Betül TARHANACI**: Conducting of trials. **Sabriye BELGÜZAR**: Bacteria treatments. **Zeliha KAYAASLAN**: Production of bacteria. **Kenan YILDIZ**: Statistical anlaysis, writing- review and editing.

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We humbly give consent for this article to be published.

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COMPARATIVE ANALYSIS OF SEED PRIMING ON THE GERMINATION AND GROWTH OF LENTIL LANDRACES (*LENS CULINARIS* MEDIK)

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A B S T R A C T

Seed priming was carried out to determine the effect of different priming agents on seed germination and growth of different landraces of lentils. The two factorial experiments were carried out in a completely blocked design of which one factorial is of 7 treatments, i.e., PEG (10%), boric acid (0.1%), urea (2%), PEG (5%), DAP (2%), $CaCO_3$ (2%) and Control. Other landraces, Sunwarshi-LR1 and Rangeli-LR2, collected from two different locations in the Morang district, were replicated three times. The overall germination performance is better on landraces Sunwarshi-LR1, but no significant difference was observed in individual treatment. The interaction between the two landraces seems effective in germination and germination energy, whereas non-significant in germination speed and vigor index. The shoot length seems non-significant at 10 and 20 DAS, and a significant result was obtained at 30 DAS. The root length seems important at 10 DAS, whereas non-significant at 20 & 30 DAS. Sunwarshi-LR1 shows better performance with PEG (10%).

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1. Introduction

Lentil (*Lens culinaris* Medik.) is a self-pollinated crop cultivated annually and is believed to have been first cultivated 7000-8000 years ago (Toklu, 2015). Lentil is generally considered a drought-tolerant species (Sağlam et al., 2010). During the critical growth stages, lentil frequently faces water deficiency as it is cultivated in rainfed condition. Some factors like heat stress, water stress, and salinity show a negative impact on lentils which causes significant yield losses due to different biotic and abiotic conditions (Amir et al., 2021). Lentil content is high in protein and is also a source of dietary fiber, folate, vitamin B1, and minerals, and it is resistant to drought conditions (Pakbaz et al., 2014; Bethapalli et al., 2020). The primary limiting factor for the growth and yield of lentils has been drought stress, which reduces biomass, harvest index, and grain yield (Ghasemi-golezani et al., 2013). It is crucial in maintaining soil health and is also used in animal and human nutrition (Sağlam et al., 2010). Irrigation is responsible for increasing the yield parameters; seed size, yield, biomass yield, and harvest index (Muscolo et al., 2014). It is usually planted in the month of mid-October to November and harvested in the months of March-April (Darai et al., 2008). It also fixes the atmospheric nitrogen and helps in fulfilling the requirement of nitrogen for the plant through biological nitrogen fixation (Sharma et al., 2017).

Priming is a well-known method for improving seed quality by the momentary activation of the pre-germinative metabolism, which includes antioxidant and DNA repair mechanisms (Tiwari, 2018), which is also known as a pre-seed treatment, which helps in increasing the yield (Ghobadi et al., 2022). Seed priming has shown a good impact on seedling growth of grass seed before germination and metabolic activity (Toklu, 2015). Pre-seeding technique like seed pretreatment alters the metabolic process before the root emergence, which helps in promoting the seed germination and seedling emergence, which shows an impact on how seedling develops (Ghobadi et al., 2022). Seed priming is a common practice to treat the seed to promote uniform plant growth and shorten the time between the planting date and the seedling formation stage (Toklu, 2015). In the case of improving the seed germination rate, priming has been successively utilized for emerging vegetable seeds and small seed grasses. It has also shown an advantageous effect on fields like wheat, sugar beet, maize, soybean, and sunflower (Sağlam et al., 2010). Treating the seed with the different mediums has shown a positive impact by decreasing the time between sowing and emergence, which increases the seedling vigor (Johnson et al., 2005). There are various priming techniques, i.e., osmo-priming (it is the process of soaking the seed in an osmotic solution, e.g., polyethylene glycol), halopriming (it is the process of soaking the seeds in a salt solution) and hydropriming (it is the process of soaking the seed in water). Among this priming technique, osmo-priming resulted in a better germination rate and seedling growth of different plant species (Golezanik et al., 2008). The positive result of priming is seen in many field crops, which includes chickpea and lentil (Eskandari and Alizadeh-Amraie, 2014). In this process, germination starts, but radical emergence is avoided; this is one of the strategies to produce a substantial crop stand, increase legumes' biological nitrogen fixation capacity, and add more benefit from poor fertile soils (Lhungdim et al., 2014). Increasing the salt concentration slows down the seed germination by delaying hydrolysis of storage compounds by restricting the alteration from storage tissues to developing axe (Bouallègue et al., 2019). After seed priming, seeds can be sown by surface drying or re-drying nearly too original weight, and after washing that surface-dried seed, they are directly planted (Farooq et al., 2020).

Seed priming is a pre-sowing technique that involves manipulating seed moisture content and temperature to enhance the speed and uniformity of seed germination. In this study, we investigated the effect of different concentrations of priming solution on the germination rate of lentils, intending to identify the optimal medium for promoting seed germination and growth. The objective of our study was to investigate and propose solutions to improve the low germination rate of lentils and provide potential solutions for lentil growers and associated researchers.

2. Materials and methods

2.1. Plant materials

The present study aimed to assess the effect of seed priming on the germination and growth performance of two lentil landraces, Sunwarshi-LR1 and Rangeli-LR2, collected from Sunwarshi and Rangeli Municipality of Morang district, Nepal. The experiment was conducted in a Completely Block Design (CBD) with two factors: Two landraces and seven different priming treatments (Table 1). The research was carried out at the G. P. Koirala College of Agriculture and Research Centre laboratory, located at Sundarharaicha, Morang, Nepal, with geographical coordinates of 26.4^0 North and 87.21^0 East latitude.

2.2. Methods

The priming was conducted from November 12 to December 12, 2022, under normal room temperature, averaging 30°C, and relative humidity of 75%. The seeds were soaked in different priming solutions for 18 h, then dried for two h. The germination test was conducted by placing 100 seeds from each treatment on germination paper, followed by regular watering with a water can. The number of seedlings that emerged was recorded daily for seven days. On the eighth day, 25 seedlings from each treatment were transplanted into a seedling tray filled with soil and vermicompost at a ratio of 5:1 to observe their growth performance. Root and shoot length and fresh and dry weight of plants were measured at 10, 20, and 30 days of sowing. The collected data were entered into MS-Excel (2019) and analyzed using Gen-stat (18th edition). DMRT was used to compare the means of each parametric data (Gomez and Gomez, 1984). In contrast, R-studio software (4.2.2 Version) was used to analyze the interaction effect between the landraces and treatments, employing daewr, gvlma, and agricolae packages.

Table 1. Landraces and priming agents utilized in the research

S. N.	Landraces		Symbols
1.	Sunwarshi-LR1		LR1
2.	Rangeli-LR2		LR2
S. N.	**Treatment**	**Doses**	**Symbols**
1	Polyethylene glycol (PEG)	10 %	T1
2	Boric acid	0.1 %	T2
3	Urea	2 %	T3
4	Polyethylene glycol (PEG)	5 %	T4
5	Diammonium phosphate (DAP)	2 %	T5
6	Calcium carbonate ($CaCO_3$)	2 %	T6
7	Control	-	T7

3. Results

3.1. Effect of priming agents on germination parameters

Priming is effective and significantly affects overall germination parameters related to lentils. Seed primed with PEG 10% resulted in higher germination percentage (97.33%). In contrast, a lower germination rate was observed when the seed was primed with Boric acid (0.1%), $CaCO_3$ (2%) and DAP (2%), but the highest germination speed was kept on $CaCO_3$ (97.79). Seed primed with PEG (5%) showed the highest germination energy (94.67%), whereas the lowest germination energy (89.67%) and germination speed (93.62) was also observed in the unprimed seed (Table 2). The vigor index was higher on the seed kept under control, whereas the lowest vigor index was observed when the seed was treated with boric acid (0.1%). Overall, Sunwarshi-LR1 was shown a better result on all the growth parameters than that Rangeli-LR2.

Table 3 shows the interaction effect of treatment on the different landraces of germination parameters. The interaction effect of the priming agent among the different landraces is effective and provides a significant result on germination percentage. Still, in the case of germination speed and vigor index, it showed a non-significant effect. All the germination parameters seem to be higher on the seed primed with $CaCO_3$ (2%) for Sunwarshi-LR1 and PEG (5%) for Rangeli-LR2, but the seed treated with PEG (5%) shows lower germination in Sunwarshi-LR1. Similarly, the Rangeli-LR2 had shown lower germination on Boric acid (0.1%). The germination speed seems more inadequate on DAP (2%) on LR1 and PEG (10%) on LR2. The germination energy was lower in DAP (2%) for LR1 and control for LR2. The vigor index was lower on seeds treated with $CaCO_3$ (2%) for LR1 and Boric acid (0.1%) for LR2.

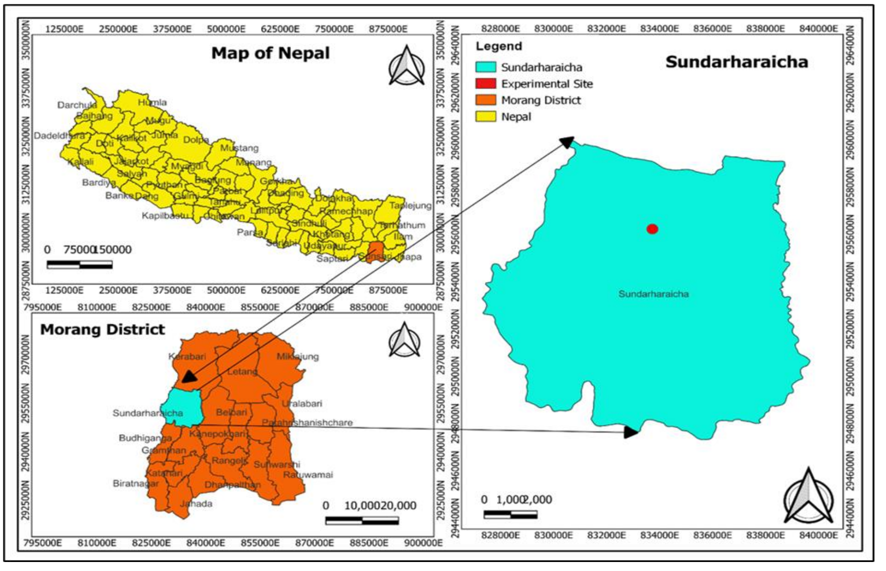

Figure 1. Experimental site of the research.

Table 2. Effect of different priming agents on germination parameters of lentil landraces.

Landraces	Germination (%)	Germination speed (%)	Germination energy (%)	Vigor index
Sunwarshi-LR1	98.67	97.10	95.81	1846
Rangeli-LR2	93.33	94.47	88.19	1766
Grand Mean	96.0	95.78	92.0	1806
SEM±	0.635	0.550	0.849	25.0
$LSD_{0.05}$	1.840	1.593	2.460	72.3
F-test	***	***	***	*
Treatments				
PEG (10%)	97.33	95.46	93.0	1803
Boric acid (0.1%)	95.0	96.05	91.33	1756
Urea (2%)	97.0	95.15	92.33	1814
PEG (5%)	97.0	97.60	94.67	1825
DAP (2%)	95.0	94.81	90.0	1781
$CaCO_3$ (2%)	95.0	97.79	93.0	1816
Control	95.67	93.62	89.67	1845
CV (%)	3.0	2.6	4.2	6.3
SEM±	1.189	1.029	1.589	46.7
$LSD_{0.05}$	3.443	2.980	4.602	135.2
F-test	NS	NS	NS	NS

*Significant at 5% level of significance, ***Significant at 0.1% level of significance, NSNon-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of variation

3.2. Effect of priming agents on growth parameters

The study examined the effect of priming on root and shoot growth of various lentil landraces. The results indicated that priming had a non-significant effect on the overall growth parameters of lentils including shoot length and root length (Table 4 and Table 5). However, priming did enhance the rate of shoot length of lentil seedlings in some landraces. Specifically, landrace Rangeli-LR2 showed higher shoot length when primed with polyethylene glycol (PEG) (10%) compared to lentil landrace Sunwarshi-LR1, while root length was observed to be higher in landrace Sunwarshi-LR1 than in Rangeli-LR2.

Table 3. Interaction of different priming agents on germination parameters of lentil landraces

Interaction of treatments		Germination (%)	Germination speed (%)	Germination energy (%)	Vigor index
Landraces	Priming agents				
Sunwarshi-LR1	PEG (10%)	99.33[a]	98.65	98.0[ab]	1868
	Boric acid (0.1%)	99.33[a]	98.00	97.33[abc]	1826
	Urea (2%)	98.0[a]	96.57	94.67[abcd]	1803
	PEG (5%)	96.0[ab]	97.92	94.0[abcd]	1823
	DAP (2%)	98.0[a]	93.87	92.0[bcde]	1749
	$CaCO_3$ (2%)	100.0[a]	100.0	100.0[a]	1954
	Control	100.0[a]	94.67	94.67[abcd]	1897
Rangeli-LR2	PEG (10%)	95.33[abc]	92.27	88.0[de]	1738
	Boric acid (0.1%)	90.67[bc]	94.11	85.33[e]	1686
	Urea (2%)	96.0[ab]	93.73	90.0[cde]	1824
	PEG (5%)	98.0[a]	97.28	95.3[abcd]	1827
	DAP (2%)	92.0[bc]	95.75	88.0[de]	1813
	$CaCO_3$ (2%)	90.0[c]	95.57	86.0[e]	1679
	Control	91.33[bc]	92.58	84.67[e]	1793
CV (%)		3.0	2.6	4.2	6.3
SEM±		1.681	1.455	2.247	66.0
$LSD_{0.05}$		4.869	4.214	6.508	191.3
F-test		**	NS	*	NS

*Significant at 5% level of significance, **Significant at 1% level of significance, NSNon-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of variation

Table 4. Effect of different priming agents on shoot and root length of lentil landraces

Landraces	Shoot length (cm)			Root length (cm)		
	10 DAS	20 DAS	30 DAS	10 DAS	20 DAS	30 DAS
Sunwarshi-LR1	9.36	12.09	14.23	5.01	7.14	8.30
Rangeli-LR2	9.62	12.65	14.60	5.0	6.88	8.02
Grand Mean	9.49	12.37	14.41	5.0	7.01	8.16
SEM±	0.219	0.309	0.191	0.178	0.203	0.191
$LSD_{0.05}$	0.107	0.127	0.073	0.113	0.108	0.098
F-test	NS	NS	NS	NS	NS	NS
Treatments						
PEG (10%)	10.10	12.67	14.80[a]	3.87[b]	6.59	7.55
Boric acid (0.1%)	9.21	11.09	13.17[b]	5.71[a]	7.78	8.49
Urea (2%)	9.47	12.77	14.73[a]	4.31[b]	7.18	7.66
PEG (5%)	9.49	13.55	14.86[a]	4.03[b]	6.51	7.91
DAP (2%)	9.13	11.78	14.19[ab]	5.62[a]	6.54	9.01
$CaCO_3$ (2%)	9.92	12.02	14.45[a]	5.71[a]	6.94	8.29
Control	9.14	12.62	14.69[a]	5.77[a]	7.53	8.18
CV (%)	5.5	5.7	3.1	8.1	6.5	5.4
SEM±	0.409	0.579	0.358	0.333	0.379	0.358
$LSD_{0.05}$	0.200	0.238	0.138	0.212	0.203	0.183
F-test	NS	NS	*	***	NS	NS

Data were transformed by √X before statistical analysis, but only non-transformed means are shown (where X is original value). *Significant at 5% level of significance, ***Significant at 0.1% level of significance, NS: Non-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of variation

Table 5. Interaction of different priming agents on shoot and root length of lentil landraces

Interaction of treatments		Shoot length (cm)			Root length (cm)		
Landraces	Priming agents	10 DAS	20 DAS	30 DAS	10 DAS	20 DAS	30 DAS
Sunwarshi-LR1	PEG (10%)	10.43	12.84	14.61	3.49	6.77	8.29[abc]
	Boric acid (0.1%)	8.63	11.27	13.18	5.76	7.82	8.47[abc]
	Urea (2%)	9.21	11.95	14.73	3.95	7.70	7.67[bc]
	PEG (5%)	10.24	13.55	14.87	4.03	6.41	7.89[bc]
	DAP (2%)	8.76	10.99	13.27	5.95	6.43	8.13[bc]
	$CaCO_3$ (2%)	9.65	11.87	14.82	5.83	7.16	9.30[ab]
	Control	8.60	12.19	14.09	6.05	7.65	8.32[abc]
Rangeli-LR2	PEG (10%)	9.76	12.50	14.99	4.25	6.40	6.82[c]
	Boric acid (0.1%)	9.78	10.91	13.16	5.66	7.73	8.51[abc]
	Urea (2%)	9.74	13.58	14.72	4.66	6.65	7.65[bc]
	PEG (5%)	8.73	13.78	14.84	4.03	6.62	7.93[bc]
	DAP (2%)	9.49	12.56	15.11	5.30	6.65	9.89[a]
	$CaCO_3$ (2%)	10.19	12.18	14.08	5.59	6.73	7.27[c]
	Control	9.67	13.06	15.28	5.50	7.40	8.05[bc]
CV (%)		5.5	5.7	3.1	8.1	6.5	5.4
SEM±		0.578	0.818	0.506	0.470	0.536	0.506
LSD0.05		0.283	0.337	0.195	0.300	0.287	0.259
F-test		NS	NS	NS	NS	NS	*

Data were transformed by √X before statistical analysis, but only non-transformed means are shown (where X is original value). *Significant at 5% level of significance, NS: Non-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of variation

The interaction between the treatment and different lentil landraces at every ten days interval was also analyzed. However, no significant difference was observed among the priming agents and landraces. Ten days after sowing (DAS), Sunwarshi-LR1 showed higher shoot growth on PEG (10%), while Rangeli-LR2 showed higher shoot growth on calcium carbonate ($CaCO_3$) (2%). The lower weight was observed on control and PEG (5%) in LR1 and LR2, respectively. At 20 DAS, higher shoot length was observed on PEG (5%) in both landraces, while lower growth was observed on DAP (2%) and boric acid (0.1%) in LR1 and LR2, respectively. Similarly, at 30 DAS, higher shoot length was observed on PEG (5%) in Sunwarshi-LR1 and DAP (2%) in Rangeli-LR2, while the lower shoot growth was observed on boric acid (0.1%) in both landraces.

Table 6 presents the fresh weight and dry weight data of primed lentil seedlings collected at intervals of 10, 20, and 30 DAS. The results indicate that Sunwarshi-LR1 showed a significantly higher weight than Rangeli-LR2. The experimental data revealed that the fresh weight of seedlings treated with boric acid (0.1%) was higher at 10 DAS (0.115g), whereas the control had a higher weight at 20 DAS (0.132g) and 30 DAS (0.16g). In contrast, seedlings treated with DAP (2%) had the lowest fresh weight at 10 DAS (0.078g) and 20 DAS, and 30 DAS. Similarly, the dry weight of the seedlings was higher in control at 10 DAS (0.015g), and 20 DAS (0.022g), but $CaCO_3$ (2%) treatment had a higher weight at 30 DAS. Moreover, Table 7 shows the interaction between different treatments and landraces at intervals of 10 days. At 10 DAS, both Sunwarshi-LR1 and Rangeli-LR2 had a higher fresh weight (0.124g and 0.106g, respectively) when treated with boric acid (0.1%), whereas a lower fresh weight was observed when treated with DAP (0.072g and 0.083g, respectively). In contrast, at 20 DAS, the control had a higher fresh weight (0.132g) on both landraces, whereas a lower fresh weight was observed when treated with DAP (0.091g and 0.093g on LR-1 and LR-2, respectively). Similarly, at 30 DAS, the control had a higher fresh weight (0.162g and 0.158g on LR-1 and LR-2, respectively), whereas a lower weight was observed when treated with DAP (0.106g and 0.114g on LR-1 and LR-2, respectively) and CaCO3. The dry weight of LR1 was higher when treated with boric acid (0.1%) at 10 and 30 DAS, whereas the control had a higher dry weight at 20 DAS. In contrast, in LR2, PEG (10%) had the highest dry weight at 10 and 20 DAS, whereas $CaCO_3$ control had the highest dry weight at 30 DAS.

4. Discussions

4.1. Effect of priming agents on germination parameters

According to Al-Tawaha and Al-Ghzawi (2013), Different types of results obtained in the seeding from germination to dry weight might be due to the tolerance capacity of the seed towards different types of treatment. We obtained the different germination rates in various treatments, which have a similar result to that of Ghasemi-golezani et al. (2013). The germination rate of the seed under untreated conditions or control differs from experiment to experiment, which might be due to environmental factors, landraces, and quality of the seed; this finding was supported by Eskandari and Alizadeh-Amraie (2014) and Kumar et al. (2019). PEG and control provide a satisfying result on the germination parameters of a lentil; this result is similar to the result obtained in Ghassemi-Golezani et al. (2008). The fastest germination rate was obtained when the seed was primed under 10% PEG, possibly due to the faster solution uptake and earlier initiation of metabolism processes on the seed. There is no significant difference in the PA on a germination parameter between primed seeds; this shows the toxicity of any primed medium on lentil seed. The above-primed result exhibited the better performance of the control or non-primed seed in the vigor index, supported by the result of Kumar et al. (2019).

4.2. Effect of priming agents on growth parameters

Similar types of differences in the weight of seeding have been obtained in Kumar et al. (2019); this might be due to the difference in treatment used for priming, which shows that the growth of the treated seed varies within primed agents. Bhateshwar et al. (2020) also observed similar growth parameters on seeding, but the result was not similar; this might be due to the differences in primed medium and the landraces. The effect of urea on growth is higher than that of PEG, and we can conclude that nitrogen can significantly improve the plant size or weight of the plants, similar to that of Hojjat (2016). This might be due to higher leaf numbers or

Table 6. Effect of different priming agents on fresh and dry weight of lentil landraces

Landraces	Fresh weight (g)			Dry Weight (g)		
	10 DAS	20 DAS	30 DAS	10 DAS	20 DAS	30 DAS
Sunwarshi-LR1	0.096	0.113	0.136	0.012	0.018	0.034
Rangeli-LR2	0.096	0.111	0.127	0.012	0.018	0.027
Grand Mean	0.096	0.112	0.132	0.012	0.018	0.030
SEM±	0.0031	0.0035	0.0036	0.0007	0.0011	0.0023
$LSD_{0.05}$	0.0057	0.0064	0.0064	0.0014	0.0021	0.0045
F-test	NS	NS	NS	NS	NS	*
Treatments						
PEG (10%)	0.094^{bc}	0.109^{bc}	0.128^{bc}	0.012	0.020	0.026
Boric acid (0.1%)	0.115^{a}	0.119^{ab}	0.137^{b}	0.011	0.016	0.033
Urea (2%)	0.095^{bc}	0.116^{ab}	0.132^{bc}	0.013	0.020	0.029
PEG (5%)	0.092^{bc}	0.107^{bc}	0.128^{bc}	0.009	0.013	0.028
DAP (2%)	0.078^{c}	0.092^{c}	0.115^{c}	0.011	0.016	0.022
$CaCO_3$ (2%)	0.097^{b}	0.107^{bc}	0.123^{bc}	0.013	0.019	0.041
Control	0.103^{ab}	0.132^{a}	0.160^{a}	0.015	0.022	0.031
CV (%)	1.2	1.3	1.3	0.3	0.5	1.0
SEM±	0.0057	0.0065	0.0067	0.0013	0.0020	0.0043
$LSD_{0.05}$	0.0107	0.0120	0.0121	0.0026	0.0039	0.0084
F-test	**	**	**	NS	NS	NS

Data were transformed by √(X+0.5) before statistical analysis, but only non-transformed means are shown (where X is original value). *Significant at 5% level of significance, **Significant at 1% level of significance, NS: Non-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of variation

Table 7. Interaction of different priming agents on fresh and dry weight of lentil landraces

Interaction of treatments		Fresh weight (g)			Dry weight (g)		
Landraces	Priming agents	10 DAS	20 DAS	30 DAS	10 DAS	20 DAS	30 DAS
Sunwarshi-LR1	PEG (10%)	0.093	0.112	0.138	0.008^{c}	0.014^{bc}	0.026
	Boric acid (0.1%)	0.124	0.124	0.144	0.013^{abc}	0.020^{abc}	0.043
	Urea (2%)	0.087	0.110	0.139	0.011^{abc}	0.018^{abc}	0.032
	PEG (5%)	0.092	0.105	0.132	0.009^{bc}	0.014^{bc}	0.026
	DAP (2%)	0.072	0.091	0.106	0.014^{abc}	0.020^{abc}	0.022
	$CaCO_3$ (2%)	0.103	0.116	0.133	0.013^{abc}	0.018^{abc}	0.050
	Control	0.101	0.132	0.162	0.015^{ab}	0.022^{abc}	0.038
Rangeli-LR2	PEG (10%)	0.094	0.105	0.117	0.016^{a}	0.025^{a}	0.030
	Boric acid (0.1%)	0.106	0.114	0.130	0.008^{c}	0.012^{c}	0.024
	Urea (2%)	0.103	0.122	0.125	0.015^{ab}	0.022^{abc}	0.026
	PEG (5%)	0.092	0.110	0.124	0.009^{bc}	0.012^{c}	0.030
	DAP (2%)	0.083	0.093	0.124	0.008^{c}	0.013^{bc}	0.023
	$CaCO_3$ (2%)	0.091	0.099	0.114	0.014^{abc}	0.020^{abc}	0.032
	Control	0.105	0.132	0.158	0.015^{ab}	0.022^{ab}	0.025
CV (%)		1.2	1.3	1.3	0.3	0.5	1.0
SEM±		0.0081	0.0092	0.0095	0.0019	0.0028	0.0061
LSD0.05		0.0151	0.0169	0.0171	0.0037	0.0056	0.012
F-test		NS	NS	NS	**	*	NS

Data were transformed by √(X+0.5) before statistical analysis, but only non-transformed means are shown (where X is original value). *Significant at 5% level of significance, **Significant at 1% level of significance, NSNon-significant, LSD: Least significant difference, SEM: Standard error of the mean, CV: Coefficient of variation

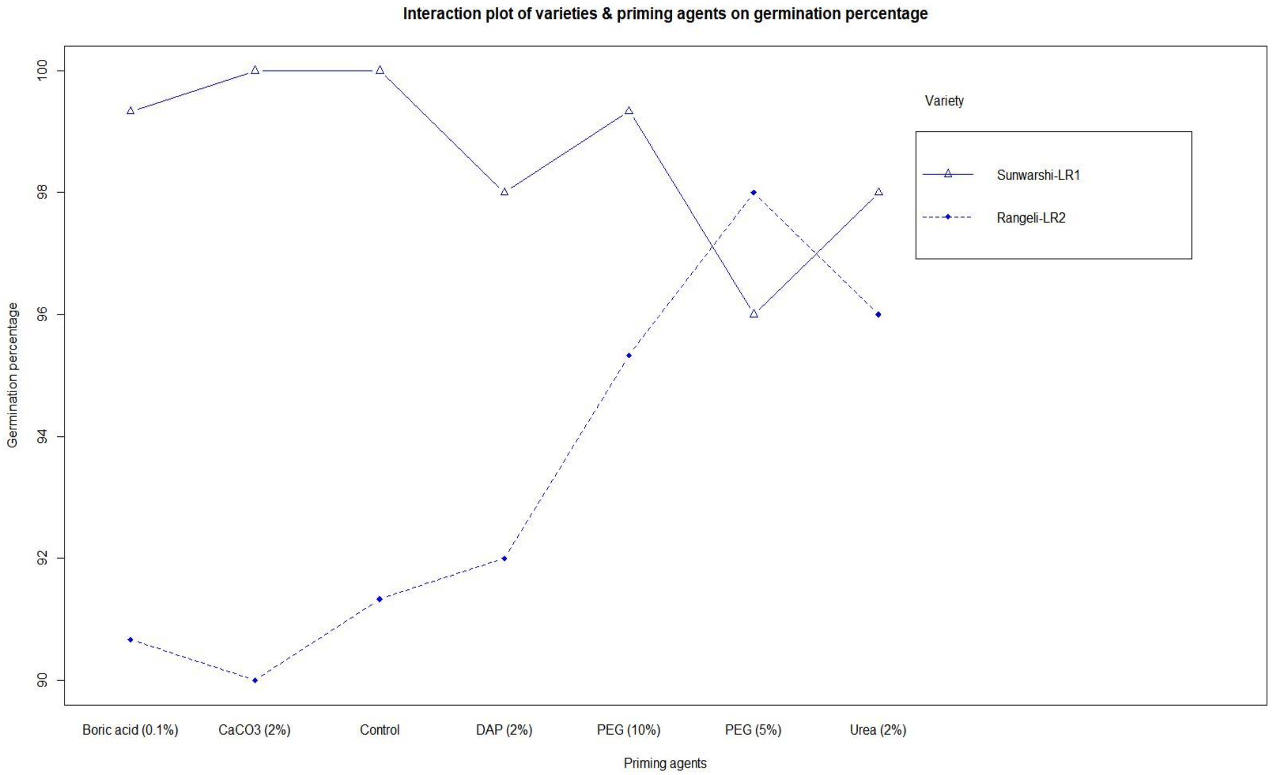

Figure 2. Interaction plot of landraces and priming agents on germination percentage

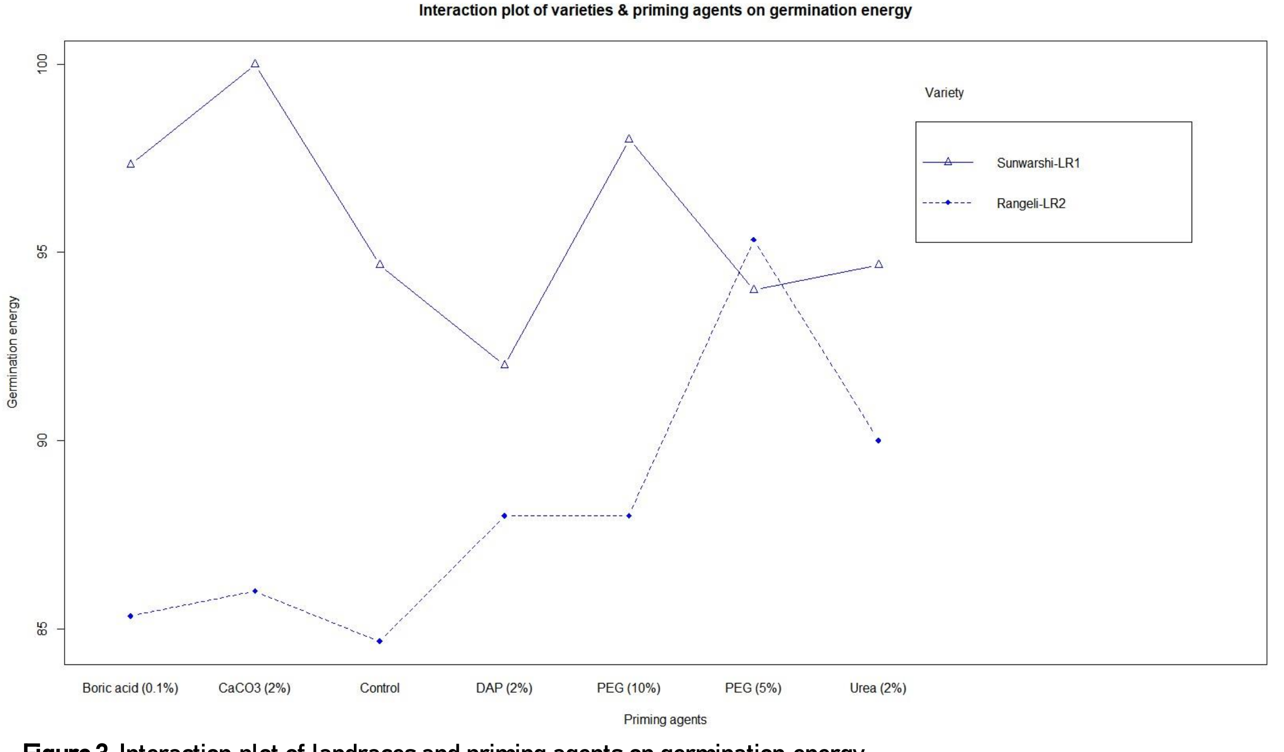

Figure 3. Interaction plot of landraces and priming agents on germination energy

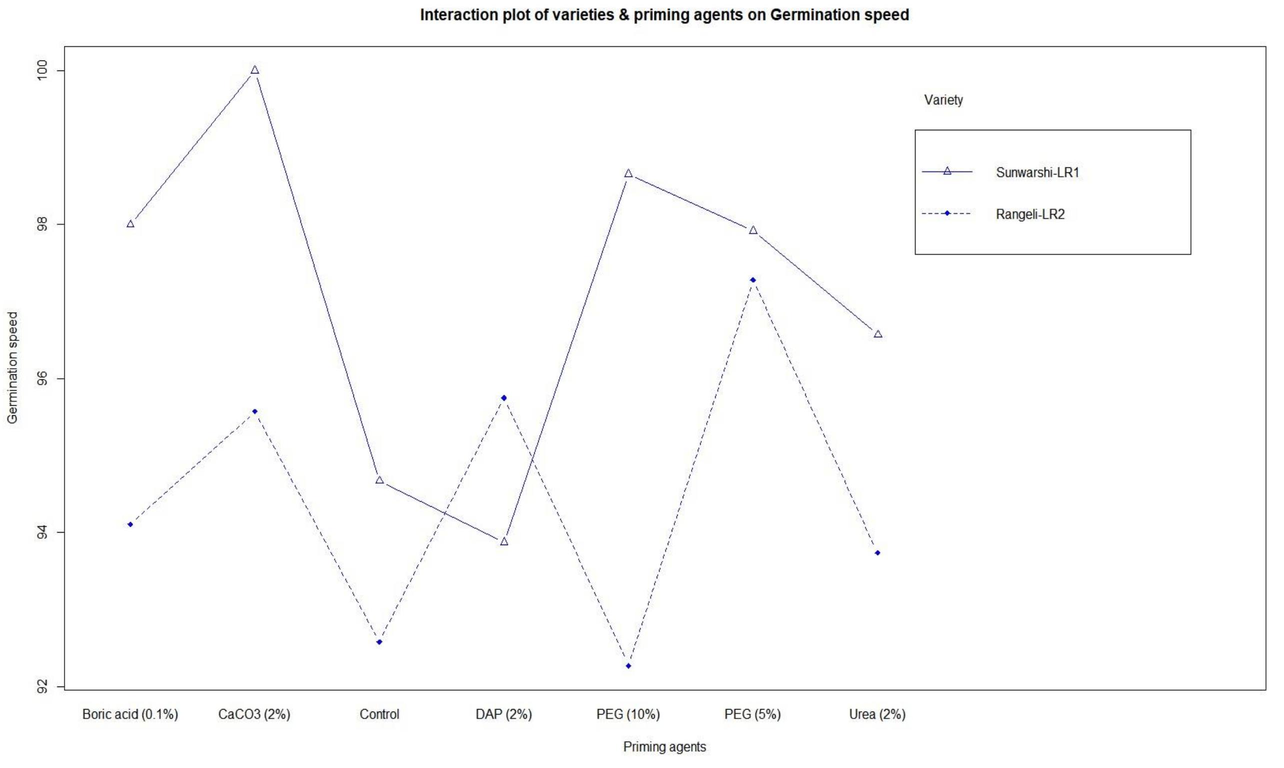

Figure 4. Interaction plot of landraces and priming agents on germination speed

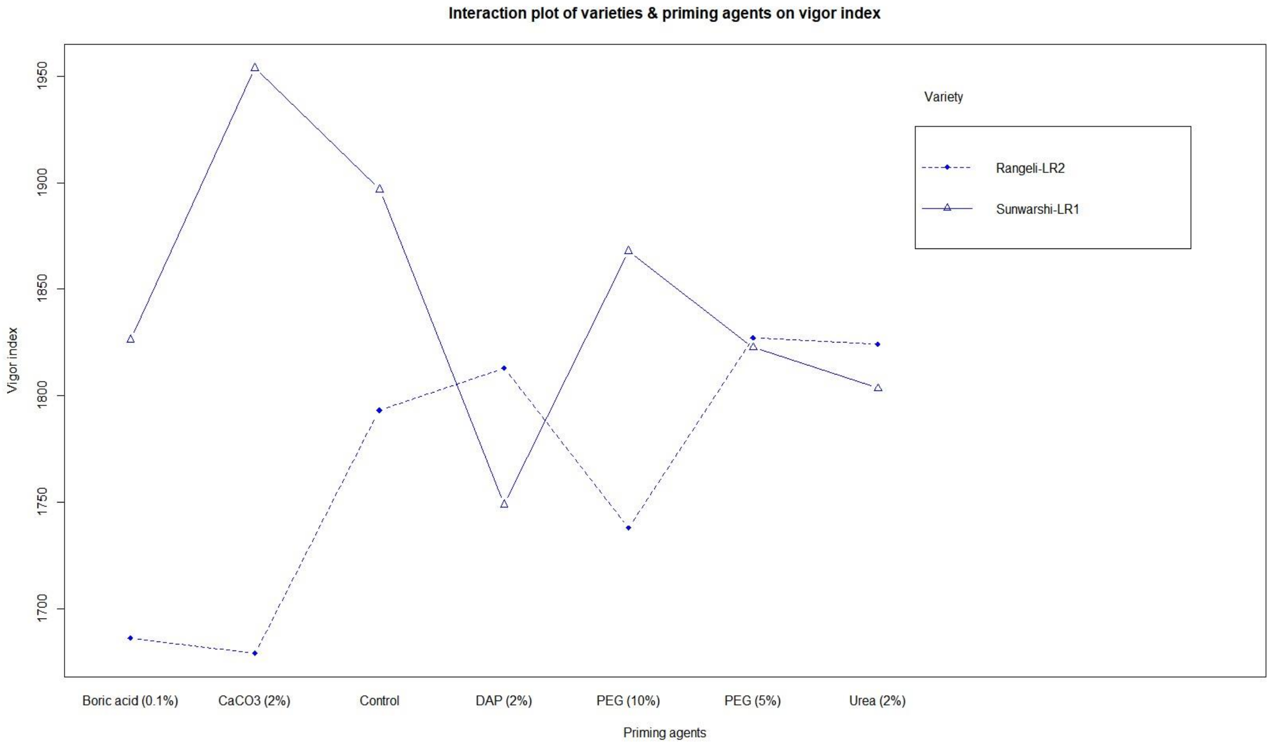

Figure 5. Interaction plot of landraces and priming agents on vigor index

a stem length. The effect of urea on growth is higher than that of PEG, and we can conclude that nitrogen can significantly improve the plant size or weight of the plants, similar to that of Hojjat (2016). This might be due to higher leaf numbers or longer stem lengths. Control shows the superior growth of the underground part of the plant at an early stage, and satisfactory results after 10DAS obtained data are similar to that of the finding Toklu (2015). The dry weight of the seed primed with 5% PEG and the conclusion of Ghassemi-Golezani et al. (2008), under PEG shows similar results but different with 10% PEG. This could be due to differences in the concentration of primed matter. Similarly, the dry weight of the primed seed was analyzed by Kumar et al. (2019), but the finding doesn't show an exact similar result which might be affected by the priming factor and landraces.

4.3. Interaction of effect of priming agents on germination and growth parameters

Based on previous studies by Ghassemi-Golezani et al. (2008), priming has been found to increase the speed of germination compared to the control group, as it increases the metabolic activity of the seed. However, the results of the current experiment did not support this hypothesis for both landraces, as Sunwarshi-LR1 showed 100% germination in the control group, while the control group for Rangeli-LR2 showed satisfactory results, as shown in Figure 2-5. Priming with different media resulted in higher shoot length, germination speed, and germination energy, as supported by the findings of Bhateshwar et al. (2020). However, the data obtained from the experiments showed that the control group also showed significantly satisfactory results at each observation step.

5. Conclusions

This study investigated the effects of seed priming with different media on the germination and growth of two lentil landraces, Sunwarshi-LR1 and Rangeli-LR2. Overall, Sunwarshi-LR1 showed higher germination and growth rates compared to Rangeli-LR2 when primed with the same media, except for root length. Specifically, seed priming with $CaCO_3$ and PEG 5% resulted in higher and similar germination rates compared to the control group in Sunwarshi-LR1. On the other hand, PEG (5%) showed higher growth parameters in Rangeli-LR2. In the early growth stage, priming with PEG 10% and $CaCO_3$ improved the growth parameters in both landraces, after which priming with PEG was more effective. These findings suggest that seed priming with different media can have varying effects on the germination and growth of different lentil landraces. Therefore, the selection of appropriate priming media should be based on the specific characteristics of the lentil landrace being studied. In addition, the results of this study could be used as a basis for further investigation into the mechanisms underlying the effects of priming media on seed germination and growth. Further research is needed to identify the biochemical and physiological changes induced by different priming media and their effects on seed germination and growth.

Compliance with Ethical Standards

Conflict of Interest

The authors declare no irreconcilable circumstances. Further, the final version of the manuscript was approved by all authors.

Authors' Contributions

Shubh Pravat Singh Yadav, Sujan Bhandari, and Sangita Bhujel: Conceived and designed the experiments. **Sujan Bhandari, Susmita Bhattarai, Shubh Pravat Singh Yadav, Indira Kattel and Puja Yadav:** Performed the experiments, interpreted the data, and wrote the paper. **Shubh Pravat Singh Yadav:** Conducted the data analysis and visualization of the data. **Sangita Bhujel:** Supervising the research.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

We humbly give consent for this article to be published.

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PROFITABILITY ANALYSIS OF POTATO GROWING IN ÖDEMIŞ DISTRICT OF IZMIR PROVINCE

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ABSTRACT

The aim of this study is to perform an economic analysis of potato growing in Ödemiş district of Izmir province. For this aim, data were collected from 90 farmers by proportional sampling and face-to-face survey methods. Potato production in 2019 was included in the study. In the study, yield, production cost, gross production value, gross and net profit calculations were performed in order to reveal the profitability level of potatoes for entrepreneurs and farmers. According to the results of the study, the average potato production area is 41.88 decares, the average potato yield is 3875.79 kg/da and the potato price received by the farmers is 1.43 TL/kg. It was determined that the farmers used 392.74 kg of seeds, 39.72 kg of nitrogen and 746.89 g of pesticides per decare. The production cost per decare for potatoes is 3274.44 TL and 85.69% of it is variable costs. The gross and net profit from potato production was calculated as 2736.55 TL/da and 2267.94 TL/da, respectively. The results of this study show that potatoes can be grown economically in the district. But, the biggest expectation of the potato farmers included in the research is sustainable and planned production. At this point; there is a need to establish cooperation and coordination among farmers, processors, industrialists, universities and exporters.

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1. Introduction

Potato is one of the important crops in terms of nutritive value and nutrition. Potatoes can be grown in most of the countries today. The most important countries in potato production are; China, India, Russia, Ukraine, USA and Germany. The potato industry of these countries is also developed. China (78 million tons) ranks first in world potato production, while India ranks second (51 million tons) and Russia (21 million tons) third. These three countries account for 42% of world potato production (FAOSTAT, 2022). The ecological adaptability of the potato and the nutrients it contains have made it important in these countries. In addition to being a raw material for the food industry, potato maintains its importance with its hoe and alternation plant feature (Çalışkan et al., 2011).

Türkiye has important ecological and natural conditions in terms of plant production. These conditions allow many plant species to grow. However, it is seen that there are some densities in the distribution of herbal products by region. One of these products is potatoes. Potato, which is mostly grown as a family farm in Türkiye, is also grown commercially. Potatoes, which are grown intensively in the Central Anatolia, Marmara and Aegean, have started to find growing areas in the Eastern Anatolia as well (Şahin, 2003a).

According to TURKSTAT data, 5.1 million tons of potatoes were produced on 138.917 hectares of land in Türkiye in 2021. The average potato yield is 3671 kg per decare. Considering the distribution of potato production by provinces; Konya (12.2%) ranks first, Niğde (11.3%) second, Afyonkarahisar (11%) third, Kayseri (10.2%) fourth and Izmir (8.8%) fifth (TURKSTAT, 2022). The fact that production can be made on the plain and on the lowland in Izmir, and that the climate and soil conditions are suitable for early, and second crops necessitate increasing research on potato production in this province.

Many studies have been conducted to analyze the economic aspects of potato growing in Türkiye (Karadaş, 2000; Özdemir, 2003; Şahin, 2003a, b; Özdüzen, 2004; Uzundumlu, 2005; Yılmaz et al., 2006; Birinci ve Küçük, 2006; Tunçtürk et al., 2007; Engiz, 2007; Engindeniz and Karakuş, 2008; Tok and Kantar Davran, 2010; Kumbasaroğlu and Dağdemir, 2010; Bağcıtek, 2017; Karsan and Gül, 2017; Örmeci Kart et al, 2017; Kılıçer, 2019; Yıldırım et al., 2019; Yücel and Oğuz, 2020; Kadakoğlu and Karlı, 2021a, b; Kadakoğlu and Karlı, 2022; Yücel Engindeniz, 2022). However, it is seen that there is not enough research in Izmir. It is necessary to continue these researches and to develop measures regarding the direction to be given to potato production. A research to be conducted in Izmir, and especially in Ödemiş, will not only reveal the economic aspects of potato cultivation, but also provide important contributions to the development of potato production and to reveal the factors that affect entrepreneurs' orientation to this field.

In this study, economic analysis of potato growing was performed in the light of the data collected from the farmers by the survey method, some suggestions were made by determining the problems encountered.

2. Materials and methods

The data constituting the main material of the study were obtained by face-to-face survey method from the farmers engaged in potato growing in Ödemiş district of Izmir. Apart from this, the agricultural data of the relevant organizations and the findings of previous researches were also used. According to the information received from the Ödemiş District Directorate of the Ministry of Agriculture and Forestry, approximately 85% of the potato production in Izmir is the Ödemiş district and the majority of the potato production in the district is Bozdağ, Gölcük, Çaylı, Cumhuriyet, Ocaklı, Umurbey, Yolüstü, Üçeylül, Gereli and Karakova carried out in the neighbourhoods. Therefore, these neighborhoods were included in the study. The total number of farmers registered in the Farmer Registration System in these neighborhoods was determined as 1242, and these farmers constitute the main population of the study.

In the study, some of the farmers were included in the scope by sampling method. At this stage, the following proportional sample size formula was used (Newbold, 1995). In fact, it is seen that this formula is used in the sampling phase of many studies (Çobanoğlu et al., 2005; Kızılaslan and Somak, 2013; Tiryakioğlu and Artukoğlu, 2015; Çakır et al., 2015; Engindeniz et al., 2017; Bozdemir et al., 2019; Akboğa and Pakyürek, 2020).

$$n = \frac{Np(1-p)}{(N-1)\sigma^2{}_{px} + p(1-p)} \quad \text{……………….(1)}$$

In the formula;
n = sample size
N = Total number of farmers
p = Proportion of farmers growing potatoes (0.5 for Maximum sample size)
σ^2px = The variance of the ratio.

In the study, 95% confidence interval and 10% margin of error were taken as basis and the sample size was calculated as 90. In determining the number of farmers to be interviewed in each neighborhood, the ratios of the neighborhoods to the total number of farmers were taken into account. The farmers interviewed in the neighborhoods were determined by using the random numbers table.

The questionnaire form prepared to collect the data included questions to determine the socio-economic characteristics and activity results of the farmers. The study was based on the 2019 production period and the survey studies were carried out in the January-February 2020 period.

In the technical and economic analysis of potato growing, input usage levels, yield levels, farmer prices, production costs, gross profit, net profit and relative profit were determined. Potato production costs consist of variable and fixed costs. Labor and machine costs, material (seed, pesticide, fertilizer, etc.) costs and interest of working capital are variable cost items; land rent and administrative costs are fixed costs. The interest for the working capital is calculated based on half of Ziraat Bank's agricultural loan interest rate (5%). The administrative costs was determined by taking 3% of the total variable costs (Kiral et al., 1999).

Labor costs were calculated by adding the equivalent of family labor to the payments made for temporary labor in farms. Material costs were determined based on the amount of inputs used and the current prices paid. In order to ensure homogeneity, the unit machine-tool rent in the region were taken into account in the determination of the machine costs (Tanrıvermis, 2000; Özkan et al., 2005; Aydın Can and Yercan, 2006; Engindeniz and Öztürk Coşar, 2013; Kadakoğlu and Karlı, 2022).

The following equations are used in the calculations of gross production value, gross profit, net profit and relative profit regarding potato production in farms (Kıral et al., 1999; Birinci and Küçük, 2006; Kumbasaroğlu and Dağdemir, 2010; Kadakoğlu and Karlı, 2022).

Gross Production Value = Production Amount x Sales Price ……………….. (2)
Gross Profit = Gross Production Value – Variable Costs ……………………...(3)
Net Profit = Gross Production Value – Production Costs …………………….(4)
Relative Profit = Gross Production Value / Production Costs ………………..(5)

In the evaluations made in the research, decare (1000 m^2 = 0.1 hectares) was used as the area and Turkish Lira (TL) was used as the currency. 1 USD=5.68 TL was in 2019.

3. Results and discussion

The ages of the farmers ranged from 27 to 76 and the average age was calculated as 52.49. The education period of the farmers varies between 5-15 years and the average is determined as 8.29 years. The experience of farmers in potato growing was found to be 24.44 years on average. Approximately 89% of the farmers are partners in any agricultural cooperative. The average potato production area in the farms is 41.88 decares. Potato yield per decare varies between 3000 and 4300 kg. Average potato yield was calculated as 3875.79 kg. For example, it was determined as 2587 kg (Özdemir, 2003) in a study conducted in Izmir, 5280 kg (Engiz, 2007) in a study conducted in Nevşehir, and 2450 kg in a study conducted in Tokat (Yıldırım et al., 2019). 60% of the farmers use loans for potato growing, approximately 76% benefit from government support, and approximately 28% plan to produce organic potatoes (Table 1). When the farmers were asked whether they found the support of the state sufficient in potato production; 61.11% stated that they found it very inadequate, 34.44% found it insufficient. It was determined that only one farmer had insurance in potato growing. It has been determined that farmers mostly grow Marabel, Marfona, Agria, Ausonia, Jearla, Impala, Resy, Concerde and Granola potato varieties.

Table 1. General characteristics of farmers and potato growing

Characteristics	Results
Age of farmers	52.49
Education level of farmers (years)	8.29
Potato growing experience of farmers (years)	24.44
Potato production area (da)	41.88
Yield (kg/da)	3875.79
The credit using rate of farmers for potato growing (%)	60.00
The rate of farmers benefiting from the supports (%)	75.56
Tendency of farmers to produce organic potatoes (%)	27.78

Table 2. Input usage amounts for potato growing

Inputs		Results
Seed (kg/da)		392.74
Fertilizer (kg/da)	N	39.72
	P_2O_5	18.61
	K_2O	11.78
Pesticide (g/da) (*)		746.89
Labor (h/da)	Sowing seeds	5.66
	Fertilization	3.57
	Irrigation	6.79
	Pesticide application	4.08
	Hoeing	23.96
	Harvesting and packaging	27.94
	Total	72.00
Machine use (h/da)		6.32

(*) It is active ingredient

When the inputs used in potato production were examined, it was determined that an average of 392.74 kg of seeds, 39.72 kg of nitrogen, 746.89 g of pesticides, 72 h of labor and 6.32 h of machine were used per decare (Table 2). 54.44% of the farmers stated that they had a soil analysis done. It was determined that farmers mostly used Compound fertilizer (15.15.15 and 20.20.0), Ammonium Sulphate, Potassium Nitrate, Ammonium Nitrate (26%, 33%), TSP, DAP and Urea as chemical fertilizers. Farmers generally use pesticides containing the active ingredient Azadirachtin, Spinosad, Lamda-Cyhalothrin, Novaluron and Thiamethoxam for potato control. Producers make use of groundwater for irrigation and flood irrigation method is generally used. The average number of irrigation in the farms was determined as 5.39.

In a study conducted in Nevşehir, it was determined that 372 kg of seeds, 103.75 h of labor, 7.88 h of machine, and 255 g of pesticide were used (Engiz, 2007). In a study conducted in Tokat, it was determined that 400 g of seeds and 700 g of pesticide were used (Yıldırım et al., 2019).

The average cost of potato growing per decare in the examined farms is 3274.44 TL. Variable costs constitute 85.69% of production costs. Material costs account for 46.93% of production costs, labor and machine costs for 34.68%, and other costs for the remaining 18.39%. Average labor and machine costs in farms were determined as 1135.55 TL/da, and average seed costs 764.44 TL/da (Table 3). The ratio of variable cost to production costs; it was found to be 83.6% in Niğde (Karsan and Gül, 2017), 91.93% in Tokat (Yıldırım et al., 2019), and 85.67% in Nevşehir (Engiz, 2007). In the study, the average kg cost of potatoes in the examined farms was determined as 0.84 TL. In a study conducted in Tokat in the same period, the unit cost was determined as 1.54 TL/kg (Yıldırım et al., 2019).

The average gross production value of potatoes per decare was determined as 5542.38 TL. The average gross profit and net profit per decare were calculated as 2736.85 and 2267.94 TL in the examined farms (Table 4). In a study conducted in Bitlis, it was determined that variable costs constitute 57% of the gross production value (Şahin, 2003a), and in a study conducted in Izmir, it was determined that the farmers could not even meet the variable costs and incur losses (Özdemir, 2003).

Relative profit refers to the production value obtained in return for one unit of cost in potato production. It was determined that a production value of 1.69 TL was obtained in exchange for a cost of 1.00 TL for potato production. In a study conducted in Afyonkarahisar, this value was calculated as 1.01 (Kadakoğlu and Karlı, 2022).

Table 3. Cost items of potato growing

Cost items		Costs (TL/da)	%
1. Labor and machine costs	Tillage and preparation	264.44	8.07
	Sowing seeds	155.56	4.75
	Fertilization	71.67	2.19
	Hoeing	86.67	2.65
	Irrigation	79.44	2.43
	Pesticide application	96.11	2.93
	Harvesting and packaging	277.22	8.47
	Transport	104.44	3.19
	Sub-total	1135.55	34.68
2. Material costs	Seed	764.44	23.35
	Fertilizer	325.56	9.94
	Pesticide	191.67	5.85
	Electricity and fuel costs (for irrigation)	193.89	5.92
	Others	61.11	1.87
	Sub-total	1536.67	46.93
3. Interest of working capital (5%)		133.61	4.08
4. Total variable costs (1+2+3)		**2805.83**	**85.69**
5. Fixed costs	Administrative costs (3%)	84.17	2.57
	Land rent	384.44	11.74
	Sub-total	**468.61**	**14.31**
Total production costs (4+5)		**3274.44**	**100.00**

Table 4. Economic results of potato growing

Economic results	Value
1. Yield (kg/da)	3875.79
2. Farmer potato price (TL/kg) (5)	1.43
3. Gross production value (TL/da) (1x2)	5542.38
4. Total variable costs (TL/da)	2805.83
5. Total production costs (TL/da)	3274.44
6. Unit potato cost (TL/kg) (5/1)	0.84
7. Gross profit (TL/da) (3-4)	2736.55
8. Net profit (TL/da) (3-5))	2267.94
9. Relative profit (3/5)	1.69

4. Conclusion

Results of this study show that potatoes can be grown economically in the district. The biggest expectation of the potato farmers included in the study is sustainable and planned production. In order for the farmers to continue their potato production and to transfer this production branch to the next generations, their current problems should be solved in the short term. In particular, potato imports should not be seen as a solution and domestic production should be supported by planning.

One of the most important cost factors in potato production is seeds. In order to increase both yield and quality, certified seed production should be expanded. This can be done with new and improved projects integrated by institutions such as research institutions and universities. Thanks to these projects, our country's foreign dependency on seeds will decrease and production costs will be reduced.

Increases in fertilizer prices require effective use in potato production. Some of the farmers (46%) make unconscious fertilization in order to get more efficiency from the field without soil analysis, which leads to a decrease in the quality of the product and environmental pollution. Farmers should be informed about soil analysis and effective fertilization should be ensured. In this way, costs can be reduced.

In order to increase yield and profitability in potato production, timely and effective plant protection is required. Considering the increase in pesticide prices, one of the ways to reduce costs is to reduce pesticide costs. Plant protection processes that are not done correctly and on time cause very important product losses. In order to prevent these losses, an effective control program should be followed, integrated control should be given importance, and both product and income loss should be prevented by informing the farmers more.

Potato is a plant that needs a lot of water. When the research area is examined, potato irrigation is generally done in the form of flood irrigation using groundwater. Farmers bear the electricity and diesel costs for irrigation. This also increases costs. In terms of cost reduction, irrigation should be done with alternative methods that will use water more efficiently.

There is no regular market structure in potato production in our country. Potatoes is one of the crops with the most fluctuations in price in Türkiye. The reason for this can be shown as environmental and climatic conditions, costs. In some periods, the amount of product supplied to the market is high, which causes the price to decrease in that period. In some periods, the quantity supplied is low and the price increases. In order to prevent product losses and seasonal fluctuations, a production plan should be made, food-industry integration should be made and diversity in production and processing should be ensured. In this way, supply fluctuations can be prevented. Policies should be developed to prevent price instability.

Farmer incomes in potato production vary due to fluctuations in potato prices, increase in input prices used in production, and failure to produce by providing a suitable input composition in farms. For this reason, it is of great importance for the sustainability of potato production in the region to reduce the production costs of the farmers by reducing the input costs and to ensure the market equilibrium price of the potato.

As a result; in order to develop potato production in the region and to ensure its sustainability, first of all, the problems encountered should be solved. At this point; there is a need to establish cooperation and coordination among farmers, processors, industrialists, universities and exporters.

Compliance with Ethical Standards

Conflict of Interest

The authors declare no conflict of interest

Authors' Contributions

The authors have equal contribution to the article.

Ethical approval

Since the survey was conducted in the research, it was examined by the Scientific Research and Publication Ethics Committee of Ege University and its suitability was reported.

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Consent for publication

We humbly give consent for this article to be published.

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Research Article

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THE EFFECT OF DIFFERENT IBA DOSES ON ROOTING IN SOFT-WOOD CUTTINGS OF ROOTSTOCK CANDIDATE SWEET CHERRY, SOUR CHERRY AND MAHALEB GENOTYPES

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ABSTRACT

This study was carried out to investigate the effect of different IBA (Indole Butyric Acid) concentrations on rooting in soft-wood cuttings of rootstock candidate sweet cherry, sour cherry, and mahaleb genotypes in a plastic greenhouse with underfloor heating and mist propagation of Black Sea Agricultural Research Institute. 500, 1000, and 2000 ppm IBA doses were applied to the soft-wood cuttings taken in june. Perlite was used as propagation medium and rooting medium was disinfected with methyl bromide before planting. The study was planned according to a randomized plot design with three replications and 20 cuttings in each replication. The rooting rate (%), number of roots (piece), number of branching roots (piece), and root length (mm) were investigated. The highest rooting ratio of 59% (08 K 056) was obtained from the 1000 ppm IBA application, while the lowest rooting ratio of 22.50% (55 K 104) was obtained from the 1000 ppm IBA application.

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1. Introduction

Rootstock is used in fruit growing for reasons such as reducing the negative effects of soil and climatic conditions, increasing fruit quality, and controlling the growth strength of the tree. Rootstocks are propagated in two different ways by seed or clonal. The plants produced from seeds cannot show uniform development, and a homogeneous production is not possible (Ağaoğlu et al., 2001). Clonal rootstocks are propagated by vegetative methods (cutting, layering, tissue culture, etc.). Vegetatively propagated rootstocks have the same characteristics as the parent material and the new individuals obtained show homogeneous development. In this way, thanks to the orchards where rootstocks with standard characteristics are used, it also contributes to the standardization in production (Akça, 2000).

With the discovery of plant growth regulators, accelerated the propagation by cuttings and it became possible to propagate plants with the use of plant growth regulators. Rootstocks propagation studies have continued for a very long time and successful results have been obtained in cuttings propagation in species other than those that are difficult to root. In propagation by cuttings, the parts prepared by cutting the leaves, branches, or root parts from the mother plant are provided with plant growth regulator application and root formation under appropriate humidity and temperature conditions. The new plant obtained in this way shows all the characteristics of the mother plant (Edizer and Demirel, 2012). The method of propagation with cuttings can be applied in many plant species in 3 different periods: soft, soft-wood and wood cutting. Plant growth regulators such as IAA, IBA, and NAA are used in vegetative propagation of many plant species (Hartmann et al., 1966). Plant growth regulators are not capable of propagating with all types of cuttings. However, they play an active role in increasing the rooting rate and shortening the rooting period (Ürgenç, 1982).

The vegetative production of clonal rootstocks are great of importance. If a clonal rootstock is difficult to propagate vegetatively, it may not be possible to spread the rootstock even though its other characteristics are very good. For this reason, it is necessary to investigate the possibilities of propagation of rootstocks especially vegetatively (Edizer and Demirel, 2012). In this context, there are studies on rooting with cuttings in fruit species of Prunus species such as peach (GF-677, Garnem), plum (Marianna GF 8-1, St. Julien), and sweet cherry (SL-64) (Reighard et al., 1990; Özkan and Madakbaş, 1995; Kankaya and Özyiğit, 1998; Ahmed et al., 2003; Edizer and Demirel, 2012; Ilgın and Bulat, 2014).

This study aims to determine the effect of 500, 1000, and 2000 ppm doses of IBA on the rooting of softwood cuttings of rootstock candidate genotypes for cherry.

2. Materials and methods

2.1. Plant materials

The study was carried out at the Black Sea Agricultural Research Institute in 2018-2019. The data were evaluated by taking the average of the years. According to the results of the project numbered TOVAG 106 O 031 in the genetic resources area of the Black Sea Agricultural Research Institute, 3 *Prunus avium* (55 K 104, 08 K 056, 52 K 063), 2 *Prunus cerasus* (28 V 001, 55 V 004), and 2 *Prunus mahaleb* (55 M 005, 52 M 003) genotypes, which may be rootstock candidates, are the materials of the study (Bilginer et al., 2009).

2.2. Methods

The soft-wood cuttings taken in june and were prepared to be 20-25 cm long and contain 3-5 nodes. The cuttings were prepared with 2 leaves and the other leaves were cut to prevent moisture losses. Prepared cuttings were immersed in IBA solution for 5 seconds. Cuttings treated with IBA were planted in perlite after the evaporation of alcohol. Soft cuttings of rootstock candidate genotypes were removed from the rooting medium after 60 days. The following properties were examined in the removed from soft cuttings.

Rooting rate (%): The cuttings forming roots were counted and expressed as %.

Root number: Root number was determined by taking the average values of the results obtained by counting the roots in all rooted cuttings.

Number of branching roots: The number of branching roots was calculated by taking the average values of the results obtained by counting the branching roots in all rooted cuttings.

Root length (mm): Root length was measured with a 0.01 mm precision digital caliper.

2.3. Statistical analysis

The experiment was set up with 3 replications and 20 cuttings in each replication. In this study, the differences between treatments in terms of rooting rate (%), number of roots, number of branching roots, and average root length (mm) were analyzed with JUMP 7.0 statistical package program.

3. Results and discussion

3.1. Rooting rate

It was determined that the effects genotypes and genotype x dose interaction on rooting rate were statistically significant ($p<0.01$). The minimum rooting rate was obtained from the 1000 ppm IBA dose of the 55 K 104 genotype (22.50%), the highest rooting rate was obtained from the 1000 ppm IBA dose of the 08 K 056 genotype (59.00%). In terms of average rooting rate, the lowest rooting rate was obtained from the 55 K 104 genotype at 23.03%, while the highest rooting value was obtained from the 08 K 056 genotype at 46.33%. While the rooting value was the lowest in the application of 500 ppm IBA dose, the rooting rate was the highest in the application of 1000 ppm IBA dose (Table 1). The rooting rate of sweet cherry, sour cherry, and mahaleb genotypes selected from Samsun province was determined as 85.0% in sour cherry genotypes, 58.3% in mahaleb genotypes, and 23.3% in sweet cherry genotypes at different IBA doses (Koç, 2009). Dick and Leakey's (2006) statement that young cuttings root better supports the idea in our study that soft cuttings root better. The rooting of mahaleb (*Prunus mahaleb*) and sweet cherry (*Prunus avium*) cuttings, the cuttings taken 8 weeks after the leafing period indicated better results (Rather et al., 2005). Özyurt et al. (2012) in their study, 2500 ppm Indol-3-Butyric Acid (IBA) was applied to soft cuttings taken from SL 64 rootstock and mahaleb (*Prunus mahaleb* L.) genotypes grown in Tokat province. While the average rooting rate of the genotypes was between 3.30% (60TM10) and 61.60% (60TM30), the rooting rate of SL 64 rootstock was 33.30%. the effect of 0, 1000, 2000, and 4000 ppm doses of IBA on rooting wood cuttings of peach (GF-677, Garnem), plum (Marianna GF 8-1, St. Julien, and cherry (SL 64) fruit clonal rootstocks. The highest rooting rate of 38% was obtained from 2000 ppm IBA application (Boyaci et al., 2017). According to the research results; All doses of IBA gave better results in terms of the properties examined than the control application. The results obtained in this study, which were carried out for the rooting of soft cuttings of rootstock candidate genotypes, agree with the results obtained from the rooting experiments of other researchers.

3.2. Root number

As can be seen from Table 2, the difference between the treatments in terms of root number was found to be statistically significant ($p<0.01$). While the minimum number of roots was obtained from the 500 ppm IBA dose of the 55 K 104 genotype (1.66), the highest number of roots was obtained from the 2000 ppm IBA dose of the 55 M 005 genotype (18.49). 52 K 063 genotype has the lowest number of roots in terms of average root number, 55 M 005 genotype has the highest number of roots with 12.78. While the number of roots is the lowest at 500 ppm IBA dose, the number of roots is highest at 2000 ppm IBA dose (Table 2). Boyaci et al. (2017) determined in their study that the average number of roots varied between 2.90 and 4.55. Özyurt et al. (2012) determined that the average number of roots in mahaleb genotypes was 2.10-9.70. Edizer and Demirel (2012) in their study on the reproduction of clonal rootstocks with softwood cuttings; the average root number of clonal rootstocks was 11.00-18.50, they stated that there was a positive relationship between IBA dose and root number. Kalyoncu et al. (2008) in their study on the propagation of cherry with soft cuttings, determined the number of roots as 1.62-6.25, although it changes according to moisture levels. Our results about root number are consistent with the results of the studies carried out.

Table 1. The effect of IBA applications on rooting rate (%) in genotypes.

Genotype Code	IBA doses			Average
	500 ppm	1000 ppm	2000 ppm	rooting rate (%)
08 K 056	37.50 bc	59.00 a	42.50 b	46.33 A
28 V 001	41.67 b	29.33 d-g	39.17 b	36.72 B
52 K 063	28.33 eg	36.67 bcd	28.33 efg	31.11 C
55 V 004	25.00 fg	42.50 b	23.33 g	30.28 C
55 M 005	26.00 efg	28.33 efg	33.33 cde	29.22 C
52 M 003	28.33 efg	31.67 c-f	25.00 fg	28.33 C
55 K 104	23.33 g	22.50 g	23.33 g	23.03 D
Average (%)	30.02 B	35.71 A	30.71 B	
cv		14		
Genotype		**		
Dose		*		
Genotype x Dose		**		

Different letters in the same line or column are statistically significant. **Significant at $p \leq 0.01$. *Significant at $p \leq 0.05$. cv: Coefficient of variation.

Table 2. Effect of IBA applications on root number in genotypes.

Genotype Code	IBA doses			Avarage
	500 ppm	1000 ppm	2000 ppm	
08 K 056	5.38 d-ı	6.32 def	7.25 cd	6.32 B
28 V 001	4.87 d-j	5.85 d-h	5.01 d-j	5.24 BC
52 K 063	2.92 ıl	2.17 kl	2.63 jl	2.57 C
55 V 004	3.92 f-l	3.25 h-l	7.38 cd	4.85 BC
55 M 005	6.35 def	13.50 b	18.49 a	12.78 A
52 M 003	4.50 ek	3.60 g-l	6.13 dg	4.74B C
55 K 104	1.66 l	7.09 cde	9.50 c	6.09 B
Avarage	4.23 C	5.97 B	8.06 A	
cv		16		
Genotype		*		
Dose		**		
Genotype x Dose		**		

Different letters in the same line or column are statistically significant. **Significant at $p \leq 0.01$. *Significant at $p \leq 0.05$. cv: Coefficient of variation.

Table 3. The effect of IBA applications on the number of branching roots in genotypes.

Genotype code	IBA doses			Average
	500 ppm	1000 ppm	2000 ppm	
08 K 056	2.90 bc	2.30 bc	2.60 bc	2.60 BC
28 V 001	2.60 bc	3.00 bc	3.40 b	3.02 ABC
52 K 063	2.10 bc	2.90 bc	2.50 bc	2.49 BC
55 V 004	1.70 c	2.20 bc	2.70 bc	2.18 C
55 M 005	2.40 bc	3.20 b	6.10 a	3.90 A
52 M 003	2.00 bc	2.50 bc	5.80 a	3.46 AB
55 K 104	2.50 bc	2.00 bc	2.20 bc	2.23 C
Average	2.31 B	2.60 B	3.60 A	
cv		19		
Genotype		*		
Dose		*		
Genotype x Dose		*		

Different letters in the same line or column are statistically significant. **Significant at $p \leq 0.01$. *Significant at $p \leq 0.05$. cv: Coefficient of variation.

Table 4. Effect of IBA applications on root length (mm) in genotypes.

Genotype code	IBA doses			Average (mm)
	500 ppm	1000 ppm	2000 ppm	
08 K 056	69.69 b	67.24 bcd	67.72 bc	68.21 AB
28 V 001	65.79 bcd	67.47 bc	67.59 bc	66.95 B
52 K 063	42.50 fg	43.97 efg	39.09 g	41.85 D
55 V 004	66.68 bcd	84.81 a	76.63 ab	76.04 A
55 M 005	43.27 fg	72.90 ab	69.97 b	62.05 BC
52 M 003	47.57 efg	71.71 b	55.93 cde	58.40 C
55 K 104	68.85 h	49.39 efg	54.92 def	37.05 D
Average (mm)	48.90 B	65.35 A	61.69 A	
cv	13			
Genotype	**			
Dose	**			
Genotype x Dose	**			

Different letters in the same line or column are statistically significant. **Significant at $p \leq 0.01$. *Significant at $p \leq 0.05$. cv: Coefficient of variation.

3.3. Number of branching roots

The minimum number of branching roots (1.70) of the 55 V 004 genotype at 500 ppm IBA dose and the highest number of branching roots (6.10) at 2000 ppm IBA dose of 55 M 005 genotype were obtained. While the number of branching roots is the lowest in the 55 V 004 genotype (2.18), the number of branching roots is the highest in the 55 M 005 genotype (3.90). There is a positive correlation between IBA doses and the number of branching roots (Table 3). Edizer and Demirel (2012) stated that IBA doses significantly increased branching in roots compared to the control. Kalyoncu et al. (2008) in their study the number of branching roots in cherry varied between 0.0-2.21. The differences between these literatures, which are compatible with our study, and the results we obtained; can be explained by the genetic structures and dose differences of genotypes.

3.4. Root length

As stated in Table 4, there were statistically significant differences in genotype x dose interaction in terms of root length ($p<0.05$). The minimum root length was obtained from the 2000 ppm IBA dose of the 52 K 063 genotype (39.09 mm), the highest root length was obtained from the 1000 ppm IBA dose of the 55 V 004 genotype (84.81 mm). In terms of root length, 55 K 104 genotype has the shortest root length at 37.05 mm, while 55 V 004 genotype has the longest root length at 76.04 mm. In terms of applied IBA doses, the shortest root length was obtained from a 500 ppm IBA dose, while the longest root length was obtained from a 1000 ppm IBA dose application (Table 4). Özyurt et al. (2012) determined that the root length in mahaleb genotypes was 10.00-51.80 mm. Edizer and Demirel (2012) found that root lengths ranged from 30.00 to 44.58 mm in their study on the propagation of some clone rootstocks with green cuttings. They stated that IBA doses significantly increased branching in roots compared to the control. Boyaci et al. (2017) determined that the root length varies between 24.0-54.0 mm in their study. Kalyoncu et al. (2008) stated that the root length is between 2.00-20.10 mm in their study on the reproduction of cherries with soft cuttings. Our results regarding root length agree with the results of the studies.

4. Conclusion

500, 1000, and 2000 ppm doses of IBA were applied to soft-wood cuttings of rootstock candidate genotypes for cherry. IBA had a significant positive effect on properties such as rooting rate (%), number of roots (number), number of branching roots (number), and average root length (mm). According to the data we obtained from the study; the highest rooting rate was obtained from 59.00% to 1000 ppm IBA dose. It was determined that 1000 ppm IBA for rooting rate and root length in softwood cuttings of rootstock candidate genotypes we used in our study, and the most appropriate IBA dose for root number and branching root number was 2000 ppm.

Compliance with Ethical Standards

Conflict of Interest

As the author of article declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authors' Contributions

Erol AYDIN: Validation, Writing - original draft, Formal analysis, Data curation. **Ercan ER**: Methodology, Investigation, Review and editing.

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We humbly give consent for this article to be published.

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