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Agro-Morphological and Biochemical Characterization of Korean Sorghum (*Sorghum bicolor* (L.) Moench) Landraces

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Abstract: Sorghum landraces are essential for developing cultivars with improved properties, such as disease tolerance, yield and metabolite content. In this study, 139 genotypes (136 Korean sorghum landraces and 3 control cultivars) collected from various provinces were investigated using eleven agronomical and five biochemical traits. The landraces showed little variation in their qualitative agronomical traits. In contrast, quantitative agronomical and biochemical traits differed significantly among the landraces. It was discovered that 16 landraces matured ahead of all control cultivars. Furthermore, 26 landraces had significantly higher thousand seed weights (TSWs) than two of the control cultivars, including Nampungchal (30.63 g) and Sodamchal (30.53 g), whereas only 1 landrace had a significantly higher TSW than the other control cultivar, Wheatland (37.93 g) ($p < 0.05$). The levels of total tannin content (TTC), total phenolic content (TPC), 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium (ABTS) radical cation scavenging activity, 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity and ferric reducing antioxidant power (FRAP) were in the ranges of 0.12–428.95 mg CE/g, 1.17–10.23 mg GAE/g, 1.64–67.60 mg TE/g, 0.48–31.99 mg AAE/g and 0.63–21.56 mg AAE/g, respectively, and were all affected by collection area, seed weight and seed color. Landraces from northern provinces were discovered to have higher metabolite contents. Furthermore, large seeds had higher TTC and TPC levels as well as DPPH, ABTS and FRAP activities than medium and small seeds, except for the TTC and FRAP, which were significantly different. In terms of seed color, white seeds had significantly lower metabolite contents and antioxidant activities and were notable in principal component analysis. Correlation analysis revealed positive and significant associations between biochemical traits, as well as between panicle-related agronomic traits. In general, the landraces with superior characteristics could be ideal candidates for sorghum breeding programs.

Keywords: agronomic traits; antioxidant activities; diversity; landrace; metabolite contents; sorghum

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1. Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is an economically important cereal crop that is grown all over the world. It is a member of the Poaceae (or Grass) family, which includes some of the world's most important crops, such as wheat, maize, rice and barley [1,2]. According to the most recent Food and Agriculture Organization (FAO) data, approximately 59 million tons of sorghum were produced in 2020 alone, with the top three producing countries being the United States, Nigeria and Ethiopia [3].

Sorghum seeds are known for their nutritional value because they are high in minerals, vitamins, proteins, fiber and carbohydrates and are thus used for human consumption and as animal feed [4,5]. Moreover, other non-nutritional and health-promoting metabolites such as phenolic compounds, tannins and phytosterols are abundant [2,6,7]. Several pharmacological studies have shown that sorghum seeds have antioxidant, antiobesity, anticancer and anti-inflammatory properties due to these metabolites. Because sorghum seeds are gluten-free, they are recommended for celiac and gluten-intolerant patients [6,8]. All of these factors may have contributed to the increased use of sorghum in the food, pharmaceutical and aquaculture industries [8].

As the global population grows, increased food production is expected to meet the growing global demand [9]. However, climate change and associated abiotic and biotic factors are posing challenges to the production of several crops, including sorghum [10,11]. As a result, researchers are constantly working to develop improved sorghum cultivars with high productivity and adaptability, rich metabolite contents and high disease tolerance [12]. Therefore, multidisciplinary studies that assist the breeding process are always needed [13,14].

Crop breeding and genetic improvements in general incorporate several technologies related to DNA markers, marker selection and genetic engineering. Several specific genes regulate the characteristics of agronomic traits, which influence their selection during breeding programs [15]. Moreover, various environmental factors influence the agronomical characteristics and metabolite contents of sorghum genotypes [16,17]. Several previous studies investigated the effects of these factors, such as temperature, cultivation conditions, stresses, diseases and genotype differences, among others, on agronomical characteristics and metabolite contents using phenotypic and genotypic methods in sorghum genetic resources [7,18–20]. Assessing the variation of such traits using a large collection of genotypes provides valuable information and aids in the development of high-quality cultivars [9,13]. Previous research has found a high level of genetic diversity in sorghum landraces from Ethiopia, India, China and Sudan, among other places [21–25].

Since 1987, the National Agrobiodiversity Center of the National Institute of Agricultural Sciences, Rural Development Administration (RDA, Jeonju, Republic of Korea), has been collecting and researching the diversity of local landraces as well as several crops of different origins for future use and conservation [26]. Despite this, genetic diversity assessments of sorghum landraces from the Republic of Korea have received little attention [27,28]. The goal of this study was to investigate the diversity of 136 recently cultivated Korean sorghum landraces by comparing their agronomical traits, biochemical contents and antioxidant activities with those of three control cultivars. The findings of this study can aid in the identification of well-performing landraces with distinct agronomic traits, high levels of metabolite content and enhanced biological activity for use in future breeding programs as well as in distribution to farmers.

2. Materials and Methods

2.1. Chemicals and Reagents

All the chemicals and reagents that were used were of analytical grade (purity > 99.8%) and were applied as obtained. Water and methanol were purchased from Fisher Scientific (Pittsburgh, PA, USA), and sulfuric acid was obtained from DAEJUNG Chemicals (Siheung-si, Korea). The other chemicals and reagents, including catechin, gallic acid, L-ascorbic acid, anhydrous sodium carbonate (Na_2CO_3), vanillin, Folin–Ciocalteu phenol reagent, potassium ferricyanide, trichloroacetic acid, ferric chloride, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid and 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical were obtained from Sigma-Aldrich (St. Louis, MO, USA).

2.2. Sorghum Materials, Cultivation and Preparation

The seeds of the 136 sorghum landraces were obtained from the gene bank at the National Agrobiodiversity Center (Jeonju, Republic of Korea). The seeds were sown on 17 June 2021, in an experimental field found at the center (latitude/longitude: 30°49′38.37″ N/127°09′7.78″ E). In brief, for each accession, ten seeds were sown in 100 × 180 cm row plots (90 cm apart) on clay loam soil with a 20 cm seed-to-seed spacing. N-P-K fertilizer was applied in a 9:7:8 (kg/10a) ratio, and the growing conditions were uniformly maintained for all landraces. Two popular Korean sorghum cultivars (Nampungchal and Sodamchal) and one US sorghum cultivar

(Wheatland) were also grown under similar conditions and used as controls. The growing season lasted until October of the same year. The average temperature and accumulated precipitation in June, July, August, September and October were 23.0 and 145.3; 27.2 and 255.1; 25.9 and 454.8; 22.9 and 162.1; and 16.4 °C and 37.0 mm, respectively, during the cultivation year. The average humidity was 71.6% in June, 74.3% in July, 78.0% in August, 74.4% in September and 70.4% in October. The agronomical features of the sorghum were inspected and recorded during the growth period. Matured seeds were hand-harvested and classified according to their collection area (Chungcheongbuk-do, Chungcheongnam-do, Gangwon-do, Gyeonggi-do, Gyeongsanbuk-do, Gyeongsangnam-do, Incheon, Jeollabuk-do and Jeollanam-do) and seed coat color (brown, orange, red, yellow, white and mixed) to view the influence of each on metabolite contents and antioxidant activities. The seeds were classified based on their thousand seed weights as large (>30 g), medium (25–30 g) and small (<25 g). Seed samples from each sorghum genotype were dried at 40 °C for 7 days in a post-harvest crop dryer (TJHP-1003, Jungang Jeongmil, Korea), powdered using a grinder (2010 Geno Grinder, SPEX, Metuchen, NJ, USA) and stored at −20 °C in sealed plastic bags pending extraction.

2.3. Extraction of Seed Samples

Seed samples were extracted in triplicate for each genotype following a previously described protocol with some changes [29]. Initially, 1 g of powdered seed sample was placed in a 45 mL extraction tube, and 5 mL of 80% aqueous methanol was added. The solution was then vortexed followed by sonication in a 25 °C water bath. After 45 min, the mixture was removed, cooled and centrifuged (3134× *g*) for 15 min before being filtered through a 0.45 µm syringe membrane filter, and the supernatant was retained. For the residue, the extraction procedure was repeated once more. In preparation for analysis, the combined supernatant was stored at a low temperature (−20 °C) and was used for the determination of total tannin content, total phenolic content and antioxidant activities within 72 h after the extraction. During each assay, measurements were conducted in triplicate for every sample, and the absorbance was measured using an Eon Microplate Spectrophotometer (Bio-Tek, Winooski, VT, USA).

2.4. Determination of Total Tannin Content (TTC)

The total tannin content was determined using the method proposed by Price et al. [30] with some modifications. Briefly, a vanillin–HCl reagent was prepared by mixing equal volumes of methanol solutions of 8% HCl and 1% vanillin. Then, 100 µL of sample extract and 200 µL of vanillin–HCl reagent were mixed in a 96-well plate followed by incubation for 20 min at room temperature in the dark. Then, absorbance was measured at 500 nm against methanol as a blank. Catechin was used as a standard to plot a calibration curve ($y = 0.0313x + 0.0167$, $R^2 = 0.9987$), and the TTC is reported as milligrams of catechin equivalent per gram of dried seed weight (mg CE/g).

2.5. Determination of Total Phenolic Content (TPC)

The total phenolic content was determined spectrophotometrically using the Folin–Ciocalteu method [31]. In brief, 100 µL of seed extract was mixed in the dark with an equal volume of Folin–Ciocalteu reagent. After 3 min of incubation at 25 °C, the mixture was treated with 100 µL of 2% Na_2CO_3 solution. After 30 min of reaction in the dark, the absorbance was measured at 750 nm. Methanol was used as a blank, and the TPC is expressed as milligrams of gallic acid equivalent per gram of dried seed weight (mg GAE/g) using gallic acid as a standard ($y = 9.5155x - 0.1955$, $R^2 = 0.9999$).

2.6. Determination of Antioxidant Activities

The antioxidant activities of sorghum seed extracts were estimated using three in vitro assays that followed our recently published protocols [31], with some modifications, as detailed below. During each assay, a methanol solution was used as a control.

2.6.1. 1,1-Diphenyl-2-Picrylhydrazyl (DPPH) Radical Scavenging Activity

Initially, 100 μL of the sorghum seed extract was mixed with an equal volume of freshly prepared DPPH solution (150 μM). The mixture was then incubated for 30 min in the dark at 25 °C, and the absorbance was measured at 517 nm. Ascorbic acid was used as a standard (y = 4686.5x − 2.9918, R^2 = 0.9989), and the DPPH radical scavenging activity is expressed in milligrams of ascorbic acid equivalent antioxidant capacity per gram of dried seed weight (mg AAE/g).

2.6.2. 2,2′-Azino-Bis(3-Ethylbenzothiazoline-6-Sulfonic Acid) Diammonium Radical Cation ($ABTS^{\bullet+}$) Scavenging Activity

Initially, a stock solution of $ABTS^{\bullet+}$ was prepared by dissolving ABTS (7 mM) in potassium persulfate ($K_2S_2O_8$, 2.45 mM). The mixture was incubated for 16 h at room temperature (~25°C) and was diluted with water until reaching an absorbance of 0.700 ± 0.02 at λ_{max} 734 nm. During the assay, 150 μL of $ABTS^{\bullet+}$ solution was mixed with 10 μL of the sorghum seed extract and was incubated at 25 °C in darkness. After 3 min, the absorbance was measured at 734 nm. Trolox was used as a standard (y = 371.93x − 1.3987, R^2 = 1.000), and the $ABTS^{\bullet+}$ scavenging activity was calculated as milligrams of Trolox equivalent antioxidant capacity per gram of dried seed weight (mg TE/g).

2.6.3. Ferric Reducing Antioxidant Power (FRAP) Assay

Initially, 60 μL of the sorghum seed extract was mixed with 150 μL of freshly prepared phosphate buffer (pH: 6.6, 0.2 M) and 150 μL of 1% potassium ferricyanide solution ($K_3Fe(CN)_6$) and incubated for 20 min at 50 °C. The mixture was then centrifuged at 13,000 rpm for 10 min with 150 μL of 10% trichloroacetic acid added. The supernatant (100 μL) was diluted with equal parts distilled water and 0.1% ferric chloride solution (20 μL). After 10 min of incubation, the absorbance at 700 nm was measured. Ascorbic acid was used as a standard (y = 4.318x + 0.0061, R^2 = 0.9999), and the FRAP activity results are reported in mg AAE/g.

2.7. Statistical Analysis

The results are expressed as the mean ± standard deviation (SD) of three measurements. An analysis of variance (ANOVA) was computed using xlstat-software (Addinsoft, New York, NY, USA), followed by Duncan's multiple range test to statistically determine significant differences between measurements at a level of $p < 0.05$. R-software (version 4.0.2, r-project) was used to generate box plots, correlation matrices and principal component analysis plots.

3. Results and Discussion

3.1. Agro-Morphological Characteristics

Agronomic traits are influenced by differences in genetic makeup, growing conditions, location, cultivation year and environmental factors, as described before, and hence are the primary sources of information to determine genetic diversity among plant genotypes [32,33]. For each sorghum genotype, four qualitative and seven quantitative agronomical features were documented from field examinations and laboratory inspections. Table S1 (Supplementary Materials) contains the qualitative agronomic data collected for each genotype along with their introduction (IT) number, and Figure 1 summarizes their relative frequencies. Endosperm type, panicle type, panicle density and seed color were among the qualitative characteristics documented, and the majority of them showed little variation among the sorghum genotypes. Except for four landraces (IT1000910, IT162843, IT270349 and IT329089) and one control cultivar (Wheatland, CA, USA), the remaining landraces (97%) had glutinous endosperm (Table S1, Figure 1a). Previous research has indicated that glutinous sorghum grains are ideal for winemaking and ethanol production due to their high amylopectin content [34,35]. Panicle-related characteristics such as panicle type and panicle density are strongly related to yield and are important traits to consider in breeding programs [36,37]. The sorghum genotypes in this study had either dense, loose or medium panicle density, with the former being the most common (88%) (Figure 1b). Among the control cultivars, Nampungchal had a dense panicle density, Wheatland had a loose panicle density and Sodamchal had a medium panicle density (Table S1). The majority of landraces (61%) had a compact panicle type, with the extremely spreading type (18%) coming in second (Figure 1c). The control cultivars, Nampungchal and Wheatland, also developed a compact panicle, whereas Sodamchal had a medium panicle type (Table S1). Sorghum genotypes with a compact and dense panicle are preferred because they are associated with a higher yield, and thus, many of the sorghum landraces could provide good breeding options [36,37].

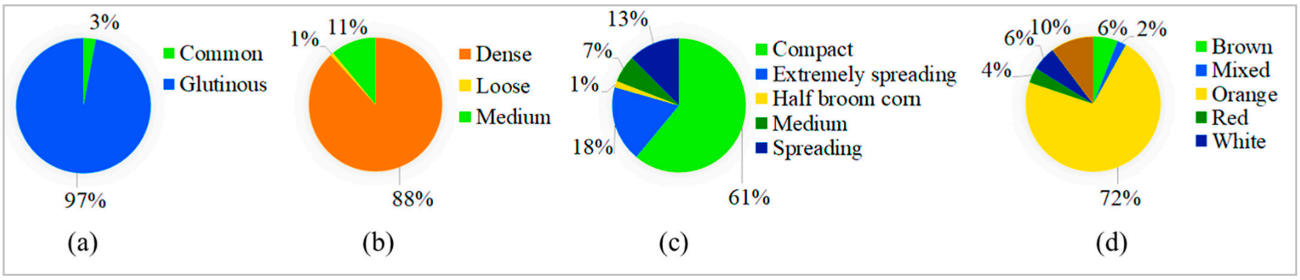

Figure 1. Frequency (%) of endosperm type (**a**), panicle density (**b**), panicle type (**c**) and seed color (**d**) in sorghum landraces.

Seed color was another trait that varied greatly, with a total of six different colors observed (Figures 1d and S1). The dominant seed color was orange, which was developed by 72% of the landraces and all of the control cultivars. Furthermore, 10% of the landraces had yellow seed colors, 6% had white seed colors and 6% had brown seed colors. The remaining 2% and 4% of landraces had red and mixed seed colors, respectively. In general, the observed color variation agreed with previous reports [5,38–40]. These previous studies have also shown that seed color variation affects the distribution of health-promoting metabolites and their pharmacological properties. Furthermore, it influences the preferences of consumers, farmers and breeders. As a result, the various seed colors observed in our study may provide a diverse range of options for various stakeholders.

Quantitative agronomical traits such as days to panicle (or heading) (DP), days to maturity (DM), stem height (SH), stem thickness (or diameter) (ST), panicle length, panicle width (PW) and thousand seeds weight (TSW) were also found to vary. The DH and DM were in the ranges of 40–74 and 77–113 days, respectively (Figure 2, Table 1). Wheatland was the fastest control cultivar to develop a panicle (in 47 days) and mature (in 88 days) among the controls, followed by Nampungchal and Sodamchal. One of the research goals in sorghum breeding is the development of early maturing genotypes [41]. In this study, 16 landraces were found to develop a panicle (in $\leq$46 days) and fully mature (in $\leq$83 days) earlier than all control cultivars, suggesting that they could be valuable resources during the development of early maturing sorghum cultivars. The variations in stem height and thickness ranged from 55.33 to 297.67 cm and 12.72 to 25.76 mm, respectively, with a five and two-fold difference ($p < 0.05$) (Table S2). Only 1 landrace (IT331878) had a significantly shorter stem length (55.33 cm) than the three control cultivars in this study. Compared with the three control cultivars, only 2 landraces (IT331936 and IT322549) had significantly higher stem thickness (>24.52 mm) (Table 1). Previous research found that plant height is related to the vegetative nature as well as the maturity period of sorghum [42]. As a result, genotypes with thick and tall stems are highly preferred for seed quality and yield, and accessions such as IT221619, IT235856, IT340260, IT340261 and IT208566 (with SH > 200 cm and ST > 20 mm) could be ideal candidates [42,43]. The PL and PW are also important quantitative traits because they are related to yield [36,37]. Significant differences in PL and PW were observed among the sorghum landraces in this study $p < 0.05$). PL and PW were in the 16–51.33 cm and 35.50–160.43 mm ranges, respectively, with means of 25.69 cm and

78.45 mm. Nampungchal, Wheatland and Sodamchal were the control cultivars, with PLs of 22.33, 21.33 and 27.00 cm and panicle widths of 88.16, 47.95 and 81.13 mm, respectively. As a result, 17.64% of the landraces had lower PL but higher PW than the three control cultivars. TSW was another quantitative trait with significant variation ($p < 0.05$). It ranged from 21.90 to 38.20 g, with a mean of 28.62 g. TSW was comparable in Nampungchal (30.63 g) and Sodamchal (30.53 g) but significantly higher in Wheatland (37.93 g) ($p < 0.05$). Only 1 landrace (IT113294) had a significantly higher TSW (38.20 g) than all three control cultivars. In contrast, 26 landraces had significantly higher TSW than Nampungchal and Sodamchal cultivars ($p < 0.05$) (Table 1). Seed weight is an important agronomic trait used to determine sorghum grain size. It is also closely related to sorghum seed yield, grain quality, metabolite content and pharmacological properties and thus influences consumer, farmer and breeder preferences [44,45]. As a result, the observed TSW variations among the sorghum landraces could provide a wealth of options in these regards. In general, this study reveals the wide-ranging variations in agro-morphological characteristics of the sorghum landraces. Landraces with distinct characteristics and superior performances to the control cultivars may be suitable candidates for the sorghum breeding program.

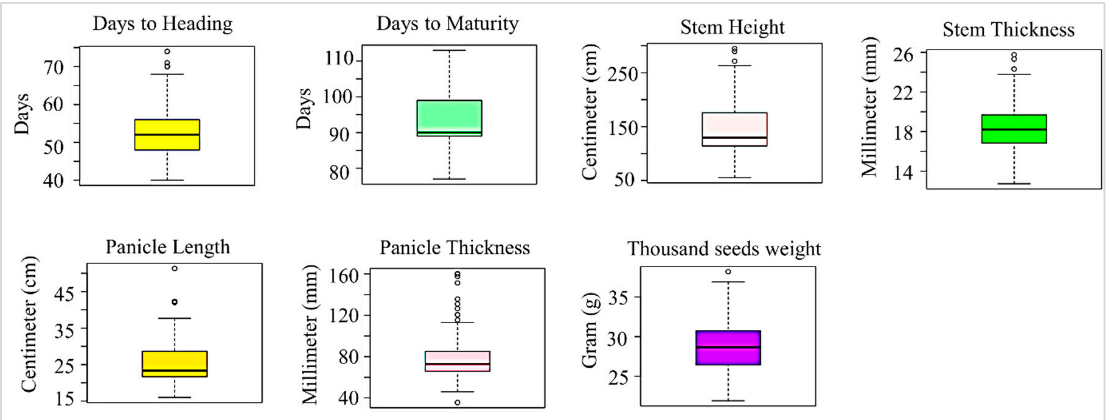

Figure 2. Boxplots showing variations in quantitative agronomical traits in sorghum landraces.

3.2. Biochemical Contents and Antioxidant Activities

The levels of phenolic and tannin contents, as well as antioxidant activities, are some of the determinant factors of sorghum seed quality on account of their health-promoting and disease-protecting properties [12]. Significant differences in metabolite contents and antioxidant activities were observed between the sorghum landraces (Tables 2 and S2). The TTC and TPC levels were 0.12–428.95 mg CE/g and 1.17–10.23 mg GAE/g, respectively ($p < 0.05$). In comparison with the control cultivars, 14.71 and 6.62% of the landraces contained higher levels of TTC and TPC, respectively, than Sodamchal (TTC: 241.15 mg CE/g, TPC: 5.74 mg GAE/g) and Nampungchal (TTC: 323.39 mg CE/g; 6.31 mg GAE/g) cultivars. Only seven landraces had a lower TTC than Wheatland (58.61 mg CE/g), and seven landraces had a lower TPC (1.82 mg GAE/g). Choi et al. [39] previously studied 11 local varieties in Korea and reported a TPC range of 1.56–11.99 mg GAE/g, which is comparable with our findings. Yoon et al. [46] reported a much lower TPC range (89.08–363.06 µg GAE/g) in Korean Sorghum accessions, whereas Ghimire et al. [47] found a much higher TPC range (18.98–171.50 mg GAE/g). In other research, Abdelhalim et al. [48] found a TPC and TTC in Sudanese landraces ranging from 9.5–76.8 mg AGE/g and 7.9–37.3 mg/g, respectively, and Rhodes et al. [38] discovered a TPC ranging from 0.00 to 37.46 mg GAE/g in sorghum genotypes that were collected from different countries. These findings indicate a wide range of TPC and TTC levels in sorghum genotypes, which could be attributed to differences in the number of genotypes investigated, cultivation conditions and extraction and analysis protocols [29,38]. Hence, the landraces that showed pronounced biochemical properties could be ideal candidates to produce cultivars with improved health benefits.

Table 1. Quantitative agronomic properties of sorghum genotypes cultivated in Korea.

IT-Number	DP (Days)	DM (Days)	SH (cm)	ST (mm)	PL (cm)	PW (mm)	TSW (g)
IT028365	50	90	120.33 ± 6.02 $^{ah-as}$	23.78 ± 0.98 $^{a-d}$	20.17 ± 2.02 $^{u-ab}$	70.59 ± 7.53 $^{q-aj}$	26.50 ± 0.36 $^{bb-be}$
IT100010	46	82	150.00 ± 5.72 $^{u-y}$	15.26 ± 0.73 $^{ah-as}$	25.67 ± 3.79 $^{j-s}$	86.90 ± 7.26 $^{j-t}$	29.83 ± 0.12 $^{z-ad}$
IT100018	46	82	169.33 ± 1.25 $^{r-s}$	15.22 ± 0.21 $^{ah-as}$	27.83 ± 2.25 $^{g-n}$	76.04 ± 3.25 $^{n-ag}$	31.47 ± 0.62 $^{o-p}$
IT100024	42	83	152.67 ± 5.44 $^{u-x}$	15.96 ± 0.41 $^{ad-ar}$	28.00 ± 1.00 $^{g-n}$	82.79 ± 11.65 $^{k-x}$	29.37 ± 0.34 $^{ad-ah}$
IT100045	46	82	95.33 ± 5.73 $^{ax-ba}$	22.04 ± 0.77 $^{c-h}$	31.33 ± 1.15 $^{d-h}$	62.70 ± 2.66 $^{y-al}$	24.20 ± 0.16 $^{br-bt}$
IT100046	46	83	115.67 ± 2.05 $^{aj-au}$	18.81 ± 0.57 $^{j-ae}$	29.83 ± 1.04 $^{e-j}$	64.30 ± 7.20 $^{v-al}$	25.00 ± 0.90 $^{bl-bo}$
IT100047	48	90	121.33 ± 3.40 $^{ah-as}$	21.75 ± 0.12 $^{c-j}$	23.33 ± 0.58 $^{o-y}$	74.20 ± 2.92 $^{n-ai}$	32.47 ± 0.17 $^{f-i}$
IT100073	46	83	182.33 ± 3.09 $^{m-r}$	17.77 ± 0.47 $^{p-al}$	31.33 ± 1.53 $^{d-h}$	73.83 ± 2.75 $^{o-ai}$	27.70 ± 0.45 $^{aq-av}$
IT100074	50	91	109.67 ± 3.86 $^{ap-ax}$	20.04 ± 0.98 $^{f-u}$	22.33 ± 1.15 $^{q-aa}$	72.61 ± 2.10 $^{o-ai}$	31.47 ± 0.12 $^{o-p}$
IT100090	46	83	177.33 ± 3.30 $^{o-r}$	16.82 ± 0.94 $^{x-ap}$	26.33 ± 0.58 $^{i-q}$	71.47 ± 2.39 $^{p-aj}$	24.37 ± 0.34 $^{bq-bs}$
IT100143	62	101	249.67 ± 4.50 $^{c-e}$	19.61 ± 0.02 $^{g-y}$	29.33 ± 2.89 $^{f-k}$	88.03 ± 5.48 $^{i-r}$	22.93 ± 0.05 ^{bu}
IT100177	46	83	159.33 ± 8.65 $^{s-u}$	16.37 ± 0.00 $^{z-aq}$	37.67 ± 2.08 ^{c}	81.57 ± 14.54 $^{k-aa}$	26.83 ± 0.05 $^{ay-bb}$
IT103099	40	78	109.67 ± 2.87 $^{ap-ax}$	12.72 ± 1.46 ^{as}	21.00 ± 1.73 $^{t-aa}$	45.94 ± 3.84 $^{al-am}$	27.10 ± 0.16 $^{aw-az}$
IT103452	48	85	177.00 ± 2.16 $^{o-r}$	15.78 ± 1.87 $^{ae-ar}$	23.33 ± 1.15 $^{o-y}$	90.73 ± 10.50 $^{i-p}$	29.17 ± 0.17 $^{ae-ai}$
IT103496	48	90	192.33 ± 8.18 $^{l-n}$	17.77 ± 0.96 $^{p-al}$	30.33 ± 0.58 $^{e-i}$	99.48 ± 5.34 $^{f-k}$	30.40 ± 0.29 $^{t-y}$
IT103970	42	83	193.67 ± 6.94 $^{l-m}$	14.55 ± 0.27 $^{am-as}$	24.67 ± 0.58 $^{l-u}$	68.15 ± 6.67 $^{s-aj}$	30.00 ± 0.22 $^{x-aa}$
IT104574	56	93	168.67 ± 8.96 $^{r-s}$	18.54 ± 0.88 $^{l-af}$	37.67 ± 4.51 ^{c}	120.50 ± 12.72 $^{b-e}$	28.17 ± 0.57 $^{an-ar}$
IT104594	46	82	100.33 ± 1.70 $^{au-ba}$	21.28 ± 0.45 $^{d-n}$	29.33 ± 1.53 $^{f-k}$	71.44 ± 3.57 $^{p-aj}$	27.00 ± 0.08 $^{ax-ba}$
IT104963	46	83	178.00 ± 2.83 $^{n-r}$	20.08 ± 0.09 $^{f-u}$	35.00 ± 3.00 $^{c-d}$	91.50 ± 8.57 $^{i-o}$	28.73 ± 0.26 $^{ai-al}$
IT113294	42	83	139.67 ± 3.86 $^{w-ae}$	16.25 ± 1.27 $^{ab-aq}$	21.00 ± 1.00 $^{t-aa}$	69.77 ± 10.44 $^{q-aj}$	38.20 ± 1.73 ^{a}
IT134976	48	90	141.67 ± 2.36 $^{w-ab}$	18.47 ± 0.32 $^{l-af}$	27.33 ± 1.53 $^{g-o}$	79.47 ± 3.46 $^{l-ac}$	30.83 ± 3.12 $^{q-t}$
IT158264	50	91	145.67 ± 4.19 $^{u-z}$	18.13 ± 0.53 $^{o-aj}$	23.00 ± 1.00 $^{o-z}$	73.04 ± 2.72 $^{o-ai}$	27.63 ± 5.12 $^{as-av}$
IT158265	52	91	122.33 ± 3.68 $^{ag-ar}$	17.77 ± 0.39 $^{p-al}$	24.00 ± 1.73 $^{m-w}$	55.02 ± 4.47 $^{ai-al}$	27.47 ± 5.50 $^{au-ax}$
IT162843	53	95	119.67 ± 10.66 $^{ah-as}$	19.68 ± 0.92 $^{g-y}$	23.33 ± 2.08 $^{o-y}$	73.43 ± 3.79 $^{o-ai}$	31.80 ± 6.22 $^{k-o}$
IT162877	53	90	78.67 ± 4.50 ^{bb}	18.46 ± 0.30 $^{l-af}$	21.67 ± 1.53 $^{m-w}$	58.08 ± 3.33 $^{af-al}$	29.07 ± 6.12 $^{af-aj}$
IT180549	50	82	242.67 ± 2.05 $^{d-f}$	15.31 ± 0.39 $^{ah-as}$	35.00 ± 5.29 $^{r-aa}$	85.32 ± 9.17 $^{j-u}$	24.10 ± 8.22 $^{bs-bt}$
IT180614	50	90	120.33 ± 2.05 $^{ah-as}$	16.73 ± 0.37 $^{x-ap}$	23.00 ± 3.61 $^{c-d}$	62.05 ± 2.42 $^{z-al}$	24.63 ± 8.05 $^{bo-br}$
IT185760	56	99	129.33 ± 0.94 $^{aa-al}$	16.43 ± 0.16 $^{z-aq}$	21.33 ± 1.53 $^{o-z}$	64.26 ± 1.64 $^{v-al}$	28.10 ± 8.16 $^{ao-as}$
IT185796	42	77	205.67 ± 7.36 $^{j-l}$	13.57 ± 0.19 $^{aq-as}$	35.00 ± 1.00 $^{c-d}$	75.01 ± 6.02 $^{n-ah}$	28.03 ± 8.17 $^{ao-as}$
IT185807	49	86	186.83 ± 3.97 $^{m-o}$	14.99 ± 0.61 $^{al-as}$	29.92 ± 1.28 $^{e-j}$	81.74 ± 1.72 $^{k-z}$	26.92 ± 8.10 $^{ay-bb}$
IT185812	50	83	206.33 ± 6.65 $^{j-l}$	13.53 ± 0.60 $^{aq-as}$	32.67 ± 2.08 $^{d-f}$	88.00 ± 21.34 $^{i-r}$	22.37 ± 8.09 ^{bv}
IT185813	42	82	202.67 ± 2.49 $^{j-l}$	15.38 ± 0.73 $^{ag-as}$	29.00 ± 1.00 $^{f-l}$	75.10 ± 7.43 $^{n-ah}$	24.07 ± 8.12 $^{bs-bt}$
IT185816	42	77	194.33 ± 2.05 $^{l-m}$	13.16 ± 0.91 $^{ar-as}$	31.33 ± 1.53 $^{d-h}$	74.82 ± 5.13 $^{n-ah}$	26.53 ± 8.12 $^{ba-bd}$
IT195442	62	99	144.67 ± 5.73 $^{u-aa}$	20.15 ± 0.36 $^{f-t}$	22.67 ± 2.08 $^{p-z}$	80.21 ± 6.46 $^{l-ab}$	30.83 ± 9.12 $^{q-t}$

Table 1. *Cont.*

IT-Number	DP (Days)	DM (Days)	SH (cm)	ST (mm)	PL (cm)	PW (mm)	TSW (g)
IT208560	47	84	174.67 ± 4.11 o-r	14.08 ± 0.76 ao-as	31.67 ± 2.08 d-g	87.80 ± 7.99 i-s	29.43 ± 0.25 ab-ag
IT208562	62	101	289.67 ± 6.85 a	18.90 ± 0.65 j-ad	51.33 ± 3.06 a	99.63 ± 11.69 f-k	25.33 ± 0.05 bj-bm
IT208566	56	95	256.33 ± 17.21 c-d	20.69 ± 0.16 e-p	37.67 ± 5.13 c	83.56 ± 4.10 k-v	27.27 ± 0.12 av-ay
IT208567	50	91	112.67 ± 3.68 am-av	17.51 ± 0.18 q-an	22.67 ± 1.15 p-z	63.62 ± 4.64 w-al	36.90 ± 0.08 b
IT208568	50	84	171.67 ± 0.47 p-s	17.09 ± 0.29 t-an	31.67 ± 0.58 d-g	74.42 ± 9.67 n-ai	29.07 ± 0.31 af-aj
IT208901	53	91	213.00 ± 14.31 i-j	17.81 ± 0.62 p-al	35.50 ± 2.60 c-d	86.64 ± 7.19 j-t	25.20 ± 0.08 bk-bn
IT221619	62	104	294.67 ± 10.50 a	23.34 ± 0.03 a-e	31.67 ± 1.53 d-g	95.76 ± 5.89 g-m	27.67 ± 2.17 ar-av
IT230297	56	97	138.33 ± 6.24 x-af	18.90 ± 0.76 j-ad	23.00 ± 2.00 o-z	73.58 ± 5.21 o-ai	32.23 ± 3.12 h-k
IT235850	50	90	139.33 ± 10.21 w-ae	19.95 ± 0.74 f-v	26.33 ± 2.52 i-q	77.14 ± 4.11 m-ag	26.50 ± 3.33 bb-be
IT235856	62	101	250.00 ± 21.21 c-e	22.76 ± 0.34 b-f	37.33 ± 4.93 c	102.99 ± 11.63 e-j	30.87 ± 3.12 q-t
IT251882	62	101	185.00 ± 2.45 m-q	20.05 ± 0.90 f-u	23.00 ± 1.00 o-z	106.43 ± 7.40 e-i	33.97 ± 5.17 d
IT262553	53	95	167.67 ± 2.05 r-t	17.60 ± 0.43 q-al	21.67 ± 2.08 r-aa	71.05 ± 4.01 q-aj	31.90 ± 6.08 j-o
IT262554	50	90	131.67 ± 9.03 z-aj	22.03 ± 0.61 c-h	20.67 ± 1.15 t-aa	74.15 ± 4.58 n-ai	29.30 ± 6.08 ae-ah
IT262557	62	104	157.33 ± 3.30 s-v	20.19 ± 0.85 f-s	23.67 ± 1.53 n-x	71.51 ± 6.23 p-aj	32.00 ± 6.08 i-n
IT262566	53	93	129.33 ± 7.36 aa-al	13.62 ± 0.66 aq-as	24.67 ± 4.04 l-u	70.35 ± 5.94 q-aj	26.10 ± 6.16 bd-bg
IT262570	50	93	154.67 ± 1.89 t-w	16.81 ± 0.18 x-ap	20.00 ± 1.00 v-ab	63.58 ± 4.43 w-al	23.87 ± 6.09 bt
IT262576	48	90	125.67 ± 1.70 ac-ap	17.89 ± 0.52 p-al	20.67 ± 2.52 t-aa	61.23 ± 5.98 ab-al	25.57 ± 6.25 bh-bk
IT264998	53	91	150.67 ± 0.47 u-x	20.23 ± 0.81 f-s	25.67 ± 1.53 j-s	74.81 ± 2.89 n-ah	25.67 ± 6.12 bg-bk
IT270343	50	90	121.33 ± 1.89 ah-as	18.54 ± 0.94 l-af	22.67 ± 1.53 p-z	57.32 ± 2.35 ag-al	25.00 ± 7.08 bl-bo
IT270346	48	85	126.67 ± 4.03 ab-an	20.58 ± 0.28 e-q	22.00 ± 1.00 q-aa	74.93 ± 4.92 n-ah	25.43 ± 7.12 bj-bl
IT270349	56	91	115.33 ± 4.50 ak-au	18.93 ± 0.18 j-ad	22.67 ± 1.15 p-z	58.59 ± 5.66 ae-al	24.90 ± 7.08 bm-bp
IT270366	70	109	93.33 ± 2.49 ay-ba	22.60 ± 0.71 b-g	28.00 ± 1.00 g-n	76.32 ± 7.73 n-ag	25.00 ± 7.08 bl-bo
IT278444	50	93	109.67 ± 5.31 ap-ax	19.18 ± 0.46 h-ac	22.67 ± 0.58 p-z	69.80 ± 5.59 q-aj	28.07 ± 7.12 ao-as
IT278445	53	93	114.00 ± 3.27 ak-av	16.73 ± 0.49 x-ap	23.00 ± 2.00 o-z	77.97 ± 3.62 m-ae	29.60 ± 7.08 aa-ae
IT286399	52	90	113.00 ± 2.94 am-av	16.40 ± 0.36 z-aq	21.67 ± 1.15 r-aa	65.56 ± 1.05 u-ak	23.07 ± 8.12 bu
IT286403	52	90	127.67 ± 3.09 ab-am	17.39 ± 0.77 r-an	18.67 ± 2.31 z-ab	52.26 ± 4.79 aj-al	32.10 ± 8.14 h-m
IT286412	53	91	140.67 ± 0.94 w-ae	17.19 ± 0.75 s-an	18.00 ± 1.00 aa-ab	69.33 ± 6.31 q-aj	30.43 ± 8.12 t-x
IT286423	50	90	108.33 ± 4.99 aq-ay	18.55 ± 0.10 l-af	20.67 ± 2.08 t-aa	67.63 ± 3.82 t-aj	28.07 ± 8.12 ao-as
IT286424	52	90	105.33 ± 8.34 as-ba	17.93 ± 0.90 p-al	20.67 ± 1.15 t-aa	75.08 ± 8.85 n-ah	25.00 ± 8.08 bl-bo
IT286446	53	91	132.67 ± 7.04 z-ai	21.98 ± 0.55 c-i	23.00 ± 1.00 o-z	80.22 ± 1.33 l-ab	29.43 ± 8.05 ac-ag
IT286448	70	109	212.33 ± 6.13 i-j	17.75 ± 0.31 p-al	42.33 ± 2.52 b	151.42 ± 6.65 a	28.78 ± 8.12 ai-al
IT297192	62	101	130.00 ± 8.16 a-ak	13.92 ± 0.20 ap-as	21.33 ± 1.53 s-aa	78.55 ± 4.73 m-ad	29.63 ± 9.52 aa-ae
IT300032	53	91	125.33 ± 3.40 ad-ap	17.77 ± 0.44 p-al	20.00 ± 0.00 v-ab	59.10 ± 1.93 ad-al	29.90 ± 0.08 z-ac
IT300088	56	93	122.33 ± 2.05 ag-ar	17.77 ± 0.11 p-al	21.33 ± 2.31 s-aa	57.81 ± 3.67 ag-al	28.90 ± 0.16 ah-ak

Table 1. *Cont.*

IT-Number	DP (Days)	DM (Days)	SH (cm)	ST (mm)	PL (cm)	PW (mm)	TSW (g)
IT320893	56	95	110.00 ± 6.38 ao-ax	15.04 ± 1.27 ak-as	19.67 ± 3.21 w-ab	63.11 ± 8.82 x-al	27.93 ± 2.12 ap-au
IT320897	53	90	107.67 ± 5.56 aq-az	14.54 ± 0.42 an-as	18.00 ± 2.00 aa-ab	64.50 ± 4.18 v-al	30.90 ± 2.08 q-t
IT320898	70	106	224.67 ± 10.87 h-i	14.90 ± 1.41 al-as	34.00 ± 3.61 c-e	126.51 ± 16.19 b-d	35.30 ± 2.16 c
IT322510	56	100	141.00 ± 8.60 w-ad	17.56 ± 0.54 q-an	21.33 ± 1.53 s-aa	66.36 ± 1.75 u-ak	30.20 ± 2.22 u-z
IT322513	50	90	117.00 ± 2.94 ai-at	16.35 ± 0.15 aa-aq	25.00 ± 1.00 k-t	68.18 ± 1.23 s-aj	26.67 ± 2.12 az-bc
IT322530	48	88	120.00 ± 4.55 ah-as	19.80 ± 0.78 f-x	24.33 ± 1.15 m-v	66.23 ± 6.20 u-ak	30.97 ± 2.17 q-s
IT322531	48	90	126.00 ± 4.08 ab-ao	21.46 ± 0.87 d-l	22.67 ± 1.53 p-z	67.96 ± 7.41 t-aj	33.90 ± 2.16 d
IT322533	50	88	113.33 ± 5.25 al-av	19.32 ± 0.35 h-ab	23.33 ± 1.53 o-y	66.60 ± 4.08 u-ak	27.13 ± 2.12 aw-az
IT322546	50	90	123.00 ± 4.90 af-aq	17.53 ± 0.11 q-an	20.33 ± 1.53 u-aa	61.91 ± 7.01 aa-al	27.30 ± 2.16 av-ay
IT322549	70	106	92.67 ± 1.89 az-ba	25.76 ± 0.35 a	26.00 ± 2.78 i-r	113.10 ± 2.54 d-g	25.70 ± 2.16 bg-bj
IT322554	52	91	108.00 ± 5.89 aq-ay	15.33 ± 0.88 ag-as	20.33 ± 0.58 u-aa	59.89 ± 5.65 ac-al	30.90 ± 2.08 q-t
IT322555	62	105	121.33 ± 0.94 ah-as	17.10 ± 0.90 t-an	23.33 ± 0.58 o-y	86.51 ± 12.07 j-t	32.13 ± 2.17 h-l
IT322558	68	109	129.33 ± 6.13 aa-al	17.58 ± 0.20 q-am	20.67 ± 1.15 t-aa	83.32 ± 3.96 k-w	29.13 ± 2.17 ae-aj
IT322570	62	105	106.67 ± 4.64 ar-ba	15.17 ± 0.25 aj-as	20.67 ± 1.15 t-aa	58.18 ± 4.85 ae-al	31.67 ± 2.17 l-o
IT322571	63	105	109.67 ± 3.30 ap-ax	17.34 ± 0.79 r-an	21.67 ± 1.53 r-aa	67.98 ± 7.64 t-aj	30.57 ± 2.17 r-v
IT322572	52	90	110.67 ± 3.30 an-ax	19.12 ± 0.20 h-ac	22.67 ± 2.31 p-z	62.53 ± 2.20 y-al	24.83 ± 2.12 bn-bq
IT322578	52	90	111.67 ± 3.40 am-aw	19.10 ± 0.77 h-ac	23.00 ± 1.73 o-z	57.60 ± 3.66 ag-al	29.53 ± 2.05 aa-af
IT322580	57	101	149.67 ± 2.87 u-y	20.72 ± 0.64 e-p	22.00 ± 1.00 q-aa	71.31 ± 10.06 p-aj	31.03 ± 2.12 p-r
IT322613	74	113	96.33 ± 2.05 aw-ba	20.38 ± 0.93 f-r	28.33 ± 1.53 g-m	72.75 ± 5.08 o-ai	26.03 ± 2.17 be-bh
IT322621	56	99	145.67 ± 4.19 u-z	19.93 ± 0.67 f-w	25.00 ± 1.73 k-t	71.97 ± 1.29 o-aj	26.03 ± 2.17 be-bh
IT322622	52	99	127.67 ± 3.40 ab-am	21.29 ± 0.68 d-n	23.33 ± 0.58 o-y	76.57 ± 4.43 m-ag	28.20 ± 2.22 an-aq
IT329008	50	90	116.67 ± 0.47 ai-at	19.37 ± 0.23 h-aa	22.00 ± 1.73 q-aa	67.70 ± 2.78 t-aj	28.70 ± 2.08 ai-am
IT329026	48	90	120.67 ± 2.87 ah-as	18.53 ± 0.11 l-af	23.33 ± 0.58 o-y	69.60 ± 2.58 q-aj	28.53 ± 2.12 ak-ao
IT329047	63	105	243.00 ± 1.63 d-f	18.94 ± 0.23 j-ad	26.33 ± 4.16 i-q	110.10 ± 6.12 d-h	29.43 ± 2.12 ac-ag
IT329048	62	106	170.67 ± 9.88 q-s	15.20 ± 0.85 ai-as	42.00 ± 1.00 b	135.68 ± 11.22 b	28.10 ± 2.16 ao-as
IT329049	57	100	256.67 ± 15.46 c-d	16.87 ± 0.51 v-ap	37.33 ± 5.13 c	159.93 ± 24.19 a	26.30 ± 2.29 bc-bf
IT329050	53	91	233.33 ± 17.00 f-h	17.76 ± 0.85 p-al	33.67 ± 1.53 c-e	130.97 ± 13.41 b-c	29.60 ± 2.08 a-ae
IT329053	47	88	141.33 ± 4.92 w-ac	18.65 ± 0.25 l-ae	24.67 ± 2.52 l-u	58.85 ± 3.17 ad-al	32.30 ± 2.16 g-j
IT329056	56	98	135.00 ± 6.16 y-ah	18.62 ± 0.19 l-ae	22.33 ± 1.53 q-aa	82.50 ± 6.57 k-x	34.10 ± 2.16 d
IT329063	52	90	110.33 ± 2.49 ao-ax	18.08 ± 0.50 o-ak	20.00 ± 0.00 v-ab	57.76 ± 3.83 ag-al	28.13 ± 2.17 ao-as
IT329064	52	90	114.67 ± 1.70 ak-av	18.27 ± 0.46 m-ah	19.67 ± 0.58 w-ab	59.06 ± 6.24 ad-al	28.63 ± 2.12 aj-an
IT329074	56	93	114.00 ± 7.87 ak-av	17.79 ± 0.96 p-al	24.00 ± 2.65 m-w	77.81 ± 7.09 m-af	28.23 ± 2.12 am-ap
IT329076	47	88	126.67 ± 2.36 ab-an	18.24 ± 0.29 n-ai	23.33 ± 2.52 o-y	71.70 ± 3.14 p-aj	22.03 ± 2.12 bv-bw

Table 1. *Cont.*

IT-Number	DP (Days)	DM (Days)	SH (cm)	ST (mm)	PL (cm)	PW (mm)	TSW (g)
IT329077	63	105	174.33 ± 12.50 [o-r]	24.32 ± 0.73 [a-c]	24.00 ± 2.65 [m-w]	73.69 ± 7.32 [o-ai]	30.50 ± 2.16 [s-w]
IT329078	50	90	130.00 ± 3.27 [aa-ak]	18.38 ± 0.90 [m-ag]	24.00 ± 2.65 [m-w]	75.83 ± 6.20 [n-ag]	25.50 ± 2.16 [bi-bk]
IT329082	53	90	125.00 ± 3.56 [ae-ap]	18.84 ± 0.91 [j-ae]	26.00 ± 1.00 [i-r]	68.06 ± 3.69 [t-aj]	27.70 ± 2.16 [aq-av]
IT329085	70	107	203.33 ± 4.71 [j-l]	18.75 ± 1.32 [j-ae]	30.00 ± 2.00 [e-j]	93.49 ± 15.44 [h-n]	27.47 ± 2.12 [au-ax]
IT329089	48	90	95.67 ± 6.65 [ax-ba]	21.32 ± 0.48 [d-m]	28.00 ± 1.00 [g-n]	55.74 ± 11.74 [ah-al]	21.90 ± 2.08 [bw]
IT329090	47	88	112.00 ± 1.63 [am-av]	16.62 ± 0.59 [y-ap]	20.67 ± 1.15 [t-aa]	57.75 ± 3.78 [ag-al]	24.47 ± 2.17 [bp-bs]
IT329108	56	98	240.67 ± 8.99 [e-g]	18.18 ± 0.32 [o-aj]	37.33 ± 5.51 [c]	157.67 ± 8.11 [a]	27.50 ± 2.08 [at-aw]
IT329120	56	98	112.33 ± 5.25 [am-av]	17.66 ± 0.82 [p-al]	22.00 ± 1.00 [q-aa]	65.71 ± 4.62 [u-ak]	32.57 ± 2.09 [f-h]
IT329124	53	90	103.00 ± 3.56 [at-ba]	18.54 ± 0.71 [l-af]	21.67 ± 2.08 [r-aa]	63.87 ± 4.87 [v-al]	32.73 ± 2.21 [f-g]
IT331874	52	90	120.00 ± 4.24 [ah-as]	18.54 ± 0.56 [l-af]	23.00 ± 1.00 [o-z]	66.09 ± 3.00 [u-ak]	27.97 ± 3.12 [ap-at]
IT331878	56	95	55.33 ± 4.11 [bc]	17.36 ± 0.64 [r-an]	16.00 ± 2.00 [a-b]	35.50 ± 3.60 [am]	27.07 ± 3.17 [aw-az]
IT331882	47	88	127.00 ± 8.04 [ab-am]	16.85 ± 0.48 [w-ap]	22.33 ± 2.08 [q-aa]	68.96 ± 7.34 [q-aj]	32.87 ± 3.54 [e-f]
IT331889	50	90	113.67 ± 3.30 [al-av]	17.28 ± 0.62 [s-an]	19.00 ± 2.65 [y-zb]	58.52 ± 3.06 [ae-al]	29.93 ± 3.05 [y-zb]
IT331894	47	88	108.33 ± 2.87 [aq-ay]	17.73 ± 0.90 [p-al]	19.33 ± 0.58 [x-ab]	58.10 ± 3.56 [ae-al]	28.33 ± 3.31 [al-ap]
IT331896	48	90	125.33 ± 4.64 [ad-ap]	17.03 ± 0.86 [u-ao]	21.67 ± 1.53 [r-aa]	67.22 ± 8.47 [t-ak]	26.00 ± 3.08 [bf-bh]
IT331899	48	88	127.00 ± 2.45 [ab-am]	19.04 ± 0.35 [h-ac]	22.67 ± 0.58 [p-z]	67.80 ± 7.06 [t-aj]	24.47 ± 3.05 [bp-bs]
IT331904	57	100	137.67 ± 9.84 [x-ag]	21.46 ± 0.87 [d-l]	27.33 ± 2.08 [g-o]	84.99 ± 7.80 [j-u]	26.30 ± 3.08 [bc-bf]
IT331907	62	100	243.67 ± 10.66 [d-f]	19.71 ± 0.48 [g-x]	26.00 ± 3.61 [i-r]	103.28 ± 16.24 [e-j]	33.30 ± 3.16 [e]
IT331921	62	105	143.33 ± 1.25 [v-aa]	21.69 ± 0.98 [c-k]	22.33 ± 3.21 [q-aa]	67.46 ± 6.86 [t-aj]	34.03 ± 3.12 [d]
IT331922	62	104	102.00 ± 2.83 [at-ba]	23.43 ± 0.11 [a-e]	24.67 ± 3.51 [l-u]	82.13 ± 12.36 [k-y]	30.13 ± 3.12 [v-z]
IT331936	70	109	99.33 ± 0.94 [av-ba]	25.32 ± 0.68 [ab]	27.00 ± 1.00 [h-p]	99.56 ± 9.56 [f-k]	25.93 ± 3.05 [bf-bi]
IT331937	47	90	114.00 ± 2.16 [ak-va]	17.53 ± 0.08 [q-an]	22.00 ± 2.65 [q-aa]	65.64 ± 4.55 [u-ak]	32.87 ± 3.12 [e-f]
IT331938	57	99	137.33 ± 4.11 [x-ag]	18.99 ± 0.42 [i-ad]	21.67 ± 1.53 [r-aa]	88.22 ± 5.34 [i-q]	30.00 ± 3.08 [x-aa]
IT331962	47	90	122.67 ± 3.30 [af-ar]	18.17 ± 0.02 [o-aj]	20.00 ± 2.00 [q-aa]	63.06 ± 11.44 [x-al]	30.03 ± 3.09 [w-aa]
IT331963	47	90	120.67 ± 1.70 [ah-as]	15.27 ± 0.92 [ah-as]	21.67 ± 2.08 [r-aa]	68.49 ± 6.70 [r-aj]	28.93 ± 3.05 [ag-ak]
IT331978	47	84	186.33 ± 2.62 [m-p]	15.54 ± 0.55 [af-as]	30.33 ± 1.53 [e-i]	88.16 ± 3.94 [i-r]	31.63 ± 3.26 [m-o]
IT331988	62	101	174.00 ± 9.93 [o-r]	17.25 ± 0.16 [s-an]	34.00 ± 0.00 [c-e]	160.43 ± 25.98 [a]	31.13 ± 3.12 [p-q]
IT332014	62	104	263.33 ± 4.71 [b-c]	19.45 ± 0.10 [h-z]	30.00 ± 2.00 [e-j]	113.09 ± 11.40 [d-g]	30.67 ± 3.26 [q-u]
IT332024	56	95	196.67 ± 17.00 [k-m]	18.66 ± 0.66 [l-ae]	22.67 ± 2.31 [p-z]	73.75 ± 3.28 [o-ai]	29.80 ± 3.08 [z-ad]
IT332042	47	88	114.33 ± 4.03 [ak-av]	18.64 ± 0.25 [l-ae]	23.00 ± 1.73 [o-z]	71.07 ± 2.36 [q-aj]	29.00 ± 3.08 [ag-ak]
IT332046	56	98	184.67 ± 11.12 [m-q]	19.62 ± 0.97 [g-y]	27.00 ± 2.65 [h-p]	88.53 ± 8.46 [i-q]	31.67 ± 3.12 [l-o]
IT340260	74	109	271.33 ± 13.82 [b]	23.33 ± 0.04 [a-e]	26.00 ± 3.46 [i-r]	115.44 ± 12.22 [c-f]	27.97 ± 4.25 [ap-at]
IT340261	71	109	228.50 ± 6.36 [g-h]	21.13 ± 0.88 [d-o]	37.50 ± 3.12 [c]	120.62 ± 5.66 [b-e]	25.40 ± 4.07 [bj-bl]

Table 1. *Cont.*

IT-Number	DP (Days)	DM (Days)	SH (cm)	ST (mm)	PL (cm)	PW (mm)	TSW (g)
ITK276521	47	88	209.00 ± 7.87 [j-k]	16.13 ± 0.73 [ac-aq]	34.67 ± 2.08 [c-d]	98.08 ± 7.60 [f-l]	31.60 ± 2.08 [n-o]
IT231310	47	90	108.00 ± 6.53 [aq-ay]	18.72 ± 0.36 [k-ae]	22.33 ± 3.21 [q-aa]	69.63 ± 1.79 [q-aj]	28.90 ± 3.08 [ah-ak]
Nampungchal	56	98	132.00 ± 3.56 [z-ai]	18.53 ± 0.33 [l-af]	22.33 ± 2.08 [q-aa]	88.16 ± 5.45 [i-r]	30.63 ± 2.09 [r-u]
Wheatland	47	88	77.00 ± 0.82 [bb]	21.04 ± 0.54 [d-o]	21.33 ± 2.31 [s-aa]	47.95 ± 3.83 [ak-am]	37.93 ± 2.17 [a]
Sodamchal	62	104	91.67 ± 2.49 [ba]	24.52 ± 0.38 [a-c]	27.00 ± 1.00 [h-p]	81.13 ± 7.89 [k-aa]	30.53 ± 3.21 [r-v]
Total range	40–74	77–113	55.33–294.67	12.72–25.76	16.00–51.33	35.50–160.43	21.90–38.20
Total mean	53.48	93.10	147.83	18.40	25.65	78.31	28.71
CV (%)	13.62	8.41	32.49	13.76	22.65	27.67	10.80

Different superscript letters in a column indicate significantly different means ($p < 0.05$). DP: Days to panicle; DM: Days to maturity; ST: Stem thickness; SH; Stem height; PL: Panicle length; PW: Panicle width; TSW: Thousand seed weight.

Table 2. Total metabolite contents and antioxidant activities of sorghum genotypes.

IT-Number	TTC (mg CE/g)	TPC (mg GAE/g)	ABTS (mg TE/g)	DPPH (mg AAE/g)	FRAP (mg AAE/g)
IT028365	179.94 ± 5.09 $^{av-aw}$	7.65 ± 0.07 ^{n}	24.15 ± 1.19 $^{ap-av}$	13.93 ± 0.17 $^{aq-as}$	10.91 ± 0.11 $^{w-z}$
IT100010	140.75 ± 4.48 $^{bd-be}$	3.24 ± 0.01 ^{bk}	6.87 ± 0.40 $^{bl-bm}$	3.22 ± 0.05 $^{bi-bj}$	2.17 ± 0.03 $^{b-c}$
IT100018	120.16 ± 1.61 ^{bf}	3.01 ± 0.05 ^{bl}	4.92 ± 0.28 ^{bn}	2.44 ± 0.10 ^{bk}	1.76 ± 0.05 $^{b-c}$
IT100024	45.76 ± 0.00 ^{bn}	3.81 ± 0.04 ^{bi}	10.06 ± 0.73 ^{bj}	4.49 ± 0.05 ^{bg}	3.43 ± 0.01 $^{az-ba}$
IT100045	83.46 ± 0.35 $^{bi-bj}$	3.29 ± 0.07 ^{bk}	7.68 ± 0.26 ^{bl}	3.24 ± 0.09 $^{bi-bj}$	2.26 ± 0.09 $^{bb-bc}$
IT100046	47.00 ± 2.30 ^{bn}	3.72 ± 0.03 $^{bi-bj}$	10.07 ± 0.65 ^{bj}	4.01 ± 0.05 ^{bh}	3.25 ± 0.12 $^{az-ba}$
IT100047	180.93 ± 3.00 $^{av-aw}$	6.00 ± 0.01 $^{am-ap}$	20.97 ± 0.19 $^{ay-ba}$	9.76 ± 0.20 $^{ax-az}$	6.95 ± 0.20 $^{au-av}$
IT100073	80.73 ± 1.05 ^{bj}	5.10 ± 0.04 ^{ba}	17.51 ± 0.81 $^{bd-be}$	8.11 ± 0.32 ^{bb}	6.04 ± 0.12 ^{aw}
IT100074	140.50 ± 3.35 $^{b-e}$	6.05 ± 0.07 $^{al-an}$	20.75 ± 0.26 $^{ay-ba}$	10.29 ± 0.13 ^{az}	7.55 ± 0.12 $^{at-au}$
IT100090	91.64 ± 1.95 $^{bh-bi}$	5.86 ± 0.04 $^{ao-ar}$	20.58 ± 0.45 $^{az-ba}$	10.27 ± 0.20 ^{az}	7.14 ± 0.12 $^{au-av}$
IT100143	282.86 ± 1.95 $^{r-v}$	8.83 ± 0.11 $^{e-f}$	31.51 ± 1.08 $^{t-x}$	17.41 ± 0.26 $^{za-ac}$	13.07 ± 0.48 $^{m-o}$
IT100177	66.16 ± 1.15 $^{bl-bm}$	4.64 ± 0.02 ^{bd}	16.07 ± 0.40 $^{bf-bg}$	6.67 ± 0.09 $^{bd-be}$	4.96 ± 0.12 $^{ax-ay}$
IT103099	377.60 ± 3.79 ^{e}	2.44 ± 0.04 ^{bn}	8.03 ± 0.07 $^{bk-bl}$	3.08 ± 0.02 ^{bj}	2.27 ± 0.04 $^{bb-bc}$
IT103452	122.64 ± 4.05 ^{bf}	4.32 ± 0.06 ^{be}	18.44 ± 0.38 $^{bc-bd}$	7.92 ± 0.09 ^{bb}	5.97 ± 0.23 ^{aw}
IT103496	76.45 ± 2.13 $^{bj-bk}$	3.99 ± 0.06 ^{bh}	16.65 ± 0.15 $^{be-bf}$	7.99 ± 0.32 ^{bb}	5.48 ± 0.18 $^{aw-ax}$
IT103970	151.91 ± 4.05 $^{bb-bc}$	4.26 ± 0.07 $^{be-bf}$	17.30 ± 0.28 $^{bd-bf}$	3.66 ± 0.00 $^{bh-bi}$	6.01 ± 0.07 ^{aw}
IT104574	114.89 ± 3.28 $^{bf-bg}$	4.11 ± 0.09 $^{bf-bh}$	17.73 ± 0.57 $^{bc-be}$	6.24 ± 0.07 ^{be}	5.39 ± 0.19 $^{aw-ax}$
IT104594	46.94 ± 1.15 ^{bn}	2.70 ± 0.01 ^{bm}	9.25 ± 0.20 $^{bj-bk}$	15.88 ± 0.21 $^{ak-am}$	2.86 ± 0.03 $^{ba-bb}$
IT104963	61.32 ± 0.18 $^{bl-bm}$	3.60 ± 0.02 ^{bj}	14.86 ± 0.41 $^{bg-bh}$	9.86 ± 0.13 $^{ax-ay}$	5.43 ± 0.17 $^{aw-ax}$
IT113294	119.97 ± 0.93 ^{bf}	2.31 ± 0.03 $^{bn-bo}$	7.39 ± 0.36 $^{bl-bm}$	1.75 ± 0.00 ^{bl}	2.12 ± 0.01 ^{bc}
IT134976	344.81 ± 12.25 $^{g-i}$	5.92 ± 0.11 $^{an-aq}$	32.62 ± 0.14 $^{p-t}$	13.65 ± 0.10 $^{ar-as}$	13.71 ± 0.33 $^{k-m}$
IT158264	162.52 ± 2.27 $^{ay-ba}$	4.84 ± 0.01 $^{bb-bc}$	25.29 ± 0.38 $^{aj-ap}$	9.93 ± 0.12 $^{ax-ay}$	10.51 ± 0.59 $^{y-ab}$
IT158265	224.06 ± 0.90 $^{ai-am}$	4.89 ± 0.03 ^{bb}	26.67 ± 0.23 $^{ah-ak}$	10.03 ± 0.17 $^{ax-ay}$	10.77 ± 0.17 $^{x-aa}$
IT162843	398.27 ± 2.08 ^{c}	4.09 ± 0.05 $^{bf-bh}$	22.03 ± 0.03 $^{aw-ay}$	8.85 ± 0.14 ^{ba}	8.45 ± 0.15 $^{an-as}$
IT162877	26.24 ± 1.23 ^{bo}	1.57 ± 0.02 ^{br}	1.64 ± 0.01 ^{bo}	0.48 ± 0.01 ^{bn}	0.63 ± 0.02 ^{bd}
IT180549	197.05 ± 3.31 $^{ar-au}$	5.11 ± 0.02 ^{ba}	27.28 ± 0.14 $^{af-ai}$	11.11 ± 0.10 ^{aw}	11.40 ± 0.33 $^{t-x}$
IT180614	350.38 ± 2.73 ^{gh}	4.70 ± 0.01 $^{bc-bd}$	25.11 ± 0.46 $^{al-aq}$	9.33 ± 0.20 $^{az-ba}$	9.28 ± 0.10 $^{af-al}$
IT185760	217.93 ± 2.74 $^{al-am}$	5.63 ± 0.05 $^{as-av}$	31.07 ± 0.14 $^{u-y}$	12.68 ± 0.01 ^{at}	13.17 ± 0.12 $^{m-o}$
IT185796	69.09 ± 1.23 $^{bk-bl}$	2.86 ± 0.03 $^{bl-bm}$	13.23 ± 0.12 ^{bi}	3.91 ± 0.03 ^{bh}	4.67 ± 0.20 ^{ay}
IT185807	164.88 ± 1.20 $^{ax-az}$	3.62 ± 0.04 ^{bj}	18.23 ± 0.40 $^{b-d}$	7.27 ± 0.18 $^{b-c}$	8.01 ± 0.28 $^{aq-at}$
IT185812	186.88 ± 2.24 $^{au-av}$	4.73 ± 0.06 $^{bb-bd}$	24.62 ± 0.24 $^{an-at}$	9.52 ± 0.15 $^{ay-az}$	10.24 ± 0.16 $^{za-ad}$
IT185813	154.72 ± 0.59 $^{az-bc}$	4.08 ± 0.06 $^{bf-bh}$	20.24 ± 0.23 $^{ba-bb}$	7.81 ± 0.13 ^{bb}	8.54 ± 0.12 $^{an-ar}$
IT185816	132.16 ± 2.66 ^{be}	4.64 ± 0.03 ^{bd}	23.05 ± 0.42 $^{au-ax}$	9.58 ± 0.04 $^{ay-az}$	9.69 ± 0.05 $^{ac-ai}$
IT195442	209.30 ± 1.75 $^{an-ap}$	6.21 ± 0.07 $^{aj-al}$	33.17 ± 0.10 $^{o-r}$	14.53 ± 0.13 $^{ao-ap}$	14.39 ± 0.23 ^{ij}
IT208560	83.33 ± 1.01 $^{bi-bj}$	2.91 ± 0.05 ^{bl}	13.30 ± 0.66 ^{bi}	5.38 ± 0.23 ^{bf}	5.54 ± 0.11 $^{aw-ax}$
IT208562	195.93 ± 1.68 $^{as-au}$	6.45 ± 0.04 $^{ac-ah}$	34.42 ± 0.18 $^{m-o}$	15.43 ± 0.27 $^{am-an}$	17.02 ± 0.20 $^{d-f}$
IT208566	108.77 ± 6.85 ^{bg}	4.24 ± 0.21 $^{be-bf}$	19.97 ± 1.01 $^{ba-bb}$	8.26 ± 0.56 ^{bb}	8.79 ± 0.56 $^{ak-ap}$
IT208567	171.99 ± 6.12 $^{aw-ay}$	5.23 ± 0.05 $^{ay-ba}$	27.30 ± 0.37 $^{af-ai}$	11.04 ± 0.22 ^{aw}	11.37 ± 0.08 $^{t-x}$
IT208568	198.72 ± 1.04 $^{aq-at}$	3.98 ± 0.05 ^{bh}	19.02 ± 0.45 $^{bb-bc}$	6.99 ± 0.24 $^{bc-bd}$	7.84 ± 0.32 $^{as-at}$
IT208901	178.53 ± 2.13 $^{av-aw}$	4.04 ± 0.04 $^{bg-bh}$	20.33 ± 0.03 $^{ba-bb}$	7.25 ± 0.04 ^{bc}	7.84 ± 0.39 $^{as-at}$
IT221619	196.35 ± 1.68 $^{ar-au}$	6.67 ± 0.01 $^{x-aa}$	36.21 ± 0.44 $^{j-k}$	16.02 ± 0.22 $^{ai-al}$	17.30 ± 0.30 $^{c-f}$
IT230297	265.22 ± 3.43 ^{yz}	6.24 ± 0.03 $^{ai-ak}$	33.34 ± 0.08 $^{n-q}$	14.18 ± 0.01 $^{ap-aq}$	14.41 ± 0.29 $^{i-j}$
IT235850	241.58 ± 9.33 $^{ad-ag}$	7.76 ± 0.26 $^{m-n}$	37.16 ± 0.83 $^{i-j}$	17.23 ± 0.67 $^{aa-ad}$	12.00 ± 0.38 $^{r-t}$
IT235856	209.41 ± 4.10 $^{an-ap}$	7.46 ± 0.12 ^{o}	33.34 ± 0.64 $^{n-q}$	16.82 ± 0.34 $^{ad-ag}$	11.90 ± 0.40 $^{r-u}$
IT251882	264.96 ± 4.97 ^{yz}	9.00 ± 0.05 $^{c-d}$	43.88 ± 0.20 ^{b}	24.83 ± 0.86 ^{f}	15.20 ± 1.02 ^{h}
IT262553	149.72 ± 2.06 $^{bc-bd}$	5.55 ± 0.09 $^{au-av}$	24.90 ± 0.52 $^{al-ar}$	10.85 ± 0.22 ^{aw}	8.28 ± 0.22 $^{ap-as}$
IT262554	146.97 ± 2.37 $^{bc-bd}$	5.52 ± 0.04 $^{av-aw}$	25.55 ± 0.17 $^{aj-ap}$	10.94 ± 0.12 ^{aw}	7.86 ± 0.21 $^{as-at}$
IT262557	199.50 ± 1.17 $^{ap-at}$	7.33 ± 0.04 $^{o-q}$	35.54 ± 0.37 $^{k-m}$	16.59 ± 0.17 $^{ae-ah}$	11.43 ± 0.39 $^{t-x}$
IT262566	223.16 ± 5.06 $^{aj-am}$	6.01 ± 0.09 $^{am-ap}$	27.71 ± 0.21 $^{ae-ah}$	12.04 ± 0.13 ^{au}	8.56 ± 0.28 $^{am-ar}$
IT262570	282.29 ± 9.34 $^{s-v}$	6.47 ± 0.04 $^{ab-ah}$	32.31 ± 0.08 $^{p-u}$	13.65 ± 0.12 $^{ar-as}$	9.26 ± 0.13 $^{af-am}$
IT262576	194.55 ± 1.35 $^{at-au}$	5.21 ± 0.07 $^{ay-ba}$	24.41 ± 0.18 $^{ao-au}$	9.92 ± 0.06 $^{ax-ay}$	7.16 ± 0.32 $^{au-av}$
IT264998	261.94 ± 1.03 $^{yz-ab}$	7.18 ± 0.03 $^{q-s}$	35.39 ± 0.30 $^{k-m}$	15.88 ± 0.14 $^{ak-am}$	10.76 ± 0.28 $^{x-aa}$
IT270343	295.76 ± 2.37 $^{p-q}$	7.76 ± 0.06 $^{m-n}$	38.71 ± 0.32 $^{g-h}$	17.24 ± 0.00 $^{aa-ad}$	11.96 ± 0.09 $^{r-t}$

Table 2. *Cont.*

IT-Number	TTC (mg CE/g)	TPC (mg GAE/g)	ABTS (mg TE/g)	DPPH (mg AAE/g)	FRAP (mg AAE/g)
IT270346	288.34 ± 4.12 q-t	7.22 ± 0.03 q-r	35.97 ± 0.28 j-l	15.93 ± 0.02 aj-am	11.33 ± 0.31 t-x
IT270349	383.50 ± 5.09 d-e	10.23 ± 0.08 a	67.60 ± 1.06 a	31.99 ± 0.16 a	20.38 ± 0.31 b
IT270366	0.48 ± 0.00 bp	1.17 ± 0.01 bs	2.56 ± 0.14 bo	0.89 ± 0.02 bm-bn	0.89 ± 0.01 bd
IT278444	209.68 ± 3.83 an-ap	7.26 ± 0.07 p-r	38.23 ± 3.18 hi	15.92 ± 0.15 aj-am	11.19 ± 0.13 u-y
IT278445	277.06 ± 1.35 u-x	8.24 ± 0.04 j	39.87 ± 0.22 e-g	18.61 ± 0.13 x	13.54 ± 0.42 l-n
IT286399	350.22 ± 4.87 g-h	3.61 ± 0.02 bj	27.24 ± 0.53 ag-ai	11.37 ± 0.16 av-aw	7.93 ± 0.47 ar-at
IT286403	227.28 ± 4.49 ai-al	6.16 ± 0.08 ak-am	25.77 ± 0.90 aj-ao	12.58 ± 0.07 at	8.60 ± 0.39 ak-ar
IT286412	260.29 ± 2.72 za-ab	6.61 ± 0.07 y-ad	26.16 ± 0.54 ai-am	13.43 ± 0.17 as	10.29 ± 0.26 za-ac
IT286423	178.05 ± 5.39 av-aw	5.92 ± 0.13 an-aq	25.22 ± 2.36 ak-ap	12.18 ± 0.14 at-au	8.98 ± 0.03 ai-ap
IT286424	179.98 ± 6.65 av-aw	5.97 ± 0.07 an-ap	26.25 ± 0.32 ai-al	12.29 ± 0.02 at-au	8.82 ± 0.10 aj-ap
IT286446	253.96 ± 3.50 aa-ac	7.67 ± 0.03 n	34.65 ± 0.32 l-n	17.28 ± 0.18 aa-ad	12.27 ± 0.17 p-r
IT286448	267.16 ± 12.85 x-z	9.31 ± 0.12 b	41.50 ± 0.36 c-d	27.00 ± 0.81 c	16.80 ± 0.57 f-g
IT297192	231.28 ± 1.85 ag-aj	6.89 ± 0.04 u-w	32.24 ± 0.75 p-u	21.80 ± 0.22 mn	12.16 ± 0.34 q-s
IT300032	293.24 ± 2.52 p-r	6.29 ± 0.07 ah-ak	29.25 ± 0.65 za-ad	19.94 ± 0.31 tu	10.77 ± 0.13 x-aa
IT300088	220.08 ± 2.96 ak-am	5.07 ± 0.06 ba	21.77 ± 0.26 ax-az	14.61 ± 0.06 ao-ap	7.81 ± 0.10 as-at
IT320893	300.13 ± 5.94 o-p	5.45 ± 0.04 av-ax	23.41 ± 0.18 ar-aw	15.95 ± 0.29 aj-am	8.75 ± 0.16 ak-ap
IT320897	262.66 ± 10.61 y-aa	6.81 ± 0.04 v-x	30.89 ± 0.35 u-y	21.40 ± 0.06 no	12.27 ± 0.16 p-r
IT320898	161.00 ± 3.92 az-bb	5.47 ± 0.19 av-ax	22.10 ± 0.60 aw-ay	16.31 ± 0.49 ag-ak	9.31 ± 0.33 af-ak
IT322510	230.64 ± 2.39 ah-ak	6.60 ± 0.01 za-ad	28.40 ± 0.63 ac-ag	21.01 ± 0.23 o-q	11.78 ± 0.26 r-u
IT322513	281.40 ± 1.26 s-v	7.19 ± 0.04 q-r	35.51 ± 0.16 k-m	22.59 ± 0.06 kl	13.55 ± 0.19 l-m
IT322530	343.04 ± 2.18 h-i	5.45 ± 0.02 h-i	24.09 ± 0.73 ap-av	16.26 ± 0.22 ah-ak	9.00 ± 0.26 ai-ao
IT322531	300.29 ± 3.06 o-p	5.86 ± 0.05 ao-ar	26.07 ± 0.19 ai-an	17.70 ± 0.03 z-aa	9.82 ± 0.02 ab-ag
IT322533	243.45 ± 0.91 ac-af	5.58 ± 0.04 at-av	23.16 ± 0.12 at-ax	16.25 ± 0.04 ah-ak	9.95 ± 0.09 ab-af
IT322546	299.01 ± 0.99 o-p	6.64 ± 0.12 x-ac	28.47 ± 0.62 ac-ag	20.72 ± 0.16 p-s	11.90 ± 0.42 r-u
IT322549	329.11 ± 2.75 j-k	8.58 ± 0.06 h	40.45 ± 0.26 d-f	23.55 ± 0.05 g-i	17.58 ± 0.63 c-e
IT322554	218.16 ± 1.96 al-an	6.59 ± 0.10 za-ae	29.71 ± 0.30 y-ad	21.09 ± 0.06 o-p	12.23 ± 0.34 p-r
IT322555	277.55 ± 8.10 t-w	7.90 ± 0.10 k-m	36.81 ± 0.51 jk	23.42 ± 0.09 g-i	15.23 ± 0.09 h
IT322558	308.13 ± 4.01 n-o	8.57 ± 0.01 h	39.54 ± 0.25 e-h	23.51 ± 0.04 g-i	17.64 ± 0.14 c-d
IT322570	229.52 ± 2.84 ah-ak	6.76 ± 0.07 w-z	29.26 ± 0.39 za-ad	21.85 ± 0.18 m-n	12.37 ± 0.17 p-r
IT322571	270.51 ± 1.04 w-z	7.42 ± 0.03 o-p	33.52 ± 1.12 n-p	22.79 ± 0.25 j-k	13.92 ± 0.36 j-l
IT322572	214.79 ± 1.71 am-ao	6.46 ± 0.09 ab-ah	28.75 ± 0.82 ab-af	19.67 ± 0.08 u-v	11.19 ± 0.08 u-y
IT322578	313.26 ± 4.24 m-n	6.79 ± 0.12 w-y	31.71 ± 0.94 r-w	21.27 ± 0.13 o	12.30 ± 0.08 p-r
IT322580	428.95 ± 4.73 a	8.77 ± 0.10 e-g	40.80 ± 0.61 c-e	23.57 ± 0.02 g-h	17.68 ± 0.48 c
IT322613	0.12 ± 0.00 bp	2.04 ± 0.02 bp	1.84 ± 0.05 bo	0.95 ± 0.01 bm-bn	0.63 ± 0.03 bd
IT322621	174.29 ± 4.34 aw-ax	5.71 ± 0.02 ar-au	25.28 ± 0.37 aj-ap	17.04 ± 0.06 ab-ae	9.14 ± 0.15 ag-an
IT322622	248.90 ± 2.83 ac-ae	6.89 ± 0.10 u-w	31.90 ± 0.76 q-v	22.46 ± 0.33 k-l	12.71 ± 0.71 o-q
IT329008	282.70 ± 6.18 r-v	7.37 ± 0.11 o-q	29.36 ± 1.41 za-ad	20.30 ± 0.21 s-t	11.03 ± 0.15 v-y
IT329026	266.55 ± 1.78 y-z	6.64 ± 0.01 x-ac	24.87 ± 0.30 al-as	18.60 ± 0.13 x	9.72 ± 0.26 ac-ah
IT329047	252.18 ± 9.59 ab-ac	8.67 ± 0.21 f-h	38.30 ± 0.76 hi	27.55 ± 0.48 b	15.29 ± 0.94 h
IT329048	233.93 ± 12.59 af-ai	8.40 ± 0.02 i	34.40 ± 0.27 m-o	25.79 ± 0.26 e	14.79 ± 0.16 hi
IT329049	266.55 ± 3.20 y-z	7.20 ± 0.05 q-r	28.42 ± 0.19 ac-ag	20.94 ± 0.10 o-q	11.71 ± 0.21 r-v
IT329050	151.08 ± 3.68 bb-bc	6.40 ± 0.07 ae-ai	23.67 ± 0.25 aq-av	17.41 ± 0.11 z-ac	9.85 ± 0.11 ab-ag
IT329053	409.72 ± 8.46 b	7.43 ± 0.12 o-p	28.95 ± 0.88 aa-ae	20.54 ± 0.35 q-s	10.77 ± 0.41 x-aa
IT329056	353.76 ± 11.25 g	7.87 ± 0.02 l-m	32.73 ± 0.87 p-t	22.79 ± 0.34 j-k	11.82 ± 0.16 r-u
IT329063	249.76 ± 1.05 ac-ad	7.09 ± 0.04 r-t	26.78 ± 0.48 ah-aj	19.33 ± 0.05 v	10.31 ± 0.21 za-ac
IT329064	197.43 ± 4.41 aq-au	6.50 ± 0.11 aa-ag	22.69 ± 0.51 av-ax	16.53 ± 0.28 ae-ai	9.68 ± 0.22 ac-ai
IT329074	335.03 ± 6.28 ij	8.81 ± 0.02 e-f	36.08 ± 0.62 jk	26.99 ± 0.11 c	15.23 ± 0.19 h
IT329076	238.61 ± 0.79 ae-ah	7.00 ± 0.05 s-u	28.27 ± 0.31 ad-ag	18.28 ± 0.27 x-y	9.90 ± 0.27 ab-af
IT329077	320.82 ± 3.76 k-m	8.89 ± 0.09 d-e	36.18 ± 0.64 jk	26.28 ± 0.28 d	14.23 ± 0.19 i-k
IT329078	201.95 ± 1.83 ap-at	6.91 ± 0.11 u-w	26.76 ± 0.36 ah-aj	17.68 ± 0.25 z-aa	10.18 ± 0.12 aa-ae
IT329082	193.88 ± 1.27 at-au	6.77 ± 0.13 w-z	24.71 ± 0.15 am-as	16.86 ± 0.25 ac-af	9.49 ± 0.45 ae-aj
IT329085	33.67 ± 1.24 bo	2.31 ± 0.01 bn-bo	24.44 ± 0.21 ao-au	3.93 ± 0.19 bh	2.09 ± 0.10 bc
IT329089	156.90 ± 2.69 az-bc	4.20 ± 0.08 be-bg	14.13 ± 0.68 bh-bi	8.94 ± 0.14 ba	5.11 ± 0.15 ax-ay

Table 2. *Cont.*

IT-Number	TTC (mg CE/g)	TPC (mg GAE/g)	ABTS (mg TE/g)	DPPH (mg AAE/g)	FRAP (mg AAE/g)
IT329090	249.43 ± 5.65 ac-ad	5.31 ± 0.06 ax-az	18.37 ± 0.22 bc-bd	11.83 ± 0.17 au-av	7.01 ± 0.14 au-av
IT329108	171.92 ± 2.57 aw-ay	6.44 ± 0.11 ad-ah	23.62 ± 0.35 aq-av	16.46 ± 0.14 af-aj	9.56 ± 0.38 ad-ai
IT329120	296.27 ± 1.58 p-q	8.04 ± 0.15 k-l	31.62 ± 0.48 s-w	21.92 ± 0.08 m-n	12.27 ± 0.17 p-r
IT329124	283.19 ± 0.00 r-u	6.38 ± 0.07 af-aj	24.05 ± 0.28 ap-av	15.69 ± 0.20 al-am	8.49 ± 0.18 an-as
IT331874	365.79 ± 0.79 f	8.06 ± 0.09 k	33.04 ± 0.15 o-s	21.90 ± 0.28 m-n	12.33 ± 0.23 p-r
IT331878	346.50 ± 6.44 g-h	9.08 ± 0.04 c	39.22 ± 0.27 f-h	27.77 ± 0.13 b	16.31 ± 0.23 g
IT331882	323.87 ± 3.38 k-l	6.05 ± 0.07 al-ao	30.35 ± 0.36 w-aa	21.27 ± 0.12 o	10.51 ± 0.22 y-ab
IT331889	272.22 ± 4.46 v-y	5.93 ± 0.07 an-aq	29.84 ± 0.22 y-ac	20.85 ± 0.33 o-r	9.81 ± 0.19 ab-ag
IT331894	342.15 ± 4.57 h-i	5.36 ± 0.02 aw-ay	25.12 ± 0.77 al-aq	18.30 ± 0.15 x-y	8.59 ± 0.25 al-ar
IT331896	346.59 ± 2.61 g-h	6.60 ± 0.01 y-ad	30.47 ± 0.16 v-z	23.01 ± 0.01 i-k	12.33 ± 0.19 p-r
IT331899	224.65 ± 6.13 ai-am	5.15 ± 0.08 az-ba	21.89 ± 0.22 ax-az	17.95 ± 0.43 y-z	8.68 ± 0.18 ak-aq
IT331904	318.37 ± 7.54 l-m	7.33 ± 0.12 o-q	32.72 ± 0.29 p-t	23.69 ± 0.05 g-h	14.72 ± 0.30 h-i
IT331907	285.36 ± 3.45 r-u	6.99 ± 0.02 t-v	31.80 ± 0.38 r-w	23.54 ± 0.04 g-i	13.31 ± 0.19 l-o
IT331921	198.21 ± 1.76 aq-at	6.65 ± 0.08 x-ab	29.71 ± 0.86 y-ad	23.15 ± 0.09 h-j	12.03 ± 0.29 q-t
IT331922	334.88 ± 0.87 i-j	7.13 ± 0.04 r-t	30.97 ± 0.26 u-y	23.55 ± 0.08 g-i	12.92 ± 0.10 n-p
IT331936	388.25 ± 7.24 d	7.99 ± 0.07 k-l	36.99 ± 0.35 i-j	23.69 ± 0.01 g-h	16.99 ± 0.24 e-f
IT331937	206.90 ± 1.53 ao-ar	5.57 ± 0.12 at-av	26.20 ± 0.42 ai-am	19.24 ± 0.13 v-w	9.68 ± 0.20 ac-ai
IT331938	265.83 ± 2.39 y-z	6.45 ± 0.06 ac-ah	28.74 ± 0.70 ab-af	22.57 ± 0.12 k-l	11.76 ± 0.17 r-u
IT331962	282.52 ± 2.39 r-v	6.35 ± 0.10 ag-aj	28.41 ± 0.73 ac-ag	22.10 ± 0.06 l-m	11.48 ± 0.46 s-w
IT331963	224.48 ± 7.33 ai-am	5.25 ± 0.03 ay-ba	22.06 ± 0.21 aw-ay	17.66 ± 0.14 z-aa	8.34 ± 0.20 ao-as
IT331978	153.66 ± 0.50 ba-bc	4.62 ± 0.01 bd	17.80 ± 0.11 bc-be	15.01 ± 0.08 an-ao	6.84 ± 0.13 av
IT331988	197.32 ± 3.70 aq-au	5.82 ± 0.05 ap-ar	23.39 ± 0.36 as-aw	19.58 ± 0.09 u-v	9.06 ± 0.12 ah-an
IT332014	239.74 ± 5.67 ad-ah	6.66 ± 0.01 x-ab	30.15 ± 0.26 x-ab	23.01 ± 0.15 i-k	12.72 ± 0.15 o-q
IT332024	253.94 ± 7.18 aa-ac	6.59 ± 0.14 za-ae	28.58 ± 0.72 ac-ag	22.74 ± 0.16 j-k	12.26 ± 0.25 p-r
IT332042	291.57 ± 10.51 p-s	5.75 ± 0.11 aq-at	25.30 ± 0.45 aj-ap	19.36 ± 0.14 v	9.06 ± 0.46 ah-an
IT332046	206.19 ± 4.11 ao-as	5.76 ± 0.05 aq-as	25.67 ± 0.21 aj-ao	20.35 ± 0.08 r-t	9.92 ± 0.20 ab-af
IT340260	285.53 ± 1.96 r-u	6.56 ± 0.02 aa-af	29.40 ± 0.40 za-ad	22.62 ± 0.14 j-l	11.72 ± 0.44 r-v
IT340261	415.58 ± 1.00 b	8.62 ± 0.01 gh	41.89 ± 0.79 c	23.80 ± 0.01 g	21.56 ± 0.52 a
K276521	93.95 ± 1.53 bh	2.25 ± 0.06 bo	9.79 ± 0.45 bj	5.10 ± 0.07 bf	3.57 ± 0.03 az
IT231310	208.06 ± 17.61 an-aq	4.85 ± 0.38 bb-bc	30.66 ± 2.47 v-z	14.01 ± 1.35 aq-ar	9.76 ± 0.99 ac-ah
Nampungchal	323.36 ± 0.73 k-l	6.31 ± 0.03 ag-ak	39.85 ± 0.42 e-g	18.79 ± 0.17 wx	13.72 ± 0.35 k-m
Wheatland	58.61 ± 2.15 bm	1.82 ± 0.14 bq	6.14 ± 0.31 bm-bn	1.05 ± 0.05 bm	1.90 ± 0.07 bc
Sodamchal	241.15 ± 3.30 ad-ag	5.74 ± 0.07 aq-at	36.79 ± 0.17 jk	17.57 ± 0.33 z-ab	12.41 ± 0.33 p-r
Total range	0.12–428.95	1.17–10.23	1.64–67.60	0.48–31.99	0.63–21.56
Total mean	224.35	5.96	26.41	15.55	10.06
CV (%)	41.12	29.93	36.13	44.61	40.04

Means in a column with different superscript letters are significantly different ($p < 0.05$). ABTS: 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium radical cation scavenging activity; DPPH: 1,1-Diphenyl-2-picrylhydrazyl radical scavenging activity; FRAP: Ferric reducing antioxidant power; TPC: Total phenolic content; TTC: Total tannin content.

The antioxidant activities of the different sorghum genotypes also varied significantly ($p < 0.05$, Table 2). The ABTS, DPPH and FRAP activities were 1.64–67.60 mg TE/g, 0.48–31.99 mg AAE/g and 0.63–21.56 mg AAE/g, respectively. The ABTS, DPPH and FRAP activities of the control cultivars were each in the order of Nampungchal > Sodamchal > Wheatland, which could be associated with their level of TPC and TTC. In comparison with the control cultivars, 12 landraces showed higher ABTS, DPPH and FRAP activities than Nampungchal and Sodamchal cultivars, and hence, these landraces could be important resources (Table 2). Interestingly, landraces with higher TPC and TTC levels had higher antioxidant activity, which corresponds with previous findings [47]. Landrace IT270349, for example, which had the highest TPC level, displayed the highest ABTS and DPPH activities, both of which were significantly different from the other landraces ($p < 0.05$). The same landrace had the second highest FRAP activity (20.38 mg AAE/g). The highest

FRAP activity was found in landrace IT340261, which had the second highest TTC level (415.58 mg CE/g) ($p < 0.05$). In general, the sorghum landraces showed significant variation in TPC, TTC and antioxidant activities. The landraces with better performances could be ideal candidates for breeding and distribution.

3.2.1. Selected Landraces with Unique Seed-Related Characteristics

Table 3 depicts some distinct sorghum landraces with widely varying days to maturity and TSW, TPC and TTC levels compared with the control cultivars. The DM range was 36 days between early and late maturing landraces, with eleven landraces having a DM of more than 105 days and three having a DM of lower than 80 days. These early maturing landraces have the potential to make a significant contribution. The TSW range was 16.30 g from highest to lowest, with three landraces having a TSW greater than 35.00 g and four having a TSW less than 23.00 g. Landrace IT113294, which outweighed all control cultivars and landraces, could be an important parental candidate. There were extremely large differences between the high and low contents of TTC and TPC. The TTC differed by over 3000-fold, whereas the TPC differed by about 9-fold. Eleven landraces had a TTC greater than 350 mg CE/g, and twelve landraces had a TPC greater than 8.5 mg GAE/g, both of which were greater than all three control cultivars. In contrast, seven landraces had a TTC less than 50 mg CE/g, and another seven had a TPC less than 2.50 mg GAE/g. In general, these distinct landraces could serve as parents in the development of early maturing, large-seeded or high TPC and TTC sorghum cultivars [25,44].

Table 3. Selected unique sorghum landraces with low and high DM, TSW, TTC and TPC levels.

Days to Maturity		**Thousand-Seed Weight**		**Total Tannin Content**		**Total Phenolic Content**	
Landrace	>105 Days	Landrace	>35.00 g	Landrace	>350 mg CE/g	Landrace	>8.5 mg GAE/g
IT322613	113	IT113294	38.20	IT322580	428.95	IT270349	10.23
IT331936	109	IT208567	36.90	IT340261	415.58	IT286448	9.31
IT340260	109	IT320898	35.30	IT329053	409.72	IT331878	9.08
IT270366	109	<23.00 g		IT162843	398.27	IT251882	9.00
IT340261	109	IT100143	22.93	IT331936	388.25	IT329077	8.89
IT286448	109	IT185812	22.37	IT270349	383.50	IT100143	8.83
IT322558	109	IT329076	22.03	IT103099	377.60	IT329074	8.81
IT329085	107	IT329089	21.90	IT331874	365.79	IT322580	8.77
IT322549	106			IT329056	353.76	IT329047	8.67
IT329048	106			IT180614	350.38	IT340261	8.62
IT320898	106			IT286399	350.22	IT322549	8.58
<80 days				<50 mg CE/g		IT322558	8.57
IT103099	78			IT100046	47.00	<2.5 mg GAE/g	
IT185796	77			IT104594	46.94	IT103099	2.44
IT185816	77			IT100024	45.76	IT113294	2.31
				IT329085	33.67	IT329085	2.31
				IT162877	26.24	K276521	2.25
				IT270366	0.48	IT322613	2.04
				IT322613	0.12	IT162877	1.57
						IT270366	1.17
Wheatland	88		37.93		58.61		1.82
Nampungchal	98		30.63		323.36		6.31
Sodamchal	104		30.53		241.15		5.74

3.2.2. Effect of Collection Area on Biochemical Contents and Antioxidant Activities

The boxplots in Figure 3a show variations in biochemical contents and antioxidant activities according to differences in collection area, and significant differences ($p < 0.05$) were discovered. The corresponding numerical values can be seen in Table S3.

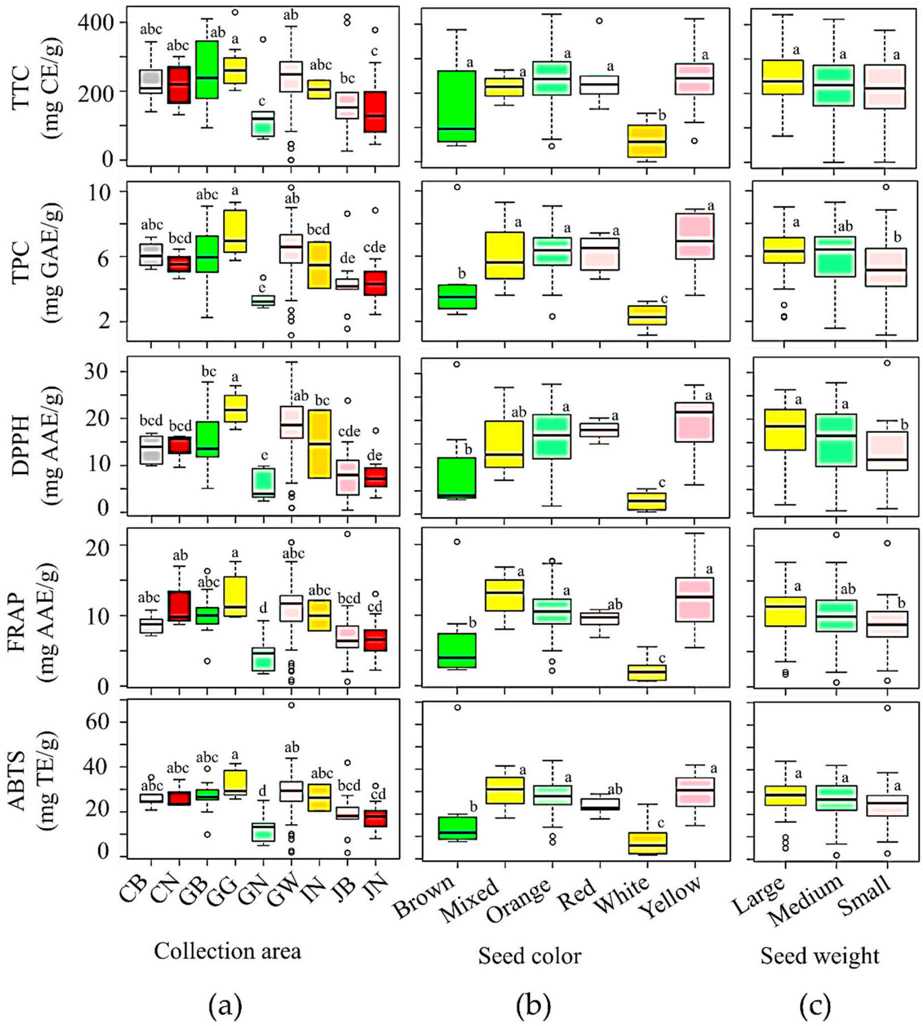

Figure 3. Variations in metabolite contents and antioxidant activities in sorghum landraces according to the collection area, seed color and seed weight. Different letters on box plots in a category show significantly different means. ABTS: 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium radical cation scavenging activity; CB: Chungcheongbuk-do; CN: Chungcheongnam-do; DPPH: 1,1-Diphenyl-2-picrylhydrazyl radical scavenging activity; FRAP: Ferric reducing antioxidant power; GB: Gyeongsangbuk-do; GG: Gyeonggi-do; GN: Gyeongsangnam-do; GW: Gangwon-do; IN: Incheon; JB: Jeollabuk-do; JN: Jeollanam-do; TPC: Total phenolic content; TTC: Total tannin content.

Gyeonggi-do landraces had the highest average TTC and TPC (273.73 mg CE/g and 7.39 mg GAE/g, respectively) levels, whereas Gyeongsangnam-do landraces had the lowest (148.34 mg CE/g and 3.48 mg GAE/g, respectively) ($p < 0.05$). The average ABTS, DPPH and FRAP levels showed similar variations, with Gyeonggi-do landraces having the highest (32.20 mg TE/g, 22.10 mg AAE/g and 12.60 mg AAE/g, respectively) and Gyeongsangnam-do landraces having the lowest (13.00 mg TE/g, 5.75 mg AAE/g and 4.66 mg AAE/g, respectively) activities ($p < 0.05$). Gangwon-do landraces showed the second highest average TPC level (6.39 mg GAE/g), DPPH activity (28.77 mg AAE/g) and ABTS activity (17.84 mg TE/g). In contrast, landraces from Jeollabuk-do and Jeollanam-do had the second and third lowest biochemical contents and antioxidant activities, respectively, except for TPC, which was reversed (Figure 3, Table S3). As a result of their high levels of metabolites and strong antioxidant activities, landraces from northern provinces such as Gyeonggi-do and Gangwon-do could be important materials. The effect of the collection area on metabolite content and antioxidant activity has been studied for a variety of dietary plants [49,50]. Such studies in sorghum genotypes, on the other hand, are uncommon, especially in the Republic of Korea. Only Yoon et al. [46], as far as we are aware, attempted to evaluate the levels of TPC and DPPH antioxidant activities of Korean sorghum accessions collected from different provinces, as previously described. Ghimire et al. [47] compared Korean sorghum accessions to genotypes from other countries in another study. As a result, this study could provide the most up-to-date information on the effect of the collection area on TPC, TTC and antioxidant activity variations in sorghum genotypes.

3.2.3. Effects of Seed Color and Weight on Biochemical Contents and Antioxidant Activities

Sorghum grains are available in a variety of colors, including white, yellow, red and black. A genomic study revealed that the accumulation or absence of several metabolites in the pericarp determines sorghum seed colors, which in turn strongly influences the overall level of metabolites in sorghum seeds [51]. This study also found differences in the level of metabolite contents and antioxidant activities between the landraces following seed color variation. Red (247.04 mg CE/g) and yellow (6.87 mg GAE/g) sorghum seeds had the highest average TTC and TPC, respectively (Figure 3b, Table S4). White sorghum, on the other hand, had the lowest TTC (62.34 mg CE/g) and TPC (2.31 mg GAE/g), both of which were significantly different from the other groups ($p < 0.05$). Previous studies have also stated that white sorghum seeds have low metabolite contents. For example, Rhodes et al. [38] discovered a significantly lower TPC level in white sorghum seeds compared with red, yellow and brown seeds, which corroborates our findings. The level of TTC in white sorghum seeds was also reported to be significantly lower [5]. Other findings, regarding the effect of seed color, can be read in a recent review by Xu et al. [40]. Similar observations were found concerning antioxidant activities. White landraces had the lowest average antioxidant activities, including ABTS (8.17 mg TE/g), DPPH (2.80 mg AAE/g) and FRAP (2.16 mg AAE/g), which were all significantly different from the other seed colors ($p < 0.05$). Brown sorghum landraces, with the second lowest average TTC (158.53 mg CE/g) and TPC (4.22 mg GAE/g) levels, also had the second lowest ABTS (19.14 mg TE/g), DPPH (9.26 mg AAE/g) and FRAP (6.31 mg AAE/g) activities. In addition to the effect of seed color, our findings support the role of high levels of phenolic compounds in increased antioxidant activity [5,6,12]. Overall, white sorghum seeds might not be good candidates in terms of metabolite content and antioxidant activity.

Seed weight is an important agronomic characteristic that has been used as a parameter in the breeding of sorghum [52]. Although several studies have revealed the effect of seed weight on metabolite content and antioxidant activity in other crops and cereals, similar studies on sorghum are scarce. In this study, the effect of seed weight on the TPC, the TTC and antioxidant activities was investigated. The average TTC level decreased in the order of large seeds (428.95 mg CE/g) > medium seeds (415.58 mg CE/g) > small seeds (383.50 mg CE/g), but the variation between each was not significantly different. The variation in the TPC level, which showed a similar pattern of variation of large seeds (2.25 mg GAE/g) > medium seeds (1.57 mg GAE/g) > small seeds (1.17 mg GAE/g), showed an approximately two-fold difference between large and small seeds ($p < 0.05$) (Figure 3c, Table S4). Interestingly, all antioxidant activities also followed a similar pattern, with large seeds showing the highest activities and small seeds showing the lowest. DPPH and FRAP activities differed significantly between large and small seeds ($p < 0.05$). In general, this study demonstrates that seed weight could influence the metabolite contents and antioxidant activities of sorghum grains (Figure 3c).

3.3. Principal Component (PCA) and Correlation Analyses

PCA is an unsupervised multivariate analysis tool used to evaluate the similarity or association of plant genotypes. Furthermore, it is widely used in conjunction with Pearson's correlation analysis to determine the relationship between variables [53]. In this study, PCA and correlation analyses were performed on the entire quantitative data set. Four components in the PCA had eigenvalues greater than one, with the first two (PC1 and PC2) accounting for 65.21% of the total variability (Figure 4, Table 4).

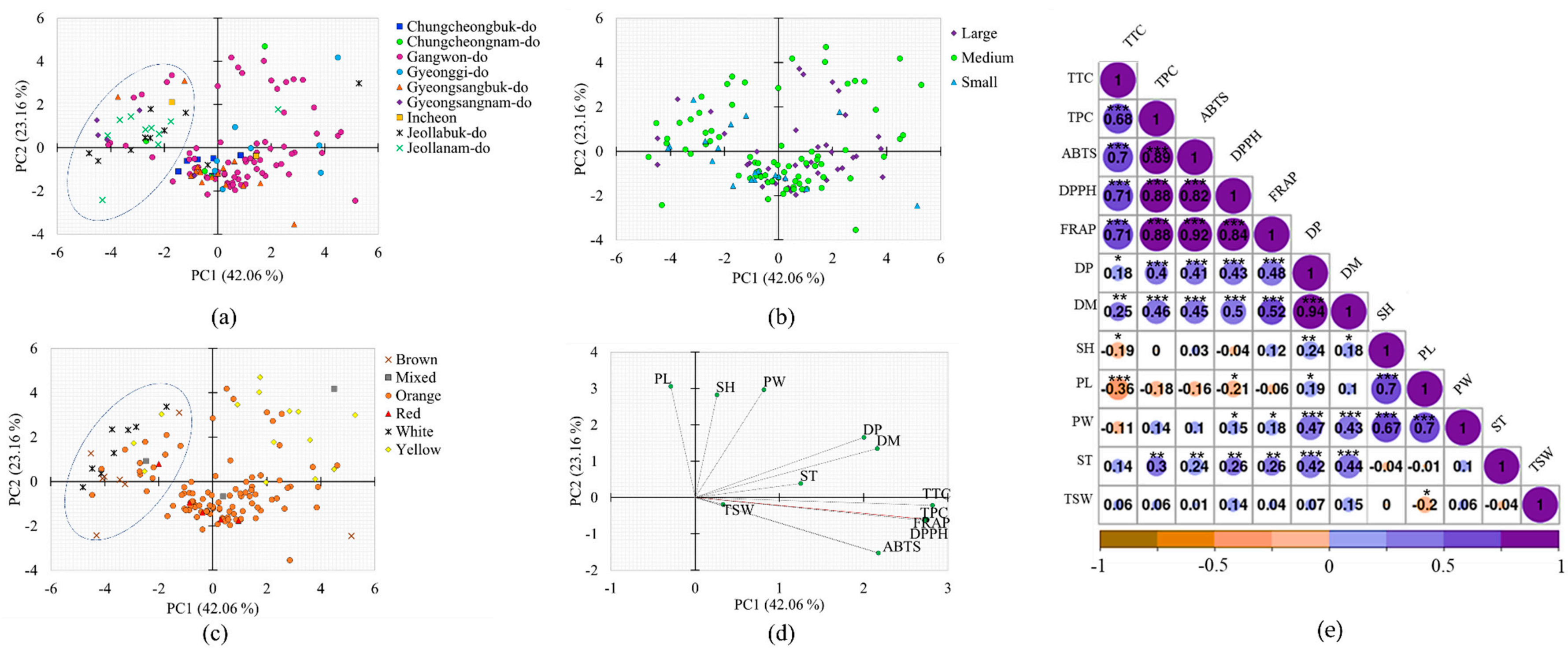

Figure 4. Score plot of sorghum landraces according to collection area (**a**), seed weight (**b**) and seed color (**c**). Loading plot of variables (**d**) from PCA, and correlation matrix of quantitative variable (**e**). *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. DM: Days to maturity; DP: Days to panicle; PL: Panicle length; PW: Panicle width; SH: Stem height; ST: Stem thickness; TSW: Thousand seed weight. Full names for the remaining abbreviations can be seen in Figure 3 footnotes.

Table 4. Contributions of variables in the first four principal components.

Variables	PC1	PC2	PC3	PC4
TTC	10.21	6.78	3.48	0.05
TPC	16.37	1.05	2.93	0.02
ABTS	16.10	1.03	4.62	0.16
DPPH	16.00	1.16	1.16	0.70
FRAP	17.16	0.13	4.23	0.03
Days to panicle	8.67	7.96	16.26	0.15
Days to maturity	10.09	5.30	18.52	0.03
Stem height	0.14	23.19	10.22	1.62
Stem thickness	3.40	0.43	23.97	16.33
Panicle length	0.18	27.17	6.42	1.29
Panicle width	1.44	25.68	1.28	1.85
Thousand seed weight	0.24	0.11	6.90	77.76
Eigenvalue	5.05	2.78	1.29	1.06
Variability (%)	42.06	23.16	10.73	8.86
Cumulative (%)	42.06	65.21	75.94	84.80

Full names for the abbreviations can be seen in Figure 3 footnotes.

Metabolite contents and antioxidant activities were the most important contributors to the variations observed along PC1. Agronomic traits, such as SH (23.19%), PL (27.17%) and PW (25.68%), on the other hand, contributed the most to the variation observed along PC2. The grouping of sorghum landraces from the Gyeongsangnam-do, Jeollabuk-do and Jeollanam-do provinces (Figure 4a) and white landraces (Figure 4c) along the PC2 axis were the most critical features in the PCA. As previously stated, these landraces had low levels of TPC and TTC as well as decreased antioxidant activities. Furthermore, the loading plot revealed that the antioxidant activities were closely related to the TTC and TPC (Figure 4d).

The levels of association between metabolite contents, antioxidant activities, and agronomic traits were examined using correlation analysis (Figure 4e). The TTC, TPC, DPPH, ABTS and FRAP all had significant and positive correlations with each other ($r \geq 0.68$, $p < 0.001$), and such associations have been reported in several studies [7,21,54]. Among the agronomical traits, DP and DM had the strongest correlation ($r = 0.94$, $p < 0.001$). Similarly, SH, PW and PL showed positive and significant correlations ($r \geq 0.67$, $p < 0.001$) with each other, which agrees with many previous reports [14,20,23]. In line with the reports of Sarshad et al. [20], the TSW had a weak or negative correlation with the rest of the other variables. In general, the multivariate and correlation analysis results support the idea that agronomic characteristics, metabolite contents and antioxidant activities could be used to discriminate a large population of sorghum genotypes based on origin, seed color and seed weight.

4. Conclusions

This study reveals significant differences in agronomical traits, metabolite contents and antioxidant activities in a large population of Korean sorghum landraces, signifying that the landraces differed genetically. Panicle width, panicle length and thousand seed weight were among the most important agronomical traits that showed significant variations. Furthermore, collection area, seed weight and seed color all had a significant effect on the variations in the total tannin content, total phenolic content and antioxidant activities, and they could thus be used to distinguish a large population of sorghum genotypes. This study also identifies unique landraces with distinct properties and superior performances compared with the control cultivars, which breeders could request and use to produce high-quality sorghum cultivars. Future research focusing on metabolite profiling and genome-wide association studies is highly recommended to gain a better understanding of the observed variations at the molecular level.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agronomy12112898/s1, Figure S1: Representative sorghum seed samples; Table S1: Qualitative agronomic properties of sorghum genotypes cultivated in Korea; Table S2: Statistical data of analysis of variance indicating the variation in biochemical and agronomical traits among sorghum genotypes; Table S3: Variation in metabolite contents and antioxidant activities in sorghum landraces according to the collection area; and Table S4: Variation in metabolite contents and antioxidant activities in sorghum landraces according to seed color and seed weight.

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