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Performance of different banana varieties (*Musa* spp. AAA) under protected cultivation in terms of morphological, yield and quality characteristics

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Abstract: Recently, protected cultivation of bananas under subtropical conditions has gained popularity due to the impact of global climate change. Several factors influence the yield and quality of banana cultivation. Among these factors, variety plays an important role along with cultural practices. This study aimed to determine the performance of 'Azman', 'Bango', 'Bonus', 'Grand Nain', 'Lider', and 'Paşa' banana varieties in terms of morphological and yield characteristics under protected cultivation, as well as to elucidate the relationship between yield and factors affecting yield. The research was conducted between 2020 and 2022 in the Manavgat district of Antalya. The research findings showed that each morphological parameter examined varied significantly. However, the 'Bango' variety exhibited superior results in terms of finger circumference (13.23 cm), finger length (21.08 cm), bunch weight (39.33 kg), and yield per hectare (72 t/ha). Moderate to high-level phenotypic correlations were found between bunch weight and pseudo stem girth, pseudo stem height, number of fingers, finger weight, finger circumference, and finger length, with values of 0.544, 0.478, 0.326, 0.669, 0.581, and 0.543, respectively. Positive and significant phenotypic correlations were determined between finger length affecting export quality, bunch weight, finger weight, and finger circumference, with values of 0.543, 0.799, and 0.625, respectively. It can be concluded that the 'Bango' variety exhibited better results as compared to other varieties in terms of both yield and quality criteria. Additionally, positive phenotypic correlations were observed between bunch weight (which directly influences yield) and finger length (which affects export quality), as well as various morphological and pomological characteristics.

Keywords: banana cultivation; adaptation; correlation; subtropical

Tropical fruit species are naturally grown in regions near the equator (Ogata et al. 2016). However, due to climate change, the cultivation of these species has expanded to subtropical regions in recent years. Especially, bananas are grown in subtropical areas such as Australia, Southern Brazil, Egypt, Israel, Morocco, Portugal (Madeira and Azores), South Africa, Spain (Canary Islands), and Tür-

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kiye (Galán Saúco 2018). The absence of surplus production in tropical fruit species, the potential for marketing them at high prices, their positive effects on health (Ranjha et al. 2022), increasing consumer interest in exotic fruits (Özer et al. 2020), and the geographical proximity of Mediterranean countries to the European market – which allows fruits to be harvested at a more mature stage, thereby improving quality (Galán Saúco et al. 2010) – significantly enhance the interest in tropical fruit cultivation in subtropical regions. Significant differences in morphological traits and yield have been demonstrated among banana varieties. Varieties of different fruit species grown under the same ecological and cultural conditions exhibit distinct phenological and morphological characteristics, reflecting their genetic makeup. Previous studies conducted on various fruit species strongly support this finding (Ercisli et al. 2008; Imrak et al. 2024; Nawaz et al. 2024).

According to 2022 data, the global banana production area for consumption was 5 940 159 ha, with a production quantity of 135 112 326 t and an average yield per hectare of 22.75 t (FAO 2024). Despite being a country that cultivates bananas in subtropical conditions, Türkiye has shown a continuous increase in the area and production quantity of bananas grown under protection. Türkiye's banana production quantity was 883 455 t in 2021, and this value increased to 997 244 t in 2022 (TUIK 2023).

The ideal temperature range for banana cultivation is between 20 and 35 °C. Temperatures below 20 °C or above 35 °C slow down growth. The accumulation of dry matter in the vegetative parts of the plant peaks at 20 °C, while the rate of new leaf emergence is highest at 30 °C with growth stopping at temperatures below 16 °C (Bahadur et al. 2020). In subtropical climates, significant factors affecting banana cultivation include low temperatures during winter months, day and night temperature variations, and high temperatures encountered during summer particularly due to global warming. These adverse climatic conditions negatively impact leaf emergence rate, the number of hands per bunch, and consequently, yield. Cold climates lead to significant challenges in banana production, including lower bunch weight, fewer hands and fingers per bunch, relatively longer vegetation periods, and ultimately, stunted growth (Daniells, O'Keefe 2010; Joshi et al. 2023). Consequently, countries like Morocco, Spain (Canary Islands), Türkiye, and Israel observed an increase in protected or semi-protected banana cultivation. Similarly, Galán Saúco (2018) reported that despite undesirable physiological effects and climatic constraints, banana yield can be increased under subtropical conditions. Thus, the yield per hectare in our country is above the global average, approximately 72 t (Baysal, Türkay 2023).

Galán Saúco et al. (1992) observed that the vegetative period is shorter in protected cultivation compared to open field cultivation. Additionally, lower temperature variations were determined under protected cultivation. It was noted that leaves were not affected by wind damage under protection, and the number of leaves was higher. Galán Saúco et al. (1997) compared the performance of five different banana varieties ('Eylon', 'Zelig', 'Gal', '19-39', 'Chinese Cavendish') in terms of morphological, phenological, yield, and quality aspects with 'Grand Nain' and 'Williams' banana varieties in the Canary Islands. These researchers observed that 'Eylon' and 'Zelig' had the shortest trunk height among the tested varieties. The study conducted in the Turkish Republic of Northern Cyprus on 20 different types of bananas showed that 6 types of bananas had the best results in terms of yield and quality criteria (Yorgancıoğlu et al. 2003). Gübbük et al. (2004) investigated the performance of 'Grand Nain', 'Petit Nain', 'Poyo', 'Williams', and 'Basrai' banana varieties in terms of yield and quality criteria under both open field and greenhouse conditions as alternatives to 'Dwarf Cavendish'. It was determined that in terms of all quality criteria, 'Williams' and 'Grand Nain' varieties performed better than 'Dwarf Cavendish' under greenhouse conditions. Yield was also found to be 19–28% higher under greenhouse compared to open field conditions. Gübbük and Pekmezci (2004) determined that the yield per hectare was 42.8 t in open field as compared to 65.5 t under protection. Gübbük and Pekmezci (2005) compared six different types of bananas in terms of morphological characteristics, bunch weight, and finger physical properties with the 'Dwarf Cavendish' variety under protection. The findings, particularly regarding bunch weight and finger properties, were higher in the studied banana varieties compared to the 'Dwarf Cavendish' variety. In Türkiye, the 'Dwarf Cavendish' variety is still widely cultivated in open fields. However, it is noteworthy that in re-

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cent years, the 'Grand Nain' and 'Azman' varieties have replaced 'Dwarf Cavendish' under protected cultivation in Türkiye. Moreover, studies conducted with different banana varieties in Türkiye have shown that some varieties can be used as alternatives to 'Dwarf Cavendish' (Gübbük 2007). Gübbük et al. (2010) compared different banana cultivation locations (Alanya, Gazipaşa, and Anamur) and cultivation systems. These researchers reported that Alanya location performed better in open field cultivation in terms of yield and the physical quality of fruits, while Anamur location showed better performance under protected cultivation. Additionally, the overall results were better in the protected cultivation system.

Rajamanickam and Rajmohan (2008) investigated genetic diversity and correlation between various fruit characters in 28 banana (*Musa* spp.) clones. They found high heritability estimates for all observed characters. Soares et al. (2012) developed a statistical model to determine the relationship between the morphological characteristics of the YB42-21 hybrid banana variety in Brazil and bunch weight. In the multiple linear regression analysis used to predict bunch weight, the most important variables were identified as the number of leaves at harvest, the average number of fingers per bunch, average finger weight and length, rachis weight, and bunch stem length. Badgujar et al. (2019) evaluated eight diploid banana genotypes for growth and yield traits. These researchers noted that understanding the mutual relationship between growth and yield parameters is crucial in selecting suitable genotypes for cultivation, with all studied parameters exhibiting positive correlations with each other. Güven and Gübbük (2021) studied the relationships between morphological and bunch characteristics of different banana varieties/clones ('Dwarf Cavendish', 'Williams', 'MA 13', 'Jobo', and 'CV 902') grown under protection through correlation analysis. These researchers found positive correlations between bunch weight, which directly affects yield, and pseudo stem girth, total leaf number, number of functional leaves, bunch diameters, number of hands, finger circumference, and finger length criteria in bananas. Additionally, they reported a positive correlation between finger length, a critical quality parameter in bananas, and pseudo stem girth, bunch diameters, number of hands, number of fingers, and finger circumference. Assefa et al. (2023) evaluated four high-yielding, drought-resistant, and disease-tolerant banana varieties in Ethiopia for agronomic, yield and yield-related characteristics. These researchers observed significant differences among plantain banana varieties in both harvest periods for all characteristics except finger diameter, number of fingers per bunch, and unmarketable yield. Results indicated a positive correlation between average bunch weight, finger diameter, number of fingers per bunch, and marketable yield with total yield.

This research investigated various banana varieties cultivated under protected conditions in subtropical climates by focusing on their phenological, morphological, pomological, and yield characteristics to identify the most suitable varieties for such cultivation. Furthermore, correlation analysis was conducted to unveil the relationships between these properties and yield and quality parameters.

MATERIAL AND METHODS

Plant material and growing conditions. The research was conducted at the Ilıca campus of the Manavgat Vocational School of Akdeniz University (Manavgat, Antalya, Türkiye, 36°48'31.08''N and 31°23'16.47''E at an altitude of 24 m) between November 2020 and December 2022. The experiment was performed in a greenhouse measuring 1 250 m^2 with side and ridge ventilation, 50 m in length, 25 m in width, gutter height of 6 m, and ridge height of 10 m. Banana cultivars 'Azman', 'Bango', 'Bonus', 'Grand Nain', 'Lider', and 'Paşa', all belonging to the AAA group, were used in the study. Four-month-old seedlings were obtained from a commercial company that produces bananas using tissue culture techniques in a laboratory environment. The plants were planted in the plastic greenhouse on November 6, 2020, with a spacing of 1.8 m between plants and 3.0 m between rows.

General characteristics of the banana varieties used. 'Paşa' is a medium-sized banana variety, resistant to frost and winter births, with a height ranging between 2.2 and 4.2 meters. The bunch length is 180 cm, bunch weight is 40–45 kg, average finger length is 20–25 cm, finger circumference is 3.5–4.0 cm, and it has a light yellow colour. It is tolerant to nematodes and root rot. 'Bonus' is a medium-sized banana variety, resistant to frost and winter births, with a height ranging between 2.2 and 4.2 meters. The bunch length is 270–275 cm, bunch weight is 40–45 kg, average

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finger length is 20–25 cm, finger circumference is 3.5–4.0 cm, and it has a light yellow colour. It is tolerant to nematodes and root rot. 'Azman' is a tall variety with a height between 4 and 4.5 meters. Its leaves are longer and grow more upright compared to the cavendish variety. The average bunch weight ranges between 50 and 60 kg. It is a large, strong, and productive banana variety. In greenhouses where this variety is cultivated, the side height should be at least 5 to 5.5 meters. 'Bango' is a tall banana variety resistant to frost and winter births, with a height ranging between 2.7 and 4.9 meters. The bunch length is 265–270 cm, bunch weight is 45–50 kg, average finger length is 20–25 cm, finger circumference is 3.5–4.0 cm, and it has a light yellow colour. It is tolerant to nematodes and root rot. 'Lider' is a tall banana variety resistant to frost and winter births, with a height ranging between 2.7 and 4.9 meters. The bunch length is 255–260 cm, bunch weight is 60–70 kg, average finger length is 25 cm, finger circumference is 2.0–2.5 cm, and it has a green colour. It is tolerant to nematodes and root rot.

A drip irrigation system with double laterals placed in each row was used for irrigation, a sprinkler irrigation system was used for humidity control, and a misting system was used to raise the ambient temperature during low temperatures in winter. Irrigation was carried out once a week using a drip irrigation system during the winter months. As temperatures increased, the irrigation frequency was raised to twice a week during the spring. In the summer months, a sprinkler system was operated for 3 hours daily to maintain ambient humidity. Temperature and humidity values were measured hourly with a mini meteorological station placed inside the greenhouse, and monthly minimum temperatures ranged from 10.57 to 24.63 °C, average temperatures ranged from 14.02 to 28.71 °C, and maximum temperatures ranged from 20.21 to 34.06 °C. Relative humidity values ranged from a minimum of 40.72 to 51.79%, an average of 56.84 to 71.18%, and a maximum of 71.24 to 85.14%. The cultural practices described by Gübbük et al. (2010) were applied uniformly to all varieties.

Before the commencement of the study, soil samples were collected from a depth of 20–40 cm and analysed at the Regional Soil, Plant, Water, and Fertilization Analysis Laboratory of the West Mediterranean Agricultural Research Institute Directorate. The levels of plant nutrients determined in the soil analyses, along with texture, lime, salt, organic matter, and pH values, are presented in Table 1.

Based on the analysis results, as a basal fertiliser before planting, 50 kg of triple superphosphate (43–46% P_2O_5), 75 kg of potassium sulphate (50% K_2O), and 8 tons of well-rotted farmyard manure per decare were applied. The fertilisation program was carried out during the vegetation period after planting via drip irrigation using potassium nitrate (13% N, 46% K_2O), mono ammonium phosphate (MAP) (12% N, 61% P_2O_5), urea (46% N), and Fe-EDDHA fertilisers, as detailed in Table 2 taking into account the analysis results and the plant's developmental stage.

Pest and disease management. Immediately after planting, Truman 5 SG (Agrikem) insecticide was applied at the base of the seedlings to control the cotton bollworm (*Heliothis armigera*). In June, a single application of Malathion WP (Koruma) was conducted against the red spider mite (*Tetranychus spp.*). Following the removal of suckers in banana plants, a protective fungicide treatment was carried out using Korsilex-T Plus (Koruma) for fungal disease management.

Parameters investigated. In the study, the measurements were taken during the first harvest period of the planted seedlings. In the study, the

Table 1. Chemical analyses of the soil sampled at a depth of 0.20–0.40 m

pH (1 : 2.5)	7.8	Slightly alkaline
Lime (%)	40.3	highly calcareous
EC micromhos/cm (25 °C)	442	non-saline
Sand (%)	47	
Clay (%)	21	loam
Silt (%)	32	
Organic matter (%)	1.0	
P ppm	3	
K ppm	44	
Ca ppm	3 075	
Mg ppm	226	
Fe ppm	1.92	
Mn ppm	1.71	
Zn ppm	1.02	
Cu ppm	0.90	

EC – electrical conductivity

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Table 2. Fertiliser amounts applied per decare per week by month according to the irrigation system (g/da/week)

	April-May–June	July-August–September	October
Potassium nitrate (13% N, 46% K_2O)	2 000	6 500	4 500
Monoammonium phosphate (MAP) (12% N, 61% P_2O_5)	1 000	1 000	350
Urea (46% N)	1 500	1 500	1 500
Fe – EDDHA	200	–	–

EDDHA – ethylenediamine-N,N'-bis(2-hydroxyphenylacetic acid))

morphological characteristics of the plants were determined at the full bunch formation stage. Pseudostem girth (cm) was measured 20 cm above the soil level, and pseudostem height (cm) was measured from the soil surface to the point where the first leaf emerged. Bunch diameter (cm) was determined using a measuring tape 5 cm above the first formed hand. The number of functional leaves (pieces) was counted as the total number of green leaves present on the plants during the bunch formation period. The number of days from flowering to harvest was calculated based on the period from the full formation of all hands in the bunch (after all female flowers had opened) to the harvest date. Yield components including the number of hands per bunch (pieces), number of fingers per bunch (pieces), bunch weight (kg), and yield per hectare (t/ha) were recorded (Gübbük et al. 2010). Harvesting of the fruits was performed when three-quarters of the angularity in the fingers disappeared. After harvesting, finger weight was measured using a precision scale (g) at stage 2. Finger circumference was measured at the midpoint of the fingers using a measuring tape (cm), and finger length was measured from the dorsal side of the finger from the fruit tip to the base of the stalk using a measuring tape (cm). The harvested bunches were treated with 1 000 ppm ethylene gas for 24 hours. Ripening was carried out at 18 °C and 80–85% relative humidity. After ripening, when the peel colour reached stage 6, measurements were conducted according to the methods of Gübbük et al. (2010). Finger weight was measured again using a precision scale (g), and peel thickness was determined with a digital calliper at the stalk, middle, and tip parts of the finger (mm). Peel ratio (%) and fruit pulp ratio (%) were calculated. Fruit firmness (kg/cm^2) was measured on three different surfaces of the fruit using a Loyka GY-3 hand penetrometer (Loyka, Türkiye)with an 8 mm diameter tip (N/mm^2). Total soluble solids (%) were determined using a digital refractometer (HANNA HI96801, Hanna instruments,Romania).

Statistical analysis. The study was designed according to a randomised plot design, and 21 plants were evaluated for each banana cultivar. The placement of the cultivars in the field was carried out using a lottery method in accordance with the principle of randomness. The collected data were subjected to normality and variance homogeneity tests. Subsequently, the data were analysed using the MINITAB software package (17.1.0.0, 2013) through one-way analysis of variance (ANOVA) and correlation analyses. For parameters found to be statistically significant ($P < 0.05$) in the ANOVA, the TUKEY multiple comparison test was applied to identify the differences among the groups.

RESULTS

Morphological, yield, physical, pomological, and quality characteristics. The findings regarding the morphological characteristics identified in the 6 banana varieties used in the research are given in Table 3. The results of all examined parameters were statistically significant ($P < 0.05$).

Table 3 showed that the lowest pseudo stem girth was recorded in the 'Paşa' variety with 79.57 cm while other varieties were statistically in the same group. Regarding pseudo stem height, the 'Azman', 'Bango', 'Grand Nain', and 'Lider' varieties were statistically in the same group, while the 'Bonus' and 'Paşa' varieties formed separate groups. The lowest pseudostem height value was observed in the 'Paşa' variety (220.05 cm). Findings related to the number of functional leaves and bunch diameters were statistically significant ($P < 0.05$), although the differences between varieties were not practically significant. Regarding the number of days from bunch formation to harvest, statistically, 2 groups

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Table 3. Results for morphological characteristics observed in different banana varieties

Varieties	PSG	PSH	NFL	BD	DFFH
	(cm)		(pieces)	(cm)	(day)
Azman	86.43 ± 1.29^{a}	281.67 ± 3.09^{a}	17.00 ± 0.25^{a}	25.52 ± 0.41^{ab}	120 ± 2.65^{ab}
Bango	86.75 ± 1.15^{a}	280.60 ± 4.01^{a}	16.45 ± 0.23^{ab}	25.63 ± 0.37^{ab}	110 ± 2.82^{b}
Bonus	83.00 ± 1.04^{ab}	245.95 ± 5.81^{b}	14.57 ± 0.30^{c}	26.14 ± 0.26^{ab}	112 ± 3.03^{b}
Grand Nain	86.68 ± 1.44^{a}	284.89 ± 4.59^{a}	16.53 ± 0.25^{ab}	25.32 ± 0.59^{b}	129 ± 3.06^{a}
Lider	82.71 ± 1.26^{ab}	268.86 ± 6.00^{a}	16.91 ± 0.20^{ab}	25.00 ± 0.34^{b}	118 ± 2.94^{ab}
Paşa	79.57 ± 0.75^{b}	220.05 ± 2.78^{c}	15.91 ± 0.23^{b}	26.95 ± 0.27^{a}	114 ± 1.88^{b}

PSG – pseudo stem girth; PSH –pseudo stem height; NFL – number of functional leaves; BD – bunch diameters; DFFH – days from flowering to harvest; $^{a–c}$shown are the mean ± standard error, and the different lowercase letters in the same column indicate a statistically significant difference at a $P < 0.05$ level

were formed. The fruit development period was found to be shorter in the 'Bango', 'Bonus', and 'Paşa' varieties. Depending on the variety, the observed fruit development period ranged between 110 and 129 days.

The effect of varieties on yield characteristics, including the number of hands per bunch, bunch weight, and yield per hectare, was statistically significant ($P < 0.05$), while their effects on the number of fingers were statistically nonsignificant ($P > 0.05$) (Table 4).

The number of hands per bunch varied between 10.76 and 11.62 pieces among the different varieties. The highest number of hands per bunch was recorded in the 'Azman', 'Bango', and 'Grand Nain' varieties. The number of fingers ranged between 202.29 and 222.10 pieces. One of the most crucial parameters affecting yield, bunch weight, ranged from 31.52 kg in the 'Paşa' variety to 39.33 kg in the 'Bango' variety. The yield per hectare value resulting from yield components varied depending on the variety, with the highest being 72.08 t/ha in the 'Bango' variety, while the lowest yield of 58.32 t/ha was in the 'Paşa' variety (Table 4).

The findings regarding the physical characteristics of fruits observed after harvesting in banana varieties are presented in Table 5. Statistically significant differences ($P < 0.05$) were found among all examined parameters across the varieties.

Table 5 showed variations regarding finger circumference among 'Azman', 'Lider', and 'Paşa' varieties while only the 'Lider' variety displayed differences in finger length and weight (stage 2). Finger length, which influences fruit quality, was found to be the lowest in the 'Lider' variety (19.32 cm) with other varieties were in the same statistical group.

Table 6 shows the findings regarding pomological characteristics of different banana varieties. There were no statistical differences among varieties in terms of pulp percentage, while significant

Table 4. Results for yield characteristics observed in different banana varieties

Varieties	NHB	NF	BW	YPH
	(pieces)		(kg)	(t/ha)
Azman	11.62 ± 0.16^{a}	222.10 ± 4.21	35.59 ± 1.52^{b}	65.840 ± 2.82^{ab}
Bango	11.60 ± 0.15^{a}	218.95 ± 2.95	39.33 ± 1.38^{a}	72.080 ± 2.51^{a}
Bonus	10.76 ± 0.15^{b}	202.29 ± 3.92	35.82 ± 0.89^{ab}	66.270 ± 1.65^{ab}
Grand Nain	11.53 ± 0.25^{a}	209.37 ± 7.63	36.28 ± 1.46^{ab}	67.110 ± 2.70^{ab}
Lider	11.43 ± 0.16^{ab}	210.71 ± 5.88	34.03 ± 1.28^{ab}	62.920 ± 2.37^{ab}
Paşa	10.81 ± 0.11^{b}	203.14 ± 4.24	31.52 ± 0.93^{b}	58.320 ± 1.72^{b}

NHB – number of hands per bunch; NF – number of fingers; BW – bunch weight; YPH – yield per hectare; $^{a–b}$shown are the mean ± standard error, and the different lowercase letters in the same column indicate a statistically significant difference at a $P < 0.05$ level

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Table 5. Results of fruit physical characteristics of different banana varieties

Varieties	FC	FL	FW
	(cm)		(g)
Azman	12.53 ± 0.21^{b}	19.78 ± 0.34^{ab}	145.97 ± 6.23^{bc}
Bango	13.23 ± 0.13^{a}	21.08 ± 0.27^{a}	165.15 ± 3.94^{ab}
Bonus	13.11 ± 0.13^{ab}	20.71 ± 0.35^{a}	167.03 ± 5.32^{a}
Grand Nain	12.86 ± 0.15^{ab}	20.19 ± 0.35^{ab}	155.72 ± 495^{abc}
Lider	12.54 ± 0.15^{b}	19.32 ± 0.26^{b}	142.19 ± 4.37^{c}
Paşa	12.66 ± 0.13^{b}	20.24 ± 0.26^{ab}	144.51 ± 4.78^{bc}

FC – finger circumference; FL – finger length; FW – finger weight (stage 2); $^{a–c}$shown are the mean ± standard error, and the different lowercase letters in the same column indicate a statistically significant difference at a $P < 0.05$ level

Table 6. Results of fruit pomological characteristics of different banana cultivars

Varieties	FW	PT	PR	FPR	FF	TSS
	(g)	(mm)	(%)		(kg/cm^2)	(%)
Azman	145.28 ± 6.81^{ab}	2.42 ± 0.10^{ab}	31.35 ± 0.98^{ab}	68.20 ± 1.07	1.79 ± 0.13^{bc}	19.06 ± 0.36^{ab}
Bango	164.15 ± 4.15^{a}	2.20 ± 0.10^{b}	29.59 ± 1.05^{b}	69.28 ± 1.04	1.94 ± 0.18^{abc}	18.34 ± 0.28^{abc}
Bonus	162.72 ± 5.51^{a}	2.54 ± 0.11^{ab}	31.60 ± 0.87^{ab}	66.86 ± 0.77	2.26 ± 0.18^{ab}	17.48 ± 0.46^{c}
Grand Nain	149.80 ± 4.78^{ab}	2.51 ± 0.08^{ab}	31.38 ± 0.58^{ab}	68.72 ± 0.57	1.33 ± 0.08^{c}	19.83 ± 0.20^{a}
Lider	140.08 ± 4.57^{b}	2.52 ± 0.07^{ab}	31.86 ± 0.47^{ab}	68.00 ± 0.48	1.56 ± 0.16^{c}	19.28 ± 0.30^{a}
Paşa	143.57 ± 4.56^{ab}	2.74 ± 0.06^{a}	33.27 ± 0.64^{a}	67.42 ± 0.77	2.53 ± 0.16^{a}	17.79 ± 0.46^{bc}

FW – finger weight (stage 6); PT – peel thickness; PR – peel ratio, FPR – fruit pulp ratio; FF – fruit firmness; TSS – total soluble solids; $^{a-c}$shown are the mean ± standard error, and the different lowercase letters in the same column indicate a statistically significant difference at a $P < 0.05$ level

differences ($P < 0.05$) were observed among other characteristics.

Table 6 showed that the lowest finger weight was in 'Lider' variety (140.08 g) with all other varieties were statistically in the same group. Regarding peel thickness, varieties ranged from 2.20 to 2.74 mm. The lowest values for peel thickness and peel ratio were obtained in the 'Bango' variety, while the

Table 7. Phenotypic correlations between some quality criteria and yield in different banana varieties

General	PSG	PSH	NFL	BD	NHB	NF	BW	FW	FC
	(cm)		(pieces)	(cm)	(pieces)		(kg)	(g)	(cm)
PSH (cm)	0.630**								
NFL (pieces)	0.303**	0.432**							
BD (cm)	0.250**	–0.140	–0.012						
NHB (pieces)	0.224*	0.302**	0.263**	0.047					
NF (pieces)	0.277**	0.204*	0.194*	0.287**	0.440**				
BW (kg)	0.544**	0.478**	0.080	0.299**	0.255**	0.326**			
FW (g)	0.342**	0.222*	–0.163	0.276**	–0.032	0.002	0.669**		
FC (cm)	0.298**	0.169	–0.041	0.313**	–0.033	0.038	0.581**	0.846**	
FL (cm)	0.312**	0.193*	–0.202*	0.241**	0.009	–0.023	0.543**	0.799**	0.625**

PSG – pseudo stem girth; PSH – pseudo stem height; NFL – number of functional leaves; BD – bunch diameters; NHB – number of hands per bunch; NF – number of fingers; BW – bunch weight; FW – finger weight; FC – finger circumference; FL – finger length; *,** significant correlation at a 0.05 and 0.01 level

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Table 8. Phenotypic correlations between bunch weight and some characters for different banana varieties

Varieties	PSG	PSH	NF	FW	FC	FL
	(cm)		(pieces)	(g)	(cm)	
General	0.544**	0.478**	0.326**	0.669**	0.581**	0.543**
Azman	0.195	0.424	0.235	0.787**	0.758**	0.667**
Bango	0.632**	0.641**	0.420	0.476*	0.222	0.250
Bonus	0.185	0.154	0.158	0.726**	0.533*	0.530*
Grand Nain	0.562*	0.600**	0.530*	0.681**	0.465*	0.800**
Lider	0.616**	0.407	0.187	0.574**	0.570**	0.361
Paşa	0.660**	0.654**	0.096	0.732**	0.715**	0.591**

PSG – pseudo stem girth; PSH – pseudo stem height; NF – number of fingers; FW – finger weight; FC– finger circumference; FL – finger length; *,** significant correlation at a 0.05 and 0.01 level

highest values were recorded in 'Paşa' variety. The fruit pulp ratio, which is important for consumers, was highest in the 'Bango' variety. Different banana varieties had statistically significant differences in terms of fruit firmness. The total soluble solids ranged from 17.48 to 19.83%, with the lowest value 17.48% obtained in 'Bonus' variety.

Correlation analysis. It is known that there is a relationship between bunch weight (The most important criterion for yield in banana cultivation) and some parameters. Table 7 shows the results of phenotypic correlation analysis to determine the relationship between different parameters.

The results of the phenotypic correlation analysis indicated significant relationships among various traits. Positive and significant phenotypic correlations were found between bunch weight, a crucial indicator of yield in banana cultivation, and parameters such as pseudo stem girth, pseudo stem height, finger weight, finger circumference, and finger length. Finger length, which affects export quality, showed moderate to high-level correlations with bunch weight, finger weight, and finger circumference while exhibiting low-level correlations with pseudo stem girth, pseudo stem height, and bunch diameters. Additionally, there were negative correlations with the number of functional leaves. No relationship was found between the number of hands per bunch and the number of fingers.

The phenotypic correlation analysis results for bunch weight and finger length among the varieties, as well as some other characteristics, are presented in Tables 8 and 9.

The correlation analysis conducted on a variety basis for the 5 characters associated with bunch weight showed that there were low correlations between pseudo stem girth and pseudo stem height with bunch weight in 'Azman' and 'Bonus' varieties, while moderate-level phenotypic correlations were determined in the other 4 varieties. The correlation between the number of fingers and bunch weight was moderate in 'Bango' and 'Grand Nain' varieties, whereas low phenotypic correlations were observed in the other 4 varieties. There was a moderate to high-level relationship between finger weight and bunch weight in all varieties. The relationship between finger circumference and finger length with bunch weight was low in the 'Bango' variety, while it was moderate to high in the other varieties. There was some variation in phenotypic correlations among the varieties.

DISCUSSION

The research findings, regarding morphological characteristics, revealed variations in pseudo

Table 9. Phenotypic correlations between finger length and some characters for different banana varieties

	BW (kg)	FW (g)	FC (cm)
General	0.543**	0.799**	0.625**
Azman	0.667**	0.772**	0.625**
Bango	0.250	0.722**	0.627**
Bonus	0.530*	0.821**	0.409
Grand Nain	0.800**	0.715**	0.401
Lider	0.361	0.817**	0.727**
Paşa	0.591**	0.870**	0.773**

BW – bunch weight; FW – finger weight; FC – finger circumference; *,** significant correlation at a 0.05 and 0.01 level

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stem girth (79–86 cm), pseudo stem height (220–284 cm), number of functional leaves (14–17 pieces), and bunch diameters (25–26 cm). The pseudo stem girth observed in our study was higher than that reported by Gübbük et al. (2010) and Güven (2011), while it was lower than Lamessa (2021). Pseudo stem height was in line with Güven (2011), while it was lower than Gübbük et al. (2010) and Lamessa (2021). The number of functional leaves was higher than the values reported by Güven and Gübbük (2021). Bunch diameter was consistent with Güven and Gübbük (2021), while it was lower than Gübbük et al. (2010). Morphological characteristics in bananas are influenced by ecological factors, variety, and cultivation systems (Gübbük et al. 2010). Pseudo stem height and pseudo stem girth development are more related to a variety of characteristics than to environmental conditions. Cabrera and Saúco (2005) reported that plants grown under cover produce taller and wider plants due to the improvement of climatic conditions as compared to those grown in open fields.

Days from flowering to harvest are crucial for fruit development. In our study, this period varied among varieties, with the longest duration recorded in 'Azman' (120 days) and with shortest duration in 'Bango' (110 days). The fruit development period was consistent with Gübbük et al. (2010), Güven (2011), and Lamessa (2021). The slight variation observed in the fruit development period can be attributed to differences in ecological conditions.

Significant differences were recorded among the factors directly affecting yield, such as the number of hands per bunch, the number of fingers, and bunch weight. In our study, the number of hands per bunch ranged from 10 to 11.60, which was consistent with Güven (2011) but lower than Gübbük et al. (2010). The number of fingers ranged from 203 to 222 (pieces), and the bunch weight ranged from 31 to 39 kg, which was lower than those reported by Gübbük et al. (2010) and Güven (2011). However, our average total yield per hectare, ranging from 58 to 72 t, was higher compared to the global average, while it was lower than that reported by Gübbük (2010), which could be attributed to differences in location.

Finger circumference, length, and weight which directly affects yield and fruit quality in banana cultivation. In our study, finger circumference ranged from 12 to 13 cm, finger length from 19 to 21 cm, and finger weight (at stage 2) from 142 to 167 g. These outcomes were consistent with the findings of Gübbük et al. (2010) and Güven (2011). The finger length and finger weight values reported by Lamessa's (2021) in a study conducted in open field conditions were lower as compared to those obtained in our study. This was an expected outcome, as higher productivity and fruit quality are anticipated in greenhouse cultivation (Cabrera, Saúco 2005).

In terms of pomological properties, finger weight (at stage 6) ranged from 140 to 164 g. The results were in line to Gübbük et al. (2010) and Güven (2011). Peel thickness ranged from 2.20 to 2.74 mm, which was lower than Güven (2011), while close to Gübbük et al. (2010). The peel ratio 29–33% was lower than those reported by Gübbük et al. (2010). The fruit pulp ratio 66–69% was consistent with the findings of Gübük et al. (2010), while it was lower than Güven (2011). The total soluble solids ranged from 17 to 19% which showed uniformity with the results of Gübbük (2010) and Güven (2011).

In our study, phenotypic correlation coefficients between bunch weight and pseudo stem girth, pseudo stem height, number of fingers, finger weight, finger circumference, and finger length were determined as 0.544, 0.478, 0.326, 0.669, 0.581, and 0.543, respectively. It is known that there is a relationship between morphological and bunch characteristics and yield in banana cultivation. Our findings were consistent with several researchers, while differed from others (Rajamanickam, Rajmohan 2008; Soares et al. 2012; Tak et al. 2015; Badgujar et al. 2019; Güven, Gübbük 2021; Pınar et al. 2021; Assefa et al. 2023). The correlation coefficient between bunch weight and the number of functional leaves was 0.080, indicating no relationship. However, Badgujar et al. (2019) and Güven and Gübbük (2021) reported a moderate positive correlation. Soares et al. (2012), on the contrary, reported a low-level negative relationship of –0.317 between these two traits.

In our study, phenotypic correlation coefficients between finger length and bunch weight, finger weight, and finger circumference were determined as 0.543, 0.799, and 0.625, respectively. These values were consistent with Güven and Gübbük (2021) and Pınar et al. (2021) while higher than Soares et al. (2012). The variations in phenotypic correlation coefficients among varieties obtained in our study as compared to previous studies are

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thought to be because of variety characteristics, cultivation system differences, and genotype-environment interactions.

CONCLUSION

This study investigated the performance of different banana varieties under protected conditions. 'Azman', 'Bango', 'Grand Nain', and 'Lider' varieties were identified as tall plants by producing export-quality fruits. Additionally, it was determined that the 'Bango' variety showed better results in terms of yield and quality criteria compared to other varieties. It was observed that the low-height plants, 'Bonus' and 'Paşa' (245.00–220.00 cm), produced export-quality fruits under greenhouse conditions, indicating that they can be easily cultivated. Additionally, it was observed that low temperatures during winter months caused less damage to the leaves of 'Bonus' and 'Paşa' varieties, suggesting their suitability for cultivation in subtropical regions. Research findings showed that positive and significant phenotypic correlations were identified between bunch weight, which directly affects yield in bananas, and pseudo stem girth, pseudo stem height, finger weight, finger circumference, and finger length. Additionally, positive and significant phenotypic correlations were found between finger length, which affects export quality, and bunch weight, finger weight, and finger circumference.

REFERENCES

Assefa G., Girma S., Deresa D. (2023): Performance evaluation of improved plantain banana (*Musa* spp.) varieties in west Hararghe zone, Eastern Ethiopia. American Journal of Agriculture and Forestry, 11: 176–180.

Badgujar C., Patil B., Patil M. (2019): Correlation study in growth, duration and yield parameters of diploid genotypes (AB) of banana. Trends in Biosciences, 12: 1404–1405.

Bahadur L., Anmol D.S., Singh S.K. (2020): A review on successful protected cultivation of banana (*Musa*). Plant Archives, 20: 1570–1573.

Baysal F., Turkay C. (2023): A national and global perspective on the challenges experienced in banana cultivation and distribution. Fruit Science, 10: 124–130. (in Turkish)

Cabrera J.C., Saúco V.G. (2005): Evaluation of the banana cultivars Zelig, Grande Naine and Gruesa under different environmental conditions in the Canary Islands. Fruits, 60: 357–369.

Daniells J.W., O'Keefe V. (2010): Banana production challenges in the subtropics: Are banana varieties part of the solution? In: 6th Int. Symp. Banana: 28th Int. Horticultural Congress on Science and Horticulture for People 928, Lisbon, August, 2010: 67–73.

Ercisli S., Orhan E., Esitken A., Yildirim N., Agar G. (2008): Relationships among some cornelian cherry genotypes (*Cornus mas* L.) based on RAPD analysis. Genetic Resources and Crop Evolution, 55: 613–618.

FAO (2024): Crops and Livestock Products. Rome, FAO. Available at www.fao.org/faostat/en/#data/QCL/visualize (accessed Nov 15, 2023).

Galán Saúco V. (2018): Broad overview of the subtropical banana industry. In: 30th Int. Horticultural Congress IHC2018: 11th Int. Symp. Banana: ISHS-ProMusa Symposium on growing and 1272, Istanbul, August 12–16, 2018: 1–12.

Galán Saúco V., Cabrera Cabrera J., Hernandez Delgado P.M. (1992): Phenological and production differences between greenhouse and open air banana (*Musa accuminata* Colla AAA cv. Dwarf Cavendish) in Canary Islands. Acta Horticulturae, 296: 97–112.

Galán Saúco V., Cabrera Cabrera J., Hernandez Delgado P.M., Rodriguez Pastor M. C. (1997): Evaluation of medium-height Cavendish banana cultivars under the subtropical conditions of the Canary Islands. In: 2nd Int. Symp. Banana: 1st Int. Symp. Banana in the Subtropics, 490: 103–116.

Galán Saúco V., Robinson J.C., Tomer E., Daniells J.W. (2010): Current situation and challenges of cultivating banana and other tropical fruits in the subtropics. In: 6th Int. Symp. Banana: 28th Int. Horticultural Congress on Science and Horticulture for People 928, Lisbon, August, 2010: 19–30.

Gübbük H. (2007): Developments in banana cultivation and the challenges encountered. Harvest, 23: 52–54. (in Turkish)

Gübbük H., Pekmezci M. (2004): Comparison of open-field and protected cultivation of banana (*Musa* spp. AAA) in the coastal area of Türkiye. New Zealand Journal of Crop and Horticultural Science, 32: 375–378.

Gübbük H., Pekmezci M. (2005): The agronomic performance of six promising off-types banana (*Musa* spp. AAA) under protected cultivation. Tropical Agriculture, 82: 30–33.

Gübbük H., Pekmezci M., Erkan M. (2004): Production potential of Cavendish cultivars (*Musa* spp. AAA) under greenhouse and field conditions in subtropical areas of Türkiye. Acta Agriculturae Scandinavica, Section B – Plant Soil Science, 54: 249–253.

Gübbük H., Pekmezci M., Selli S., Erkan M., Kafkas E., Pınar H., Guven D., Guneş E. (2010): Research on the

https://doi.org/10.17221/51/2024-HORTSCI

determination of yield, certain quality criteria, aroma compounds, and postharvest characteristics of 'Dwarf Cavendish' banana cultivar grown in open field and under protected cultivation in different locations. Tübitak, Project No: 1070156. (in Turkish)

Güven D. (2011): Determination of phenological and pomological characteristics, and the seasonal changes of plant nutrients and hormones in some new banana cultivars and clones. [PhD. Thesis.]. Antalya, Akdeniz University. (in Turkish)

Güven D., Gübbük H. (2021): Determination of the correlations among traits affecting yield and quality in greenhouse banana cultivation. Bahçe, 50: 1–6. (in Turkish)

Imrak B., Golcu A.E., Comlekcioglu S., Bozhuyuk M.R., Mlcek J., Ozkan G., Skrovankova S. (2024): Quality characteristics of the cv. Albion strawberry (*Fragaria* × *ananassa* Duch.) in different locations. Turkish Journal of Agriculture and Forestry, 48: 720–730.

Joshi R.U., Singh A.K., Singh V.P., Rai R., Joshi P. (2023): A review on adaptation of banana (*Musa* spp.) to cold in subtropics. Plant Breeding, 142: 269–283.

Lamessa K. (2021): Performance evaluation of banana varieties, through farmer's participatory selection. International Journal of Fruit Science, 21: 768–778.

Nawaz M.A., Razgonova M.P., Rusakova E.A., Petrusha E.N., Sabitov A.S., Chunikhina O.A., Ercisli S., Tikhonova N.G., Golokhvast K.S. (2024): Global metabolome profiles of *Lonicera caerulea* L. and *Lonicera caerulea* ssp. kamtschatica (Sevast.) Gladkova. Turkish Journal of Agriculture and Forestry, 48: 745–759.

Ogata T., Yamanaka S., Shoda M., Urasaki N., Yamamoto T. (2016): Current status of tropical fruit breeding and genetics for three tropical fruit species cultivated in Japan: pineapple, mango, and papaya. Breeding Science, 66: 69–81.

Özer Ç., Bruwier F., Olgay P., Elmacıoglu F. (2020): The nutritional importance of some tropical fruits grown in Turkey and new approaches in gastronomy. Journal of Cultural and Tourism Studies, 3: 437–459. (in Turkish)

Pinar H., Bircan M., Unlu M., Turkay C., Uzun A., Ercisli S., Hanci F. (2021): Selection and identification of superior banana phenotypes from Türkiye. Genetic Resources and Crop Evolution, 68: 667–677.

Rajamanickam C., Rajmohan K. (2008): Genetic variability and correlation studies in banana (*Musa* spp.). Madras Agricultural Journal, 95: 258–265.

Ranjha M.M.A.N., Irfan S., Nadeem M., Mahmood S. (2022): A comprehensive review on nutritional value, medicinal uses, and processing of banana. Food Reviews International, 38: 199–225.

Soares J.D.R., Pasqual M., Rodrigues F.A., Lacerda W.S., Donato S.L.R., Silva S.D.O., Paixão C.A. (2012): Correlation between morphological characters and estimated bunch weight of the Tropical banana cultivar. African Journal of Biotechnology, 11: 10682–10687.

Tak M.K., Kumar V., Attar S., Revale A.K., Patel R. (2015): Correlation of banana cv Grand Naine with growth and yield aspect. Journal of Plant Development Sciences, 7: 1–6.

TUİK (2023): Turkish Statistical İnstitute, Crop Production Statistics. Available at http://www.tuik.gov.tr (accessed May 5, 2023). (in Turkish)

Yorgancıoğlu L., Şekerli M., Pekmezci M., Gübbük H. (2003): The possibilities of growing different banana types under greenhouse conditions in the climate of the Turkish Republic of Northern Cyprus. In: 4th National Horticulture Congress of Turkey, Antalya, Sept 8-12, 2003: 311–312. (in Turkish)

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